

DECISIONS IN DUTCH HIP FRACTURE CARE

(How) To treat or not to treat?

Miliaan L. Zeelenberg

Decisions in Dutch hip fracture care

(How) To treat or not to treat?

Miliaan L. Zeelenberg

Printing and distribution of this thesis was financially supported by: The department of surgery, Erasmus Medical Center Rotterdam | The Erasmus University Rotterdam | Nederlandse Vereniging voor Traumachirurgie | Hyperbaar Geneeskundig Centrum Rijswijk

ISBN: 978-94-6510-687-8

Copyright ©
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, without prior written permission by the author.

Decisions in Dutch hip fracture care

(How) To treat or not to treat?

Keuzes in de Nederlandse heupfractuurzorg
(Hoe) Te behandelen of niet te behandelen?

Proefschrift

ter verkrijging van de graad van doctor aan de
Erasmus Universiteit Rotterdam
op gezag van de
rector magnificus

Prof. Dr. Ir. A.J. Schuit

en volgens besluit van het College voor Promoties.
De openbare verdediging zal plaatsvinden op:
Woensdag 3 september 2025 om 15:30 uur

door

Miliaan Lorenzo Zeelenberg
geboren te Rotterdam.

Erasmus University Rotterdam

Promotiecommissie

Promotoren	Prof. Dr. M.H.J. Verhofstad Prof. Dr. T. Gosens
Overige leden	Prof. Dr. P.C. Jutte Prof. Dr. I.B. Schipper Dr. R.L. van Bruchem - Visser
Copromotoren	Dr. E.M.M. van Lieshout Dr. D. den Hartog

Table of contents

Chapter 1: General introduction, aims and outline of this thesis 9

Part I: Epidemiology and costs of hip fractures over time

Chapter 2: Trends in incidence, health care consumption, and costs for proximal femoral fractures in the Netherlands between 2000-2019; a nationwide study 29

Chapter 3: Trends in incidence, health care use and costs for subtrochanteric femur fractures in the Netherlands 2000-2019 51

Part II: Extramedullary or intramedullary fixation of trochanteric fractures

Chapter 4: Extramedullary versus intramedullary fixation of stable trochanteric femoral fractures: a systematic review and meta-analysis 71

Chapter 5: Extramedullary versus intramedullary fixation of unstable trochanteric femoral fractures (AO type 31-A2): a systematic review and meta-analysis 113

Chapter 6: Mobility and living status at discharge and after three-months for extramedullary versus intramedullary fixation of AO type 31-A1 trochanteric fractures; an analysis of Dutch Hip Fracture Audit data 165

Part III: Hip fractures in very frail older patients

Chapter 7: Satisfaction and quality of dying with nonoperative end-of-life care for hospitalized and non-hospitalized frail older patients with (suspected) hip fractures: a combined cohort study 189

Chapter 8: The value of preoperative diagnostic testing and geriatric assessment in frail institutionalized elderly with a hip fracture; a secondary analysis of the FRAIL-HIP study 207

Chapter 9: Shared decision making for nonoperative management versus operative management of hip fractures in selected frail older adults with a limited life expectancy; a protocol for a nationwide implementation study 243

Chapter 10: Patient and proxy satisfaction regarding Shared Decision Making for operative and nonoperative hip fracture treatment in frail older adults: A mixed methods study 261

Part IV: General discussion and Conclusions

Chapter 11: General discussion and future perspectives 285

Chapter 12: Summary and conclusions in Dutch and English 301

Appendices: **Contributing authors** 315
List of publications 319
PhD portfolio 323
Dankwoord 325
About the author 329



1

General introduction, aims and outline of this thesis

A historical perspective

A proximal femoral fracture, or more commonly known as a hip fracture, is an injury with millions of cases around the world each year. It is a condition that is as old as humanity itself. From ancient civilizations to the modern era, the treatment of hip fractures has undergone significant transformations driven by advancements in understanding of anatomy, vascularization, anesthesia, infection control, and surgical implants (1). Before focusing on more current developments it can be interesting to look back to where the level of modern care, we are now used to, started:

In antiquity and the middle ages, hip fractures were almost exclusively managed nonoperatively, with methods such as immobilization, traction, and traditional bone-setting techniques (Figure 1). Hippocrates, the famous Greek physician, already mentioned techniques of immobilization and provided reduction through traction of femoral fractures using splints and bandages in his *Hippocratic Corpus* (2). He also, accurately, assumed that anatomical reduction and fixation of, what he called, 'micromovements' improves fracture healing (2, 3). While some fractures may have been caused by (violent) high-energy trauma, age-related fractures were more common than one would expect based on the low crude life-expectancy figures (4, 5). While infant and child mortality was generally high, if childhood was survived many people lived well into their sixties and even seventies. This would make them susceptible to age-related disease such as osteoporosis and associated hip fractures, in a surprisingly similar fashion to our modern times (6). While for many patients a hip fracture could mean complete loss of mobility and often a death sentence, there are examples of patients surviving and regaining mobility. One such examples is archaeological evidence found at an ancient cemetery near Erculam in southern Italy. Archeologists found remains of an older man who sustained a hip fracture somewhere between the first and second century AD (7). This 'patient' shows a healed fracture of the femoral neck that resulted in significant leg shortening. The right foot shows bony alterations that appear to have developed as a consequence. The severity of degenerative joint disease in the knee and ankle suggests that the injury occurred years before the man's death and he regained (restricted) mobility in the period after the fracture. This case and other similar findings show that people could adapt to impaired mobility in the past using only rudimentary tools and available pain medication. Fracture healing and return of mobility was possible but only if they had people that could care for them and assist them during recovery and later life. For the less fortunate a hip fracture would mean loss of occupation, extreme poverty, and in many cases death secondary to severe complications. One could imagine that this was a very painful and lengthy process that forever changed, not only the patient's life, but also the lives of the people around them. It shows the possible impact of (untreated)

hip fractures and how far we have come in the previous millennia, but also that some problems still remain similar.

Later, during the late Renaissance and Enlightenment era, there was a resurgence of interest in anatomy and surgery, leading to modest improvements in fracture management (8). Surgeons began to explore more invasive procedures, albeit with rudimentary tools and very high rates of mortality and complications. Invasive surgery mainly limited itself to treatment of infections trough amputation and the opening and drainage of cysts and abscesses. It was not until the Victorian era and early modern age with the invention of narcosis ("rendering patients unconscious to torture") and later antiseptics and antibiotics that more complex operations could be conducted and the first experiments using the scientific method started to take place (1, 8, 9). After implementation of these advancements, progress moved in quicker succession and various types of implants were development since the start of the twentieth century. Many advances in orthopedic and trauma surgery were made during or shortly after both Worlds Wars. Examples are the first intramedullary nails by Gerhard Küntscher (1939), hemiarthro-



Figure 1: The Scamnum or Hippocratic bench.
It was used to treat various types of fractures, including femoral fractures and was a forerunner of more modern traction and bone setting devices.
Painting by H.M. Hayman, 1923, Wellcome collection London

plasty devices by Austin Moore (1939), sliding hip screws by Ernst Pohl (1951), and low friction total hip replacement by John Charnley (1962), eventually leading to the diverse hip fracture care we know today (10, 11). These historical changes show the constant drive for improvement and refinement of our hip fracture care, with each new finding creating new possibilities and shifting the goals of both care and research.

The global hip fracture epidemic

Although hip fractures were already a common occurrence, the previous century saw a huge increase in life-expectancy in industrialized countries. As people aged, the incidence rate of age-related diseases increased. This led to an increase of conditions like cancer, cardiovascular disease, and importantly osteoporosis (12, 13). Osteoporosis is characterized by a low bone density, microarchitectural disruptions, and skeletal fragility, resulting in decreased bone strength and an increased risk of fractures (14, 15). Osteoporosis and increased fall risk in older patients are the most important risk factors for hip fractures (16). Despite large scale fall prevention campaigns, and early treatment and detection of osteoporosis, hip fracture incidence rates worldwide increased to an estimated 182 per 100,000 person years in 2019, and Are expected to increase even further in many countries (17-19). Due to these large increases in incidence rates, hip fractures have become one of the leading causes of disability and mortality in the elderly population worldwide (19, 20). In the Netherlands specifically, the absolute number of hip fractures doubled between 1981 and 2008 in patients over 65 years (21). In addition to their effect on individual quality of life and mortality, hip fractures are a substantial drain on resources, in both health care costs and associated indirect costs (22, 23). Previous research also found a worrying increasing trend among the oldest age groups (80+ years) and forecasted a relative increase in the number of fractures among the male population (21). More than a decade later this poses the question whether we can expect the 'global hip fracture epidemic' to persist in the Netherlands or have we already passed its peak?

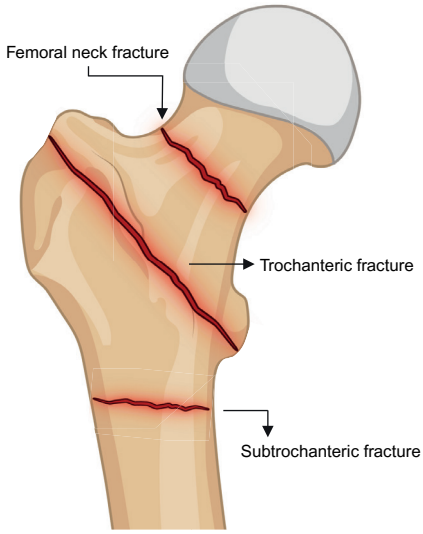


Figure 2: Areas for hip fracture subtypes

Classification and operative management

While all proximal femoral fractures are often described as a single entity or 'hip fractures', they can be subdivided in three distinct anatomical categories (Figure 2): femoral neck fractures, trochanteric fractures, and subtrochanteric fractures.

The most frequently occurring subtype, about 40-50% of all hip fractures, is the femoral neck or transcervical proximal femoral fracture (21, 24). They can be classified using the AO and Pauwels classification but are often classified clinically using the Garden classification (25, 26). Operative treatment of femoral neck fractures can be performed in many ways including cancellous/cannulated screws, dynamic hip screw, hemiarthroplasty, or total hip arthroplasty, depending on the fracture classification, patient status, goals of care, and the surgeons experience and preferred implant. Recent large scale international studies have determined that all previously mentioned approaches can be used with low rates of reoperations and other adverse events, and similar quality of life (27, 28). For some subgroups of patients, however, specific implants (*e.g.*, total hip arthroplasty for younger and more active patients) can have additional beneficial effects.

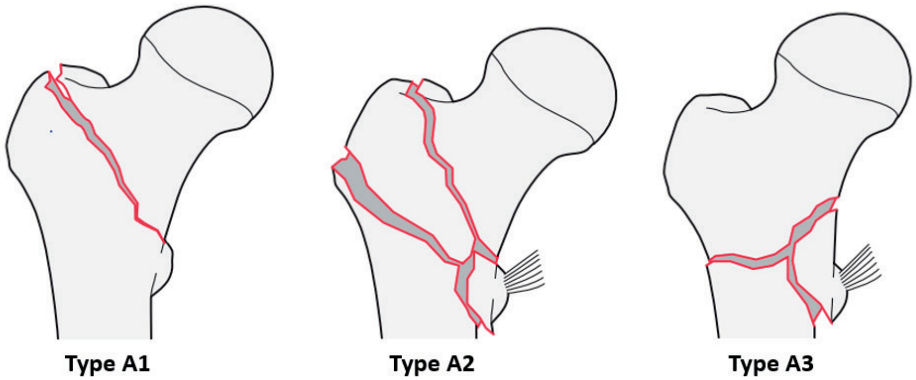
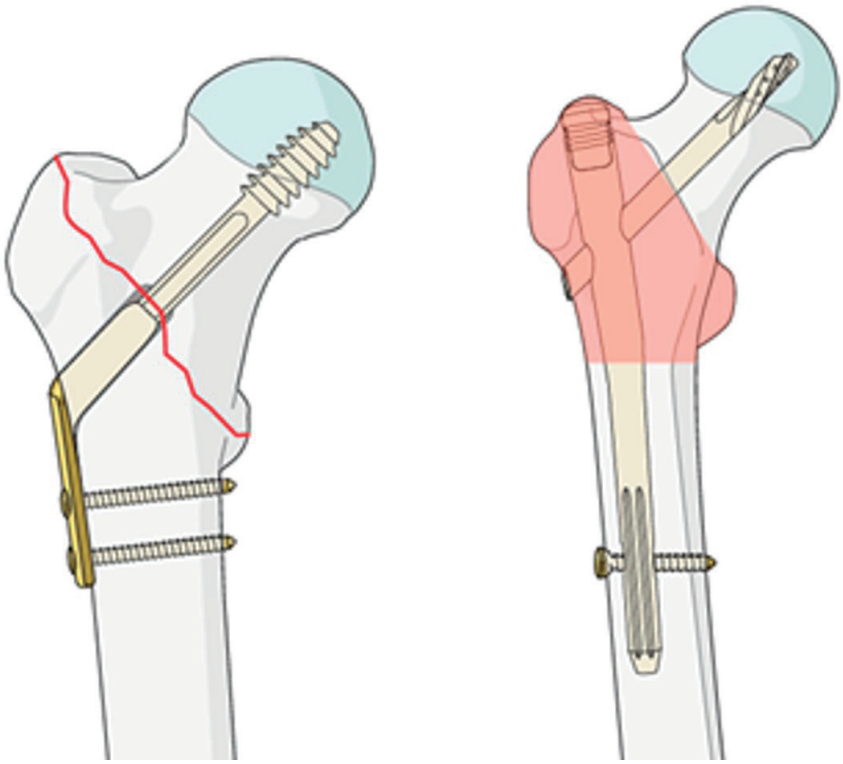


Figure 3: Trochanteric fracture subtypes as classified by the AO classification
Copyright by AO Foundation, Switzerland.

The second most frequent type of hip fracture, about 40% of all hip fractures, is the trochanteric fracture (21, 24). This fracture is most commonly classified using the AO/OTA classification. This classification distinguishes three types of trochanteric fractures (Figure 3). The stable two-part fracture (31-A1), unstable multi-fragmentary fracture (31-A2), and unstable intertrochanteric reverse obliquity fractures (31-A3). Treatment options include extramedullary fixation, using a type of sliding hip screw, or intramedullary fixation, using one of the various types of intramedullary nails (Figure 4). While intramedullary fixation is the clinically and scientifically favored approach for type A3 fractures (29), the best approach for type A1 and A2 fractures is less clear. Several international guidelines advise extramedullary fixation for A1 fractures and consider both extra- and intramedullary fixation as a viable option in A2 fractures (29-31). Intramedullary devices can cost well over $1000 more than extramedullary options, depending on the specific device and individual hospital contracts. Extramedullary fixation, or more specifically dynamic/sliding hip screw is therefore likely the most cost-effective implant (32, 33). With the high volume of trochanteric fractures fixated each year, choosing a less expensive implant could make a significant difference. While the Dutch and British guidelines favor extramedullary fixation for A1 fractures for this reason, the American guideline considers both fixation types equally suitable. Older literature discouraged intramedullary devices due to a higher failure and reoperation rates (34). While more recent studies report improving outcomes for intramedullary fixation, the increasing trend of intramedullary fixation may be caused by other factors than clinical data alone (35-39). Despite the fact that the optimal device for both type A1 and A2 fractures remains a topic of debate, in recent years the use of intramedullary fixation has

even risen to up to 90% in the U.S. (37, 38). Although superiority of intramedullary devices remains questionable a similar increasing trend is expected in the Netherlands. This increase would be contrary to the current guidelines, that advise the most cost-effective approach: extramedullary fixation.

Subtrochanteric fractures are located up to 5 cm distal from the lesser trochanter and occur in an area between trabecular and cortical bone where high levels of mechanical stress can occur (40, 41). Subtrochanteric fractures account for only 3-4% of all hip fractures in the Netherlands (42). They are a less frequently studied subtype of hip fractures and the few studies into their epidemiology mention a bimodal age distribution with a peak in adolescence, due to high energy trauma, and a peak at older age, due to osteoporosis related fractures (43, 44). These international studies also mention increasing incidence rates and a possible association with bisphosphonate usage. Whether these findings are also true for the Dutch population is currently unknown.



In**tramedullary fixation using a dynamic hip screw (left) and intramedullary fixation using a type of intramedullary nail (right).**
Copyright by AO Foundation, Switzerland.

Nonoperative management in frail older adults

For all these fracture types the best path of action has historically changed through the availability of new implants, operative techniques, and recovery pathways. These changes are set in motion by changes in the general paradigm of what we think is 'quality of care'. From internal fixation of the fracture, minimizing complications, to regaining pre-trauma function, and so on. The definition of quality of care is dynamic and changes based on scientific and technological advancement, time periods, or societal norms (45). Since the beginning of this millennium, authority-based practice changed to evidence-based practice. During this decade, one of the prominent changes is the change from a main focus on quality aspects central to the medical professional (e.g. complications, success rates, scientific evidence on a population basis/evidence-based practice, and professional expertise) towards including quality aspects central to the individual patient (e.g. individual needs/wishes, patient experiences, and perceived quality of life), and society as a whole (cost of treatment, environmental issues and relative shortage of health care personnel). What a healthcare provider thinks is the best treatment and associated outcome, can often differ entirely from what a patient prioritizes or what society can spend and deliver. The traditional quantitative research is supplemented with qualitative research, healthcare economics, and patient experiences. Scientific outcomes are becoming not only a basis for development of new treatment guidelines for doctors but also a basis for exploration and explanation of pro's and cons of treatment options together with patients. Diagnosis with disease X does not mean treatment A, but a careful discussion of treatment A, B, and C. Where C can also mean conservative treatment or refraining from further treatment, despite this not being the scientifically proven 'best' treatment option with the longest survival or smallest chance of complications in large populations.

One of the major novelties in this paradigm within trauma surgery is the ascent of nonoperative management hip fractures in geriatric hip fractures patients with a short life-expectancy. While a frequent occurrence in older adults and a routine operation for many (orthopedic) trauma surgeons, complication rates and mortality are high after a geriatric hip fracture (46-48). A hip fracture in a frail older adult is often an indication for an approaching end of life. Advanced age, multiple comorbidities, and severe mobility limitations are important risk factors for early post-operative mortality after a hip fracture (49, 50). Studies show that >30% of patients die within one year post hip fracture, with six-month mortality rates in older adults with dementia exceeding 55%, often with low quality of life in the months preceding death (47, 51, 52). These patients, in their final phase of life, do not benefit from an operative treatment that aims to restore mobility. Often they benefit far more from supportive (palliative) care in a familiar environment. Based on this insight, a shift is occurring in clinical approach,

emphasizing the importance of individualized care plans focused on optimal quality of life (53, 54).

Consequently, a relatively new development in the treatment of hip fractures is the return of nonoperative management. This is not the conservative treatment using traction and immobilization, from the ancient times mentioned in the first paragraphs of this introduction. Nonoperative treatment in modern medicine, is treatment focused on achieving the best possible quality of life and dying in frail older adults with hip fractures. A recent study, the FRAIL-HIP study, has demonstrated that in a select group of very frail older adults, health-related quality of life is non-inferior for patients who opt for nonoperative treatment than in patients who opt for operative treatment (52, 55). While survival was shorter in the nonoperative group, proxies and caregivers reported a high treatment satisfaction and quality of dying in both groups. Though not the leading motive for development of this treatment option, nonoperative management was also associated with lower costs, leading to a lower burden for both the patient and society (56). However, this is not a good option for every frail patient. The key in choosing the right treatment after admission to the hospital lies in well conducted shared decision making. Previous research reported that some of the most important aspects in comfortable palliative care for hip fracture patients are control of pain, easy access to- and communication with your loved ones and a calm and peaceful moment of dying (57). Other studies also identified maintaining quality of life (over prolonging of life) and being with family as more important goals of care than hospital admission and intensive rehabilitation for frail patients (with dementia) (54, 58). It is important for medical professionals to be able to guide a patient and their family through the decision process. Combining information about treatment options with the expectations and wishes for the final stages of life.

Until recently, a major limiting factor for this was the availability of a scientific basis for nonoperative management and the common perspective that 'palliative surgery' was the only ethical treatment option (59). Since the publication of the FRAIL-HIP study and linked projects, many hospitals have declared interest in- or started implementing nonoperative management in their regular hip fracture care for specific patients. However, there are still many hurdles towards effective and uniform nationwide implementation. Several of the many questions under consideration are: should some groups of very frail patients even be sent to the hospital or should nonoperative treatment be started without the hassle of hospitalization and diagnostics if this does not align with their priorities for the final phase of life or pre-existing advance care plans?; when these patients are admitted, what diagnostics should be performed to aid in the decision process?; and by who, how, and where should the shared-decision making process be conducted?

General aim

In addition to providing an epidemiological overview of hip fractures in the Netherlands, this thesis aims to aid physicians in answering two questions often asked when treating patients with hip fractures: "What is the superior method of fixation for trochanteric fractures?" and "How to best approach and treat a frail older patient with a hip fracture?".

Outline of this thesis

Chapter 1 provides a general introduction to the topic. The current hip fracture care is placed in a historical perspective, the most prevalent types of fractures are explained, and the most common types of fixation are described, followed by an overview of recent developments in nonoperative treatment of frail older adults with hip fractures.

Part I of this thesis focusses on the epidemiology of hip fractures. As our population ages the absolute number of hip fractures is expected to increase. **Chapter 2** discusses the epidemiology and costs of femoral neck and trochanteric hip fractures in the Netherlands between 2000 and 2019. It also describes changes over time in hospital length-of-stay, trauma mechanism, and years lived with disability. This analysis is repeated in **Chapter 3** for a less studied and less common type of hip fracture, the subtrochanteric fracture.

Trochanteric fractures, one of the two most common subtypes, are usually fixated using an extramedullary or an intramedullary approach. The best approach for fixation of these fractures is a continuing point of discussion among surgeons. **Part II** of this thesis focusses on selecting the best approach for fixation of stable and unstable trochanteric hip fractures. **Chapter 4** compares recent literature on current extramedullary and intramedullary fixation devices in stable trochanteric fractures (AO type 31-A1). It makes this comparison for functional outcomes, complications, and surgical outcomes/operation characteristics and determines which device category should be favored based on the pooled results. While the balance in recent studies seems to be leaning towards intramedullary fixation, the question of device superiority can also be asked for, specifically, unstable (AO type 31-A2) trochanteric fractures. **Chapter 5** assesses this question with a systematic review and meta-analysis on functional outcomes, complications, and surgical outcomes/operation characteristics for unstable trochanteric fractures. On an international scale many surgeons opt for intramedullary fixation of stable trochanteric fractures. To assess the situation in the Netherlands, **Chapter 6** compares device usage and outcomes for extramedullary and intramedullary fixation for stable trochanteric

fractures in several high volume Dutch hospitals using data from the Dutch Hip Fracture Audit.

Part III of this thesis focuses on the treatment of frail older adults with hip fractures. Often a decision has to be made between operative management or nonoperative (palliative) management. For some institutionalized patients with a limited life expectancy the question remains whether they should be admitted to the emergency department with a suspected hip fracture for further diagnostics or if the decision for nonoperative treatment should take place in the institution where they are living. **Chapter 7** compares the treatment satisfaction and outcomes of nonoperatively treated patients that were admitted to the hospital with patients that remained in the institution where they resided and received nonoperative treatment for their suspected hip fracture there.

When patients are admitted, an extensive diagnostic process is frequently started. **Chapter 8** describes the number of diagnostic tests performed and discusses the value of these tests after a frail hip fracture patient is admitted to the emergency department. After a hip fracture diagnosis, shared decision making is the corner stone in proving patients with the best care that fits their wishes and expectations for the final stages of life. It is often unknown how to best approach such a difficult discussion and in which patient population the option of nonoperative management should be discussed. To guide physicians and patients in this decision, **Chapter 9** proposes a study protocol for a nationwide implementation of shared decision making on operative and nonoperative treatment for select frail hip fracture patients with a limited life expectancy. To better tailor the decision making process and information provided to patients' wishes, **Chapter 10** describes a mixed-methods analysis of patients' and proxies' satisfaction and views on the shared decision making process around operative and nonoperative management after a hip fracture in frail older adults, parallel to the nationwide implementation efforts.

Part IV of this thesis contains **Chapter 11** with the general discussion and future perspectives and **Chapter 12**, that summarizes the main findings of the included works in both Dutch and English.

References

1. Bartonicek J. Early history of operative treatment of fractures. Arch Orthop Trauma Surg. 2010;130(11):1385-96.
2. Hippocrates tbFA. Hippocratic Corpus: The internet classics archive; 400 B.C.E.
3. Koutserimpas C, Naoum S, Piagkou M, Alpantaki K, Samonis G. Hippocrates: A Pioneer in Orthopaedics and Traumatology. Surg Innov. 2024;31(1):123-7.
4. Montagu JD. Length of life in the ancient world: a controlled study. J R Soc Med. 1994;87(1):25-6.
5. Griffin JP. Changing life expectancy throughout history. J R Soc Med. 2008;101(12):577.
6. Turner-Walker G, Syversen U, Mays S. The archaeology of osteoporosis. European Journal of Archaeology. 2001;4(2):263-96.
7. Lovell NC. Tiptoeing through the rest of his life: A functional adaptation to a leg shortened by femoral neck fracture. Int J Paleopathol. 2016;13:91-5.
8. Lindeboom GA. Inleiding tot de geschiedenis der geneeskunde: Erasmus Publishing; 1993.
9. Connor JT. Beyond the ivory tower. The Victorian revolution in surgery. Science. 2004;304(5667):54-5.
10. Baig MN, Kearns SR, Shannon FJ, Devitt A. Ten Inventions That Shaped Modern Orthopedics. Cureus. 2021;13(1):e12819.
11. Bartonicek J, Rammelt S. The history of internal fixation of proximal femur fractures Ernst Pohl-the genius behind. Int Orthop. 2014;38(11):2421-6.
12. Le Couteur DG, Thillainadesan J. What Is an Aging-Related Disease? An Epidemiological Perspective. J Gerontol A Biol Sci Med Sci. 2022;77(11):2168-74.
13. Salari N, Ghasemi H, Mohammadi L, Behzadi MH, Rabieenia E, Shohaimi S, Mohammadi M. The global prevalence of osteoporosis in the world: a comprehensive systematic review and meta-analysis. J Orthop Surg Res. 2021;16(1):609.
14. Raisz LG. Pathogenesis of osteoporosis: concepts, conflicts, and prospects. J Clin Invest. 2005;115(12):3318-25.
15. Pouresmaeili F, Kamalidehghan B, Kamarehei M, Goh YM. A comprehensive overview on osteoporosis and its risk factors. Ther Clin Risk Manag. 2018;14:2029-49.
16. Cummings SR. Treatable and untreatable risk factors for hip fracture. Bone. 1996;18(3 Suppl):165S-7S.
17. Collaborators GBDF. Global, regional, and national burden of bone fractures in 204 countries and territories, 1990-2019: a systematic analysis from the Global Burden of Disease Study 2019. Lancet Healthy Longev. 2021;2(9):e580-e92.
18. Cooper C, Campion G, Melton LJ, 3rd. Hip fractures in the elderly: a world-wide projection. Osteoporos Int. 1992;2(6):285-9.
19. Kanis JA, Oden A, McCloskey EV, Johansson H, Wahl DA, Cooper C, et al. A systematic review of hip fracture incidence and probability of fracture worldwide. Osteoporos Int. 2012;23(9):2239-56.
20. Fakhry SM, Shen Y, Garland JM, Wilson NY, Wyse RJ, Morse JL, et al. The burden of geriatric traumatic brain injury on trauma systems: Analysis of 348,800 Medicare inpatient claims. J Am Geriatr Soc. 2023;71(2):516-27.
21. Hartholt KA, Oudshoorn C, Zielinski SM, Burgers PT, Panneman MJ, van Beeck EF, et al. The epidemic of hip fractures: are we on the right track? PLoS One. 2011;6(7):e22227.
22. Kanters TA, van de Ree CLP, de Jongh MAC, Gosens T, Hakkaart-van Roijen L. Burden of illness of hip fractures in elderly Dutch patients. Arch Osteoporos. 2020;15(1):11.

23. Kosten van ziekten in Nederland 2007. Trends in de Nederlandse zorguitgaven 1999–2010 [press release]. Bilthoven: RIVM2011.
24. Hemmann P, Friederich M, Korner D, Klopfer T, Bahrs C. Changing epidemiology of lower extremity fractures in adults over a 15-year period - a National Hospital Discharge Registry study. BMC Musculoskelet Disord. 2021;22(1):456.
25. Kazley JM, Banerjee S, Abousayed MM, Rosenbaum AJ. Classifications in Brief: Garden Classification of Femoral Neck Fractures. Clin Orthop Relat Res. 2018;476(2):441-5.
26. Shen M, Wang C, Chen H, Rui YF, Zhao S. An update on the Pauwels classification. J Orthop Surg Res. 2016;11(1):161.
27. Fixation using Alternative Implants for the Treatment of Hip fractures I. Fracture fixation in the operative management of hip fractures (FAITH): an international, multicentre, randomised controlled trial. Lancet. 2017;389(10078):1519-27.
28. Investigators H, Bhandari M, Einhorn TA, Guyatt G, Schemitsch EH, Zura RD, et al. Total Hip Arthroplasty or Hemiarthroplasty for Hip Fracture. N Engl J Med. 2019;381(23):2199-208.
29. Multidiciplinaire werkgroep Nederlandse Orthopaedische Vereniging & Nederlandse Vereniging voor Heelkunde Behandeling pertrochantere fracturen: Federatie Medisch Specialisten; 2016 [updated 1 september 2016. Available from: https://richtlijnendatabase.nl/richtlijn/proximale_femurfracturen/pertrochantere_femurfractuur/behandeling_pertrochantere_fracturen.html.
30. NICE. National Institute for Health and Care Excellence: Guidelines, Hip fracture management. 2020/02/20 ed2017.
31. American Academy of Orthopaedic Surgeons Management of Hip Fractures in Older Adults Evidence-Based Clinical Practice Guideline. : American Academy of Orthopaedic Surgeons 2021 [updated December 2021. Available from: https://www.aaos.org/hipfxcpg.pdf
32. Swart E, Makhni EC, Macaulay W, Rosenwasser MP, Bozic KJ. Cost-effectiveness analysis of fixation options for intertrochanteric hip fractures. J Bone Joint Surg Am. 2014;96(19):1612-20.
33. Bohl DD, Basques BA, Golinvaux NS, Miller CP, Baumgaertner MR, Grauer JN. Extramedullary compared with intramedullary implants for intertrochanteric hip fractures: thirty-day outcomes of 4432 procedures from the ACS NSQIP database. J Bone Joint Surg Am. 2014;96(22):1871-7.
34. Jones HW, Johnston P, Parker M. Are short femoral nails superior to the sliding hip screw? A meta-analysis of 24 studies involving 3,279 fractures. Int Orthop. 2006;30(2):69-78.
35. Pyrhonen HS, Lagergren J, Wolf O, Bojan A, Mukka S, Moller M, Rogmark C. No Difference in Conversion Rate to Hip Arthroplasty After Intramedullary Nail or Sliding Hip Screw for Extracapsular Hip Fractures: An Observational Cohort Study of 19,604 Individuals. 2022.
36. Gronhaug KML, Dybvik E, Matre K, Ostman B, Gjertsen JE. Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures : 17,341 patients from the Norwegian Hip Fracture Register. Bone Joint J. 2022;104-B(2):274-82.
37. Anglen JO, Weinstein JN, American Board of Orthopaedic Surgery Research C. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database. The Journal of bone and joint surgeryAmerican volume. 2008;90(4):700-7.
38. Mellema JJ, Janssen S, Schouten T, Haverkamp D, van den Bekerom MPJ, Ring D, et al. Intramedullary nailing versus sliding hip screw for A1 and A2 trochanteric hip fractures. Bone Joint J. 2021;103-B(4):775-81.
39. Forte ML, Virnig BA, Eberly LE, Swiontkowski MF, Feldman R, Bhandari M, Kane RL. Provider factors associated with intramedullary nail use for intertrochanteric hip fractures. The Journal of bone and joint surgeryAmerican volume. 2010;92(5):1105-14.

40. Garrison I, Domingue G, Honeycutt MW. Subtrochanteric femur fractures: current review of management. EFORT Open Rev. 2021;6(2):145-51.
41. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, et al. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma. 2007;21(10 Suppl):S1-133.
42. Dutch Hip fracture Audit (DHFA) DHFA report 2019: Dutch Instute for Clinical Auditing (DICA); 2019 [Available from: https://dica.nl/jaarrapportage-2019/dhfa.
43. Maravic M, Ostertag A, Cohen-Solal M. Subtrochanteric/femoral shaft versus hip fractures: incidences and identification of risk factors. J Bone Miner Res. 2012;27(1):130-7.
44. Wang Z, Bhattacharyya T. Trends in incidence of subtrochanteric fragility fractures and bisphosphonate use among the US elderly, 1996-2007. J Bone Miner Res. 2011;26(3):553-60.
45. Kremer J, Ottes L. Kwaliteitsdenken in de zorg: verleden, heden en toekomst. Den Haag: Raad voor Volksgezondheid & Samenleving; 2023.
46. Balzer-Geldsetzer M, Buecking B, Ruchholtz S, Kis B, Dodel R, Hessmann P. Association between longitudinal clinical outcomes in patients with hip fracture and their pre-fracture place of residence. Psychogeriatrics. 2020;20(1):11-9.
47. Hu F, Jiang C, Shen J, Tang P, Wang Y. Preoperative predictors for mortality following hip fracture surgery: a systematic review and meta-analysis. Injury. 2012;43(6):676-85.
48. Van de Ree CLP, Landers MJF, Kruithof N, de Munter L, Slaets JPJ, Gosens T, de Jongh MAC. Effect of frailty on quality of life in elderly patients after hip fracture: a longitudinal study. BMJ Open. 2019;9(7):e025941.
49. Nijmeijer WS, Folbert EC, Vermeer M, Slaets JP, Hegeman JH. Prediction of early mortality following hip fracture surgery in frail elderly: The Almelo Hip Fracture Score (AHFS). Injury. 2016;47(10):2138-43.
50. Van de Ree CL, Gosens T, Van der Veen AH, Oosterbos CJ, Heymans MW, De Jongh MA. Development and validation of the Brabant Hip Fracture Score for 30-day and 1-year mortality. Hip Int. 2020;30(3):354-62.
51. Morrison RS, Siu AL. Survival in end-stage dementia following acute illness. JAMA. 2000;284(1):47-52.
52. Loggers SAI, Van Balen R, Willems HC, Gosens T, Polinder S, Ponsen KJ, et al. The Quality of Dying in Frail Institutionalized Older Patients After Nonoperative and Operative Management of a Proximal Femoral Fracture: An In-Depth Analysis. Am J Hosp Palliat Care. 2023:10499091231180556.
53. Schuijt HJ, Lehmann LS, Javedan H, von Keudell AG, Weaver MJ. A Culture Change in Geriatric Traumatology: Holistic and Patient-Tailored Care for Frail Patients with Fractures. J Bone Joint Surg Am. 2021;103(18):e72.
54. Nijdam TMP, Laane DWPM, Schiepers TEE, Smeeing DPJ, Kempen DHR, Willems HC, van der Velde D. The goals of care in acute setting for geriatric patients in case of a hip fracture. Eur J Trauma Emerg Surg. 2023;49(4):1835-44.
55. Loggers SAI, Willems HC, Van Balen R, Gosens T, Polinder S, Ponsen KJ, et al. Evaluation of Quality of Life After Nonoperative or Operative Management of Proximal Femoral Fractures in Frail Institutionalized Patients: The FRAIL-HIP Study. JAMA Surg. 2022;157(5):424-34.
56. Loggers SAI, Geraerds A, Joosse P, Willems HC, Gosens T, Van Balen R, et al. Nonoperative versus operative management of frail institutionalized older patients with a proximal femoral fracture: a cost-utility analysis alongside a multicenter prospective cohort study. Osteoporos Int. 2023;34(3):515-25.

57. Nijdam TMP, Laane DWPM, Spierings JF, Schuijt HJ, Smeeing DPJ, van der Velde D. Proxy-reported experiences of palliative, non-operative management of geriatric patients after a hip fracture: a qualitative study. BMJ Open. 2022;12(8):e063007.
58. Mitchell SL, Palmer JA, Volandes AE, Hanson LC, Habtemariam D, Shaffer ML. Level of Care Preferences Among Nursing Home Residents With Advanced Dementia. J Pain Symptom Manage. 2017;54(3):340-5.
59. Spronk I, Loggers SAI, Joosse P, Willems HC, Van Balen R, Gosens T, et al. Shared decision making for the treatment of proximal femoral fractures in frail institutionalized older patients: healthcare providers' perceived barriers and facilitators. Age Ageing (in print). 2022.

PART

I

PART I

Epidemiology and costs of hip fractures over time

Chapter 2: Trends in incidence, health care consumption, and costs for proximal femoral fractures in the Netherlands between 2000-2019; a nationwide study

Chapter 3: Trends in incidence, health care use and costs for subtrochanteric femur fractures in the Netherlands 2000-2019



2

Trends in incidence, health care consumption, and costs for proximal femoral fractures in the Netherlands between 2000-2019; a nationwide study

Miliaan L. Zeelenberg, Dennis Den Hartog, Martien J.M. Panneman, Suzanne Polinder, Michiel H.J. Verhofstad, Esther M.M. Van Lieshout

Osteoporosis International 2023, Volume 34, Issue 8, Pages 1389-1399

Abstract

Purpose

The aim of this nationwide study was to provide an overview of the incidence rate and economic burden of acute femoral neck and trochanteric fractures in The Netherlands.

Methods

Data of patients who sustained acute proximal femoral fractures in the period January 1, 2000, to December 31, 2019, were extracted from the National Medical Registration of the Dutch Hospital Database. The incidence rate, hospital length of stay (HLOS), health care and lost productivity costs, and years lived with disability (YLD) were calculated for age- and sex-specific groups.

Results

A total of 357,073 patients were included. The overall incidence rate increased by 22% over the 20-year study period from 16.4 to 27.1/100,000 person-years (py). The age-specific incidence rate in elderly > 65 years decreased by 16% (from 649.1 to 547.6/100,000 py). The incidence rate in men aged > 90 has surpassed the incidence rate in women. HLOS decreased in all age groups, hip fracture subtypes, and sexes from a mean of 18.5 to 7.2 days. The mean health care costs, over the 2015-2019 period, were lower for men (€17,723) than for women (€23,351) and increased with age to €26,639 in women aged > 80. Annual cumulative costs reached €425M, of which 73% was spent on women.

Conclusion

The total incidence of hip fractures in The Netherlands has increased by 22%. Although incidence in the elderly population is decreasing and HLOS is at an all-time low, the burden of medical costs and crude numbers of proximal femoral fractures are still rising in our aging population.

Introduction

Proximal femoral fractures are one of the leading causes of disability and mortality in the elderly population worldwide (1, 2). Due to an aging population, the burden of disease is expected to increase further in the upcoming decades (3-5).

Proximal femoral fractures are generally subdivided into three subcategories: femoral neck, trochanteric, and subtrochanteric/proximal shaft fractures (6, 7). Proximal femoral fractures are most common in female and elderly patients. The elderly mainly sustain a hip fracture after a simple fall and these fractures are often associated with osteoporosis. Less than 10% of hip fractures occur in adults aged <50 years (8, 9). Fractures in the younger population are often associated with chronic, endocrine or neurological diseases, or high-energy trauma (10).

Hartholt *et al.* reported that between 1981 and 2008, the absolute number of hip fractures in the Netherlands doubled in patients aged 65 years or older (11). The incidence rates of hip fracture-related hospital admissions increased with age and the age-adjusted incidence rate increased from 52.0 to 67.6 per 10,000 persons per year. During the 25-year study, the total number of hospital days was reduced by a fifth, due to a reduced admission duration in all age groups. This study, however, also showed a worrying increasing trend of fracture incidence in men over 80 years, one of the fastest growing segments of aging societies, and forecasted more growth in fractures in this segment of the population. More than a decade later, this poses the question of whether we have adequately stemmed the trend by providing better care and more effective prevention measures and having more experience treating an aging population. Can we expect this epidemic of hip fractures to continue or have we already passed the peak?

No recent epidemiological analysis of the Dutch hip fracture population, in the last decade, has been published and few studies publish data on specific fracture locations. Population-based knowledge on the occurrence of specific fracture types and age groups is essential for the allocation of health care services, optimization of preventive measures, and providing a more accurate forecast for the future. The aims of this study were to examine long-term population-based trends in the incidence rate, trauma mechanism, and hospital length of stay and to assess the current health care costs, lost productivity costs, and years lived with disability for patients with femoral neck or trochanteric hip fractures, admitted to a hospital in the Netherlands between 2000 and 2019.

Methods

In this retrospective epidemiological study data were collected for patients admitted to a hospital in the Netherlands with a hip fracture in the period January 1, 2000, up to and including December 31, 2019. The methods are similar to previous studies (12-15). Injury cases were extracted from the National Medical Registration (LMR) of the Dutch Hospital Database (DHD), Utrecht, the Netherlands. The DHD collects hospital data from all hospitals in the Netherlands with a uniform classification system and has an almost complete national coverage (missing values < 5%, except in 2007 12%). These figures were extrapolated by the Netherlands knowledge center for injury prevention (VeiligheidNL) to full national coverage for each year. An extrapolation factor was estimated by comparing the adherence population of the participating hospitals with the total Dutch population each year using the population data obtained from Statistics Netherlands (16). Patients are included in the LMR for their main diagnosis at discharge, defined by the International Classification of Diseases (ICD) 9th and (since 2010) 10th revision. Codes for hip fractures are presented in Supplementary Table S1. Injuries include both traumatic and pathological fractures. This study mainly focused on the femoral neck and trochanteric fracture subtypes. Subtrochanteric fractures were considered a separate entity within the hip fracture population, with a different age distribution and larger proportion of high energy and pathological fractures (17). Subtrochanteric fractures, 3.9% of proximal femoral fracture in the 20-year study period, were therefore excluded from the analysis.

The study was exempted by the local Medical Research Ethics Committee Erasmus MC (MEC-2022-0326)

Outcome measures and analysis

Incidence rates

Age- and sex-specific incidence rates were calculated in 5-year age groups for each year of the study. Due to low incidence rates in the age groups below 50 years, those groups were combined in 0-24 and 25-50 years. Incidence rates were standardized for age (per age group) and sex using a direct standardization method, as used in previous studies (12). In short, the age- and sex-specific incidence rates per 100,000 person years were calculated based on the Dutch mid-year standard population (calculated using the formula $((N_{2005} + N_{2019})/2)$. In 2013 there was a change in diagnosis registration systems, leading to a decrease in registration numbers for this year and, to a lesser degree, the following 2 years.

Trauma mechanism and hospital length of stay

Data regarding hospital length of stay (HLOS) and trauma mechanism were extracted from the LMR database for the previously mentioned age groups. Trauma mechanisms were categorized as "fall due to all causes" versus "other". Fall included both domestic accidents (fall from person-height or fall from stairs) and non-domestic accidents such as fall from a bicycle or fall from height. To assess trends in HLOS and trauma mechanisms over time, the mean HLOS and percentage of trauma mechanisms were averaged over 5-year intervals from 2000 to 2019. Cumulative HLOS was calculated by multiplying the means per case with the total number of cases.

Health care costs and loss of productivity

To assess the current health care costs and loss of productivity, data on patient numbers and health care use were retrieved from the LMR database for 5-year age categories and males and females separately. These were supplemented with data from a patient follow-up survey with questions relating to health care use outside the hospital, work absence, and health-related quality of life (HRQoL) using the EQ-5D questionnaire, conducted in a random sample of patients at 2.5, 5, 9, and 24 months after injury (18). The Dutch Burden of Injury Model was used to assess the health care costs of injury (15, 19, 20). Health care costs of injuries were calculated by multiplication of the incidence, health care volumes (*e.g.*, length of stay in hospital or institution, the number of outpatient visits, general practitioner visits, home care hours, and physical therapy treatments), and unit costs (*e.g.*, costs per day in hospital). National guidelines for health care costing were used to estimate unit costs (21). Medical costs included ambulance care, in-hospital care, general practitioner (G.P.) care, home care, physical therapy, social support care, and rehabilitation/nursing home care.

Productivity costs were defined as the costs associated with production loss and replacement due to illness, disability, and premature death (22). Loss of productivity costs were assessed using data from the LMR and a patient survey on health care use as described previously (15, 18, 23). To estimate costs for productivity loss for all patients aged 15-64 years the absenteeism model was used. Additionally, the friction cost method was used because healthcare needs are most substantial in the first year after injury for the majority of injuries (24). To calculate the annual costs, data were averaged for the 2015-2019 period. For all cost calculations 2019 was used as the index year. Costs were calculated for the previously mentioned age-categories and for males and females separately.

Years lived with disability

The number of years lived with disability (YLD) was calculated as described previously (12, 15, 21). HRQL was assessed using the EQ-5D questionnaire, mentioned above

(18). The YLD was obtained by linking the incidence data (subdivided into injury diagnosis groupings) with disability information which is the proportion of injury cases with lifelong consequences, and injury-specific disability weights of temporary and lifelong consequences. The disability weights were derived from empirical follow-up data on the health-related quality of life of individual trauma patients and adjusted for population norms, age, and gender (18, 25). The disability weight reflects the impact of a health condition in terms of health-related quality of life; it has a value ranging from 1, indicating the worst imaginable health state, to 0, indicating full health (25). To assess the trends over time, data were averaged over 5-year intervals from 2000-2019. Data were calculated for the previously mentioned age categories and for males and females separately.

Available data did not allow for extrapolation of costs and YLD for hip fracture subtypes. Analyses for both costs and YLD were all performed for the combined fracture population including femoral neck and trochanteric fractures.

Results

Incidence rates

Between 2000 and 2019, 357,073 patients were admitted with a femoral neck (224,307) or trochanteric fracture (132,766) in the Netherlands. Figure 1A,B shows the total number of femoral neck and trochanteric fractures per year. During the study period, the total number of femoral neck and trochanteric fractures shows an increasing trend for both sexes.

Figure 1C,D shows the incidence rates per 100,000 person years (py) for both fracture locations. In femoral neck fractures, men showed an increasing trend (35.7/100,000 py in 2000 to 53.0/100,000 py in 2019), while the incidence in women remained relatively constant over time (96.8/100,000 py in 2000 to 96.2/100,000 py in 2019). Trochanteric fracture incidence increased both in men (from 16.4 to 27.1/100,00 py) and in women (from 48.4 to 64.1/100,000 py). Overall this amounts to an increase of 22% in incidence rate across both subtypes of fractures over the 20-year period (99.1 to 120.5/100,000 py).

Despite this overall increase in incidence rate, the elderly of 65 years and older (Table 1) display a different trend. In this subgroup, incidence even decreased by 16% overall (from 649.2 per 100,000 py in 2000 to 547.6 per 100,000 py in 2019). This can primarily be attributed to a decrease in female >65 years fracture incidence 850.0 to 706.5 per 100,000 py (-17%) versus 358.5 to 362.5 per 100,000 py (0.1% increase) for males.

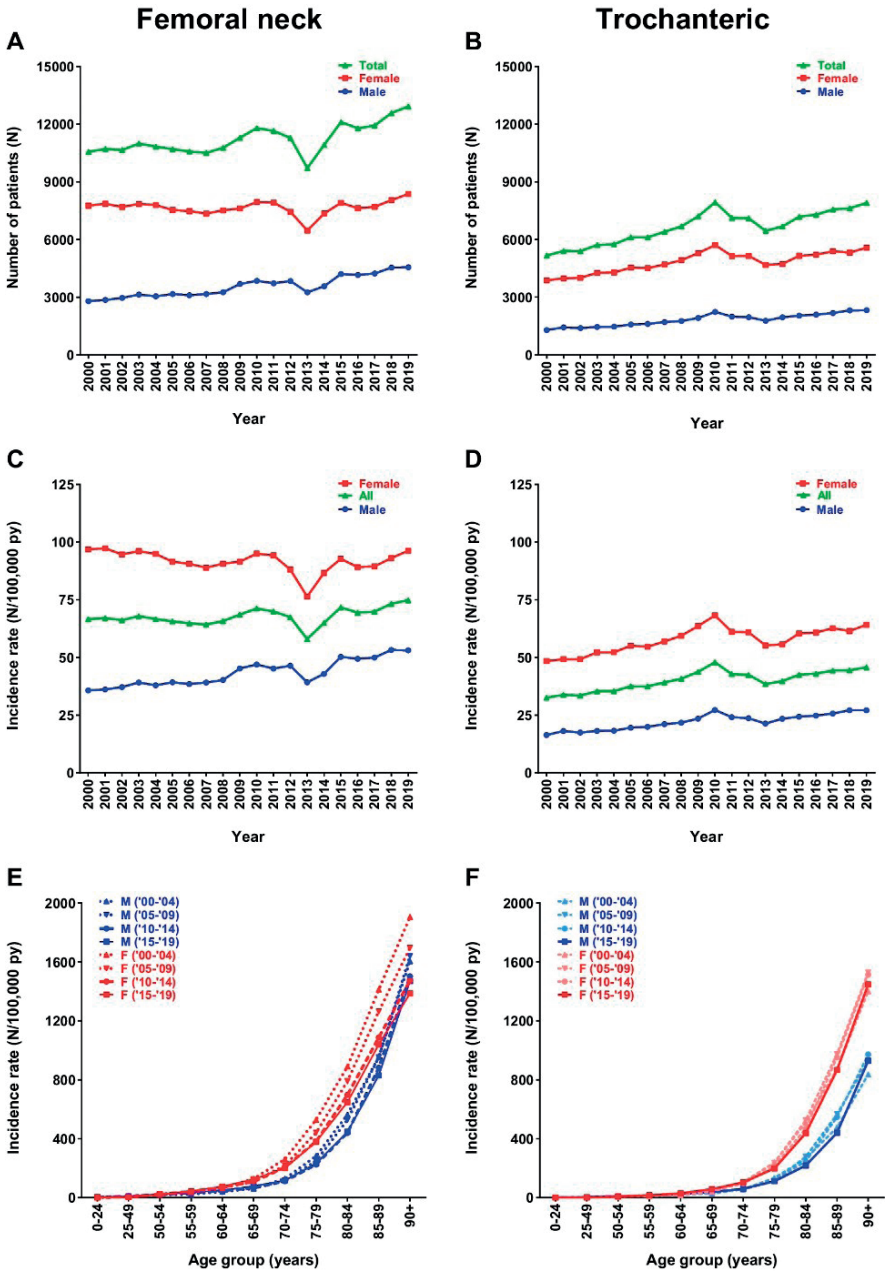


Figure 1: Patient numbers (A and B), incidence rate (per 100,000 person-years) (C and D), and age-related incidence (per 100,000 person-years) (E and F) of femoral neck fractures (A, C, and E) and trochanteric fractures (B, D, and F) in the Netherlands in the years 2000-2019

Data are shown for all patients (green) and for males (blue) and females (red) separately. For Figures E and F, data are averaged over 5-year periods (*i.e.*, 2000-2004, 2005-2009, 2010-2014, and 2015-2019) and are shown for 0-24 years, 25-50 years, and subsequently in 5-year age groups up to and including 90+.

In the same time period the incidence rates of femoral neck fractures in all patients >65 years decreased by 23% (431.5 to 332.4 per 100,000 py), where trochanteric fracture rate decreased by only 1.1% (217.7 to 215.2 per 100,000 py).

Figure 1E,F shows the age-specific incidence rate for the four consecutive 5-year time periods of the study. Incidence rates increase with age for both fracture types, but the increase becomes less prominent over time. However, in femoral neck fractures, incidence rates for men in the highest age group (2015-2019; 90+ years) have surpassed incidence in women (men 1,470/100,000 py versus women 1,386/100,000 py). While age specific incidence rates have decreased over time in femoral neck fractures, in trochanteric fractures, an increase in incidence rate could be seen up to 2010 in the highest age group in men, after which incidence rates stop increasing and seem to have plateaued in the most recent years. The overall incidence in trochanteric fractures has slightly decreased in the most recent five-year period in both sexes.

Table 1: Age related incidence rates (per 100,000 person-years) of femoral neck and trochanteric fractures for both sexes in 2000 and 2019

Age group	Femoral neck						Trochanteric					
	2000			2019			2000			2019		
	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total
Incidence rate[1]												
< 50 years	5.2	2.9	4.0	5.7	2.5	4.1	2.2	0.9	1.6	2.5	0.9	1.7
≥ 50 years	111.2	289.9	207.3	127.6	230.0	180.6	51.3	146.0	102.2	65.7	154.4	111.6
≥ 65 years	245.8	559.7	431.5	239.2	412.5	332.4	112.7	290.3	217.7	123.4	294.0	215.2
≥ 80 years	759.8	1,239.0	1,094.1	673.8	911.3	819.7	353.5	751.9	631.4	357.2	769.7	610.7
Total	35.7	96.8	66.6	53.0	96.2	74.8	16.4	48.4	32.5	27.1	64.1	45.7

[1]Incidence rates per 100,000 person-years

Trauma mechanism

The proportion of patients sustaining a femoral neck or trochanteric fracture due to a fall increased with age from 65.0% and 62.5% in the 0-24 age group to 97.3% and 98.0% in the 90+ age group for femoral neck and trochanteric fractures, respectively (Supplementary Figure S1). This effect remained fairly constant over time in the 4 study periods. During the entire study period, the proportion of falls was consistently slightly higher in women than in men, except for the youngest age group. In the 0-24 year age group in 2015-2019, men show a notably larger fall percentage than women for both fracture types (femoral neck: 73.8% versus 67.9%, trochanteric: 65.5% versus 42.9%).

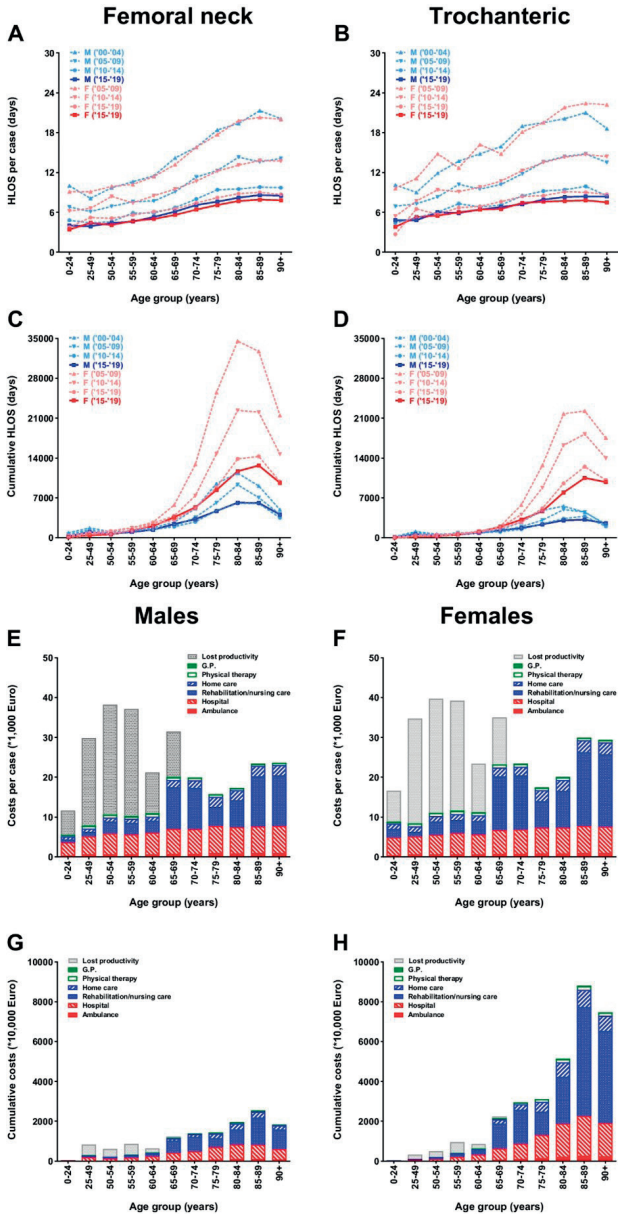


Figure 2: Age-related hospital length of stay per case (A and B), total hospital length of stay (C and D), direct medical costs, indirect medical costs, and loss of productivity costs per case (E and F), and total population costs (G and H)

Data are averaged over 5-year periods (*i.e.*, 2000-2004, 2005-2009, 2010-2014, and 2015-2019) and are shown for 0-24 years, 25-50 years, and subsequently in 5-year age groups up to and including 90+. HLOS data is shown for the cervical neck (A and C) and trochanteric (B and D) fracture subgroups separately with blue for male and red for female patients. Costs data is shown for the combination of both fracture types and is split between males (E and G) and females (F and H). Costs described are mean annual costs per case (E and F) and annual total population costs (G and H) over the 2015-2019 period.

Hospital length of stay

Hospital length of stay in four consecutive five-year periods for both fracture categories is shown in Figure 2. Mean HLOS per patient (Figure 2 A,B) has decreased over time for both fracture types, from an overall mean of 18.4 days in 2000-2004 to 7.2 days in 2015-2019. The magnitude of this decrease is declining in the more recent time periods. In the most recent time period (2015-2019), the mean HLOS per case was similar in femoral neck fractures (7.0 days) and in trochanteric fractures (7.5 days). For both fracture types, HLOS increased with age up to the 85-89 age group and decreased slightly in the 90+ age group. The mean HLOS per patient in 2015-2019 is similar in men (7.3 days) and in women (7.2 days).

Total HLOS due to femoral neck and trochanteric fractures (Figures 2C,D) increased with age following the incidence trends and, correspondingly, decreases in more recent cohorts. Total HLOS per year (Table 2) in the 2015-2019 cohort is higher in femoral neck fractures (86,439 days), than in trochanteric fractures (56,363 days). In this time period, total HLOS per year for women (95,478 days) was two times higher than in men (47,324 days).

Table 2: Age related yearly hospital length-of-stay (HLOS) per case and total yearly HLOS for femoral neck and trochanteric fractures for both sexes in 2015-2019

Age group	Femoral neck			Trochanteric		
	Males	Females	Total	Males	Females	Total
HLOS per case						
< 50 years	3.90	4.18	3.98	4.83	5.06	4.88
≥ 50 years	7.36	7.05	7.16	7.72	7.51	7.57
≥ 65 years	7.83	7.32	7.48	7.97	7.59	7.69
≥ 80 years	8.43	7.78	7.98	8.37	7.70	7.85
Total	7.12	7.01	7.05	7.54	7.49	7.50
HLOS total						
< 50 years	1,205	510	1,715	686	204	890
≥ 50 years	29,649	55,074	84,723	15,784	39,690	55,473
≥ 65 years	26,639	51,264	77,903	14,039	37,910	51,949
≥ 80 years	16,317	33,986	50,303	8,728	28,203	36,932
Total	30,855	55,584	86,439	16,470	39,894	56,363

HLOS, Hospital length-of-stay

Health care costs and lost productivity

The annual health care costs in the period 2015-2019 were €425M. These costs can be split into €116M (27%) for men and €310M (73%) for women. An overview of costs per case (E-F) and total population costs (G-H) is shown in Figure 2. The mean health care costs per case are €17,723 for men and €23,351 for women (Table 3). For both sexes costs per patient increased with age, this increase was more prominent in women (up to a maximum at >80 years of €21,162 for men and €26,639 for women). Total healthcare costs also increase with age and peak at 85-89 years for both sexes. The main cost driver is rehabilitation/nursing care, with up to €7,958 per case for men versus up to €12,789 per case for women (Table 4). Costs per case <50 years were substantially lower for both sexes (mean €7,638) than in the ≥50 year age groups, and increase evenly with increasing age. Costs in the <50 age group make up only 1.1% (€4.6M) of the cumulative yearly costs, with patients ≥80 making up 65.1% (€277M) of the cumulative yearly costs.

Between 2015 and 2019, an annual average of 860 (13.1% of total) men and 641 (4.8% of total) women suffered work absenteeism due to their hip fracture, with a mean duration of absence per case of 402 days in males and 472 days in females. Costs per case due to lost productivity were slightly higher for females (Figure 2E, F), with a mean of €20,366 for men and €21,240 for women. The total costs of lost productivity, due to both types of fracture were higher in men (annual total of €17.5M) than in women (annual total of €13.6M) (Table 4). The total combined health care and loss of productivity costs amounted to €456M and increased with age following the pattern of incidence (Figure 2G,H). Loss of productivity makes up only 6.8% of this total number. Men have a lower total combined cost per patient than women (€20,408 versus €24,379). Due to higher incidence rates, women also had substantially higher total costs for health care and lost productivity combined (€323M) than men (€133M).

Table 3: Yearly age related medical costs per case and cumulative medical costs for femoral neck and trochanteric hip fractures in males and females in 2015-2019

Age group	Males	Females	Total
Costs per case (€)			
< 50 years	7,366	8,394	7,638
≥ 50 years	18,492	23,537	21,939
≥ 65 years	19,886	24,652	23,218
≥ 80 years	21,162	26,639	25,158
Total	17,723	23,351	21,495
Cumulative costs (€)			
< 50 years	3,333,144	1,363,150	4,685,294
≥ 50 years	112,260,582	308,179,972	420,440,554
≥ 65 years	102,706,682	295,921,622	398,628,304
≥ 80 years	63,006,286	214,014,216	277,020,502
Total	115,582,726	309,543,122	425,125,848

Table 4: Direct and indirect costs per case and for complete population by gender

Cost determinant Costs/case (€)		Male		Female	
		Total Costs (€)	Costs/case (€)	Total costs (€)	
Direct costs	Ambulance care	777	5,046,216	812	10,768,460
	Hospital care	6,236	40,672,488	6,367	84,397,984
	Rehabilitation/Nursing care	7,958	51,897,250	12,789	169,533,298
	Home care	2,105	13,730,496	2,654	35,175,664
	Physical therapy	560	3,651,784	635	8,420,506
	G.P. care	87	566,492	94	1,247,210
	Total direct costs	17,723	115,582,726	23,351	309,543,122
Indirect costs	Productivity loss[1]	20,366	17,511,129	21,240	13,618,093
Total costs	Total costs[2]	20,408	133,093,855	24,379	323,161,215

[1]Only for population with loss of productivity

[2]Average for the complete population including patient with and without loss of productivity

GP, general practitioner

Years lived with disability

YLD per case declined approximately linearly with age from 4.2 years in the 0-24 age group to 0.59 years in the 90+ age group, with a mean of 1.3 years (Supplementary Figure S2). This decline seemed unrelated to sex, although YLD for women was higher than for men, especially in the 0-24 age group (5.1 versus 3.7). Total YLD increased

with age following the overall hip fracture incidence pattern and peaks at the 75-79 age group for men (1,057 years) and the 80-84 age group for women (2,596 years). The total cumulative annual YLD due to femoral neck and trochanteric fractures was 24,764 years.

Discussion

Between 2000 and 2019 a total of 357,073 patients sustained a femoral neck or trochanteric fracture in the Netherlands. Across the study period, the data show an increase in combined femoral neck and trochanteric fracture incidence, while it shows a decrease in fracture incidence in the elderly (>65) population. It further shows that while HLOS is decreasing, total health care costs due to hip fractures continue to rise in the aging Dutch population.

During this 20-year period, the overall incidence rate of femoral neck and trochanteric fractures increased by 22%. This increase can be mostly attributed to an increase in femoral neck fractures in men and an increase in trochanteric fractures in both sexes. A study by Hartholt *et al.* (11) reported an increase of 20.6% over the years 1981-2008 in patients ≥ 65 years in a similar nationwide study. They reported an incidence rate of 66.5/10,000 py in the elderly. The current study shows an incidence rate of 62.9 /10,000 for patients ≥ 65 years in 2008, which decreased to 54.8/10,000 py in 2019 (13% decrease). This effect was strongest in women. So while the overall incidence rate has increased, the incidence rate in elderly patients is decreasing. Answering the question posed by Hartholt *et al.*; "Are we on the right track?", in terms of incidence in the elderly population, we are. This change in incidence, however, can largely be explained by population dynamics. While the current study finds an increasing number of hip fractures each year, an increase of 18% in absolute numbers from 2008 to 2019, the ≥65 population has increased by 37% in the same time period. Other factors, outside the scope of this study, that are likely lowering hip fracture incidence in the elderly are the increase in anti-osteoporosis drug use, more awareness of nutritional deficiencies (specifically calcium and vitamin D), exercise, fall prevention, and other fracture prevention and awareness programs (26-29). This study's findings of decreasing incidence in the elderly, in contrast with increasing crude numbers, are also consistent with other recent European and Japanese studies (30-34).

This study also found that the incidence rate of femoral neck fractures in men, in the highest age group (>90 years), while decreasing over time, has surpassed incidence in women. Incidence is decreasing faster in women than in men. This trend was already described by Hartholt *et al.* and has persisted in the previous decade (11). Possible

explanations are more effective diagnosis and treatment of osteoporosis in women and faster growth of this age segment (approximate 1000% increase for men versus 700% for women) of the male population in the previous two decades (16, 35). More attention should be paid to the subpopulation of elderly men in future fracture prevention campaigns to prevent further expansion of this trend.

This study shows a gradual decrease in both mean and total HLOS over time, a decrease that is shrinking in size and seems to be moving towards a plateau. Hartholt *et al.* (11) reported decreasing HLOS since 1981 and presented a mean HLOS of 14 days in 2008. Current data showed a mean of 7.2 days over the 2015-2019 period, which indicates that the downward trend has persisted, at least until recently. While crude numbers of hip fractures and overall incidence are increasing, the total burden on hospital occupancy for this group is decreasing and now constitutes 1.7% of total yearly hospital occupancy based on data from Statistics Netherlands (16). This trend can be explained by several developments in the past decades including the implementation of dedicated clinical pathways, improved surgical techniques and revalidation, and changes in health care organizations that moved a large proportion of revalidation and treatment outside the initial hospital stay (36, 37).

The average health care cost per patient, is €17,723 for men and €23,351 for women. This difference is even more evident when comparing the total cumulative costs, where women make up 73% of total health care costs, mainly due to the large difference in incidence rate between the sexes. In 2007 the Dutch National institute for public health and the environment reported a total healthcare cost for hip fractures of €102M for men and €276M for women (0.39% of the total yearly health care expenditure) (38). This increased to €130M and €331M in 2017 (0.48% of total expenditure), an increase of 17% (39). Findings of the current study, using the average costs over the 2015-2019 period are consistent with these numbers and those found in other studies, and show an increasing trend in health care costs of hip fractures (39, 40). The costs per patient are higher than those of other fracture types and hip fracture is the most costly fracture subtype in total health care cost, and poses a significant strain on national healthcare expenditure (14, 15, 23, 39, 41). Loss of productivity plays a marginal role in the total cumulative costs due to the mainly geriatric population, costing only 6.8% of the total yearly economic burden. Relatively low productivity costs with a long average work absence of 431 days can be explained by the use of the friction cost method for cost calculation, as employers generally replace long absent workers to reduce productivity loss (22).

The mean YLD per case in patients with a proximal femoral fracture in the Netherlands is 1.3 years, and this decreases with advancing age. This is likely caused by decreased

life expectancy for elderly patients with hip fractures and lower baseline life expectancy before fracture for elderly patients. Hagen *et al.*, in a 2020 Norwegian study, reports an average YLD of 0.83 years for women and 0.92 for men in the 55+ age group (42). While our mean YLD is higher, the current data included the complete population including younger patients with higher expected YLD values. Cultural differences may also have attributed to this difference.

The strength of this study is that it provides a nationwide overview of femoral neck and trochanteric hip fracture incidence rates, HLOS, costs for health care and lost productivity, and YLD, and provides a continuation of previous epidemiological research in the Dutch population. Secondly, it is the first nationwide study providing incidence numbers on specific hip fracture subtypes with long-term trends and reliable population-based data. Like any population-based study, however, the current study also has limitations. Due to a change in registration systems, the crude numbers and incidence rates for the year 2014 and to a lesser degree adjacent years are lower than expected, as most likely cases have not been registered (correctly). These numbers should be interpreted with care. Registration quality was restored in the following years which still allowed an accurate analysis of fracture trends and incidence over the two-decade period. Patient selection using ICD codes in the LMR uses only patients' main diagnosis at discharge, usually the most severe injury. Patients with more severe injuries than hip fractures could be missing. Another limitation is the lack of clinical information about patients and injury mechanisms. Most injuries, however, can be expected to be low-energy traumatic hip fractures in elderly (osteoporotic) patients with relative certainty. The diversity in trauma mechanism and patient characteristics will be higher in the younger population, although the incidence in this group is much lower. Secondary injuries could affect HLOS and YLD. This study was specifically focused on the Dutch population and the Dutch healthcare system. This makes the extrapolation of results to other countries challenging, especially concerning costs, as most countries use different valuations and healthcare frameworks. Trends in incidence, HLOS, and costs can however be compared to assess the international changes in the burden of disease and the progress of the hip fracture epidemic.

Conclusion

This study shows an increase in the femoral neck and trochanteric fracture incidence of 22% across the 2000-2019 study period, although the age-specific incidence ≥65 years is decreasing in recent years. This trend was strongest in elderly female patients with femoral neck fractures and affirms the effect of improved operation techniques, healthcare organization and (pharmacological) prevention campaigns of the past decades. In contrast, male incidence rates of femoral neck fractures in the 90+ age category have surpassed female incidence. This subpopulation could benefit from more attention in future hip fracture prevention and management campaigns. In the past 20 years, HLOS has decreased in all age groups, hip fracture subtypes, and sexes from an average of 18.4 to 7.2 days. The average healthcare costs over the 2015-2019 period are higher in women, costing €17,723 for men versus €23,351 for women, and rise with increasing age. Yearly cumulative costs in the same period reach €425M, with women accounting for 73% of these costs. The total costs for lost productivity is €31M (€20,366 for men versus €21,240 for women), and makes up only 6.8% of the total combined cost burden. YLD decreases with age and is similar between sexes. Although hip fracture incidence in the elderly population is decreasing and HLOS is at an all-time low, the societal burden of costs and crude numbers of hip fractures are still rising in our aging population.

References

1. Fakhry SM, Shen Y, Biswas S, Duane TM, McBride KM, Elkbuli A, et al. The public health burden of geriatric trauma: Analysis of 2,688,008 hospitalizations from Centers for Medicare and Medicaid Services inpatient claims. J Trauma Acute Care Surg. 2022;92(6):984-9. https://doi.org/10.1097/TA.0000000000003572
2. Kanis JA, Oden A, McCloskey EV, Johansson H, Wahl DA, Cooper C, et al. A systematic review of hip fracture incidence and probability of fracture worldwide. Osteoporos Int. 2012;23(9):2239-56. https://doi.org/10.1007/s00198-012-1964-3.
3. Jennison T, Brinsden M. Fracture admission trends in England over a ten-year period. Ann R Coll Surg Engl. 2019;101(3):208-14. https://doi.org/10.1308/rcsann.2019.0002.
4. Rosengren BE, Karlsson MK. The annual number of hip fractures in Sweden will double from year 2002 to 2050: projections based on local and nationwide data. Acta Orthop. 2014;85(3):234-7. https://doi.org/10.3109/17453674.2014.916491.
5. Cooper C, Campion G, Melton LJ, 3rd. Hip fractures in the elderly: a world-wide projection. Osteoporos Int. 1992;2(6):285-9. https://doi.org/10.1007/BF01623184.
6. AO foundation. AO classification proximal femur fractures: Arbeitsgemeinschaft für Osteosynthesefragen (AO); 2023 [updated 2020. Available from: https://surgeryreference.aofoundation.org/orthopedic-trauma/adult-trauma/proximal-femur.
7. WHO. International Statistical Classification of Diseases and Related Health Problems 10th Revision, version 2019: WHO; 2019 [updated 2019. Available from: https://icd.who.int/browse10/2019/en#/.
8. Lin JC, Wu CC, Lo C, Liang WM, Cheng CF, Wang CB, et al. Mortality and complications of hip fracture in young adults: a nationwide population-based cohort study. BMC Musculoskelet Disord. 2014;15:362. https://doi.org/10.1186/1471-2474-15-362.
9. Omari A, Madsen CM, Lauritzen JB, Jorgensen HL, Vojdeman FJ. Comorbidity and mortality after hip fracture in nineteen thousand six hundred and eighty two patients aged eighteen to sixty five years in Denmark from 1996 to 2012. Int Orthop. 2019;43(11):2621-7. https://doi.org/10.1007/s00264-019-04323-z.
10. Wang MT, Yao SH, Wong P, Trinh A, Ebeling PR, Tran T, et al. Hip fractures in young adults: a retrospective cross-sectional study of characteristics, injury mechanism, risk factors, complications and follow-up. Arch Osteoporos. 2017;12(1):46. https://doi.org/10.1007/s11657-017-0339-y.
11. Hartholt KA, Oudshoorn C, Zielinski SM, Burgers PT, Panneman MJ, van Beeck EF, et al. The epidemic of hip fractures: are we on the right track? PLoS One. 2011;6(7):e22227. https://doi.org/10.1371/journal.pone.0022227.
12. Leliveld MS, Polinder S, Panneman MJM, Verhofstad MHJ, Van Lieshout EMM. Epidemiologic trends for isolated tibia shaft fracture admissions in The Netherlands between 1991 and 2012. Eur J Trauma Emerg Surg. 2020;46(5):1115-22. https://doi.org/10.1007/s00068-018-01072-3.
13. De Boer AS, Schepers T, Panneman MJM, Van Beeck EF, Van Lieshout EMM. Health care consumption and costs due to foot and ankle injuries in the Netherlands, 1986-2010. BMC Musculoskelet Disord. 2014;15:128. https://doi.org/10.1186/1471-2474-15-128.
14. Mahabier KC, Den Hartog D, Van Veldhuizen J, Panneman MJM, Polinder S, Verhofstad MHJ, et al. Trends in incidence rate, health care consumption, and costs for patients admitted with a humeral fracture in The Netherlands between 1986 and 2012. Injury. 2015;46(10):1930-7. https://doi.org/10.1016/j.injury.2015.07.025.

15. Polinder S, Iordens GIT, Panneman MJM, Eygendaal D, Patka P, Den Hartog D, et al. Trends in incidence and costs of injuries to the shoulder, arm and wrist in The Netherlands between 1986 and 2008. BMC Public Health. 2013;13:531. https://doi.org/10.1186/1471-2458-13-531.
16. Statistics Netherlands: Dutch Demographics and Population Prognosis.: Statistics Netherlands (CBS); 2022 [Available from: https://opendata.cbs.nl/statline/#/CBS/en/dataset/83474ENG/table?ts=1659532503170.
17. Garrison I, Domingue G, Honeycutt MW. Subtrochanteric femur fractures: current review of management. EFORT Open Rev. 2021;6(2):145-51. https://doi.org/10.1302/2058-5241.6.200048.
18. Polinder S, van Beeck EF, Essink-Bot ML, Toet H, Looman CW, Mulder S, et al. Functional outcome at 2.5, 5, 9, and 24 months after injury in the Netherlands. J Trauma. 2007;62(1):133-41. https://doi.org/10.1097/TA.0b013e31802b71c9.
19. Meerding WJ, Mulder S, van Beeck EF. Incidence and costs of injuries in The Netherlands. Eur J Public Health. 2006;16(3):272-8. https://doi.org/10.1093/eurpub/ckl006.
20. Polinder S, Meerding WJ, van Baar ME, Toet H, Mulder S, van Beeck EF, et al. Cost estimation of injury-related hospital admissions in 10 European countries. J Trauma. 2005;59(6):1283-90; discussion 90-1. https://doi.org/10.1097/01.ta.0000195998.11304.5b.
21. Polinder S, Haagsma JA, Toet H, van Beeck EF. Epidemiological burden of minor, major and fatal trauma in a national injury pyramid. Br J Surg. 2012;99 Suppl 1:114-21. https://doi.org/10.1002/bjs.7708.
22. Koopmanschap MA, Rutten FF, van Ineveld BM, van Roijen L. The friction cost method for measuring indirect costs of disease. J Health Econ. 1995;14(2):171-89. https://doi.org/10.1016/0167-6296(94)00044-5.
23. Leliveld MS, Polinder S, Panneman MJM, Verhofstad MHJ, van Lieshout EMM. Health care and productivity costs for isolated tibia shaft fracture admissions in The Netherlands. Acta Orthop Belg. 2020;86(2):320-6.
24. Van Beeck EF, Van Roijen L, Mackenbach JP. Medical costs and economic production losses due to injuries in the Netherlands. J Trauma. 1997;42(6):1116-23. https://doi.org/10.1097/00005373-199706000-00023.
25. Haagsma JA, Polinder S, Lyons RA, Lund J, Ditsuwan V, Prinsloo M, et al. Improved and standardized method for assessing years lived with disability after injury. Bull World Health Organ. 2012;90(7):513-21. https://doi.org/10.2471/BLT.11.095109.
26. Van der Burgh AC, de Keyser CE, Zillikens MC, Stricker BH. The Effects of Osteoporotic and Non-osteoporotic Medications on Fracture Risk and Bone Mineral Density. Drugs. 2021;81(16):1831-58. https://doi.org/10.1007/s40265-021-01625-8.
27. Gillespie LD, Robertson MC, Gillespie WJ, Sherrington C, Gates S, Clemson LM, et al. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2012(9):CD007146. https://doi.org/10.1002/14651858.
28. Nederlandse Vereninging voor Reumatologie. Dutch Guideline osteoporosis and fracture prevention (Richtlijn osteoporose en fractuurpreventie). Utrecht; 2011.
29. Avenell A, Mak JC, O'Connell D. Vitamin D and vitamin D analogues for preventing fractures in post-menopausal women and older men. Cochrane Database Syst Rev. 2014(4):CD000227. https://doi.org/10.1002/14651858.CD000227.pub4.
30. Talbot S, Denton H, Dodds MK, Lynch D. Changing trends in hip fracture epidemiology in the Republic of Ireland: a follow-up study. Arch Osteoporos. 2022;17(1):79. https://doi.org/10.1007/s11657-022-01112-x.

31. Korhonen N, Niemi S, Parkkari J, Sievanen H, Palvanen M, Kannus P. Continuous decline in incidence of hip fracture: nationwide statistics from Finland between 1970 and 2010. Osteoporos Int. 2013;24(5):1599-603. https://doi.org/10.1007/s00198-012-2190-8.
32. Imai N, Endo N, Shobugawa Y, Ibuchi S, Suzuki H, Miyasaka D, et al. A decrease in the number and incidence of osteoporotic hip fractures among elderly individuals in Niigata, Japan, from 2010 to 2015. J Bone Miner Metab. 2018;36(5):573-9. https://doi.org/10.1007/s00774-017-0863-2.
33. Lippuner K, Rimmer G, Stuck AK, Schwab P, Bock O. Hospitalizations for major osteoporotic fractures in Switzerland: a long-term trend analysis between 1998 and 2018. Osteoporos Int. 2022 https://doi.org/10.1007/s00198-022-06481-0.
34. Hemmann P, Friederich M, Korner D, Klopfer T, Bahrs C. Changing epidemiology of lower extremity fractures in adults over a 15-year period - a National Hospital Discharge Registry study. BMC Musculoskelet Disord. 2021;22(1):456. https://doi.org/10.1186/s12891-021-04291-9.
35. Willson T, Nelson SD, Newbold J, Nelson RE, LaFleur J. The clinical epidemiology of male osteoporosis: a review of the recent literature. Clin Epidemiol. 2015;7:65-76. https://doi.org/10.2147/CLEP.S40966.
36. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, et al. Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet. 2015;385(9978):1623-33. https://doi.org/10.1016/S0140-6736(14)62409-0.
37. Burgers PTPW, Van Lieshout EMM, Verhelst J, Dawson I, de Rijcke PA. Implementing a clinical pathway for hip fractures; effects on hospital length of stay and complication rates in five hundred and twenty six patients. Int Orthop. 2014;38(5):1045-50. https://doi.org/10.1007/s00264-013-2218-5.
38. Kosten van ziekten in Nederland 2007. Trends in de Nederlandse zorguitgaven 1999–2010 [press release]. Bilthoven: RIVM2011.
39. RIVM. Kosten van ziekten 2017: RIVM; 2019 [updated 29-10-2019. Available from: https://statline.rivm.nl/#/RIVM/nl/dataset/50050NED/table?ts=1659597701111.
40. Kanters TA, van de Ree CLP, de Jongh MAC, Gosens T, Hakkaart-van Roijen L. Burden of illness of hip fractures in elderly Dutch patients. Arch Osteoporos. 2020;15(1):11. https://doi.org/10.1007/s11657-019-0678-y.
41. Prins JTH, Wijffels MME, Wooldrik SM, Panneman MJM, Verhofstad MHJ, Van Lieshout EMM. Trends in incidence rate, health care use, and costs due to rib fractures in the Netherlands. Eur J Trauma Emerg Surg. 2021 https://doi.org/10.1007/s00068-021-01662-8.
42. Hagen G, Magnussen J, Tell G, Omsland T. Estimating the future burden of hip fractures in Norway. A NOREPOS study. Bone. 2020;131:115156. https://doi.org/10.1016/j.bone.2019.115156.

Supplementary materials

Table S1. Proximal femur fractures classified in ICD-9 and ICD-10

Fracture region	Fracture closed or open	ICD-9[a]	ICD-10
Femoral neck	Closed femoral neck fracture	820.0	S72.0
	Open femoral neck fracture	820.1	S72.0
Pertrochanteric	Closed pertrochanteric fracture	820.2	S72.1
	Open pertrochanteric fracture	820.3	S72.1
Subtrochanteric	Closed subtrochanteric fracture	820.22	S72.2
	Open subtrochanteric fracture	820.32	S72.2

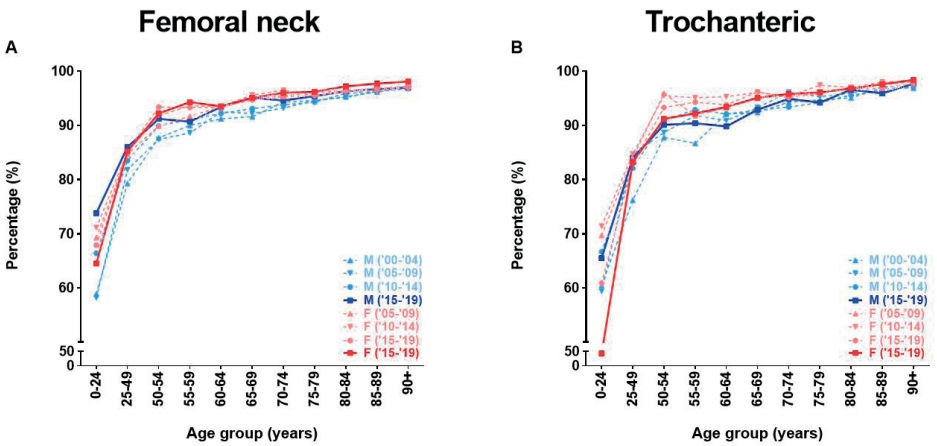


Figure S1: Age-related proportion of patients sustaining a femoral neck fracture (A) or trochanteric fracture (B) due to a fall in the years 2000-2019

Data are averaged over 5-year periods (*i.e.*, 2000-2004, 2005-2009, 2010-2014, and 2015- 2019) and are shown for 0-24 years, 25-50 years, and subsequently in 5-year age groups up to and including 90+.

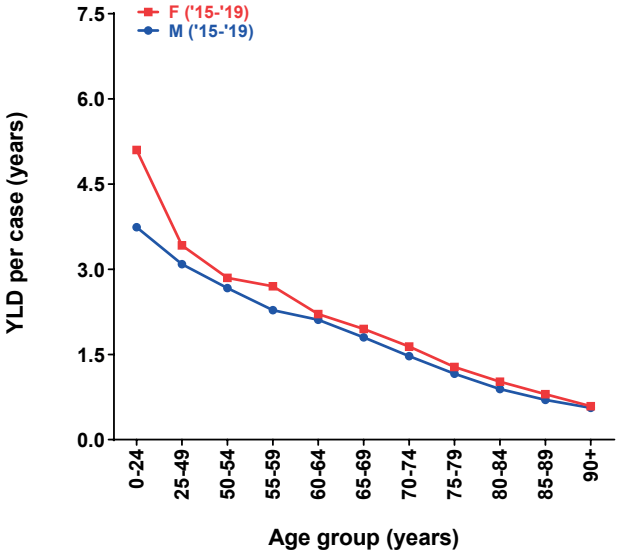


Figure S2: Age-related years lived with disability per patient with a proximal femoral fracture
Data (averaged for the years 2015-2019) are shown for males (blue) and females (red) in age groups of: 0-24 years, 25-50 years and subsequently in 5-year age groups up to and including 90+.



3

Trends in incidence, health care use and costs for subtrochanteric femur fractures in the Netherlands 2000-2019

Miliaan L. Zeelenberg, Esther M.M. Van Lieshout, Suzanne Polinder, Martien J.M. Panneman, Michiel H.J. Verhofstad, Dennis Den Hartog

Injury 2024 Volume 55, Issue 4, Pages 111461

Abstract

Objective

This study aimed to provide population based trends in incidence rate, hospital length of stay (HLOS), trauma mechanism, and costs for healthcare and lost productivity of subtrochanteric femur fractures in the Netherlands.

Methods

Data on patients with subtrochanteric femur fractures sustained between January 1, 2000 and December 31, 2019 were extracted from the National Medical Registration of the Dutch Hospital Database. Incidence rates, HLOS, health care and productivity costs were calculated in sex- and age-specific groups.

Results

A total of 14,399 patients sustained a subtrochanteric fracture in the 20-year study period. Incidence rates in the entire population dropped by 15.5 % from 4.5 to 3.8 per 100,000 person years (py). This decline was larger in women (6.4 to 5.2 per 100,000 py, -19.8 %) than in men (2.6 to 2.5 per 100,000 py, -4.0 %). HLOS declined by 62.5 % from a mean of 21.6 days in 2000-2004 to 8.1 days in 2015-2019. Subtrochanteric fractures were associated with total annual costs of €15.5 M, of which 91 % (€14.1 M) were health care costs and €1.3 M were costs due to lost productivity. Mean healthcare costs per case were lower in men (€16,394) than in women (€23,154).

Conclusion

The incidence rates and HLOS of subtrochanteric fractures in the Netherlands have decreased in the 2000-2019 study period and subtrochanteric fractures are associated with a relatively small total annual cost of €15.5 M. Increasing incidence rates and a bimodal age distribution, described in previous studies from other European countries, were not found in the Dutch population.

Introduction

Hip fractures are the most common fracture to cause hospital admission in the Netherlands, with over 20,000 fractures each year (1, 2). Hip fractures are generally classified into three categories: femoral neck, trochanteric, and subtrochanteric fractures (3). The first two, or typical hip fractures; they are the most common, are mostly seen in the elderly population, and are generally associated with osteoporosis and/or low-energy trauma (4). Subtrochanteric fractures are located up to 5 cm distal from the lesser trochanter and occur in an area between trabecular and cortical bone where high levels of mechanical stress can occur (5, 6). They make up 3-4% of annual hip fracture admissions in the Netherlands (7). Subtrochanteric fractures are considered difficult to manage and associated with a higher risk of (sequelae of) complications, such as secondary (mal)displacement, implant failure, non-unions and reoperations (8, 9).

In contrast to femoral neck and trochanteric fractures, subtrochanteric fractures follow a bimodal age distribution (6). Fractures generally occur in young men due to high-energy trauma or in older patients with osteoporosis, often with an atypical fracture presentation. Recent studies also found positive associations between subtrochanteric fractures and sustained bisphosphonate use or diabetes (10-12). Reported incidence rates are much lower than those of typical hip fractures. Wang *et al.* reported a 9.6% increase (from 31.2 to 34.2 per 100,000 person-years) in the incidence of subtrochanteric fractures in the US between 1996 and 2007 in women (13). In contrast, typical hip fracture incidence decreased by 32% (1020.5 to 697.4 per 100,000 person-years) in the same period. Another study found an increase in incidence for combined subtrochanteric and femoral shaft fractures for both sexes, also contrasted by decreasing typical hip fracture incidence (14).

Whether these incidence changes and sex specific differences also hold true for the Dutch population is currently unknown, as no nationwide study on the burden of disease of subtrochanteric fractures in the Dutch population exists. Changes in incidence could provide targets for future research and (inter)national comparisons of disease burden and associated costs. Therefore, the aim of this study was to provide an overview of age and sex trends in incidence, hospital stay, and costs associated with subtrochanteric fractures in the Netherlands between 2000-2019.

Methods

Data for this retrospective epidemiological study were collected for patients admitted to hospitals in the Netherlands between January 1, 2000 and December 31, 2019, with a subtrochanteric fracture diagnosis. Methods used were similar as in previous studies (15-19) and data were extracted simultaneously with the data on femoral neck and trochanteric fractures (2). Injury cases were extracted from the National Medical Registration (LMR) of the Dutch Hospital Database (DHD), Utrecht, The Netherlands. Patients are included in the LMR for their main diagnosis at discharge, defined by the International Classification of Diseases (ICD) 9th and (since 2010) 10th revision. All patients labeled with an ICD-9 code of 820.22 or ICD-10 code of 72.2, including al subdivisions, were classified as patients with a subtrochanteric fracture and were included in this analysis. Injuries include both traumatic and pathological fractures. These figures were then extrapolated to full national coverage for each year by the Dutch Consumer and Safety Institute ('VeiligheidNL').

Outcome measures

Outcome measures included sex- and age-specific incidence rates, hospital length of stay (HLOS), trauma mechanism, and costs for health care and lost productivity. Trauma mechanism was categorized as "fall due to all causes" versus "other". Costs for lost productivity were defined as the costs associated with production loss and replacement due to illness, disability, and premature death. Outcomes were calculated for 5-year age groups for each year of the study. Because of low patient numbers in the age groups below 50 years, the five-year groups were combined into 0-24 and 25-50 years. To calculate annual health care and productivity costs, data were averaged for the 2015-2019 period. For all costs calculations the reference year 2019 was used.

All analyses and calculations of outcomes were conducted as previously described (15-19). Table 1 summarizes the performed analysis per outcome measure.

Table 1 Summary of performed analysis per included outcome measure

Outcome measure	Summary of performed analysis
Incidence rates	Patient numbers were extracted from the LMR database. Direct standardization (based upon the Dutch mid-year standard population) was used in order to calculate incidence rates stratified for 5-year age groups and sex and reported per 100,000 person years.
Trauma mechanism	Data (patient numbers for subtrochanteric fracture by fall or by other causes) were extracted from the LMR database, stratified for age groups and sex. Fall included both domestic accidents (fall from person-height or fall from stairs) and non-domestic accidents such as fall from a bicycle or fall from height. The percentage of each trauma mechanism was calculated stratified for 10-year age groups and sex
HLOS	Data (HLOS per case and total HLOS) were extracted from the LMR database, stratified for 5-year age groups and sex
Health care costs	Data on patient numbers and healthcare use were extracted from the LMR database, stratified for age groups and sex. The Dutch Burden of Injury Model was used to assess the health care costs of injury (17, 19, 20). Patients were followed up to two years after trauma. Health care costs of injuries were calculated by multiplication of the incidence, health care volumes, and unit costs (as stated in national guidelines for healthcare costing (21)). Medical costs included ambulance care, in-hospital care, general practitioner (G.P.) care, home care, physical therapy, social support care, and rehabilitation/nursing home care. To calculate annual health care costs, data were averaged for the 2015-2019 period.
Productivity costs	Data on the number of patients unable to work after their fracture and the duration of their work absence were extracted by Dutch Consumer and Safety Institute for all patients aged 15-65 years. Costs were calculated using the Dutch Burden of Injury Model [18, 20, 21]. The friction cost method was used as health care needs are most substantial in the first year after injury [22]. To calculate annual costs for lost productivity, data were averaged for the 2015-2019 period.

Results

Incidence rates

A total of 14,399 patients were admitted with a subtrochanteric fracture in the 20-year study period. The annual number of admissions showed a slightly decreasing trend and a minor decline from 715 to 658 (-8.0%) over the two decade period, with more fractures in women than in men. (Figure 1A). The incidence rate also declines over time and dropped, by 15.5% from 4.5 (in 2000) to 3.8 (in 2019) per 100,000 py (Figure 1B). This decline was larger in women (6.4 to 5.2 per 100,000 py, -19.8%) than in men (2.6 to 2.5 per 100,000 py, -4.0%).

Figure 1C shows the age-specific incidence rates for the four consecutive 5-year time periods. Incidence increases with age across all four time periods, with a steep rise seen in patients of 75 years and older. In the most recent period (2015-2019), the highest incidence rates were 62.4 per 100,000 py in men aged >90 years and 101.2 per 100,000 py in women aged >90 years. Incidence rates (2015-2019) were higher for women in all

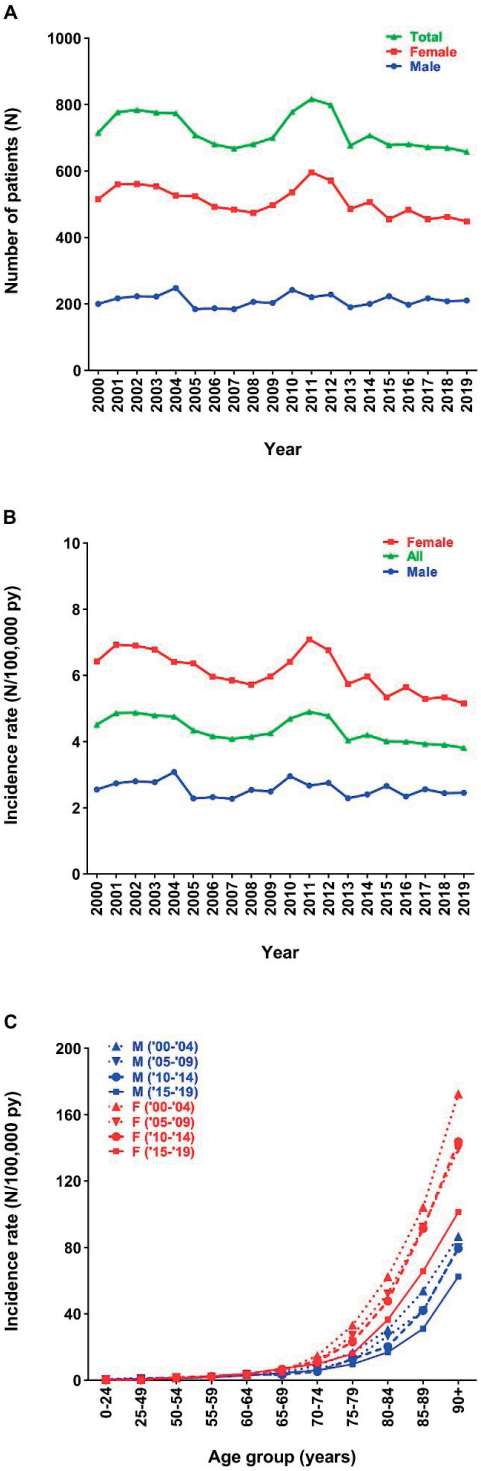


Figure 1: Number of patients (A), incidence rates per 100,000 person-years (B), and age-related incidence rates per 100,000 person-years (C) of subtrochanteric fractures in the Netherlands in the 2000-2019 study period

Data are shown separately for males (blue), females (red) and all patients (green). For Figure C, data are averaged over 5-year periods (*i.e.*, 2000-2004, 2005-2009, 2010-2014, and 2015-2019) and are shown for 0-24 years, 25-50 years, and subsequently in 5-year age groups up to and including 90+.

age-segments, except for the 0-24 (0.39 versus 0.29 per 100,000 py) and 25-50 years age groups, where incidence rates in men were over three times higher than in women (0.83 versus 0.26 per 100,000 py).

Similar to incidence rates, age-specific incidence rates have also declined over time from 2000-2019, from 27.4 to 15.9 per 100,000 py, in patients aged >65 years (-41.9%) and from 0.7 to 0.4 per 100,000 py in patients ≤50 years (-40.6%). All other age segments also showed declining incidence over time (Table 2). This effect was more pronounced in women than in men.

Trauma mechanism

The percentage of patients sustaining a subtrochanteric fracture due to a fall from any height increased with age (Figure 2A). In the most recent time period (2015-2019), 57.1% of patients under 25 years were admitted with a subtrochanteric fracture due to a fall. In patients over 65 years this proportion was 95%. Figure 2A shows high variation between the four time periods but the numbers of admissions due to fall generally increase with age. Patients up to 55 years show a decreasing trend for both men and women in the most recent time period, whereas the trends for older age groups (over 55 years) have remained relatively stable over time.

Table 2: Age- and sex related incidence rates (per 100,000 person-years) of subtrochanteric fractures in 2000 and 2019

	2000						2019					
	Males		Females		Total		Males		Females		Total	
	n	Incidence	n	Incidence	n	Incidence	n	Incidence	n	Incidence	n	Incidence
< 50 years	53	0.95	22	0.41	75	0.68	28	0.53	14	0.27	42	0.41
≥ 50 years	147	6.52	493	18.78	640	13.11	182	5.46	434	12.11	616	8.90
≥ 65 years	122	13.87	468	36.77	590	27.41	145	9.48	383	21.47	528	15.93
≥ 80 years	61	40.30	315	90.26	376	75.15	73	23.70	256	52.15	329	41.19
Total	200	2.55	515	6.42	715	4.51	210	2.45	448	5.15	658	3.81

[1]Incidence rates per 100,000 person-years

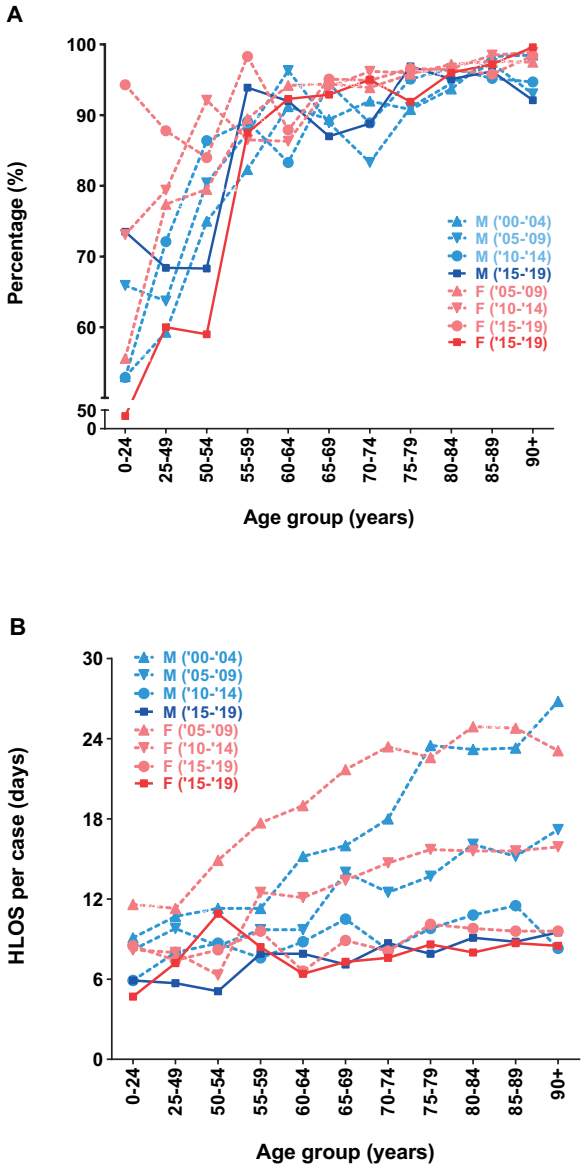


Figure 2: Percentage of patients per age group sustaining a subtrochanteric fracture due to a fall (A) and age-related hospital length of stay per case (B) for patients with a subtrochanteric fracture in the 2000-2019 period

Data are averaged over 5-year periods (*i.e.*, 2000-2004, 2005-2009, 2010-2014, and 2015-2019) and are shown for 0-24 years, 25-50 years, and subsequently in 5-year age groups up to and including 90+.

Hospital length of stay

HLOS in patients across all ages has declined by 62.5% from a mean of 21.6 days in 2000-2004 to 8.1 days in 2015-2019 (Figure 2B). This declining trend has decreased in size in the more recent time periods and moves towards a plateau. HLOS increases with age from a mean of 5.4 days at 0-24 years to a mean of 8.7 days in patients over 90 years (2015-2019). This age-related trend has decreased substantially when compared to the 2000-2004 period (9.1 at 0-24 years versus 26.8 at 90+ years). Men (7.9 days) and women (8.1 days) shows similar mean HLOS in the most recent period (2015-2019) (Table 3). Mean HLOS in patients under 50 years (5.77 days) is substantially lower than in patients over 50 years (8.2 days). Annual cumulative HLOS in the same period reached a total of 5,410 days, of which 30.6% (1,658 days) was attributed to men and 69.4% (3,752 days) to women. Cumulative HLOS has decreased by 67% from an annual 16,496 days in 2000-2005 to 5,410 days in 2015-2019.

Table 3: Annual age-related hospital length-of-stay per case and annual total hospital length-of-stay for subtrochanteric fractures in the 2015-2019 period

	Males			Females			Total		
	n	HLOS/ case	Total HLOS	n	HLOS/ case	Total HLOS	n	HLOS/case	Total HLOS
< 50 years	33	5.72	186	14	5.90	83	47	5.77	269
≥ 50 years	178	8.25	1,472	447	8.22	3,669	625	8.23	5,141
≥ 65 years	145	8.50	1,235	404	8.25	3,331	549	8.32	4,566
≥ 80 years	75	9.07	680	278	8.42	2,340	353	8.56	3,020
Total	211	7.86	1,658	461	8.14	3,752	672	8.06	5,410

HLOS, hospital length-of-stay

Health care costs and lost productivity

Between 2015-2019 subtrochanteric fractures were associated with total annual costs of €15.5M, of which €14.1M were health care costs and €1.3M were costs due to lost productivity (Table 4). Of the total health care costs, 75.5% (€10.7M) was spent on women and 24.5% (€3.5M) on men. The largest health care cost drivers for both sexes were rehabilitation or nursing care (€7,113 per case for men versus €12,699 for women), hospital care (€5,974 per case for men and €6,313 for women), home care (€1,906 per case for men and €2,611 for women), and physical therapy (€560 per case for men and €634 for women). The majority (91.6%) of health care costs were made in patients aged ≥65 years (Table 4). Mean costs per case were lower in men (€16,394)

than in women (€23,154). Health care costs increased with age from a mean of €7,512 in patients under 50 years to mean of €25,539 in patients aged 80 years and older. Of the total annual number of patients, 181 (26.9% of total) suffered work absenteeism due to subtrochanteric fractures. Only 27 (15.0%) of these patients were female. The costs per case associated with lost productivity were €20,203 for men and €21,570 for women.

Table 4: Annual health care costs determinants and loss of productivity costs for both sexes in 2015-2019 period, including age-specific medical costs

Cost determinant n/year		Male			Female		
		Costs/ case (€)	Total costs (€)	n/year	Costs/ case (€)	Total costs (€)	
Direct costs	Ambulance care	211	736	155,194	461	803	396,648
	Hospital care	211	5,974	1,260,596	461	6,313	2,907,746
	Rehabilitation/Nursing care	211	7,113	1,500,750	461	12,699	5,849,194
	Home care	211	1,926	406,332	461	2,611	1,202,762
	Physical therapy	211	560	118,062	461	634	292,126
	G.P. care	211	86	18,164	461	94	43,446
Indirect costs	Productivity loss[1]	38	20,203	762,750	27	21,570	586,137
Total costs	Total costs[2]	211	20,009	4,221,848	461	24,427	11,251,061

Age specific direct (medical) costs	Male			Female		
	n/year	Costs/case (€)	Total costs (€)	n/year	Costs/case (€)	Total costs (€)
< 50 years	33	7,065	230,308	14	8,555	119,770
≥ 50 years	178	18,099	3,228,790	447	23,612	10,545,154
≥ 65 years	145	19,808	2,880,130	404	24,929	10,061,164
≥ 80 years	75	21,148	1,586,074	278	26,725	7,424,118
Total	211	16,394	3,459,098	461	23,154	10,664,924

All costs are averaged over the 2015-2019 period and are calculated for index-year 2019.
[1]Only for population with loss of productivity
[2]Average for complete population including patients with and without loss of productivity
GP, general practitioner

Discussion

This is the first nationwide study on the incidence rate and societal burden of subtrochanteric fractures in the Netherlands. This study found a decrease in the incidence rate of subtrochanteric fractures, across all age groups and sexes, of 15.5% over the 2000-2019 study period. In the same timeframe, HLOS per case due to subtrochanteric fractures declined by 62.6% to a mean of 8.1 days. Total health care and lost productivity costs associated with subtrochanteric fractures were €15.5M per year.

Very few studies have been published on the incidence or costs of subtrochanteric fractures. Subtrochanteric fractures are an infrequent injury with an overall incidence rate of 3.81 per 100,000 py in the Netherlands. A French study in patients over 50 years found an incidence of 16.8 per 100,000 py for men and 41.2 per 100,000 py in women, for combined subtrochanteric and diaphyseal fractures in 2008 (14). It showed an increase of 32% in men and 13% in women since 2002. A study from the USA also reported increasing subtrochanteric fracture incidence rates over the 1996-2007 study period (20.4% increase to 34.2 per 100,000 py in women, no significant increase in men to 15.4 per 100,000 py) (13). The current data show a decreasing incidence in both the complete population and also in patients >50 years (-16.% for men and -35.5% for women), across the whole study period. In contrast to both Wang *et al.* and Maravic *et al.*, incidence rates in this study for, specifically 2008, were lower at 6.2 per 100,000 py for men over 50 years and 15.5 per 100,000 py for women over 50 years, a decrease of, respectively, -16% and -22% since 2002. The international differences and inclusion of also diaphyseal fractures could explain the inflated incidence rates found in the study by Maravic *et al.* Both studies could not provide an explanation for its increasing incidence rates over time but mentioned a possible association with increased bisphosphonate usage. Our data do not confirm this trend. Since 2011 a new GP guideline for osteoporosis treatment has changed the indication for bisphosphonates to only high fracture-risk patients and their annual daily doses prescribed decreased from 84M doses in 2013 to 74M doses in 2019 (-11%) while the elderly population steadily increased (20-22). However, the decreasing trend in fracture incidence was already clearly visible before 2011 and might be more related to a general increase in (hip) fracture and osteoporosis prevention campaigns, medication and awareness, than a decrease in bisphosphonate usage. In literature, subtrochanteric fractures are known to have a bimodal incidence, with a peak in young adults, often described in males between 20 and 40 years, and a second peak at elderly age (6, 23-25). In this study, incidence increased with advancing age but no clear peak can be found in the 0-24 or 25-49 age groups, for both sexes. However, younger men do show a higher incidence in these age groups than women. While subtrochanteric fractures, and hip fractures in general, are an injury most common in older women, the higher likelihood for high-

energy trauma in younger men will have increased these incidence rates (26, 27). These differences, all below 0.6 per 100,000 py, are overshadowed by incidence rates well over 50 per 100,000 py in older patients. Smaller peaks in the younger age groups could have been masked by the larger 25-year range of the two youngest age groups.

Subtrochanteric fractures form only a small portion of the total burden of hip fractures in the Netherlands. With an incidence of 120.5 (femoral neck/trochanteric) versus 3.8 (subtrochanteric) per 100,000 py in 2019 for the whole Dutch population, the burden of subtrochanteric fractures is small when compared to other hip fracture subtypes (2). This is also reflected in the cost of subtrochanteric fractures. Although subtrochanteric fractures are expensive injuries per patient when compared to other trauma cases like rib, ankle, humerus, or tibia fractures, at €21,030 health care costs per patient (16, 17, 19, 28). They have similar, though slightly higher, costs when compared with cervical neck or trochanteric fractures (€21,495) from a previous study (2). Due to lower incidence, the total annual health care costs of subtrochanteric fractures are 'only' €14.1M. An amount that is over 30 times outnumbered by the total costs €425.1M for the other hip fracture subtypes (2). The total costs of lost productivity are even lower at an annual total of €1.3M in 65 patients. While rare in the working population, subtrochanteric fractures can lead to long periods of absence (mean 438 days) and are associated with a high cost per case.

HLOS for subtrochanteric fractures follows the general decreasing pattern seen in other injuries and has decreased from a mean of 21.6 days in 2000 to 8.1 days in 2019 (1, 15, 17, 19). The effect of age on HLOS has also decreased over time. It has changed from a difference of 11.7 days between the youngest and oldest age groups (0-24 years and 90+ years) in 2000-2004, to a difference of 3.2 days in 2015-2019. These changes can be explained by the implementation of dedicated clinical pathways, improved surgical and rehabilitation techniques, and changes in health care organization that moved large parts of the treatment and revalidation process out of the hospital (29, 30). Annual total HLOS is only 5,410 days, less than 4% of HLOS due to all hip fracture subtypes (2).

Although subtrochanteric fractures are only a small fraction of the total hip fracture burden, more insight into their epidemiology and costs can lead to a better (inter) national overview of (hip-)fracture subtypes and related future health care demands. Future research should focus on establishing if there is a causal link between bisphosphonate use and major changes in (atypical) subtrochanteric fracture incidence.

This is the first study on trends in incidence and costs of subtrochanteric fractures in the Dutch population and, although a with a smaller sample size then compared to other hip

fracture subtypes, it provides reliable population-based data from the National Hospital database over a 20-year period. Like other population-based studies, it has limitations. Subtrochanteric fracture patients were selected based on ICD codes from the LMR and researchers did not receive or interpret individual patient data including specific operation characteristics or patients' comorbidities that could influence HLOS or costs. Outcomes should be interpreted on a population level. The LMR categorizes patients based on exclusively their main diagnosis, which is generally their most severe injury. While hip fracture is a severe injury and is often isolated, especially in the elderly, fractures in polytrauma patients could be missed. This may have deflated the incidence rates, especially in younger patients. Also, no distinction could be made between diagnoses in the calculation of HLOS, as patients with a main diagnosis of subtrochanteric fracture could have longer HLOS due to other injuries. Although ICD-codes are validated for differentiating between hip fracture subtypes, no distinction could be made between pathological, typical, or atypical subtrochanteric fractures (31). As a result no changes in incidence and possible associations with medication used (i.e. bisphosphonate use), based on different subtrochanteric fracture subtypes or risk factors could be studied. Due to a national change in registration systems, the crude numbers and incidence rates for the year 2013 and are lower than expected and are higher than expected for the preceding years 2010-2012, as most likely cases have not been correctly registered (for the right year). While adequate registration was restored in the following years, these numbers should be interpreted with care. A final limitation is the fact that this study focused on the Dutch healthcare system. This makes interpretation and extrapolation of results to other nations challenging. However, trends in incidence, HLOS, and costs could be of value in international comparisons of changes in the (economical) burden of disease.

Conclusion

Subtrochanteric fractures are a relatively infrequent subtype of hip fracture with an incidence rate in 2019 of 3.81 per 100,000 py. Incidence is higher in women and shows a steep increase in the 75+ age-groups. In the two-decade (2000-2019) study period its incidence has decreased by 15.5% for the complete Dutch population. This decrease was larger in women (-19.8%) than in men (-3.0%). Increasing incidence rates, possibly linked to bisphosphonate usage, and a bimodal age distribution found in previous international studies, were not found in the Dutch population. HLOS consistently decreased over time with 62.6% from 21.6 days to 8.1 days in 2015-2019. In this latest period the cumulative annual HLOS was 5,410 days. Subtrochanteric fractures were associated with healthcare costs per patient of €16,394 for men and €23,154 for women. The total annual burden of costs in the 2015-2019 period was €14.1M in healthcare costs with an additional €1.4M in costs due to lost productivity.

References

1. CBS. Hospital admissions and patient diagnosis (Ziekenhuisopnamen en -patiënten; diagnose-indeling): Centraal Bureau Statistiek (Dutch Central Bureau for Statistics) 2022 [updated 16-06-2022. Available from: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84069NED/table?ts=1670493690817
2. Zeelenberg ML, Den Hartog D, Panneman MJM, Polinder S, Verhofstad MHJ, Van Lieshout EMM. Trends in incidence, health care consumption, and costs for proximal femoral fractures in the Netherlands between 2000 and 2019: a nationwide study. Osteoporos Int. 2023 https://doi.org/10.1007/s00198-023-06774-y.
3. WHO. International Statistical Classification of Diseases and Related Health Problems 10th Revision, version 2019: WHO; 2019 [updated 2019. Available from: https://icd.who.int/browse10/2019/en#/.
4. Kanis JA, Oden A, McCloskey EV, Johansson H, Wahl DA, Cooper C, et al. A systematic review of hip fracture incidence and probability of fracture worldwide. Osteoporos Int. 2012;23(9):2239-56. https://doi.org/10.1007/s00198-012-1964-3.
5. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, et al. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma. 2007;21(10 Suppl):S1-133. https://doi.org/10.1097/00005131-200711101-00001.
6. Garrison I, Domingue G, Honeycutt MW. Subtrochanteric femur fractures: current review of management. EFORT Open Rev. 2021;6(2):145-51. https://doi.org/10.1302/2058-5241.6.200048.
7. Dutch Hip Fracture Audit. DHFA report 2019: Dutch Instute for Clinical Auditing (DICA); 2019 [Available from: https://dica.nl/jaarrapportage-2019/dhfa.
8. Kasha S, Yalamanchili RK. Management of subtrochanteric fractures by nail osteosynthesis: a review of tips and tricks. Int Orthop. 2020;44(4):645-53. https://doi.org/10.1007/s00264-019-04404-z.
9. Horner NS, Samuelsson K, Solyom J, Bjorgul K, Ayeni OR, Ostman B. Implant-Related Complications and Mortality After Use of Short or Long Gamma Nail for Intertrochanteric and Subtrochanteric Fractures: A Prospective Study with Minimum 13-Year Follow-up. JB JS Open Access. 2017;2(3):e0026. https://doi.org/10.2106/JBJS.OA.17.00026.
10. Dell RM, Adams AL, Greene DF, Funahashi TT, Silverman SL, Eisemon EO, et al. Incidence of atypical nontraumatic diaphyseal fractures of the femur. J Bone Miner Res. 2012;27(12):2544-50. https://doi.org/10.1002/jbmr.1719.
11. Kharwadkar N, Mayne B, Lawrence JE, Khanduja V. Bisphosphonates and atypical subtrochanteric fractures of the femur. Bone Joint Res. 2017;6(3):144-53. https://doi.org/10.1302/2046-3758.63.BJR-2016-0125.R1.
12. Papapoulos S, Bone H, Cosman F, Dempster DW, McClung MR, Nakamura T, et al. Incidence of Hip and Subtrochanteric/Femoral Shaft Fractures in Postmenopausal Women With Osteoporosis in the Phase 3 Long-Term Odanacatib Fracture Trial. J Bone Miner Res. 2021;36(7):1225-34. https://doi.org/10.1002/jbmr.4284.
13. Wang Z, Bhattacharyya T. Trends in incidence of subtrochanteric fragility fractures and bisphosphonate use among the US elderly, 1996-2007. J Bone Miner Res. 2011;26(3):553-60. https://doi.org/10.1002/jbmr.233.
14. Maravic M, Ostertag A, Cohen-Solal M. Subtrochanteric/femoral shaft versus hip fractures: incidences and identification of risk factors. J Bone Miner Res. 2012;27(1):130-7. https://doi.org/10.1002/jbmr.517.

15. Leliveld MS, Polinder S, Panneman MJM, Verhofstad MHJ, Van Lieshout EMM. Epidemiologic trends for isolated tibia shaft fracture admissions in The Netherlands between 1991 and 2012. Eur J Trauma Emerg Surg. 2020;46(5):1115-22. https://doi.org/10.1007/s00068-018-01072-3.
16. De Boer AS, Schepers T, Panneman MJM, Van Beeck EF, Van Lieshout EMM. Health care consumption and costs due to foot and ankle injuries in the Netherlands, 1986-2010. BMC Musculoskelet Disord. 2014;15:128. https://doi.org/10.1186/1471-2474-15-128.
17. Mahabier KC, Den Hartog D, Van Veldhuizen J, Panneman MJM, Polinder S, Verhofstad MHJ, et al. Trends in incidence rate, health care consumption, and costs for patients admitted with a humeral fracture in The Netherlands between 1986 and 2012. Injury. 2015;46(10):1930-7. https://doi.org/10.1016/j.injury.2015.07.025.
18. Polinder S, Iordens GIT, Panneman MJM, Eygendaal D, Patka P, Den Hartog D, et al. Trends in incidence and costs of injuries to the shoulder, arm and wrist in The Netherlands between 1986 and 2008. BMC Public Health. 2013;13:531. https://doi.org/10.1186/1471-2458-13-531.
19. Prins JTH, Wijffels MME, Wooldrik SM, Panneman MJM, Verhofstad MHJ, Van Lieshout EMM. Trends in incidence rate, health care use, and costs due to rib fractures in the Netherlands. Eur J Trauma Emerg Surg. 2021 https://doi.org/10.1007/s00068-021-01662-8.
20. Meerding WJ, Mulder S, van Beeck EF. Incidence and costs of injuries in The Netherlands. Eur J Public Health. 2006;16(3):272-8. https://doi.org/10.1093/eurpub/ckl006.
21. Polinder S, Meerding WJ, van Baar ME, Toet H, Mulder S, van Beeck EF, et al. Cost estimation of injury-related hospital admissions in 10 European countries. J Trauma. 2005;59(6):1283-90; discussion 90-1. https://doi.org/10.1097/01.ta.0000195998.11304.5b.
22. Koopmanschap MA, Rutten FF, van Ineveld BM, van Roijen L. The friction cost method for measuring indirect costs of disease. J Health Econ. 1995;14(2):171-89. https://doi.org/10.1016/0167-6296(94)00044-5.
23. NHG. NHG Richtlijn Osteoporose en fractuurpreventie: Nederlands Huisarts Genootschap (NHG); 2011 [updated 2011. Available from: https://richtlijnen.nhg.org/multidisciplinaire-richtlijnen/osteoporose-en-fractuurpreventie.
24. Stichting Farmaceutische Kengetallen. Bisfosfonaatgebruik bij osteoporose neemt af. Pharmaceutisch Weekblad. 2016;9(151)
25. Zorginstituut Nederland. Open data usage of farmaceuticals: Zorginstituut Nederland (Dutch health care institute); 2023 [updated 09-05-2023. Available from: https://www.gipdatabank.nl/.
26. Bedi A, Toan Le T. Subtrochanteric femur fractures. Orthop Clin North Am. 2004;35(4):473-83. https://doi.org/10.1016/j.ocl.2004.05.006.
27. Ng AC, Drake MT, Clarke BL, Sems SA, Atkinson EJ, Achenbach SJ, et al. Trends in subtrochanteric, diaphyseal, and distal femur fractures, 1984-2007. Osteoporos Int. 2012;23(6):1721-6. https://doi.org/10.1007/s00198-011-1777-9.
28. Waddell JP. Subtrochanteric fractures of the femur: a review of 130 patients. J Trauma. 1979;19(8):582-92. https://doi.org/10.1097/00005373-197908000-00006.
29. Schoeneberg C, Kauther MD, Hussmann B, Keitel J, Schmitz D, Lendemans S. Gender-specific differences in severely injured patients between 2002 and 2011: data analysis with matched-pair analysis. Crit Care. 2013;17(6):R277. https://doi.org/10.1186/cc13132.
30. Pape M, Giannakopoulos GF, Zuidema WP, de Lange-Klerk ESM, Toor EJ, Edwards MJR, et al. Is there an association between female gender and outcome in severe trauma? A multi-center analysis in the Netherlands. Scand J Trauma Resusc Emerg Med. 2019;27(1):16. https://doi.org/10.1186/s13049-019-0589-3.

31. Leliveld MS, Polinder S, Panneman MJ, Verhofstad MHJ, Van Lieshout EMM. Health care and productivity costs for isolated tibia shaft fracture admissions in The Netherlands. Acta Orthop Belg. 2020;86(2):320-6.
32. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, et al. Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet. 2015;385(9978):1623-33. https://doi.org/10.1016/S0140-6736(14)62409-0.
33. Burgers PTPW, Van Lieshout EMM, Verhelst J, Dawson I, de Rijcke PA. Implementing a clinical pathway for hip fractures; effects on hospital length of stay and complication rates in five hundred and twenty six patients. Int Orthop. 2014;38(5):1045-50. https://doi.org/10.1007/s00264-013-2218-5.
34. Narongroeknawin P, Patkar NM, Shakoory B, Jain A, Curtis JR, Delzell E, et al. Validation of diagnostic codes for subtrochanteric, diaphyseal, and atypical femoral fractures using administrative claims data. J Clin Densitom. 2012;15(1):92-102. https://doi.org/10.1016/j.jocd.2011.09.001.

PART

II

PART II

Extramedullary or intramedullary fixation of trochanteric fractures

Chapter 4: Extramedullary versus intramedullary fixation of stable trochanteric femoral fractures: a systematic review and meta-analysis

Chapter 5: Extramedullary versus intramedullary fixation of unstable trochanteric femoral fractures (AO type 31-A2): a systematic review and meta-analysis

Chapter 6: Mobility and living status at discharge and after three-months for extramedullary versus intramedullary fixation of AO type 31-A1 trochanteric fractures; an analysis of Dutch Hip Fracture Audit data



4

Extramedullary versus intramedullary fixation of stable trochanteric femoral fractures: a systematic review and meta-analysis

Miliaan L. Zeelenberg*, Lennard H.T. Nugteren*, A. Cornelis Plaisier, Sverre A.I. Loggers, Pieter Joosse, Dennis Den Hartog, Michiel H.J. Verhofstad, Esther M.M. Van Lieshout, on behalf of the STABLE-HIP Study Group

*Authors contributed equally

Archives of Orthopaedic and Trauma Surgery 2023, Volume 143, Issue 8, Pages 5065-5083

Abstract

Objective

This systematic review and meta-analysis compared extramedullary fixation and intramedullary fixation for stable two-part trochanteric femoral fractures (AO type 31-A1) with regards to functional outcomes, complications, and surgical outcomes.

Methods

Embase, Medline, Web of Science, Cochrane Central Register of Controlled Trials, and Google Scholar were searched for randomized controlled trials (RCTs) and observational studies. Effect estimates were pooled across studies using random effects models. Results were presented as weighted risk ratio (RR) or weighted mean difference (MD) with corresponding 95% confidence interval (95% CI).

Results

Five RCTs (397 patients) and 14 observational studies (21,396 patients) were included. No significant differences in functional outcomes, complications, or surgical outcomes were found between extramedullary and intramedullary fixation devices, except for a difference in duration of surgery (MD 14.1 min, CI 5.76-22.33, $p < 0.001$) and intraoperative blood loss (MD 92.30 mL, CI 13.49-171.12, $p = 0.02$), favoring intramedullary fixation.

Conclusion

Current literature shows no meaningful differences in complications, surgical, or functional outcomes between extramedullary and intramedullary fixation of stable two-part trochanteric femoral fractures. Both treatment options result in good outcomes. This study implicates that, costs should be taken into account when considering implants or comparing fixation methods in future research.

Introduction

Proximal femoral fractures are one of the most common types of fracture in the elderly population worldwide with a global incidence of over 182.5 per 100,000 person-years (1-3). The total annual medical costs associated with proximal femoral fractures are over $50,000 per patient in the U.S or over €20,000 in the Netherlands (4, 5). Due to an aging population and increased life expectancy worldwide, the burden of these fractures on health care systems is increasing. About half of proximal femoral fractures are trochanteric fractures (AO type 31-A1, A2, or A3) (3). These can be divided in stable two-part fractures (AO type 31-A1) and unstable fractures (AO type 31-A2 and A3) (6). Of these fractures, type 31-A1 fractures make up 36% (7).

Various studies suggest that intramedullary fixation is the most appropriate approach for treatment of unstable fractures (8-10). For stable fractures the implant of choice remains a topic of debate. A plethora of fixation devices for both intramedullary and extramedullary fixation is available and high variability in implant preference exists between countries, hospitals, and even individual surgeons (11).

The use of intramedullary fixation devices in both stable and unstable trochanteric fractures has risen in recent years (12, 13). Less than 2 decades ago intramedullary fixation was discouraged as older reviews reported higher risks of revision, re-operation, and other complications (10, 14-16). However, recent studies, that directly compared extramedullary and intramedullary fixation of stable two-part trochanteric fractures and a review of AO type A1-A3 trochanteric fractures reported none to minor differences favoring one of the two fixation types (17-21). Due to an increased experience, development of new devices, and abolition of devices of lower quality with inferior results, the present-day intramedullary devices result in better results and are no longer inferior to extramedullary devices (22). However, superiority over extramedullary devices has never been proven.

Therefore, current surgical guidelines, such as the Dutch Guideline for treatment of proximal femoral fractures and United Kingdom's NICE (National Institute for Health and Care Excellence) guideline, state that due to a lack of difference in effectiveness between extramedullary and intramedullary fixation, the device with the lowest costs (*i.e.*, a sliding hip screw) is preferred (23, 24). The optimal and most cost-effective treatment remains a topic of debate and the steep increase in the use of intramedullary fixation may be influenced by other factors than only clinical data on complications or outcomes, such as individual preference, training, or geographical differences (12, 25).

As no extensive systematic review and meta-analysis of the literature has been conducted on treatment of, exclusively, stable two-part trochanteric fractures, the aim of this study was to compare extramedullary versus intramedullary fixation for stable two-part trochanteric femoral fractures (AO type 31-A1) only using present-day devices.

Methods

This systematic review and meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guideline (26). A protocol was developed prior to conducting the current study.

Search strategy and selection criteria

Embase, Pubmed/Medline, Web of Science databases, and the Cochrane Central Register of Controlled Trials (CENTRAL) were initially searched on 22 March 2021 for studies comparing extramedullary and intramedullary fixation of AO type trochanteric fractures. The initial search was updated on 26 September 2022. Appendix 1 shows the search string used and the search results. After deduplication two reviewers (LHTN and ACP) independently screened titles and abstracts for eligibility for inclusion. Any disagreement was resolved by consensus. The same two reviewers subsequently conducted the full-text screening of eligible articles.

Studies were included when they presented data (a) published after 1990 of (b) acute (c) AO-OTA 31-A1 trochanteric fractures, (d) comparing intramedullary and extramedullary fixation (e) in patients >50 years, (f) using currently available devices (an overview of included devices per study is provided in appendix 2). Studies were excluded when they (a) presented no original data, (b) did not mention relevant outcomes (e.g. only incidence of fixation with specific devices), (c) were biomechanical, *in vitro* or cadaveric studies, (d) pathological fractures, (e) bilateral fractures, (f) periprosthetic fractures, (g) were case reports, or (h) did not make distinction between type of fracture or treatment.

Data extraction

All baseline characteristics were independently extracted by two reviewers (LHTN and ACP) using a predefined data extraction sheet and included: first author, publication year, setting, study design, study period, follow-up time, total study population, and study population with type 31-A1 fracture. In addition, patient characteristics were collected including age, sex, implant type, and number of patients treated using extramedullary or intramedullary fixation.

Data were collected for the following outcome measures: Functional outcomes: Harris hip score, pain, Parker mobility score, and walking ability (cases of unassisted/good walking ability were compared with assisted or no walking ability). Complications: reoperation, non-union, cut-out, peri-implant fracture, conversion to prosthesis, implant/fixation failure, superficial and deep infection, malunion, limb-length discrepancy, heterotopic ossification, osteolysis in fixed implants, and mortality. Surgical outcomes/operation characteristics: operation time, blood loss, bone healing time, quality of reduction, hospital stay, fluoroscopy time, and costs/cost-effectiveness. All outcomes were included as defined by individual presenting articles.

If case data were not described sufficiently in the full-text or supplementary materials, the authors were contacted by e-mail once. If this approach was unsuccessful, missing data were imputed based on the average standard deviation for the total included population across all studies with no missing data and adjusted for population size. This was done for the standard deviations of Harris hip score in Sevinc *et al.*(27), the standard deviations of 1-year pain scores by Matre *et al.* (28), and standard deviations for bone-healing time by Cho *et al.* (29).

Quality assessment

Two reviewers (LHTN and ACP) independently assessed the methodological quality of all included studies using the Risk of Bias 2 (RoB 2) tool for assessing risk of bias in randomized trials and MINORS, a methodological index for non-randomized studies (30, 31). Disagreement was resolved by consensus. The RoB 2 is structured into a fixed set of domains of bias, trial design, conduct, and reporting. Within each domain, a series of signaling questions indicate features that are relevant to risk of bias. A proposed judgement about the risk of bias for each domain is generated by an algorithm, based on the signaling questions. Judgement can be 'Low' or 'High' risk of bias, or can express 'Some concerns'. The MINORS ranges from 0 (poor quality) to 24 (high quality).

Statistical analysis

Data were analyzed using Review Manager (Revman, version 5.3.5). Input in the analysis was sample size, mean, and standard deviation (SD) for continuous outcomes and sample size and number of cases with the specific outcome for binary outcomes. Random effects models were used for measuring treatment effects because of the expected heterogeneity due the inclusion of both RCT and observational studies and comparison of multiple types of devices in different countries and clinical settings. No (age-)adjusted analyses were performed, all data were analyzed as described in the original studies. Treatment effects of the binary outcome measures were pooled using the Cochran Mantel Haenszel statistic and are presented as risk ratio (RR) with 95% confidence intervals (CI). Treatment effects of the continuous outcome measures were

pooled using the inverse variance weighting method and are presented as mean difference (MD) or standardized mean difference (SMD) with 95% confidence intervals (CI). SMD was used when included studies used different measurement scales for the same variable. All analyses were stratified on study design (randomized controlled trials (RCTs) or observational studies) and were presented as Forest plots. Differences between pooled estimates for the two types of study design were compared using the χ^2-test test. Heterogeneity between studies was assessed qualitatively using the Cochran's Q-test and quantified using the I^2 statistic. Statistical significance was assumed using a p-value threshold of 0.05. Publication bias was assessed by visual inspection of funnel plots for all studied variables (Appendix 3).

Results

Search

The literature search and selection of included studies is shown in Fig. 1. The primary search resulted in 14,577 records. After deduplication, 7,213 records were screened on title and abstract. Out of the 473 articles assessed for eligibility, a total of 19 studies (five RCTs (17, 32-35) and 14 observational studies (18, 19, 27-29, 36-44)) were included in the final analysis. All studies were published between 2005 and 2022.

Baseline study characteristics

The 19 included studies (Table 1) comprised a total of 21,793 patients. The RCTs included a total of 397 patients and the observational studies a total of 21,396 patients. Extramedullary fixation was used in 15,910 patients and 5,883 patients were treated using intramedullary fixation. The follow-up ranged from 6 to 60 months. A complete overview of reported variables per study is shown in Table 2.

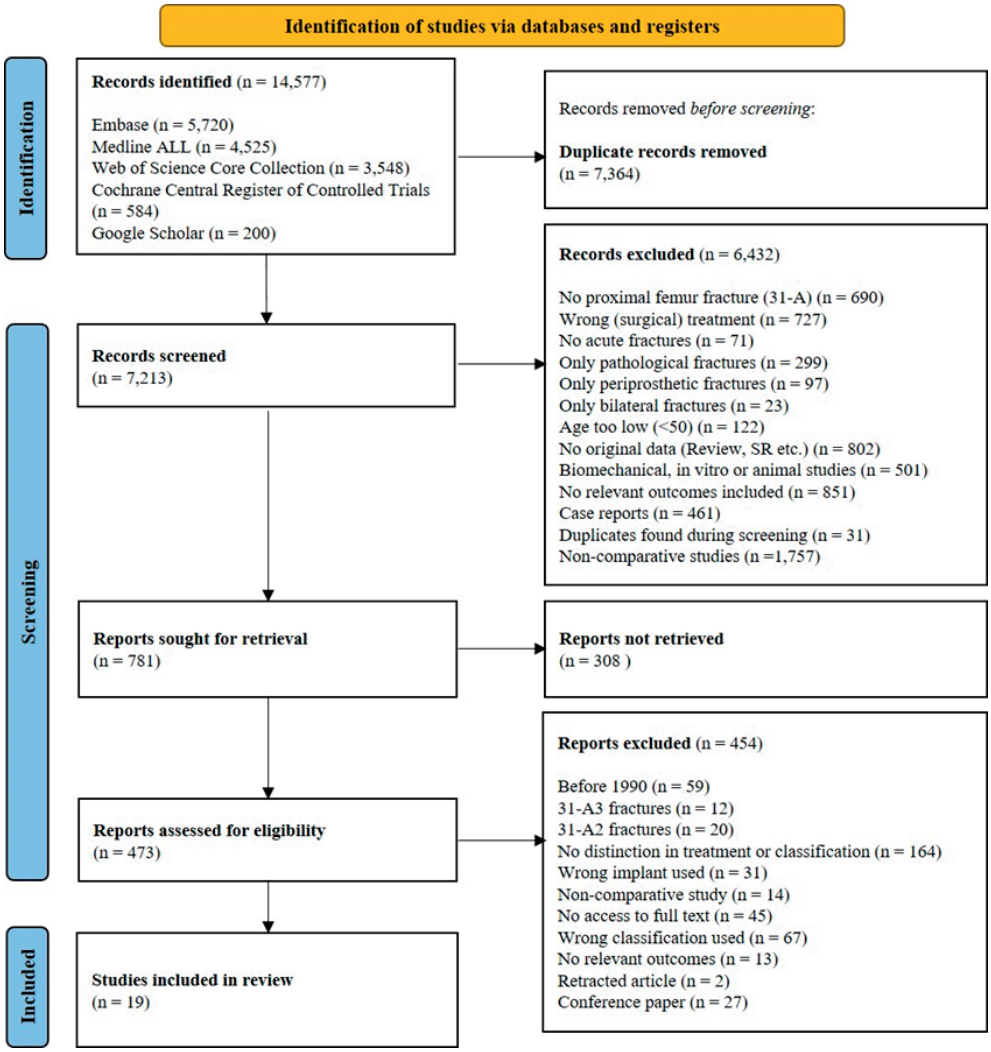


Figure 1: Flowchart of search results, article inclusion and exclusion

Table 1: Overview of included studies comparing intramedullary versus extramedullary fixation in AO type 31-A1 fractures

Study (publication date)	Country	Study design	Inclusion period	Total population AO type 31-A1 fracture Number of patients	Extramedullary fixation				Intramedullary fixation				Follow–up (months)
					Device	Male (%)	Mean Age (years)	Number of patients	Device	Male (%)	Mean Age (years)		
RCTs													
Ovesen *et al.* (2006) (33)	Denmark	RCT	2001-2003	40	17	DHS	40.4[a]	78.5[a]	23	GN	79.9[a]	37.7[a]	12
Pajarinen *et al.* (2005) (32)	Finland	RCT	1999-2001	47	26	DHS	25.9[a]	80.3[a]	21	PFN	80.9[a]	24.9[a]	4
Parker *et al.* (2017) (17)	UK	RCT	2002-2009	170	83	SHS	23.2[a]	82.1[a]	87	TPF +TPFT	82.2[a]	22.4[a]	12
Tao *et al.* (2013) (35)	China	RCT	2010-2011	19	9	Reverse LISS	60.0	80.3	10	PFNA	80.1	22.2	12
Zou *et al.* (2009) (34)	China	RCT	2006-2007	121	63	DHS	24	65	58	PFNA	65	21	12
Observational studies													
Alessio-Mazzola *et al.* (2022) (41)	Italy	Retrospective cohort	2015-2019	85	44	DHS	20.5	83.7	41	PFN	14.6	86.6	41.6[c]
Andruszkow *et al.* (2012) (36)	Germany	Retrospective cohort	2007-2010	106	101	DHS	29.8[a,b]	80.8[a,b]	5	GN	80.8[a,b]	29.8[a,b]	N.D.
Cho *et al.* (2016) (29)	South Korea	Retrospective cohort	2004-2014	194	113	DHS	38.1	84.2	81	PFNA	81	32.1	25
Crespo *et al.* (2012) (37)	Spain	Retrospective cohort with follow-up	2004-2009	179	125	PCCP	26.7[a]	82.5[a]	54	GN	83.1[a]	18.4[a]	12
Grønhaug *et al.* (2022) (42)	Norway	Prospective cohort	2013-2019	6,841	4,811	SHS	32	83.0	2,030	IMN	69	83.0	36
Matre *et al.* (2013) (28)	Norway	Retrospective cohort	2005-2010	7,643	6,355	DHS + ACHS	29	82	1,288	GN + PFNA + TITAN	82	27	22

Study (publication date)	Country	Study design	Inclusion period	Total population AO type 31-A1 fracture Number of patients	Extramedullary fixation				Intramedullary fixation				Follow–up (months)
					Device	Male (%)	Mean Age (years)	Number of patients	Device	Male (%)	Mean Age (years)		
Mohan *et al.* (2019) (18)	India	Retrospective cohort	2017-2018	53	23	DHS	67	45	30	PFN	60	60	6
Pehlivanoğlu *et al.* (2021) (43)	Turkey	Retrospective cohort	2005-2013	122	65	DHS	47.7	72	57	PFN	38.8	74.7	DHS 54.7[c] PFN 44.2[c]
Pyrhönen *et al.* (2022) (44)	Sweden	Retrospective cohort	2012-2018	5,460	3,733	SHS	36.1	84	1,727	IMN	31.0	85	60
Sevinç *et al.* (2020) (27)	Turkey	Prospective cohort	N.D.	104	48	DHS	59.1[a]	77.1[a]	56	PFNA	78.9[a]	48.2[a]	12
Talmaç *et al.* (2019) (19)	Turkey	Retrospective cohort	2011-2016	203	68 + 62	DHS + PCCP	52.5	70.9	73	PFNA	73.9	44.4	12
Tian *et al.* (2010) (39)	China	Retrospective cohort	2013-2017	58	20	DHS	40.0	70.4	38	PFNA	73.1	68.4	24
Van der Sijp *et al.* (2021) (40)	The Netherlands	Prospective cohort	2016-2018	126	32	DHS	28.1	81.3	94	PFNA	80.9	24.2	12
Yu *et al.* (2016) (38)	China	Retrospective cohort	2005-2015	222	112	DHS	50.9	73.1	110	PFNA	72.0	46.3	48-60

[a]Value for total study population including AO type 31-A2 and/or A3 fractures.

[b]Value for individual groups not specified in study.

[c]Mean follow-up, minimum of 12 months

ACHS, AMBI/CLASSIC hip screw system; DHS, Dynamic hip screw; EM, Extramedullary fixation; GN, Gamma nail; IM, Intramedullary fixation; ND, Not described; PCCP, Percutaneous compression plating; PFN, Proximal femoral nail; PFNA, Proximal femoral nail antirotation; Reverse LISS, Reverse less invasive stabilization system; SHS, Sliding hip screw; TITAN, Trigen intertan trochanteric antegrade nail; TPF Targon proximal femoral nail, TPFT Targon proximal femoral telescrew nail.

Table 2: Outcomes measured reported in the included studies

Outcome	Corresponding Figure	Alessio-Mazzola *et al.* (2022) (41)	Andruszkow *et al.* (2012) (36)	Cho *et al.* (2016) (29)	Crespo *et al.* (2012) (37)	Grønahug *et al.* (2022) (42)	Matre *et al.* (2013) (28)	Mohan *et al.* (2019) (18)	Ovesen *et al.* (2006) (33)	Pajarinen *et al.* (2005) (32)	Parker *et al.* (2017) (17)	Pehlivanoğlu *et al.* (2021) (43)	Pyrhönen *et al.* (2022) (44)	Sevinç *et al.* (2020) (27)	Talmaç *et al.* (2019) (19)	Tao *et al.* (2013) (35)	Tian *et al.* (2010) (39)	Van der Sijp *et al.* (2021) (40)	Yue *et al.* (2016) (38)	Zou *et al.* (2009) (34)
Harris Hip Score	2	+	-	-	-	-	-	+	-	-	-	-	-	+	+	+	-	+	+	-
Pain score	3	-	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-	+	-	-
Parker mobility score	OR4-1	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Post-operative walking ability	OR4-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Reoperation	4	+	-	-	-	+	+	-	+	-	+	-	+	-	+	-	+	+	+	+
Non-union	5	+	-	+	-	-	+	+	-	-	+	-	-	-	+	-	+	-	+	+
Cut-out/protrusion	6	-	+	+	+	-	+	+	+	+	+	-	-	-	+	-	+	-	+	+
Peri-implant fracture	7	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+	+
Conversion to prosthesis	8	+	-	+	-	+	+	-	+	-	+	-	+	-	-	-	+	-	-	-
Implant/fixation failure	9	+	-	+	-	-	+	-	-	-	-	-	-	-	+	-	+	+	+	+
Deep infections	OR4-3	+	-	+	-	-	-	+	+	+	-	-	-	-	-	-	-	-	+	+
Superficial infections	OR4-4	+	-	+	-	-	-	+	-	+	-	+	-	-	+	-	+	-	+	+
Mal-union	OR4-5	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-
Limb-length discrepancy	OR4-6	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-
Heterotopic ossification	OR4-7	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-
Osteolysis	OR4-8	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-
Mortality	OR4-9	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-
Surgery duration	10	+	-	+	-	-	+	+	-	-	-	+	-	-	+	+	+	+	-	-
Blood loss	11	-	-	+	-	-	-	+	-	-	-	+	-	-	+	+	+	+	-	-
Bone healing time	OR4-10	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+	-	+	-
Quality of reduction	OR4-11	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	+	-
Hospital stay	OR4-12	+	-	-	-	-	-	-	-	-	-	+	-	-	+	+	+	-	-	-
Fluoroscopy time	OR4-13	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-

+Outcome measure reported in study; - Outcome measure not reported in study; OR4, Online resource/Appendix 4

Table 3: Quality assessment of included RCTs using the RoB 2 criteria

Study	D1	D2	D3	D4	D5	Overall
Ovesen *et al.* (2006) (33)	+	+	+	+	+	+
Pajarinen *et al.* (2005) (32)	+	-	!	+	+	-
Parker *et al.* (2017) (17)	+	+	!	+	+	!
Tao *et al.* (2013) (35)	+	+	+	+	+	+
Zou *et al.* (2009) (34)	!	+	+	!	+	!

+ Low risk of bias; ! Some concern of bias; - High risk of bias.
D1: Randomization process; D2: Deviations from the intended interventions; D3: Missing outcome data; D4: Measurement of the outcome; D5: Selection of the reported result.

Table 4: Quality assessment of included observational studies using the MINORS criteria

Study	Aim	Inclusion	Collection	Endpoints	Assessment	Follow-up period	Loss of follow-up	Study size calculation	Control group	Contemporary group	Baseline equivalence	Statistics	Total
Alessio-Mazzola *et al.* (2022) (41)	2	2	2	1	1	2	1	1	2	2	2	2	20
Andruszkow *et al.* (2012) (36)	2	2	0	2	0	1	2	0	1	2	1	2	15
Crespo *et al.* (2012) (37)	1	2	0	2	0	2	1	0	2	2	1	2	15
Grønhaug *et al.* (2022) (42)	2	2	2	2	0	2	1	0	2	2	2	2	19
Sevinç *et al.* (2020) (27)	2	0	2	2	0	2	2	0	2	0	1	2	15
Cho *et al.* (2016) (29)	2	2	2	2	0	2	2	0	2	2	2	2	20
Matre *et al.* (2013) (28)	2	2	1	2	0	2	1	2	2	2	2	2	20
Mohan *et al.* (2019) (18)	2	1	0	2	0	1	2	0	2	2	1	2	15
Pehlivanoğlu *et al.* (2021) (43)	2	2	2	1	0	2	0	0	2	2	1	1	15
Pyrhönen *et al.* (2022) (44)	2	2	2	2	0	2	2	0	2	2	2	2	20
Talmaç *et al.* (2019) (19)	2	2	2	2	0	2	2	0	2	2	1	2	19
Tian *et al.* (2010) (39)	2	2	0	2	0	2	2	0	2	2	1	2	17
Van der Sijp *et al.* (2021) (40)	2	2	2	2	2	2	1	2	2	2	1	2	22
Yu *et al.* (2016) (38)	1	2	1	2	0	2	2	0	2	2	2	2	18

Total scores can range from 0 up to 24, with lower scores indicating higher risk of bias.
0, not reported; 1, reported but inadequate; 2, reported and adequate.

Outcome measure	Pooled value	RCTs			Observational			EM fixation		IM fixation		Combined studies		
		Studies	n	Pooled value (95% CI)	Studies	n	Pooled value (95% CI)	n	Mean/ cases	n	Mean/ cases	Pooled value (95% CI)	I^2	P-value
Harris Hip Score (1 year)	MD	1	19	1.6 (-3.9;7.1)	5	502	1.3 (-4.0;6.8)	261	82.2	249	82.9	1.4 (-3.3;6.1)	92%	0.57
Pain score (1 year, 0-10 scale)	SMD	1	138	0.2 (-0.2;0.5)	3	3,547	0.03 (-0.1;0.1)	2,679	2.4	1,006	2.2	0.04 (-0.04;0.1)	0%	0.36
Parker Mobility Score (1 year)	MD	x	x	x	2	114	0.52 (-0.1;1.1)	54	6.9	60	6.2	0.52 (-0.1;1.1)	0%	0.11
Good walking ability (1 year)	RR	1	19	1.1 (0.8;1.6)	1	57	1.1 (0.7;1.8)	28	19 (68%)	48	28 (58%)	1.1 (0.8;1.6)	0%	0.51
Reoperation	RR	3	304	1.1 (0.2;8.0)	8	20,633	0.94 (0.7;1.2)	15,389	483 (3.1%)	5,548	199 (3.6%)	0.94 (0.7;1.2)	34%	0.67
Non-union	RR	2	264	No events	7	8,459	1.4 (0.6;3.4)	6,933	26 (0.4%)	1,790	7 (0.4%)	1.4 (0.6;3.4)	0%	0.45
Cut-out	RR	4	351	1.1 (0.2;5.4)	8	8,659	0.7 (0.4;1.2)	7,158	36 (0.5%)	1,852	20 (1.1%)	0.7 (0.4;1.2)	0%	0.19
Peri-implant fracture	RR	2	264	No events	3	8,068	1.1 (0.2;8.2)	6,732	16 (0.2%)	1,600	7 (0.4%)	1.2 (0.2;8.2)	66%	0.89
Conversion to prosthesis	RR	2	264	No events	6	20,190	0.9 (0.7;1.2)	15,118	269 (1.8%)	5,282	105 (2.0%)	0.9 (0.7;1.2)	15%	0.32
Implant/fixation failure	RR	1	94	2.4 (0.1;58.3)	7	8,531	1.8 (0.8;4.5)	6,858	70 (1.0%)	1,767	15 (0.85%)	1.8 (0.8-4.5)	20%	0.15
Deep infection	RR	3	87	No events	6	707	2.4 (0.5;12.3)	408	4 (1.0%)	386	1 (0.3%)	2.4 (0.5;12.3)	0%	0.30
Superficial infection	RR	2	141	2.4 (0.1;58.3)	6	884	1.0 (0.4;2.8)	562	9 (1.6%)	463	6 (1.3%)	1.1 (0.4;2.9)	0%	0.81
Malunion	RR	x	x	x	3	510	0.8 (0.3;1.8)	286	10 (3.5%)	224	10 (4.5%)	0.8 (0.3;1.8)	0%	0.58
Limb length discrepancy	RR	x	x	x	3	619	3.4 (0.3;45.0)	355	11 (3.1%)	264	1 (0.3%)	3.4 (0.3;45.0)	42%	0.36
Heterotopic ossification	RR	x	x	x	3	510	0.76 (0.3;2.3)	286	10 (3.5%)	224	3 (4.9%)	0.76 (0.3;2.3)	23%	0.62
Osteolysis	RR	x	x	x	2	463	0.7 (0.05;11.0)	242	1 (0.4%)	183	1 (0.5%)	0.7 (0.05;11.0)	0%	0.83
1-year mortality	RR	x	x	x	2	329	1.0 (0.6;1.6)	162	31 (19%)	167	30 (18%)	1.0 (0.6;1.6)	0%	0.92
Operation time (minutes)	MD	1	19	**26 (17;36)**	8	8,370	**13 (5.4;20)**	6,704	53.5	1,685	53.2	**14 (7;21)**	96%	**<0.001**
Blood loss (mL)	MD	1	19	23 (-54;100)	6	641	**103 (17;189)**	305	351	355	204	**92 (17;171)**	98%	**0.02**
Time to union (weeks)	MD	1	19	**3.2 (0.2;6.2)**	4	599	-0.4 (-1.4;0.7)	334	17.2	284	16.9	-0.04 (-1.1;1.0)	84%	0.94
Good quality of reduction	RR	1	19	0.9 (0.7;1.2)	4	558	1.04 (0.96;1.1)	277	191 (71%)	300	176 (59%)	1.03 (1.0;1.1)	0%	0.46
Hospital stay (days)	MD	1	19	2.7 (-3.7;9.1)	4	390	0.48 (-0.3;1.3)	218	7.9	191	8.0	0.5 (-0.3;1.3)	58%	0.19
Fluoroscopy time (seconds)	MD	1	19	**71 (14;128)**	2	210	7.8 (-2.7;18.3)	133	63.2	96	50.4	13 (-3.2;30)	73%	0.12

Table 5: Summary of results of meta-analyses of extra- versus intramedullary fixation of A1 trochanteric hip fractures

EM, extramedullary; IM, Intramedullary; MD, mean difference; OM, outcome measure; RCTs, Randomised controlled trials; RR, risk ratio; x, not reported. **Boldface** values indicate a $p<0.05$.

Quality assessment

The details and distribution of the quality assessment using the RoB 2 for RCTs and MINORS for observational studies are described in Tables 3 and 4. The overall bias assessment in the RoB 2 ranged from high overall risk of bias in Pajarinen *et al.* (32) to low overall risk of bias in Tao *et al.* (35) and Ovesen *et al.* (33). The mean score for the MINORS was 18 (SD 2.5) and ranged from 15 (moderate quality) to 22 (high quality).

A summary of all study results and meta-analyses is provided in table 5. The most (clinically) relevant and statistically significant outcome measures are described below. Forrest plots for additional outcome measures can be found in Appendix 4.

Functional outcomes

Harris Hip Score (HHS)

The mean HHS (six studies, Fig. 2) at a minimum of one year after trauma was 82.2 in 261 patients for extramedullary fixation and 82.9 in 249 patients for intramedullary fixation. There was no significant difference between groups, with a considerable level of heterogeneity of effect across studies (MD 1.38, CI -3.43 to 6.18, I^2=92%, p=0.57) (19, 27, 35, 38, 39, 41).

Pain

The mean 1-year post-operative pain score (four studies, Fig. 3) was 2.4 in 2,679 patients for extramedullary fixation and 2.2 in 1,006 patients for intramedullary fixation, on a 10-point scale. There was no significant difference in standardized 1-year post-operative pain between groups (SMD 0.04, CI -0.04 to 0.11, I^2=0%, p=0.36) (17, 28, 40, 42).

Other functional outcomes

No significant difference between groups was found in Parker mobility score (MD 0.52, CI -0.11 to 1.14, I^2=0%, p=0.11) (Appendix 4, Fig. 1) (18, 41) and one-year post-operative walking ability (RR 1.11, CI 0.82 to 1.50, I^2=0%, p=0.97) (OR4, Fig. 2) (35, 39).

Complications

Reoperation

Reoperation (11 studies, Fig. 4) was performed in 483 out of 15,389 (3.1%) in extramedullary fixation and 199 out of 5,548 (3.6%) patients in intramedullary fixation. No significant difference between groups was found, with a moderate level of heterogeneity of effect across studies (RR 0.94, 0.72 to 1.23, I^2=34%, p=0.85) (17, 19, 28, 33, 34, 38-42, 44).

Nonunion

Nonunion (nine studies, Fig. 5) occurred in 26 cases out of 6,933 (0.4%) in extramedullary fixation and seven cases out of 1,790 (0.4%) in intramedullary fixation. There was no significant difference in nonunion between groups (RR 1.41, CI 0.58 to 3.42, I^2=0%, p=0.45 (17-19, 28, 29, 34, 38, 39, 41).

Cut-out

Cut-out (12 studies, Fig. 6) occurred in 36 cases out of 7,158 (0.5%) in extramedullary fixation and 20 cases out of 1,852 (1.1%) in intramedullary fixation. There was no significant difference in cut-out rate between groups (RR 0.69, CI 0.40 to 1.20, I^2=0%, p=0.19) (17-19, 28, 29, 32-34, 36-39).

Peri-implant fracture

Peri-implant fracture (five studies, Fig. 7) occurred in 16 cases out of 6,732 (0.2%) in extramedullary fixation and 7 cases out of 1,600 (0.4%) in intramedullary fixation. There was no significant difference in peri-implant fracture rate between fixation groups, with a moderate to substantial level of heterogeneity of effect across studies (RR 1.14, CI 0.16 to 8.18, I^2=66%, p=0.89) (17, 19, 28, 34, 38).

Conversion to prosthesis

Conversion to prosthesis (eight studies, Fig. 8) occurred in 269 cases out 15,118 (1.8%) in extramedullary fixation and 105 cases out of 5,282 (2.0%) in intramedullary fixation. There was no significant difference between groups (RR 0.87, CI 0.66 to 1.15, I^2=15%, p=0.32) (17, 28, 29, 33, 39, 41, 42, 44).

Implant/fixation failure

Implant or fixation failure (eight studies, Fig. 9) was reported in 70 cases out of 6,858 (1.0%) in extramedullary fixation and 15 cases out of 1,767 (0.8%) in intramedullary fixation. There was no significant difference between groups (RR 1.78, CI 0.82 to 3.86, I^2=20%, p=0.15) (19, 28, 29, 34, 38-41).

Other complications

There were no significant differences between groups in deep infection (RR 2.39, CI 0.47 to 12.25, I^2=0%, p=0.30, OR4 Fig. 3) (18, 29, 32-34, 38, 39, 41), superficial infection (RR 1.12, CI 0.43-2.90, I^2=0%, p=0.81, OR4 Fig. 4) (19, 29, 32, 34, 38, 39, 41, 43), malunion (RR 0.78, CI 0.33 to 1.84, I^2=0%, p=0.58, OR4 Fig. 5) (19, 38, 41), limb length discrepancy >25mm (RR 3.36, CI 0.25 to 45.01, I^2=48%, p=0.36, OR4 Fig. 6) (19, 29, 38), heterotopic ossification (RR 0.76, CI 0.26 to 2.25, I^2=23%, p=0.62, OR4 Fig. 7) (19, 38, 41), osteolysis in well-fixed implants (RR 0.74, CI 0.05 to 11.03, I^2=30%, p=0.83, OR4 Fig. 8) (19, 38), and 1-year mortality (RR 0.98, CI 0.61 to 1.56, I^2=0%, p=0.92, OR4 Fig. 9) (19, 40).

Surgical outcomes

There was a significantly longer operation time (9 studies, Fig. 10) for extramedullary fixation, with a mean of 53.5 minutes in 6,704 patients versus 53.2 minutes in 1,685 patients in the intramedullary group (MD 14.1, CI 6.98 to 21.29, I^2=96%, p<0.001) (18, 19, 28, 29, 35, 39-41, 43). Operative blood loss (7 studies, Fig. 11) in the extramedullary group was significantly higher as well, with a mean of 351 mL in 305 patients versus a mean of 204 mL in 355 patients in the intramedullary group (MD 92.30, CI 13.49 to 171.12, I^2=98%, p=0.02) (18, 19, 29, 35, 39, 40, 43).

No significant differences between the groups were found in the other surgical outcomes or operation characteristics: Time to radiological union (MD -0.04, CI -1.10 to 1.02, I^2=84%, p=0.94, OR4 Fig. 10) (19, 29, 35, 38, 39), good quality of reduction (RR 1.03, CI 0.95 to 1.11, I^2=0%, p=0.46, OR4 Fig. 11) (19, 35, 38, 40, 41), hospital stay (MD 0.50, CI -0.25 to 1.25, I^2=48%, p=0.19, OR4 Fig. 12) (19, 35, 39, 41, 43), or fluoroscopy time (MD 13.12, CI -3.28 to 29.52, I^2=73%, p=0.12, OR 4 Fig. 13) (19, 35, 41).

Only two studies reported data on hospital or surgery-related costs (41, 43). Due to differences in included cost variables no pooled effect could be calculated. None of the included studies reported data on cost-effectiveness.

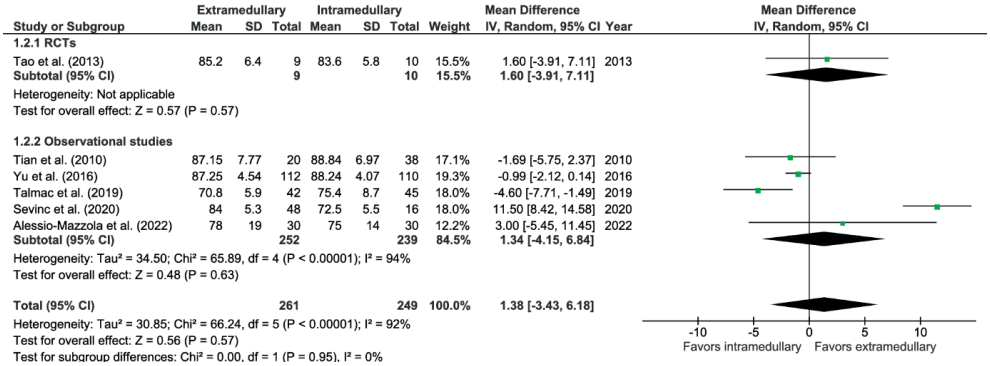


Figure 2: Forrest plot for Harris hip score after extramedullary versus intramedullary fixation of stable trochanteric fractures

IV, inverse variance; RCT, randomized controlled trial; SD, standard deviation

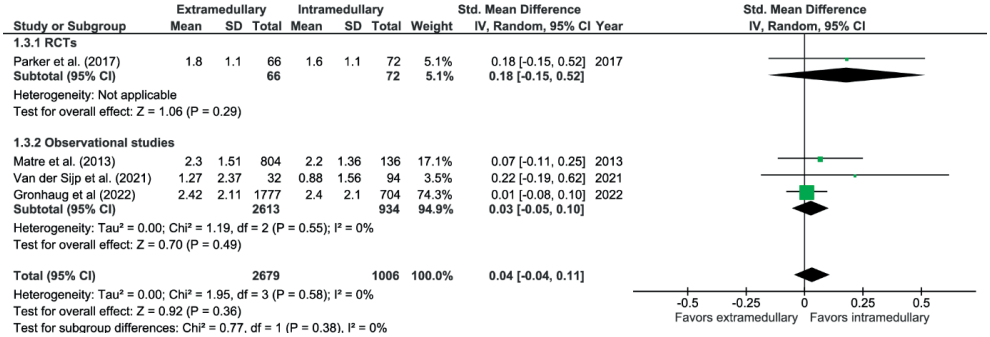


Figure 3: Forrest plot of 1-year pain score after extramedullary versus intramedullary fixation of stable trochanteric fractures

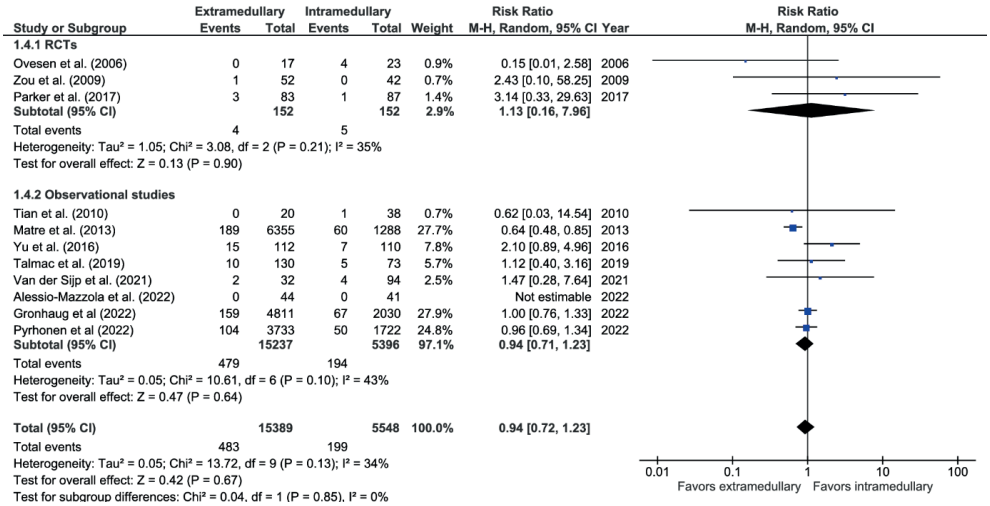


Figure 4: Forrest plot of reoperation rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

M-H, Mantel-Haenszel; RCT, randomized controlled trial; SD, standard deviation

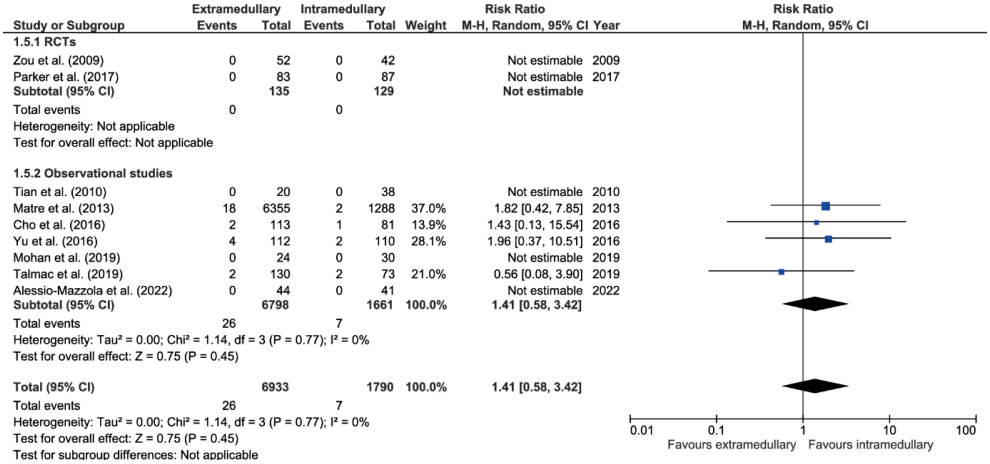


Figure 5: Forrest plot of nonunion rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

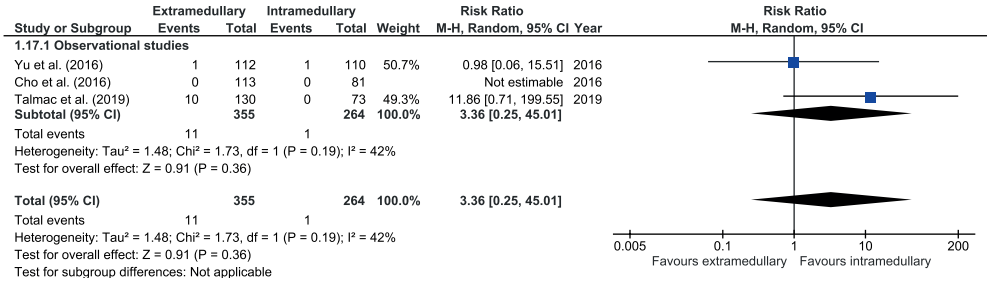


Figure 6: Forrest plot of cut-out rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

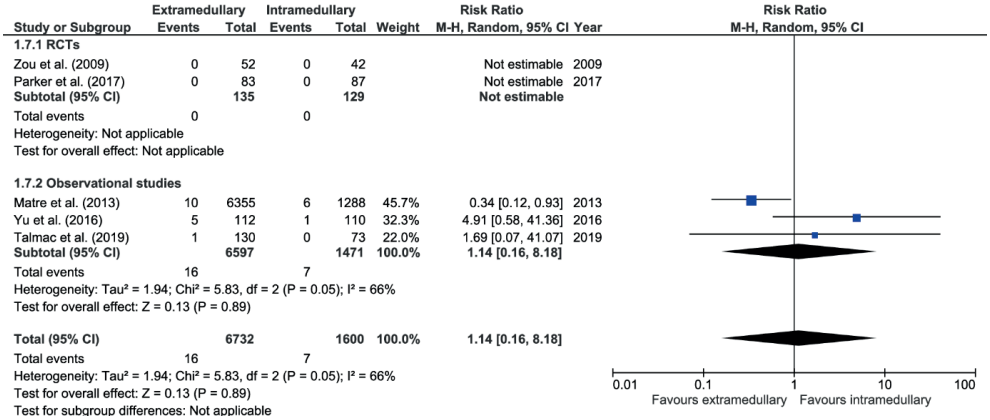


Figure 7: Forrest plot of peri-implant fracture rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

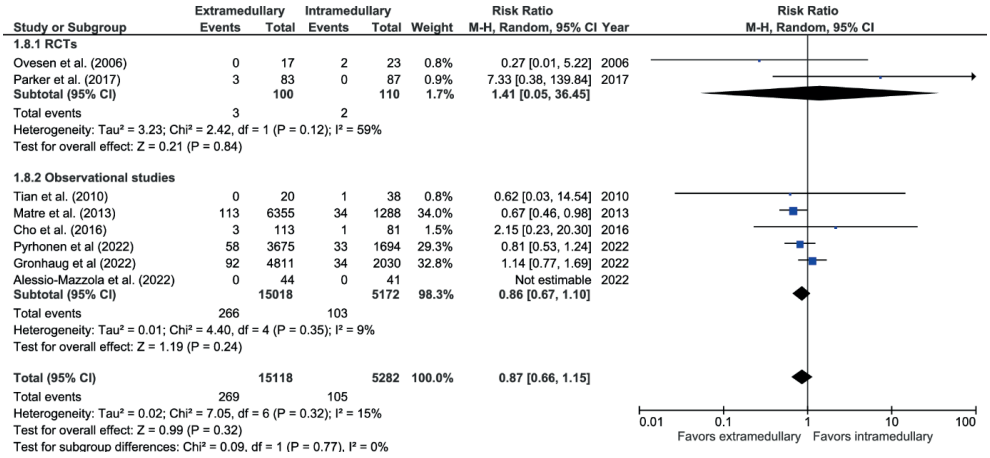


Figure 8: Forrest plot of conversion to prosthesis rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

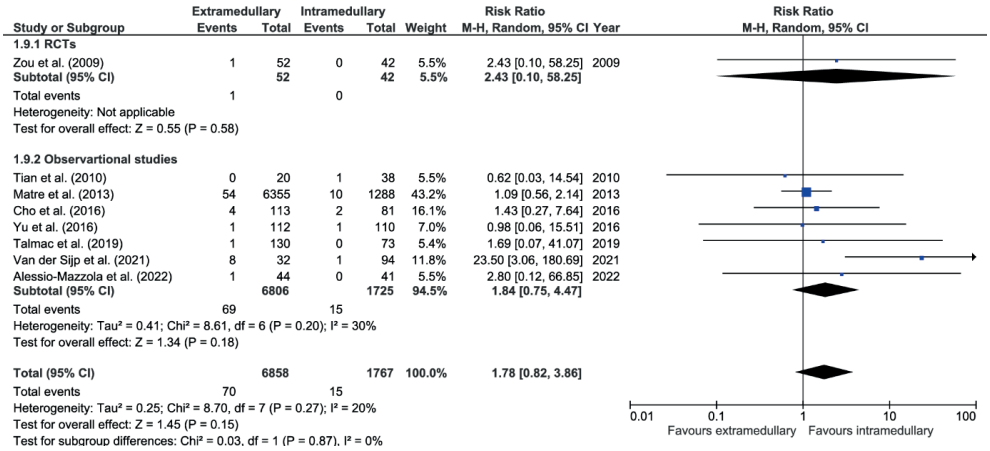


Figure 9: Forrest plot of implant/fixation failure rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

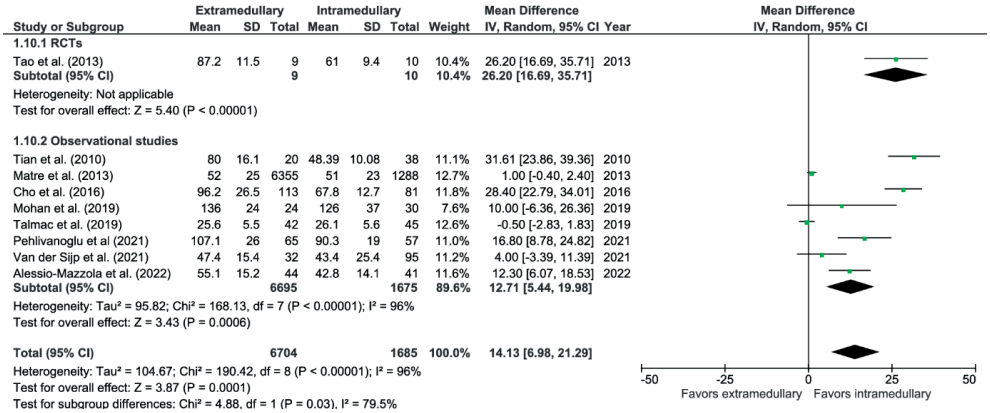


Figure 10: Forrest plot of mean operation time in minutes after extramedullary versus intramedullary fixation of stable trochanteric fractures

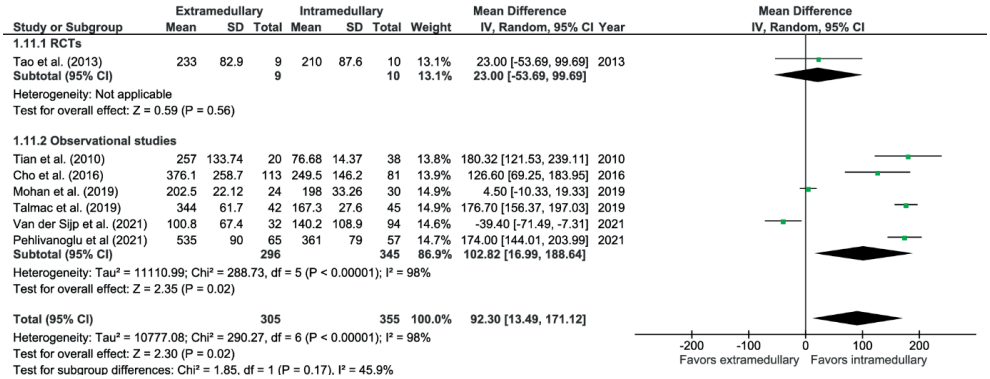


Figure 11: Forrest plot of mean blood loss in milliliters after extramedullary versus intramedullary fixation of stable trochanteric fractures

Discussion

This systematic review and meta-analysis compared extramedullary and intramedullary fixation for stable two-part trochanteric fractures (AO 31-A1). No differences between fixation groups were found in functional outcomes and complications. Duration of surgery and intraoperative blood loss were found to be statically different between fixation groups, in favor of intramedullary fixation, though with a high level of heterogeneity.

This is the first systematic review and meta-analysis that restricted the evaluation of treatment effect, in present-day devices, to patients with only stable two-part trochanteric fractures. It includes a substantially larger number of patients than all previous meta-analyses (9, 14, 21, 22, 45, 46). The most recent Cochrane review, by Lewis *et al.* (45), on RCTs and 'RCT-like' cohort studies published up to July 2020 compared EM and IM fixation for a combination of AO A1-A3 fractures. In the only stratified analysis on A1 fractures, and in accordance with the current study's data, it found no differences between fixation groups for reoperation. For all combined fractures it found no difference in reoperation, mortality, and several functional outcomes. Contrary to this review, it did find an increased risk of many complications including non-union, both superficial and deep infection, cut-out and implant failure for extramedullary devices. Intramedullary devices were associated with an increased intra- and postoperative periprosthetic fracture rate. The differences between this Cochrane review and our meta-analysis can largely be explained by the absence of several recently published large cohort studies, its combination of both stable, and unstable fractures, and inclusion of older studies with a relatively higher rate of complications.

Another review by Wessels *et al.* (2022) (21), comparing SHS vs IMN for AO A1-A3 trochanteric fractures, also found no significant differences between fixation devices in the A1 fracture subgroup. Wessels *et al.* only described a combination of major complications and, specifically, non-union. Both Lewis *et al.* and Wessels *et al.* did not include surgical outcomes or operation characteristics and also included pathological fractures.

Older reviews by Parker *et al.* (2010) (46) and Jones *et al.* (2006) (14) studied fixation of all types of trochanteric fractures by cephalomedullary nail or sliding hip screw. As opposed to the current meta-analysis and review by Wessels *et al.*, they reported a significantly higher number of post- and intra-operative femoral fractures and higher reoperation rate for patients treated with a cephalomedullary nail. Both did not provide a stratified analysis for type of fracture. The difference between Jones *et al.*, our findings and other recent reviews is likely caused by the fact that it included older studies, from the earlier days of intramedullary fixation. Since then device quality, design and surgical experience with intramedullary devices have greatly improved. Where older

research advised against the use of intramedullary fixation, current data on clinical and functional outcomes do not warrant any statement on the preferred type of device from a clinical perspective.

Interpretation of results

This meta-analysis found that only the duration of surgery and intra-operative blood loss to be statistically significantly in favor of intramedullary fixation. These results should be interpreted with care. The level of heterogeneity of effects across the studies was over 90% with large differences in mean operation time or blood loss (e.g. a range of 25.6 to 136 min for extramedullary fixation (18, 19)). This large variety may partly be explained by differences in surgery protocols, device used, experience of surgeons, the small number of inclusions, and inclusion or exclusion of anesthesia times across the included studies. The largest study by Matre *et al.* (28), with 7,643 patients, and arguably the best sample size for this comparison, found no significant difference in operation time. The only other review reporting duration of surgery, by Parker *et al.* (46), included studies all conducted before the year 2005 and concluded that no definitive conclusion could be drawn because of limited data.

As current literature shows no differences between intra- and extramedullary fixation in functional outcomes or complications, it is tempting to conclude that surgeons could use either type of device. However, the difference in device costs should also be considered in this decision. Extramedullary fixation, or more specifically dynamic/sliding hip screw is most likely the most cost-effective implant. (47, 48). Intramedullary devices can cost well over $1000 more than extramedullary options with, as demonstrated by this review, the same surgical and clinical results for stable fractures. More expensive devices, such as PFNA, should be avoided when enough surgical expertise with extramedullary devices exists. This financial argument is also used in the Dutch Guideline for treatment of proximal femoral fractures and NICE guideline, as an argument for usage of extramedullary devices when clear evidence for superiority is absent (23, 24).

Some limitations should be considered when interpreting the results of this study: First, in every meta-analysis, there is a chance of publication bias, however, the funnel plots show no clear indication for one-sided publication for the included variables. The large majority of patients (>98%) included in this study came from observational studies resulting in a larger risk of selection bias. Many of the studied variables have a moderate to high level of heterogeneity between studies. Part of this could be explained by random chance and can be corrected for by using random effect models. Another part could be explained by the (small) differences in devices used, different moments in time studies were conducted, differences in study populations (e.g. age, fracture type prevalence, and inclusion of patients with concomitant injuries),and international dif-

ferences between included studies. Most of the included RCTs and to a lesser degree, observational studies appear underpowered or only adequately powered for the total group of combined stable and unstable trochanteric femoral fractures. As many of the studied outcomes and complications are rare, and occur at rates of 1% or lower, studies are often not adequately powered to study these outcomes for a restricted group of stable fractures. A combination of heterogeneity and low power could conceal treatment effects that now seem insignificant. Although the clinical relevance of these effects may be questionable. Larger and adequately powered RCTs or high-quality prospective observational studies comparing extramedullary and intramedullary fixation in, specifically, stable trochanteric femoral fractures are needed to provide a definitive answer to the question of superiority for treatment for stable trochanteric fractures. Considering the low frequency of complications and sparsity of data on functional outcome and patient reported outcomes, future research should focus on both functional and quality of life data, and provide a large scale cost-effectiveness analysis.

Conclusion

There are no meaningful differences in complications, surgical-, or functional outcomes between intramedullary and extramedullary fixation of stable two-part trochanteric femoral (AO type 31-A1) fractures. Both treatment options result in good outcomes and few complications. As outcomes do not differ, costs should be taken into account when considering devices. Therefore the use of extramedullary devices should be advised when enough surgical expertise with these devices is available. Future research should focus on (functional) outcomes for individual fracture AO type A1-A3 subgroups, and cost-effectivity of treatment and (medical) decision making for both techniques.

References

1. Amin S, Achenbach SJ, Atkinson EJ, Khosla S, Melton LJ, 3rd. Trends in fracture incidence: a population-based study over 20 years. J Bone Miner Res. 2014;29(3):581-9. https://doi.org/10.1002/jbmr.2072.
2. Collaborators GBDF. Global, regional, and national burden of bone fractures in 204 countries and territories, 1990-2019: a systematic analysis from the Global Burden of Disease Study 2019. Lancet Healthy Longev. 2021;2(9):e580-e92. https://doi.org/10.1016/S2666-7568(21)00172-0.
3. Tsuda T. Epidemiology of fragility fractures and fall prevention in the elderly: a systematic review of the literature. Curr Orthop Pract. 2017;28(6):580-5. https://doi.org/10.1097/BCO.0000000000000563.
4. Adeyemi A, Delhougne G. Incidence and Economic Burden of Intertrochanteric Fracture: A Medicare Claims Database Analysis. JB JS Open Access. 2019;4(1):e0045. https://doi.org/10.2106/JBJS.OA.18.00045.
5. Kanters TA, van de Ree CLP, de Jongh MAC, Gosens T, Hakkaart-van Roijen L. Burden of illness of hip fractures in elderly Dutch patients. Arch Osteoporos. 2020;15(1):11. https://doi.org/10.1007/s11657-019-0678-y.
6. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and Dislocation Classification Compendium-2018. J Orthop Trauma. 2018;32 Suppl 1:S1-S170. https://doi.org/10.1097/BOT.0000000000001063.
7. DHFA. DHFA report 2019: Dutch Instute for Clinical Auditing (DICA); 2019 [Available from: https://dica.nl/jaarrapportage-2019/dhfa.
8. Kaplan K, Miyamoto R, Levine BR, Egol KA, Zuckerman JD. Surgical management of hip fractures: an evidence-based review of the literature. II: intertrochanteric fractures. J Am Acad Orthop Surg. 2008;16(11):665-73. https://doi.org/10.5435/00124635-200811000-00007.
9. Zhang WQ, Sun J, Liu CY, Zhao HY, Sun YF. Comparing the Intramedullary Nail and Extramedullary Fixation in Treatment of Unstable Intertrochanteric Fractures. Sci Rep. 2018;8(1):2321. https://doi.org/10.1038/s41598-018-20717-2.
10. Schipper IB, Marti RK, van der Werken C. Unstable trochanteric femoral fractures: extramedullary or intramedullary fixation. Review of literature. Injury. 2004;35(2):142-51. https://doi.org/10.1016/s0020-1383(03)00287-0.
11. Forte ML, Virnig BA, Eberly LE, Swiontkowski MF, Feldman R, Bhandari M, et al. Provider factors associated with intramedullary nail use for intertrochanteric hip fractures. J Bone Joint Surg Am. 2010;92(5):1105-14. https://doi.org/10.2106/JBJS.I.00295.
12. Anglen JO, Weinstein JN, American Board of Orthopaedic Surgery Research C. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database. J Bone Joint Surg Am. 2008;90(4):700-7. https://doi.org/10.2106/JBJS.G.00517.
13. Rogmark C, Spetz CL, Garellick G. More intramedullary nails and arthroplasties for treatment of hip fractures in Sweden. Acta Orthop. 2010;81(5):588-92. https://doi.org/10.3109/17453674.2010.506631.
14. Jones HW, Johnston P, Parker M. Are short femoral nails superior to the sliding hip screw? A meta-analysis of 24 studies involving 3,279 fractures. Int Orthop. 2006;30(2):69-78. https://doi.org/10.1007/s00264-005-0028-0.
15. Parker MJ, Handoll HH, Bhonsle S, Gillespie WJ. Condylocephalic nails versus extramedullary implants for extracapsular hip fractures. Cochrane Database Syst Rev. 2000(2):CD000338. https://doi.org/10.1002/14651858.CD000338.

16. Parker MJ, Handoll HH, Chinoy MA. Extramedullary fixation implants for extracapsular hip fractures. Cochrane Database Syst Rev. 2001(2):CD000339. https://doi.org/10.1002/14651858.CD000339.
17. Parker MJ. Sliding hip screw versus intramedullary nail for trochanteric hip fractures; a randomised trial of 1000 patients with presentation of results related to fracture stability. Injury. 2017;48(12):2762-7. https://doi.org/10.1016/j.injury.2017.10.029.
18. Mohan H, Kumar P. Surgical Treatment of Type 31-A1 Two-part Intertrochanteric Femur Fractures: Is Proximal Femoral Nail Superior to Dynamic Hip Screw Fixation? Cureus. 2019;11(2):e4110. https://doi.org/10.7759/cureus.4110.
19. Talmac MA, Gorgel MA, Armagan R, Sonmez MM, Ozdemir HM. Examining implant superiority in the treatment of simple pertrochanteric fractures of the proximal femur in elderly patients Yasli hastalarda proksimal femur basit pertrokanterik kiriklarin tedavisinde hangi implant ustundur? Ulus Travma Acil Cerrahi Derg. 2019;25(4):410-6. https://doi.org/10.14744/tjtes.2019.21270.
20. Singh NK, Sharma V, Trikha V, Gamanagatti S, Roy A, Balawat AS, et al. Is PFNA-II a better implant for stable intertrochanteric fractures in elderly population ? A prospective randomized study. J Clin Orthop Trauma. 2019;10(Suppl 1):S71-S6. https://doi.org/10.1016/j.jcot.2019.02.004.
21. Wessels JO, Bjarnesen MP, Erichsen JL, Palm H, Gundtoft PH, Viberg B. Sliding hip screw vs intramedullary nail for AO/OTA31A1-A3: a systematic review and meta-analysis. Injury. 2022;53(3):1149-59. https://doi.org/10.1016/j.injury.2021.12.034.
22. Bhandari M, Schemitsch E, Jonsson A, Zlowodzki M, Haidukewych GJ. Gamma nails revisited: gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: a meta-analysis. J Orthop Trauma. 2009;23(6):460-4. https://doi.org/10.1097/BOT.0b013e318162f67f.
23. Nederlandse Vereniging voor Heelkunde. Behandeling pertrochantere fracturen: Federatie Medisch Specialisten; 2016 [updated 1 september 2016. Available from: https://richtlijnendatabase.nl/richtlijn/proximale_femurfracturen/pertrochantere_femurfractuur/behandeling_pertrochantere_fracturen.html.
24. NICE Guidelines. National Institute for Health and Care Excellence: Guidelines, Hip fracture management. 2020/02/20 ed2017 https://doi.org/NBK553768 [bookaccession].
25. Mellema JJ, Janssen S, Schouten T, Haverkamp D, van den Bekerom MPJ, Ring D, et al. Intramedullary nailing versus sliding hip screw for A1 and A2 trochanteric hip fractures. Bone Joint J. 2021;103-B(4):775-81. https://doi.org/10.1302/0301-620X.103B.BJJ-2020-1490.R1.
26. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71.
27. Sevinc HF, Cirpar M, Canbeyli ID, Daglar B, Oktas B, Durusoy S. Comparison of functional outcomes in patients fixed with dynamic hip screw and proximal femur nail-anti-rotation in A1 and A2 type intertrochanteric femur fractures A1 ve A2 tipi femur intertrokanterik kiriklarinda kayan kalca vidasi ve proksimal femur civisi-antirotasyon ile tespit sonrasi hastalarin fonksiyonel sonuclarinin karsilastirilmasi. Ulus Travma Acil Cerrahi Derg. 2020;26(5):811-7. https://doi.org/10.14744/tjtes.2020.39888.
28. Matre K, Havelin LI, Gjertsen JE, Espehaug B, Fevang JM. Intramedullary nails result in more reoperations than sliding hip screws in two-part intertrochanteric fractures. Clin Orthop Relat Res. 2013;471(4):1379-86. https://doi.org/10.1007/s11999-012-2728-2.
29. Cho HM, Lee K. Clinical and Functional Outcomes of Treatment for Type A1 Intertrochanteric Femoral Fracture in Elderly Patients: Comparison of Dynamic Hip Screw and Proximal Femoral Nail Antirotation. Hip Pelvis. 2016;28(4):232-42. https://doi.org/10.5371/hp.2016.28.4.232.

30. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg. 2003;73(9):712-6. https://doi.org/10.1046/j.1445-2197.2003.02748.x.
31. Sterne JAC, Savovic J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ. 2019;366:l4898. https://doi.org/10.1136/bmj.l4898.
32. Pajarinen J, Lindahl J, Michelsson O, Savolainen V, Hirvensalo E. Pertrochanteric femoral fractures treated with a dynamic hip screw or a proximal femoral nail. A randomised study comparing post-operative rehabilitation. J Bone Joint Surg Br. 2005;87(1):76-81.
33. Ovesen O, Andersen M, Poulsen T, Nymark T, Overgaard S, Rock ND. The trochanteric gamma nail versus the dynamic hip screw: a prospective randomised study. One-year follow-up of 146 intertrochanteric fractures. Hip Int. 2006;16(4):293-8. https://doi.org/10.5301/hip.2008.2820.
34. Zou J, Xu Y, Yang H. A comparison of proximal femoral nail antirotation and dynamic hip screw devices in trochanteric fractures. J Int Med Res. 2009;37(4):1057-64. https://doi.org/10.1177/147323000903700410.
35. Tao R, Lu Y, Xu H, Zhou ZY, Wang YH, Liu F. Internal fixation of intertrochanteric hip fractures: a clinical comparison of two implant designs. ScientificWorldJournal. 2013;2013:834825. https://doi.org/10.1155/2013/834825.
36. Andruszkow H, Frink M, Fromke C, Matityahu A, Zeckey C, Mommsen P, et al. Tip apex distance, hip screw placement, and neck shaft angle as potential risk factors for cut-out failure of hip screws after surgical treatment of intertrochanteric fractures. Int Orthop. 2012;36(11):2347-54. https://doi.org/10.1007/s00264-012-1636-0.
37. Crespo E, Galvez J, Tenias JM, Cano I, Crespo R, Palacios V. A comparative study between gamma nail and percutaneous compression plating for the treatment of intertrochanteric hip fractures. Eur J Trauma Emerg Surg. 2012;38(4):443-9. https://doi.org/10.1007/s00068-012-0181-2.
38. Yu W, Zhang X, Zhu X, Yu Z, Xu Y, Zha G, et al. Proximal femoral nails anti-rotation versus dynamic hip screws for treatment of stable intertrochanteric femur fractures: an outcome analyses with a minimum 4 years of follow-up. BMC Musculoskelet Disord. 2016;17:222. https://doi.org/10.1186/s12891-016-1079-7.
39. Tian YY WZ. Short-term follow-up of dynamic hip screw versus proximal femoral nail anti-rotation for type AO/OTA A1 intertrochanteric femoral fracture in older adults. Chinese Journal of Tissue Engineering Research. 2018;23(12):1834-9.
40. Van der Sijp MPL, de Groot M, Meylaerts SA, du Pre KJ, Verhage SM, Schipper IB, et al. High risks of failure observed for A1 trochanteric femoral fractures treated with a DHS compared to the PFNA in a prospective observational cohort study. Arch Orthop Trauma Surg. 2021 https://doi.org/10.1007/s00402-021-03824-0.
41. Alessio-Mazzola M, Traverso G, Coccarello F, Sanguineti F, Formica M. Dynamic hip screw versus intramedullary nailing for the treatment of A1 intertrochanteric fractures: A retrospective, comparative study and cost analysis. Jt dis relat surg. 2022;33(2):314-22. https://doi.org/10.52312/jdrs.2022.646.
42. Gronhaug KML, Dybvik E, Matre K, Ostman B, Gjertsen JE. Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures : 17,341 patients from the Norwegian Hip Fracture Register. Bone Joint J. 2022;104-B(2):274-82. https://doi.org/10.1302/0301-620x.104b2.Bjj-2021-1078.R1.
43. Pehlivanoglu T, Bayram S, Demirel M, Chodza M, Kocazeybek E, Salduz A, et al. Proximal Femoral Nailing Versus Dynamic Hip Screw in Management of Stable Intertrochanteric Femur

Fractures: A Comparison of Clinical and Radiological Outcomes. Journal of Istanbul Faculty of Medicine-Istanbul Tip Fakultesi Dergisi. 2021;84(4):514-20.

44. Pyrhonen HS, Lagergren J, Wolf O, Bojan A, Mukka S, Moller M, et al. No Difference in Conversion Rate to Hip Arthroplasty After Intramedullary Nail or Sliding Hip Screw for Extracapsular Hip Fractures: An Observational Cohort Study of 19,604 Individuals. 2022 https://doi.org/10.2106/jbjs.22.00316.
45. Lewis SR, Macey R, Gill JR, Parker MJ, Griffin XL. Cephalomedullary nails versus extramedullary implants for extracapsular hip fractures in older adults. Cochrane Database Syst Rev. 2022;1:CD000093. https://doi.org/10.1002/14651858.CD000093.pub6.
46. Parker MJ, Handoll HH. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. Cochrane Database Syst Rev. 2010(9):CD000093. https://doi.org/10.1002/14651858.CD000093.pub5.
47. Swart E, Makhni EC, Macaulay W, Rosenwasser MP, Bozic KJ. Cost-effectiveness analysis of fixation options for intertrochanteric hip fractures. J Bone Joint Surg Am. 2014;96(19):1612-20. https://doi.org/10.2106/JBJS.M.00603.
48. Bohl DD, Basques BA, Golinvaux NS, Miller CP, Baumgaertner MR, Grauer JN. Extramedullary compared with intramedullary implants for intertrochanteric hip fractures: thirty-day outcomes of 4432 procedures from the ACS NSQIP database. J Bone Joint Surg Am. 2014;96(22):1871-7. https://doi.org/10.2106/JBJS.N.00041.

Supplementary materials

Appendix 1: Syntax and search results

Table S1 results of initial search (22 March 2021)

Database searched	via	References	After de-duplication
Embase	Embase.com	5,107	5,023
Medline ALL	Ovid	4,037	536
Web of Science Core Collection *	Web of Knowledge	2,807	432
Cochrane Central Register of Controlled Trials	Wiley	538	126
Subtotal		**12,489**	**6,117**
Other sources: Google Scholar		200	39
Total		**12,689**	**6,156**

*Science Citation Index Expanded (1975-present) ; Social Sciences Citation Index (1975-present) ; Arts & Humanities Citation Index (1975-present) ; Conference Proceedings Citation Index- Science (1990-present) ; Conference Proceedings Citation Index- Social Science & Humanities (1990-present) ; Emerging Sources Citation Index (2015-present)

Table S2 results of search update (26 September 2022)

Database searched	Platform	Years of coverage	Records	Records after duplicates removed
Medline ALL	Ovid	1946 - Present	4525	4490
Embase	Embase.com	1971 - Present	5720	1766
Web of Science Core Collection*	Web of Knowledge	1975 - Present	3548	573
Cochrane Central Register of Controlled Trials**	Wiley	1992 - Present	584	107
Additional Search Engines: Google Scholar (200 top-ranked)			200	40
Total			**14577**	**6976**

*Science Citation Index Expanded (1975-present) ; Social Sciences Citation Index (1975-present) ; Arts & Humanities Citation Index (1975-present) ; Conference Proceedings Citation Index- Science (1990-present) ; Conference Proceedings Citation Index- Social Science & Humanities (1990-present) ; Emerging Sources Citation Index (2005-present)** Manually deleted abstracts from trial registries. No other database limits were used than those specified in the search strategies

Syntax used in both initial search and update:

Embase

('femur intertrochanteric fracture'/exp OR 'femur pertrochanteric fracture'/exp OR 'femur trochanteric fracture'/exp OR 'proximal femur fracture'/de OR (((trochanter* OR pertrochanter* OR intertrochanter*) NEAR/6 (fractur*)) OR ((prox*-femur* OR prox*-femoral*) NEAR/3 (fract*)) OR 31A OR 31A1 OR 31A2 OR 31A3 OR 31-A1 OR 31-A2 OR 31-A3):ab,ti,kw) **AND** ('intramedullary nailing'/exp OR 'intramedullary nail'/exp OR 'bone nail'/exp OR 'bone pin'/exp OR 'bone plate'/exp OR 'bone screw'/exp OR 'plate fixation'/exp OR 'internal fixator'/de OR 'osteosynthesis'/exp OR (CMN OR EPFN OR PFNA OR PFN OR IMN OR BCM OR DLT OR SHS OR DHS OR PCCP OR PFLP OR TFNA OR intramedullar* OR extramedullar* OR intra-medullar* OR extra-medullar* OR cephalomedullar* OR cephalomedullar* OR nail* OR plate* OR plating OR screw* OR pin* OR rod* OR nagel* OR dyna-locking* OR antigrad* OR ((internal*) NEAR/3 (fixat*)) OR osteosynthes* OR osteo-synthes*):ab,ti,kw) NOT ([Conference Abstract]/lim)

Medline

((((trochanter* OR pertrochanter* OR intertrochanter*) ADJ6 (fractur*)) OR ((prox*-femur* OR prox*-femoral*) ADJ3 (fract*)) OR 31A OR 31A1 OR 31A2 OR 31A3 OR 31-A1 OR 31-A2 OR 31-A3).ab,ti,kf.) AND (exp Fracture Fixation, Internal/ OR Internal Fixators OR Bone Nails/ OR Bone Plates/ OR exp Bone Screws/ OR (CMN OR EPFN OR PFNA OR PFN OR IMN OR BCM OR DLT OR SHS OR DHS OR PCCP OR PFLP OR TFNA OR intramedullar* OR extramedullar* OR intramedullar* OR extra-medullar* OR cephalomedullar* OR cephalomedullar* OR nail* OR plate* OR plating OR screw* OR pin* OR rod* OR nagel* OR dyna-locking* OR antigrad* OR ((internal*) ADJ3 (fixat*)) OR osteosynthes* OR osteo-synthes*).ab,ti,kf.) NOT (news OR congres* OR abstract* OR book* OR chapter* OR dissertation abstract*).pt.

Cochrane

((((trochanter* OR pertrochanter* OR intertrochanter*) NEAR/6 (fractur*)) OR (((prox* NEXT/1 femur*) OR (prox* NEXT/1 femoral*)) NEAR/3 (fract*)) OR 31A OR 31A1 OR 31A2 OR 31A3 OR (31 NEXT/1 A1) OR (31 NEXT/1 A2) OR (31 NEXT/1 A3)):ab,ti,kw) **AND** ((CMN OR EPFN OR PFNA OR PFN OR IMN OR BCM OR DLT OR SHS OR DHS OR PCCP OR PFLP OR TFNA OR intramedullar* OR extramedullar* OR (intra NEXT/1 medullar*) OR (extra NEXT/1 medullar*) OR cephalomedullar* OR cephalomedullar* OR nail* OR plate* OR plating OR screw* OR pin* OR rod* OR nagel* OR (dyna NEXT/1 locking*) OR

antigrad* OR ((internal*) NEAR/3 (fixat*)) OR osteosynthes* OR (osteo NEXT/1 synthes*)):ab,ti,kw)

Web of Science
TS=(((((trochanter* OR pertrochanter* OR intertrochanter*) NEAR/5 (fractur*)) OR (((prox* NEAR/1 femur*) OR (prox* NEAR/1 femoral*)) NEAR/2 (fract*)) OR 31A OR 31A1 OR 31A2 OR 31A3 OR 31-A1 OR 31-A2 OR 31-A3)) AND ((CMN OR EPFN OR PFNA OR PFN OR IMN OR BCM OR DLT OR SHS OR DHS OR PCCP OR PFLP OR TFNA OR intramedullar* OR extramedullar* OR intra-medullar* OR extra-medullar* OR cephalomedullar* OR cephalomedullar* OR nail* OR plate* OR plating OR screw* OR pin* OR rod* OR nagel* OR dyna-locking* OR antigrad* OR ((internal*) NEAR/2 (fixat*)) OR osteosynthes* OR osteo-synthes*))) AND DT=(Article OR Review OR Letter OR Early Access)

Google Scholar
"intertrochanteric|pertrochanteric|trochanteric fracture" intramedullar|extramedullar

PubMed
((((trochanter*[tiab] OR pertrochanter*[tiab] OR intertrochanter*[tiab]) AND (fractur*[tiab])) OR ((prox*[tiab]-femur*[tiab] OR prox*[tiab]-femoral*[tiab]) AND (fract*[tiab])) OR 31A OR 31A1 OR 31A2 OR 31A3 OR 31-A1 OR 31-A2 OR 31-A3)) AND (Fracture Fixation, Internal[mh] OR Internal Fixators OR Bone Nails[mh] OR Bone Plates[mh] OR Bone Screws[mh] OR (CMN OR EPFN OR PFNA OR PFN OR IMN OR BCM OR DLT OR SHS OR DHS OR PCCP OR PFLP OR TFNA OR intramedullar*[tiab] OR extramedullar*[tiab] OR intra-medullar*[tiab] OR extra-medullar*[tiab] OR cephalomedullar*[tiab] OR cephalomedullar*[tiab] OR nail*[tiab] OR plate*[tiab] OR plating OR screw*[tiab] OR pin*[tiab] OR rod*[tiab] OR nagel*[tiab] OR dyna-locking*[tiab] OR antigrad*[tiab] OR ((internal*[tiab]) AND (fixat*[tiab])) OR osteosynthes*[tiab] OR osteo-synthes*[tiab])) NOT (news[pt] OR congres*[tiab] OR abstract*[tiab] OR book*[tiab] OR chapter*[tiab] OR dissertation abstract*[tiab])

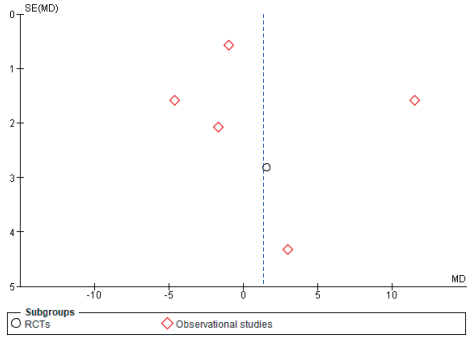
Appendix 2 Specific devices used in included studies as mentioned by authors

	Intramedullary device	Extramedullary device
RCTs		
Ovesen *et al.* (2006)	Trochanteric gamma nail (GN)[1], second generation	Dynamic hip screw (DHS)[2], with or without stabilizing plate
Pajarinen *et al.* (2005)	Proximal femoral nail (PFN)[2]	Dynamic hip screw (DHS)[2]
Parker *et al.* (2017)	Targon proximal femoral (TPF) nail[3] + Targon proximal femoral telescrew (TPFT) nail[3]	Sliding hip screw (SHS), NFS
Tao *et al.* (2013)	Proximal femoral nail antirotation (PFNA)[2]	Reverse less invasive stabilization system (LISS)[2]
Zou *et al.* (2009)	Proximal femoral nail antirotation (PFNA)[2]	Dynamic hip screw (DHS)[2]
Observational studies		
Alessio-Mazzola *et al.* (2022)	Intramedullary proximal femoral nail (PFN)[3]	Dynamic hip screw (DHS)[2]
Andruszkow *et al.* (2012)	Gamma 3 nail (GN)[1]	Dynamic hip screw (DHS)[2]
Cho *et al. (*2016)	Proximal femoral nail antirotation (PFNA)[2]	Dynamic hip screw (DHS)[2]
Crespo *et al.* (2012)	Short gamma nail (GN)[1]	Percutaneous compression plate (PCCP)[5]
Grønhaug *et al.* (2022)	Intramedullary nail (IMN) short or long, NFS	Sliding hip screw (SHS) with or without a trochanteric support plate (TSP), NFS
Matre *et al.* (2013)	Gamma 3 nail (GN)[1], second and third generation + Proximal femoral nail antirotation (PFNA)[2] + Trigen intertan trochanteric antegrade nail[6]	AMBI/CLASSIC hip screw system[6] + Dynamic hip screw (DHS)[2], with or without compression plate
Mohan *et al.* (2019)	Proximal femoral nail (PFN)[2]	Dynamic hip screw (DHS)[2]
Pehlivanoglu *et al.* (2021)	Proximal femoral nail antirotation (PFNA)[2]	Dynamic hip screw (DHS)[2]
Pyrhönen et al. (2022)	Intramedullary nail (IMN), short and long, NFS	Sliding hip screw (SHS,) NFS
Sevinç *et al.* (2020)	Proximal femoral nail antirotation (PFNA)[2]	Dynamic hip screw (DHS)[2]
Talmaç *et al.* (2019)	Proximal femoral nail antirotation (PFNA)[2]	Dynamic hip screw (DHS)[2] + Percutaneous compression plate (PCCP)[5]
Tian *et al.* (2010)	Proximal femoral nail antirotation (PFNA)[2]	Dynamic hip screw (DHS)[2]
Van der Sijp *et al.* (2021)	Proximal femoral nail antirotation (PFNA)[2]	Dynamic hip screw (DHS)[2]
Yu *et al.* (2016)	Proximal femoral nail antirotation (PFNA)[2]	Dynamic hip screw (DHS)[2]

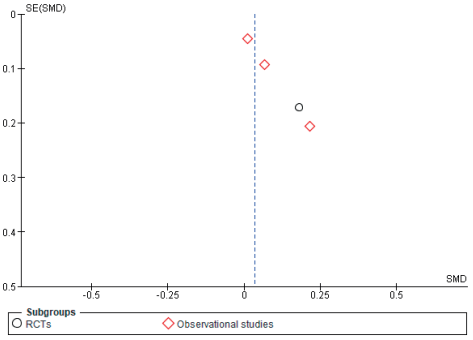
[1] Stryker Howmedica, Freiburg, Germany/ Mahwha, New Jersey, USA[2] Depuy-Synthes, Oberdorf, Switzerland/ Westchester, PA, USA [3] Endovis B.A., EBA, Citieffe, Italy [4] B. Braun, Tuttlingen, Germany [5] Orthofix, Bussolengo, Italy [6] Smith & Nephew, London, UK
NFS, not further specified

Appendix 3: Funnel Plots of included outcome measures

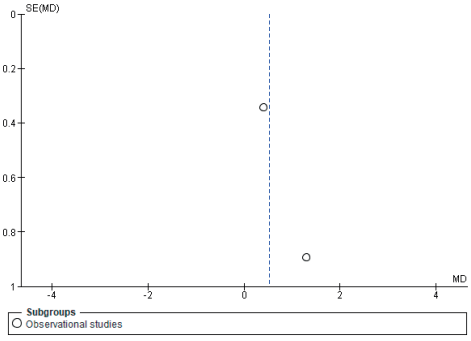
A: Harris Hip Score



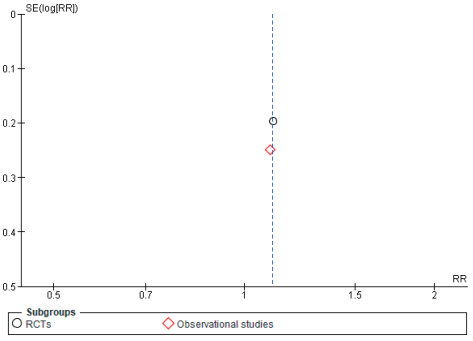
B: One-year pain score



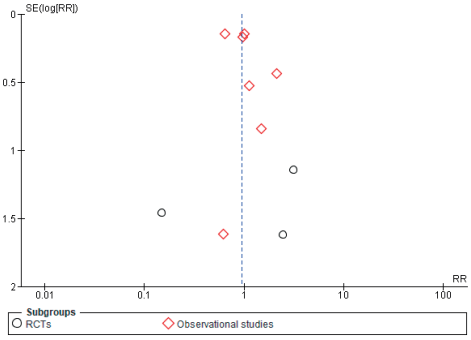
C: Parker mobility score



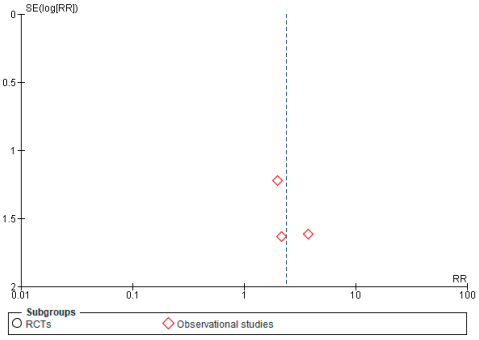
D: Good walking ability



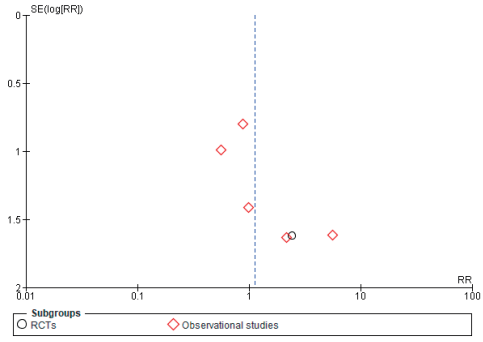
E: Reoperation



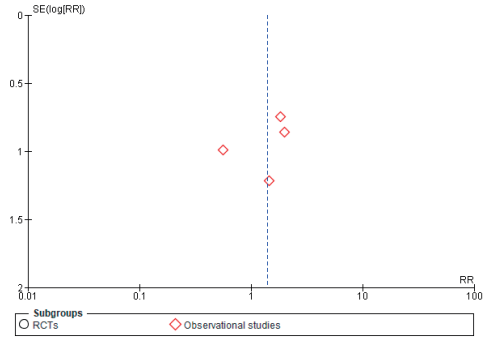
F: Deep infection



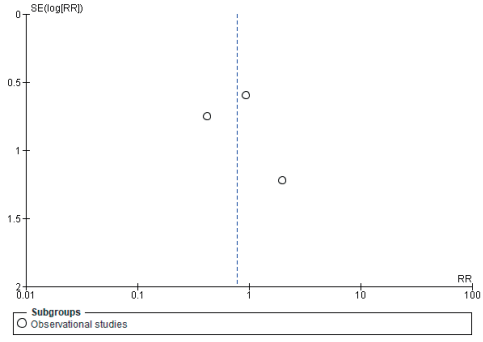
G: Superficial infection



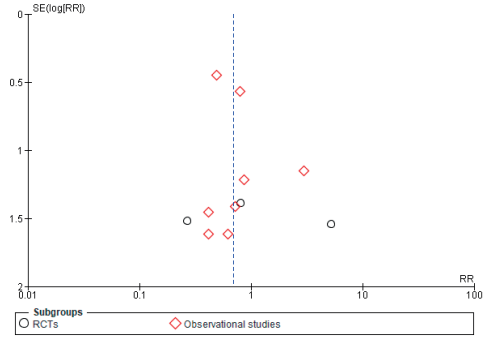
H: Non-union



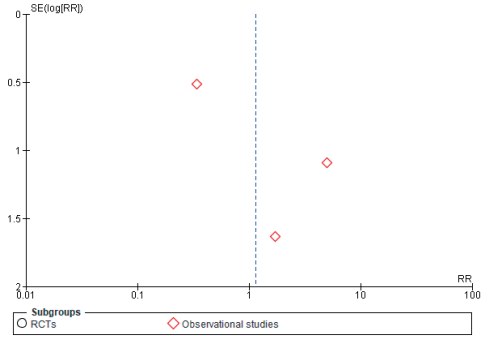
I: Malunion



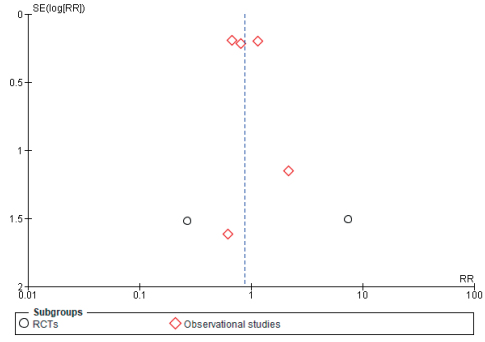
J: Cut-out



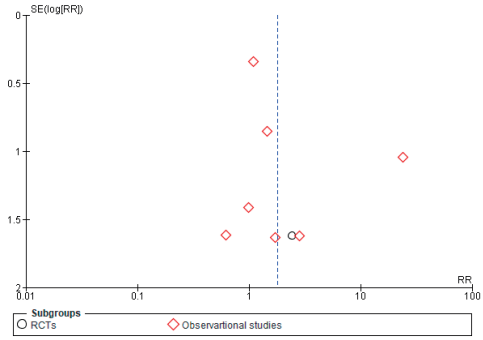
K: Peri-implant fracture



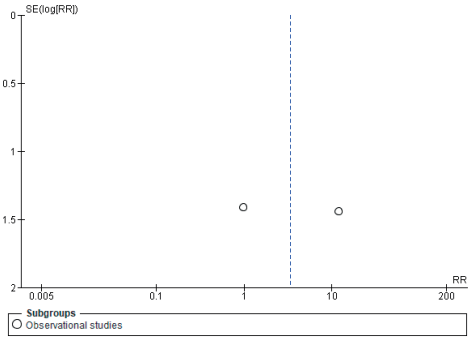
L: Conversion to prosthesis



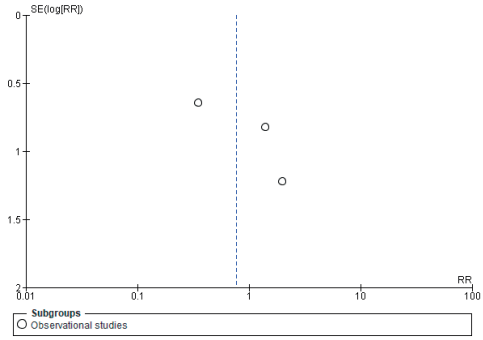
M: Implant/fixation failure



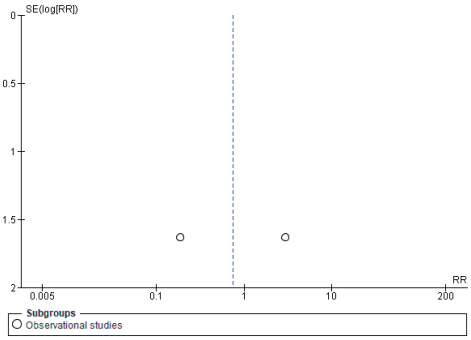
N: Limb-length discrepancy



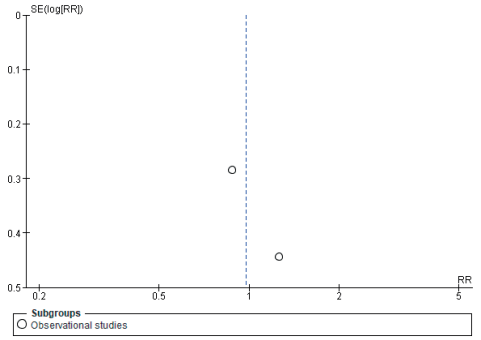
O: Heterotopic ossification



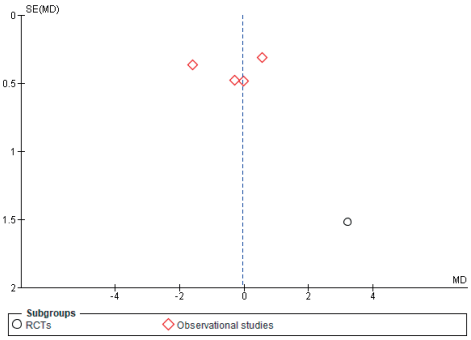
P: Osteolysis



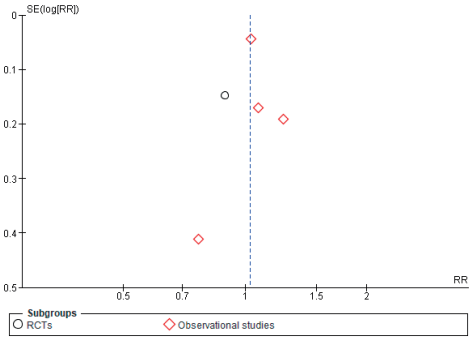
Q: Mortality



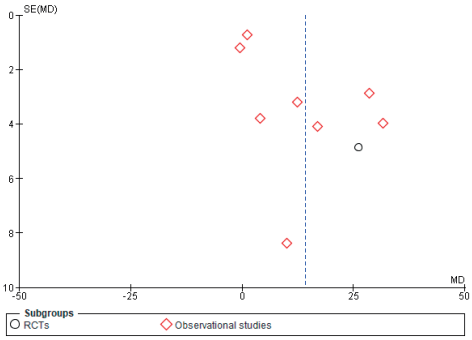
R: Bone healing time



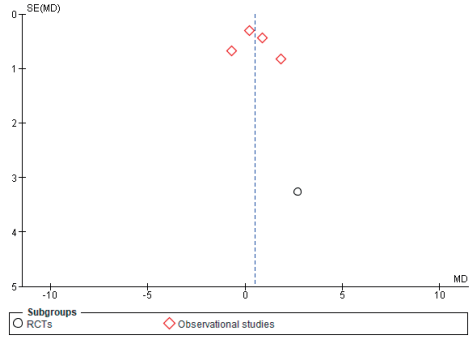
S: Good quality of reduction



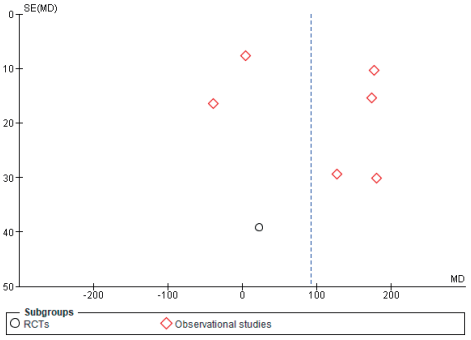
T: Operation time



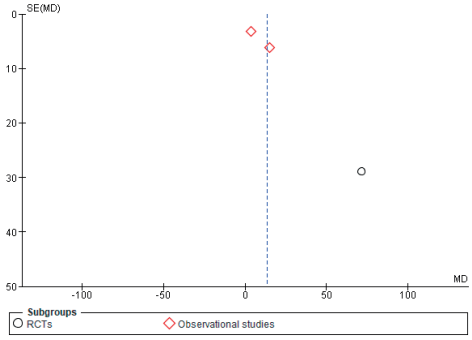
U: Hospital stay



V: Blood loss



W: Fluoroscopy time



Appendix 4: Additional forest plots of included variables

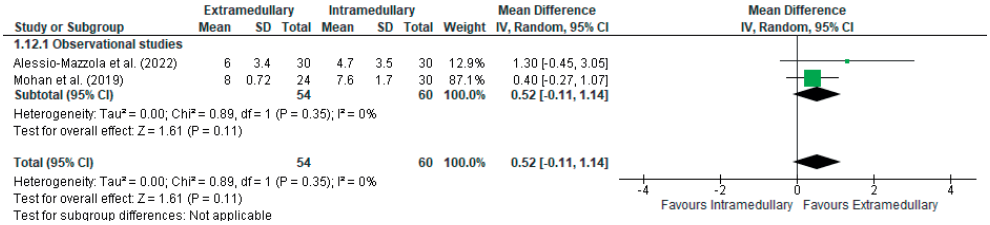


Figure a1: Forrest plot of Parker mobility score after extramedullary versus intramedullary fixation of stable trochanteric fractures

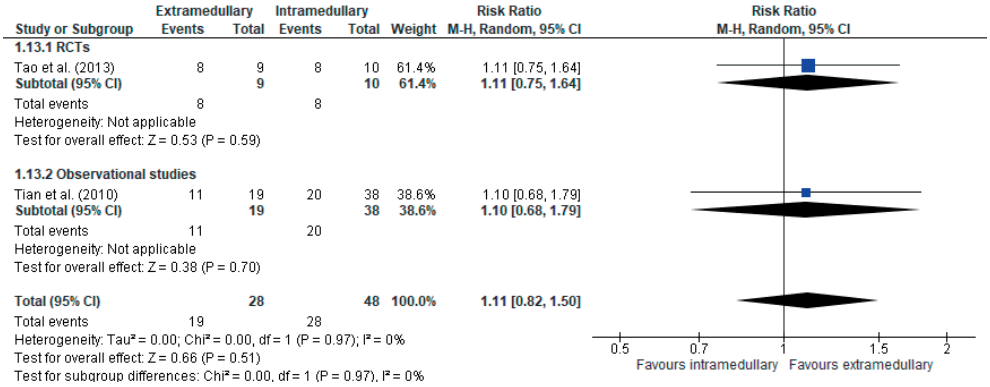


Figure a2: Forrest plot of good walking ability after extramedullary versus intramedullary fixation of stable trochanteric fractures

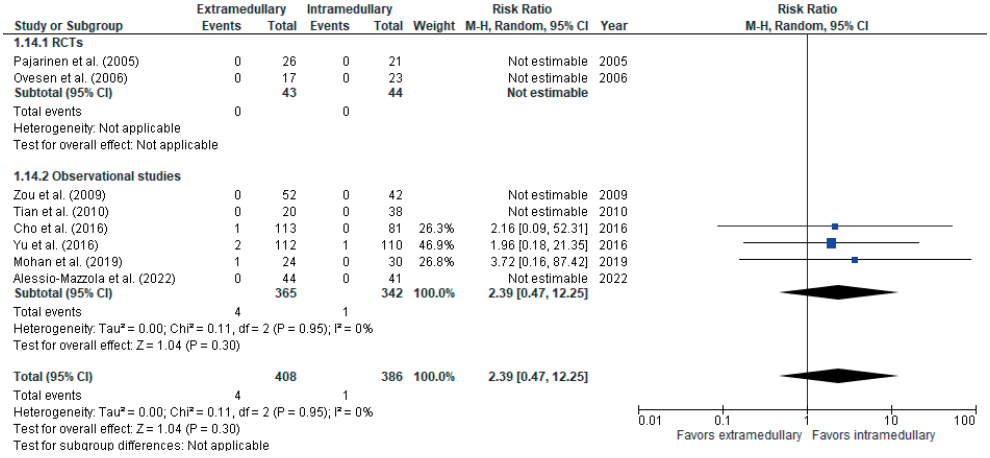


Figure a3: Forrest plot of deep infection rate after extramedullary versus intramedullary fixation of stable trochanteric fractures[1]

[1]Deep infection was defined as post-operative (wound) infection needing the use of intravenous antibiotics and/or operative intervention

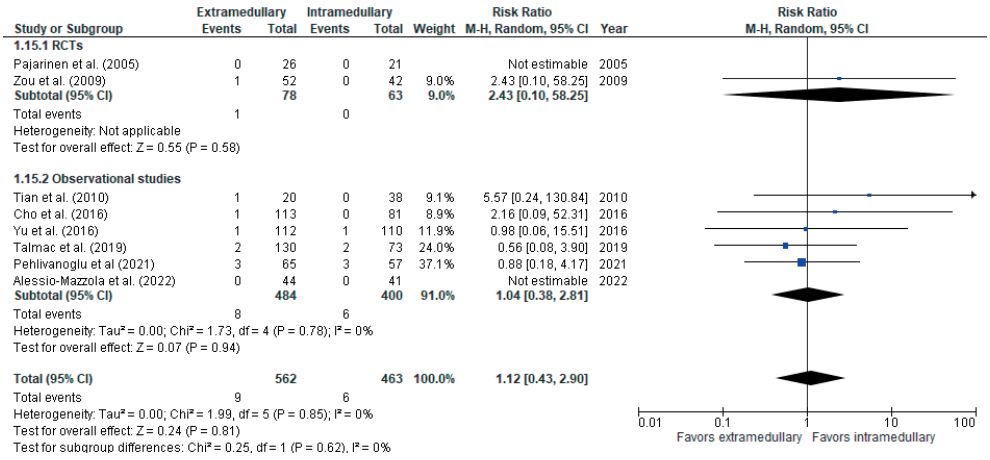


Figure a4: Forrest plot of superficial infection rate after extramedullary versus intramedullary fixation of stable trochanteric fractures[1]

[1]Superficial infection was defined as post-operative wound infection not needing intravenous antibiotics or operative intervention.

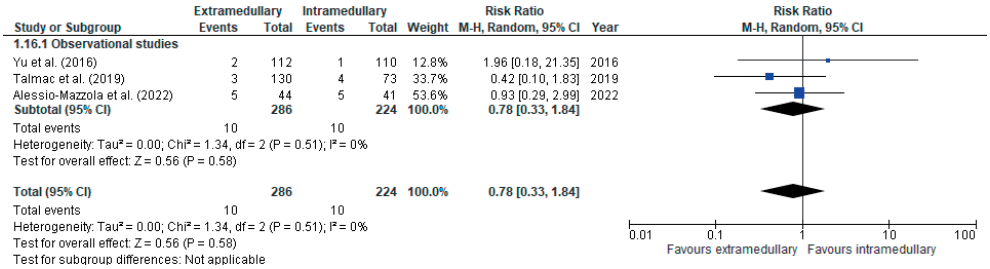


Figure a5: Forrest plot of malunion rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

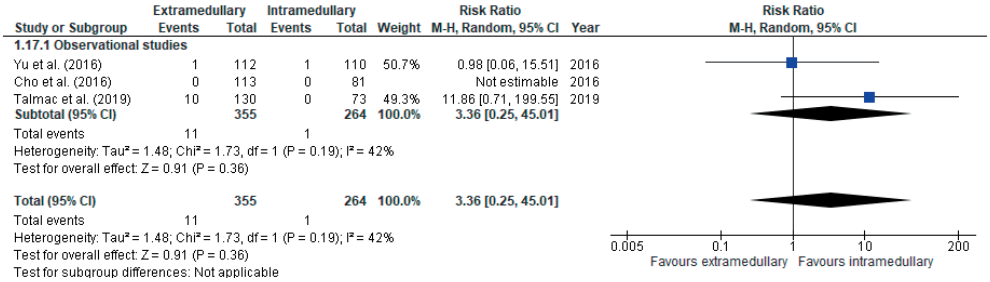


Figure a6: Forrest plot of limb-length discrepancy rate after extramedullary versus intramedullary fixation of stable trochanteric fractures



Figure a7: Forrest plot of heterotopic ossification rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

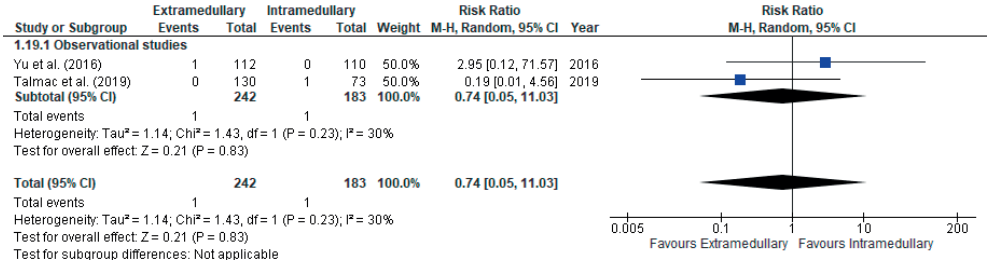


Figure a8: Forrest plot of osteolysis rate in well-fixed implants after extramedullary versus intramedullary fixation of stable trochanteric fractures

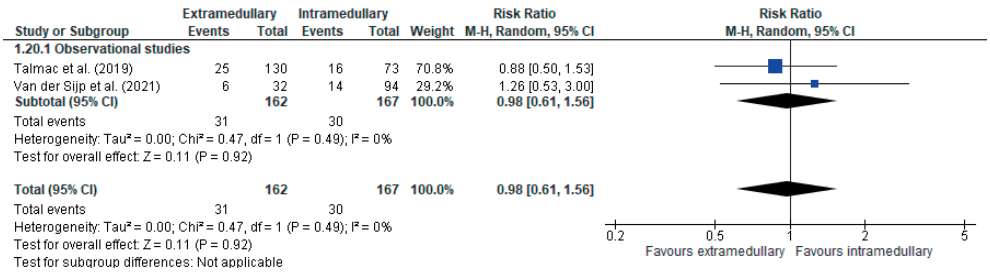


Figure a9: Forrest plot of one-year mortality rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

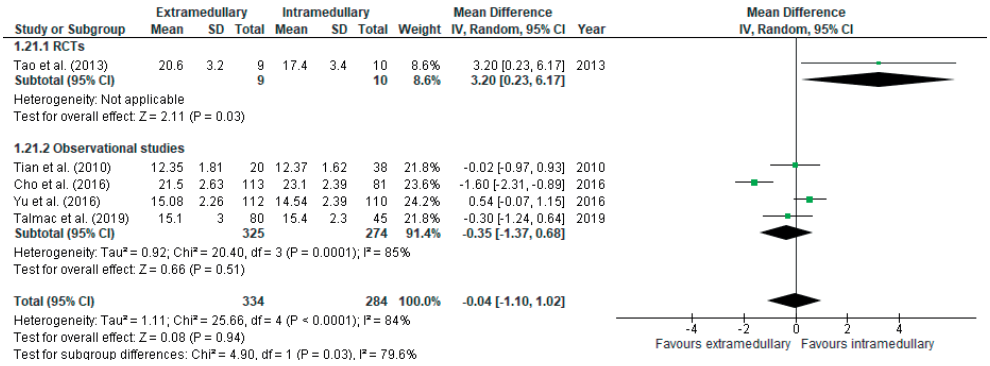


Figure a10: Forrest plot of mean bone healing time in weeks after extramedullary versus intramedullary fixation of stable trochanteric fractures

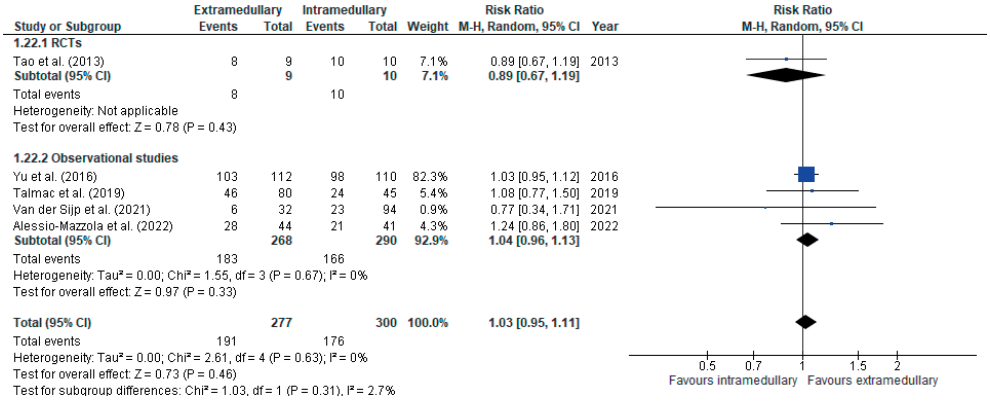


Figure a11: Forrest plot of good quality of reduction rate after extramedullary versus intramedullary fixation of stable trochanteric fractures

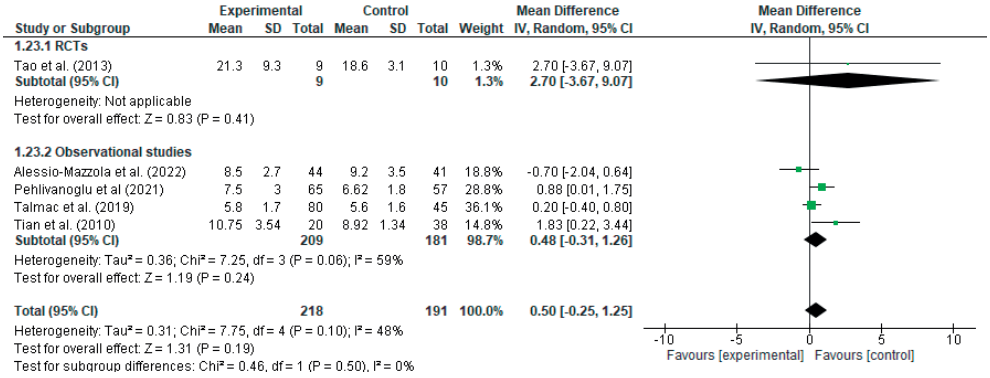


Figure a12: Forrest plot of mean hospital stay in days after extramedullary versus intramedullary fixation of stable trochanteric fractures

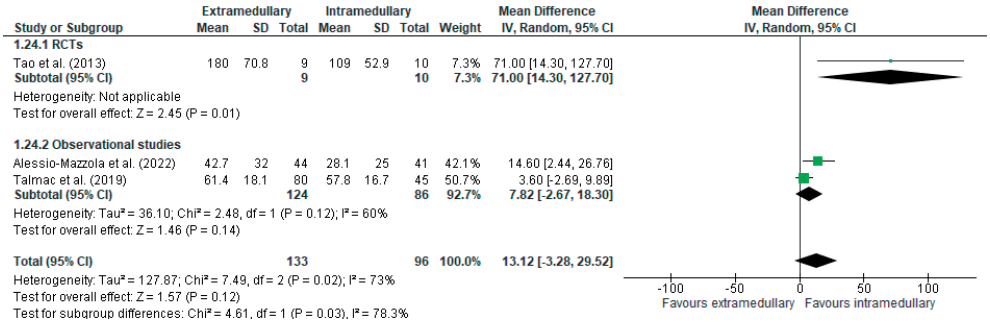


Figure a13: Forrest plot of mean fluoroscopy time in seconds after extramedullary versus intramedullary fixation of stable trochanteric fractures



5

Extramedullary versus intramedullary fixation of unstable trochanteric femoral fractures (AO type 31-A2): a systematic review and meta-analysis

Miliaan L. Zeelenberg*, A. Cornelis Plaisier*, Lennard H.T. Nugteren, Sverre A.I. Loggers, Pieter Joosse, Michiel H.J. Verhofstad, Dennis Den Hartog, Esther M.M. Van Lieshout, on behalf of the STABLE-HIP Study Group

*Authors contributed equally

Archives of Orthopaedic and Trauma Surgery 2024, Volume 144, Issue 3, Pages 1189-1209

Abstract

Objective

The aim of this systematic review was to compare extramedullary fixation and intramedullary fixation for AO type 31-A2 trochanteric fractures in the elderly, with regards to functional outcomes, complications, surgical outcomes, and costs.

Methods

Embase, Medline, Web of Science, Cochrane Central Register of Controlled Trials, and Google Scholar were searched for randomized controlled trials (RCTs) and observational studies. Effect estimates were pooled across studies using random effects models. Results were presented as weighted risk ratio (RR) or weighted mean difference (MD) with corresponding 95% confidence interval (95% CI).

Results

Fourteen RCTs (2,039 patients) and 13 observational studies (22,123 patients) were included. Statistically superior results in favor of intramedullary fixation were found for Harris Hip Score (MD 4.09, 95% CI 0.91-7.26, p=0.04), Parker mobility score (MD -0.67 95% CI -1.2 to -0.17, p=0.009), lower extremity measure (MD -4.07 95% CI -7.4 to -0.8, p=0.02), time to full-weight bearing (MD 1.14 weeks CI 0.92-1.35, p<0.001), superficial infection (RR 2.06, 95% CI 1.18-3.58, p=0.01), non-union (RR 3.67, 95% CI 1.03-13.10, p=0.05), fixation failure (RR 2.26, 95% CI 1.16-4.44, p=0.02), leg shortening (MD 2.23 mm, 95% CI 0.81-3.65, p=0.002), time to radiological bone healing (MD 2.19 months, 95% CI 0.56-3.83, p=0.009), surgery duration (MD 11.63 min, 95% CI 2.63-20.62, p=0.01), operative blood-loss (MD 134.5 mL, 95% CI 51-218, p=0.002), and Tip-Apex Distance >25mm (RR 1.73, 95% CI 1.10-2.74, p=0.02). No comparable cost/costs-effectiveness data was available.

Conclusion

Current literature shows that several functional outcomes, complications, and surgical outcomes were statistically in favor of intramedullary fixation when compared with extramedullary fixation of AO/OTA 31-A2 fractures. However, as several of the differences found appear not to be clinically relevant and for many outcomes data remains sparse or heterogeneous, complete superiority of IM fixation for AO type 31-A2 fractures remains to be confirmed in a detailed cost-effectiveness analysis.

Introduction

Proximal femoral fractures are a major health problem among the elderly worldwide and the incidence rate is rising due to progressive aging. It is expected that the total number of patients with a proximal femoral fracture will rise from 1.66 million in 1990 to 6.26 million worldwide by 2050 (1-3). These fractures are not exclusively a problem for public health systems, they also form a burden for society, due to high disability, costs, and morbidity (4-8).

Trochanteric fractures make up 33 to 52% of the total number of proximal femoral fractures (9, 10). They are subdivided into stable (two-part) trochanteric with intact lateral wall (31-A1), unstable multi-fragmentary trochanteric with incomplete lateral wall (31-A2), and unstable intertrochanteric (reverse obliquity) fractures (31-A3) by the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification (11). Of all proximal femoral fractures, 18-20% are classified as 31-A2 trochanteric fractures (12). Surgical treatment options for trochanteric fractures are either fixation using an intramedullary nail or extramedullary fixation using plates with or without a sliding hip screw.

Current surgical guidelines, such as the United Kingdom's National Institute for Health and Care Excellence (NICE) guideline and the Dutch Guideline for treatment of proximal femoral fractures advise the use of extramedullary fixation for both AO type 31-A1 and 31-A2 fractures, mainly due to better cost-effectivity (13, 14). Extramedullary fixation is more cost-effective than intramedullary fixation in the majority of cases, largely because of lower implant costs (15). The guidelines do, however, see both fixation strategies as viable treatment options for type 31-A2 fractures and underline the absence of conclusive evidence of superiority for either device. Older literature, mainly utilizing the now obsolete first generation of cephalomedullary nails, discouraged intramedullary devices due to a higher failure and reoperation rate (16).

While clear historic evidence of superiority is missing, in recent years the use of intramedullary fixation is rising to up to 90% in the U.S. (17, 18). While more recent studies report improving outcomes for intramedullary fixation, the optimal treatment strategy, remains a topic of debate and the increasing trend of intramedullary fixation may be caused by other factors than clinical data alone (17-21).

Therefore, the objective of this study was to compare recent literature assessing the differences in functional outcomes, complications, surgical outcomes, and costs/cost-effectiveness between extramedullary and intramedullary fixation using currently available implants in elderly patients with AO type 31-A2 fractures.

Methods

This systematic review and meta-analysis was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (22). A protocol was developed prior to conducting the current study. This study did not require approval from the local medical research ethics committee.

Search and eligibility criteria

Embase, PubMed/Medline, Web of Science, Cochrane Central Register of Controlled Trials and Google Scholar were searched on 22 March 2021 and updated on 26 September 2022, including terms related to 'trochanteric fractures', 'intramedullary treatment' and 'extramedullary treatment'. An overview of the complete search strategy used is included in Appendix 1 of Chapter 4. After deduplication, two reviewers (LHTN and ACP) independently screened all articles for eligibility by title and abstract. Thereafter, independent full-text analysis for eligibility was conducted. Disagreements were resolved by consensus.

Studies were included when they presented data (a) published after 1990 of (b) acute (c) AO 31-A2 trochanteric fractures, (d) comparing intramedullary (IM) and extramedullary (EM) fixation (e) in patients aged 50 years and older, (f) using currently available devices. Studies were excluded when they (a) presented no original data, (b) did not mention relevant outcomes, (c) were biomechanical, *in vitro* or cadaveric studies, (d) pathological fractures, (e) bilateral fractures, (f) peri-implant fractures, (g) were case reports, (h) did not make distinction between type of fracture or treatment.

Quality assessment

The included studies were assessed by two reviewers (LHTN and ACP) independently, using the Cochrane Risk of Bias tool, version 2 (RoB2) for the randomized controlled trials (RCTs) and the methodological index for non-randomized studies (MINORS) for the observational studies (23, 24). RoB2 provides a risk of bias judgement resulting in low, some concerns or high risk of bias. The MINORS provides a score with a maximum of 16 points for non-comparative studies and 24 points for comparative studies. A higher score indicates higher quality.

Data collection

Data from all included studies were independently extracted by two reviewers (LHTN and ACP) according to a predefined data sheet. The baseline characteristics collected for each study contained: first author, year of publication, setting (country), inclusion period, study design, type of fixation device used, follow-up period, and mean age,

gender distribution, and total number of patients with AO-OTA 31-A2 fracture in the study population. See Appendix 1 for specific devices used per included study.

Data were collected on the following outcome measures: Functional outcomes: Harris Hip score (HHS), Parker mobility score, Lower extremity measure (a modification of the Toronto extremity salvage score (TESS) (25)), recovery to pre-operative walking ability, time to full-weight bearing; Complications: reoperation, superficial wound infection, deep wound infection, nonunion, cut-out/protrusion (varus collapse of the neck-shaft angle leading to extrusion of the screw), peri-prosthetic fracture, conversion to prosthesis, implant/fixation failure (mechanical loosening or fracturing of the implant), heterotopic ossification, leg shortening, screw migration, femur shaft fracture, mortality; Surgical outcomes/operation characteristics: mean time to bone healing, radiologic quality of reduction, surgery duration, hospital stay, blood loss, blood transfusion (units per patient), blood transfusion, fluoroscopy time, tip-apex distance (TAD), TAD >25mm, femoral neck shortening, neck-shaft-angle (NSA);Costs/cost-effectiveness. All outcome measures were included and analyzed as defined by the original article.

Authors of studies with missing data (standard deviations) were contacted by email once (26-30). When no data was received, standard deviations were imputed by weighted mean SD of the other included studies, if at least two other studies were available.

Statistical analysis

RevMan version 5.4 was used to analyze data. Binary outcomes were pooled using the Cochran-Mantel-Haenszel statistic and presented as risk ratio (RR) and continuous outcomes were pooled using the inverse variance weighting method and presented as mean difference (MD), both with corresponding 95% confidence intervals (95% CI). All analyses were done separately for each of the different study designs (RCTs and observational studies) and for overall effect and were presented in Forest plots. Random effects models were used in all comparisons because of a high likelihood of heterogeneity between studies due to inclusion of both RCT and observational studies and comparison of multiple types of devices in different countries and clinical settings. Assessment of heterogeneity between studies was done by using the Cochrane Q-test and was quantified using the I^2 statistic. A p-value <0.05 was considered statistically significant. According to the Cochrane Handbook for Systematic Reviews of Interventions, the level of heterogeneity was found to be unimportant when the I^2 value is between 0% and 40%, moderate between 30% and 60%, substantial between 50% and 90% and considerable between 75% and 100% (31). Funnel plots were visually inspected to assess publication bias (Appendix 2).

Results

Search

The primary search resulted in a total of 14,577 records. After deduplication 7,213 studies remained for screening (Figure 1). Out of 473 full-text articles assessed for eligibility, 27 were included in this systematic review and meta-analysis. Fourteen were RCTs (26, 28, 30, 32-42) and 13 were observational studies (19, 20, 27, 29, 43-51).

Study characteristics

The included studies were published from 2006 to 2022 and provided data of 24,232 patients with an AO-OTA 31-A2 trochanteric fracture, of whom 2,039 patients were included in RCTs and 22,123 in observational studies (Table 1). Of all included patients, 11,932 were treated with an extramedullary (EM) device and 12,300 with an intramedullary (IM) device. Table S2 in Appendix 3 (OR3) provides an overview of the outcome measures reported in the individual studies. The mean follow-up time was 12 months.

Quality assessment

The RoB 2 overall bias assessment indicated high risk of bias in three RCTs (30, 33, 39), medium risk in six RCTs (28, 32, 36, 40, 42, 52), and low risk in five RCTs (26, 34, 37, 38, 41) (OR3, Table S3). The MINORS score for observational studies ranged from a minimum of 13 (44) (moderate quality) to a maximum of 22 (47) (high quality) with a mean of 17 (SD 2.5) (OR3, Table S4).

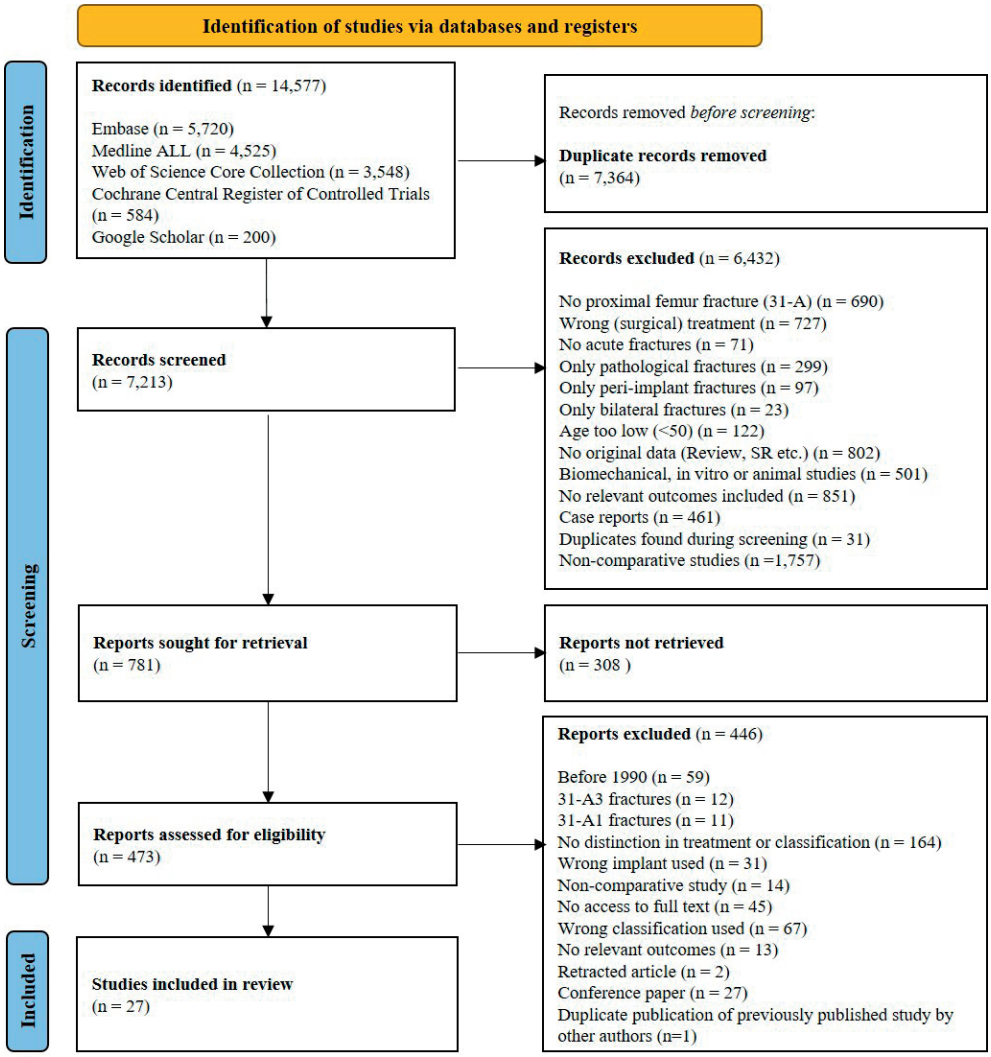


Figure 1: Flowchart of search results, article inclusion and exclusion

Table 1: Overview of included studies comparing intramedullary versus extramedullary fixation in AO type 31-A2 fractures

Study (publication date)	Country	Study design	Inclusion period	Total population AO type 31-A2 fracture	Extramedullary fixation				Intramedullary fixation				Follow-up (months)
					Number of patients	Device	Age (years)	Males (%)	Number of patients	Device	Age (years)	Males (%)	
Randomized controlled trials													
Aktselis *et al.* (2014) (32)	Greece	RCT	2008-2011	71	35	AMBI DHS	83.1	20.0	36	G3 Nail	82.9	22.2	12
Andalib *et al.* (2020) (33)	Iran	RCT	2016-2018	93	55	DHS, DCS	61.45	47.2	38	CMN	64.40	44.7	12
Barton *et al.* (2010) (26)	United Kingdom	RCT	N.D.	210	110	SHS	83.3	22.7	100	Long GN	83.2	19.0	12
Garg *et al.* (2022) (42)	India	RCT	2013-2018	105[*]	35	DHS	69.8	31.4	35	PFN	70.38	28.6	12
Ovesen *et al.* (2006) (38)	Denmark	RCT	2001-2003	96	52	DHS	78.5[a]	28.8[a]	44	TGN	79.9[a]	27.4[a]	12
Pajarinen *et al.* (2005) (39)	Finland	RCT	1999-2001	50	24	DHS	80.3[a]	25.9[a]	26	PFN	80.9[a]	24.1[a]	4
Parker *et al.* (2017) (40)	United Kingdom	RCT	2002-2009	717	364	SHS	82.1[a]	23.2[a]	353	IN	82.2[a]	22.4[a]	12
Reindl *et al.* (2015) (28)	Canada	RCT	N.D.	204	92	DHS	80	33.7	112	Intertan, GN	82	51.0	12
Saleem *et al.* (2020) (34)	Pakistan	RCT	2017-2019	108	54	DHS	60.2	68.5	54	PFN	58.54	57.4	5.5
Singh *et al.* (2017) (35)	India	RCT	2009-2011	26	12	PF-LCP	60.5[a]	39.1[a]	14	PFN	58.3[a]	31.8[a]	24
Tao *et al.* (2013) (41)	China	RCT	2010-2011	42	21	Reverse LISS	80.7	23.8	21	PFNA	82.5	52.4	12
Verettas *et al.* (2010) (30)	Greece	RCT	N.D.	118	59	DHS	79.22	25.4	59	IMN	81.03	33.9	0.3
Xu *et al.* (2010) (36)	China	RCT	2006-2008	106	55	DHS	77.9	29.1	51	PFNA	78.5	29.4	12
Zehir *et al.* (2015) (37)	Turkey	RCT	2010-2013	198	102	DHS	78.86	38.2	96	PFNA	77.22	38.5	15.95[c]
Observational studies													
Andruszkow *et al.* (2012) (43)	Germany	Retrospective cohort	2007-2010	120	86	DHS	80.8[a,b]	29.8[a,b]	34	GN	80.8[a,b]	29.8[a,b]	N.D.
Butt *et al.* (2017) (44)	United Kingdom	Retrospective cohort	2015-2016	79	50	DHS	74.8[a]	29.8[a,b]	29	PFNA	80.6[a]	29.8[a,b]	N.D.

Crespo *et al.* (2012) (45)	Spain	Retrospective cohort	2004-2009	235	115	PCCP	82.5[a]	26.7[a]	120	GN	83.1[a]	18.4[a]	12
Duymus *et al.* (2019) (46)	Turkey	Retrospective cohort	2012-2014	91	30 + 29	DHS + PF-LCP	70.68	44.1	32	PFN	71.66	40.6	EM: 26.22 IM: 25.77
Gronhaug *et al.* (2022) (20)	Norway	Prospective cohort	2013-2019	7,168	4,193	SHS	83.5	26.5	2,975	IMN	83.3	26.4%	36
Knobe *et al.* (2009) (27)	Germany	Retrospective cohort	2002-2007	135	36 + 46	DHS + PCCP	78.3	31.7	53	PFN	77.2	39.6	EM: 16.2 IM: 19.2
Knobe *et al.* (2012) (47)	Germany	Prospective cohort	2005-2008	108	54	PCCP	81	24.1	54	PFNA	78	24.1	24
Müller *et al.* (2020) (48)	Germany	Retrospective cohort	2006-2015	375	75 + 100	DHS +AR (+TSP)	83.5	21.1	200	PFNA	82.6	23.0	24
Page *et al.* (2016) (49)	United Kingdom	Retrospective cohort	2011-2015	370	267	DHS	85.90	27.7	103	IMN	86.03	18.4	N.D.
Pyrhonen *et al.* (2022) (19)	Sweden	Retrospective cohort	2012-2018	10,213	3,187	SHS	85[d]	28.8	7,026	IMN	85[d]	27.7	60
Sevinç *et al.* (2020) (29)	Turkey	Prospective cohort	N.D.	58	18	DHS	77.1[a]	59.1[a]	40	PFNA	78.9[a]	48.2[a]	12
Suh *et al.* (2015) (50)	Korea	Retrospective cohort	2010-2012	100	50	CHS	77.3	42	50	PFNA	73.8	48	12
Tucker *et al.* (2018) (51)	United Kingdom	Prospective cohort	2000-2015	3071	2377 + 149	SHS (+TSP)	80.2[a,b]	23.5[a,b]	545	CMN	80.2[a,b]	23.5[a,b]	12

[a]Value for total study population including AO type 31-A1 and/or A3 fractures. [b]Value for individual groups not specified in study.
[c]Median follow-up duration [d]Median age [*]Of the total population, 35 patients were treated by (hemi)arthroplasty
RCT, Randomized Controlled Trial; (AMBI) DHS, Dynamic Hip Screw; G3, Gamma3 Nail; DCS, Dynamic Condylar Screw; CMN, Cephalomedullary Nail; SHS, Sliding Hip Screw; GN, Gamma Nail; TGN, Trochanteric Gamma Nail; PFN, Proximal Femoral Nail; PFNA, Proximal Femoral Nail Antirotation; IN, Intramedullary Nail; PF-LCP, Proximal Femoral Locking Compression Plate; Reverse LISS, Reverse Less Invasive Stabilization System; IMN, Intramedullary Nail; PCCP, Percutaneous Compression Plate; ARS, Antirotation Screw; TFN, Trochanteric Fixation Nail; TSP, Trochanteric Stabilization Plate; CHS, Compression Hip Screw; N.D., Not Described; N.S., Not Specified

Functional outcomes

Harris hip score (HHS)

The Harris hip score at one-year follow-up was reported in eight studies; three RCTs (35, 41, 42) and five observational studies (27, 29, 46, 47, 50), in which 265 patients were treated with EM fixation and 287 patients with IM fixation (Figure 2). The mean HHS was 72 for EM fixation and 75 for IM fixation. The HHS significantly favored IM fixation (MD -4.09, 95% CI -7.26 to -0.91, p=0.01, I^2=47%).

Parker mobility score (PMS)

Parker mobility score at one-year follow-up was reported in three RCTs (Figure 3) (32, 36, 42), in which 125 patients were treated with EM fixation and 122 with IM fixation. The mean PMS was 5.8 for EM devices and 6.5 for IM devices. The PMS significantly favored IM fixation (MD -0.67, 95% CI -1.2 to -0.17, p=0.009, I^2=0%).

Lower extremity measure (LEM)

Lower extremity measure at one-year follow-up was reported in two RCT's (OR3, Figure S2) (28, 33), in which 135 patients were treated with EM devices and 125 were treated with IM devices. The mean LEM was 64.5 for EM devices and 67.0 for IM devices. The LEM significantly favored IM fixation (MD -4.07, 95% CI -7.39 to -0.75, p=0.02, I^2=0%).

Recovery to pre-operative walking ability

Recovery to pre-operative walking ability was reported in two RCTs (OR3, Figure S3) (36, 37). This was measured at 6 months by Zehir *et al*. and up to 1 year by Xu *et al*. Recovery to pre-operative walking ability was achieved in 87 out of 145 (60.0%) patients treated with an EM device and in 100 out of 136 (73.5%) patients treated with an IM device. There was no significant difference between fixation groups (RR 0.80, 95% CI 0.61 to 1.05, p=0.11, I^2=0%).

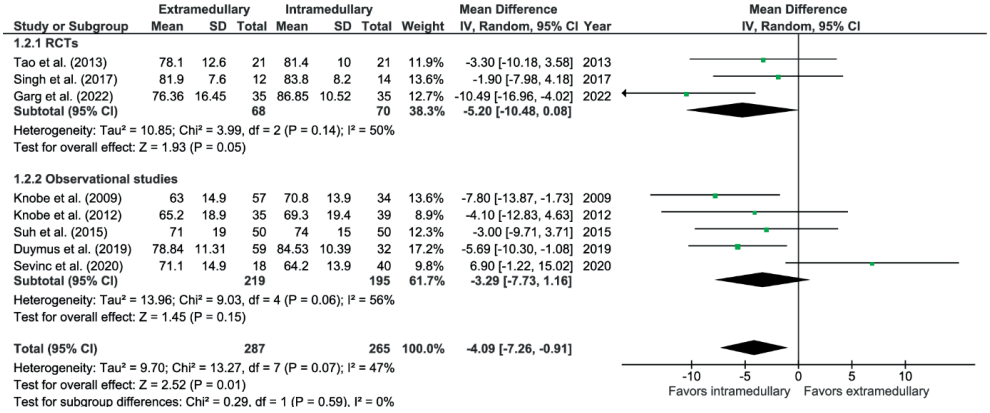
Time to full weight bearing (weeks)

Time to full weight bearing was reported in one RCT and one observational study, with 94 patients treated by extramedullary fixation and 67 by intramedullary fixation (OR3, Figure S4) (42, 46). Mean time to full weight bearing was 2.5 weeks for EM fixation and 1.4 weeks for IM fixation. It significantly favored IM fixation (MD 1.14, 95% CI 0.92 to 1.35, p<0.001, I^2=51%)

Pain scores

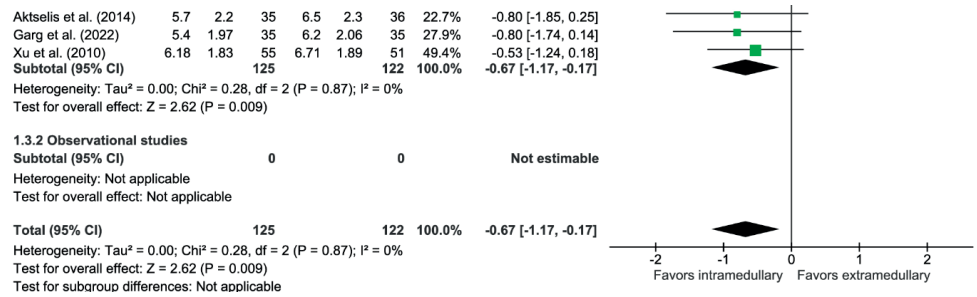
Different measurement scales were used for the pain scores, namely the VAS (27, 30, 50), and HHS pain score (27). None of the studies reported a significant difference.

Figure 2: Forest plot of Harris Hip Score after extramedullary versus intramedullary fixation of AO 31-A2 fractures



Standard deviations for Knobe *et al.* (2009) and Sevinc *et al.* (27, 29) were imputed.
IV, inverse variance; RCT, randomized controlled trial; SD, standard deviation

Figure3: Forestplot of Parker mobility score after extramedullary versus intramedullary fixation of AO 31-A2 fractures



Standard deviations for Garg *et al.* (2022) were imputed

Meta-analysis of the VAS score was not possible, because two studies out of three did not report SDs and thus no imputed SD could be calculated (30, 50).

Other functional scores

Multiple other measurement scales are used for the functional outcomes and quality of life, in addition to those previously mentioned: Merle d'Aubigné & Postel score (27, 47), EQ-5D (32), Barthel index (32), functional independence measure (FIM) (28), Coval score (50), and HHS function score (27). None of the included studies reported a significant difference between fixation groups. Due to the high diversity in included functional and quality of life scores and/or missing SDs, no meta-analysis was performed.

An overview of functional outcomes is shown in table 2

Table 2: Overview of functional outcomes

Outcome	Study type	References	OM	Total population EMF	Total population IMF	Mean/cases		Pooled effect (95% CI), p-value	I^2
						EMF	IMF		
Harris hip score	3 RCTs 5 OS	(27, 29, 35, 41, 46, 47, 50)	MD	287	265	72[1]	75[1]	-4.09 (-7.26 to -0.91) **p=0.04**	47%
Parker mobility score	3 RCTs	(32, 36)	MD	125	122	5.8[1]	6.5[1]	-0.67 (-1.2 to -0.17) **p=0.009**	0%
Lower extremity measure	2 RCTs	(28, 33)	MD	135	125	64.5[1]	67.0[1]	-4.07(-7.39 to -0.75) **p=0.02**	0%
Recovery to preoperative walking ability	2 RCTs	(36, 37)	RR	145	136	87[2] (60%)	100[2] (74%)	0.88 (0.61 to 1.05) p=0.11	44%
Time to full-weight bearing (weeks)	1 RCT 1 OS	(42, 46)	MD	94	67	2.5[1]	1.4	1.14 (0.92 to 1.35) **p<0.001**	51%

[1]Subgroup mean [2]Cases reported in subgroup

OM, Outcome measurement; EMF, Extramedullary fixation; IMF, Intramedullary fixation; RCT, Randomized Controlled Trial; OS, Observational Studies; RR, Relative Risk; MD, Mean Difference; N.A., Not available

Complications

Reoperations

Reoperation rate was reported in 11 studies; five RCTs (26, 33, 37, 38, 40) and eight observational studies (Figure 4) (19, 20, 27, 46-49, 51). Reoperation occurred in 604 out of 11,172 (5.4%) patients treated with an EM device and 578 out of 11,619 (5.0%) treated with an IM device. There was no significant difference between fixation groups (RR 1.25, 95% CI 0.94 to 1.66, p=0.12, I^2=59%).

Deep infections

Deep infection rate was reported in nine studies; six RCTs (26, 28, 33, 37-39, 42) and four observational studies (Figure 5) (27, 46, 49, 50). Deep infection occurred in 15 out of 928 (1.6%) patients treated with an EM device and 4 out of 689 (0.6%) patients treated with an IM device. Five studies reported zero cases (26, 28, 39, 42, 50). There was no significant difference between fixation groups (RR 1.45, 95% CI 0.52 to 4.03, p=0.48, I^2=0%).

Superficial infections

Superficial infection rate was reported in 11 studies; eight RCTs (28, 30, 33, 34, 36, 37, 39, 42) and four observational studies (Figure 6) (44, 46, 48, 50). Superficial infection occurred in 47 out of 810 (5.8%) patients treated with an EM device and 18 out of 782 (2.3%) patients treated with an IM device. Three studies reported zero cases (28, 39, 50). The risk of superficial infections was significantly lower in the IM group (RR 2.06, 95% CI 1.18 to 3.58, p=0.01, I^2=0%).

Nonunion

Nonunion rate was reported in four studies; five RCTs (33, 34, 36, 40, 42) and one observational study (Figure 7) (46). Nonunion occurred in 18 out of 622 (2.9%) patients treated with an EM device and 2 out of 563 (0.4%) patients treated with an IM device. The risk for nonunion was significantly lower in the IM group (RR 3.67, 95% CI 1.03 to 13.10, p=0.05, I^2=0%).

Cut-out/protrusion

Cut-out rate was reported in fourteen studies; seven RCTs (28, 32, 36-40) and seven observational studies (Figure 8) (27, 43-48). Cut-out occurred in 52 out of 1345 (3.9%) patients treated with an EM device and 35 out of 1240 (2.8%) patients treated with an IM device. Three studies (32, 36, 39) reported zero cases. There was no significant difference between fixation groups (RR 1.18, 95% CI 0.68 to 2.05, p=0.55, I^2=28%).

Peri-implant fractures

Peri-implant fracture rate was reported in six studies; three RCTs (37, 40, 42) and three observational studies (Figure 9) (44, 47, 48). Peri-implant fracture occurs in 8 out of 780 (1.0%) patients treated with an EM device and 12 out of 767 (1.6%) patients treated with an IM device. Garg *et al.* reported zero cases (42). There was no significant difference between fixation groups (RR 0.70, 95% CI 0.29 to 1.71, p=0.44, I^2=0%).

Conversion to prosthesis

Conversion rate was reported in nine studies; four RCTs (33, 37, 38, 40) and seven observational studies (Figure 10) (19, 20, 27, 44, 46, 47, 49). Conversion to prosthesis was reported in 274 out of 8,386 (3.3%) patients treated with an EM device and 287 out of 10,784 (1.7%) patients treated with an IM device. There was no significant difference between fixation groups (RR 1.11, 95% CI 0.93 to 1.32, p=0.25, I^2=0%).

Fixation failure

Fixation/implant failure rate was reported in seven studies; three RCTs (32, 33, 36) and four observational studies (Figure 11) (27, 46, 48, 50). Fixation failure occurred in 52 out of 511 (10.2%) patients treated with an EM device and 17 out of 460 (3.7%) patients treated with an IM device. Suh et al. (50) reported zero cases. The risk for fixation failure was significantly lower in the IM group (RR 2.26, 95% CI 1.16 to 4.44, p=0.02, I^2=23%).

Heterotopic ossification

Heterotopic ossification was reported in three studies; two RCTs (28, 42) and one observational study (50). In Reindl *et al.*(28) heterotopic ossification occurred in 23 out of 130 (17.7%) patients treated with an EM device and 49 out of 137 (35.8%) patients treated with an IM device (RR 0.51, 95% CI 0.35-0.76, p=0.008). In respectively, 12 and 35 cases this was Brooker stage 1 heterotopic ossification. No pooled risk ratio for heterotopic ossification could be calculated, because both Garg *et al.* and Suh et al. (42, 50) reported zero cases.

Leg shortening (mm)

Leg shortening was reported in four studies; two RCTs (34, 36) and two observational studies (OR3, Figure S5) (47, 50), in which 194 patients were treated with an EM device and 194 with an IM device. The mean leg shortening length was 4.3 mm for EM devices and 2.3 mm for IM devices. Leg shortening was significantly lower for IM fixation (MD 2.23 mm, 95% CI 0.81 to 3.65, p=0.002, I^2=65%).

Screw migration

Migration of cephalomedullary screw was reported in three studies; two RCTs (37, 46) and one observational study (OR3, Figure S6) (47). Screw migration occurred in 10 out of 215 (4.7%) patients treated with an EM device and in 10 out of 182 (5.5%) patients treated with an IM device. There was no significant difference between fixation groups (RR 0.76, 95% CI 0.11 to 5.08, p=0.77, I^2=55%).

Femoral shaft fractures

Femoral shaft fractures were reported in two RCTs (OR3, Figure S7) (36, 37). Femoral shaft fractures occurred in 1 out of 157 (0.6%) patients treated with an EM device and in 4 out of 147 (2.7%) patients treated with an IM device. There was no significant difference between fixation groups (RR 0.38, 95% CI 0.05 to 2.81, p=0.34, I^2=0%).

Mortality

Mortality rate, after at least one-year follow-up was reported in seven studies; three RCTs (26, 36, 37) and four observational studies (Figure 12) (27, 47, 48, 51). In 764 out of 3104 (24.6%) patients treated with an EM device and 269 out of 1099 (24.5%) patients treated with an IM nail mortality occurred during follow-up. There was no significant difference between fixation groups (RR 1.04, 95% CI 0.85 to 1.28, p=0.72, I^2=43%).

An overview of all complications can also be found in table 3.

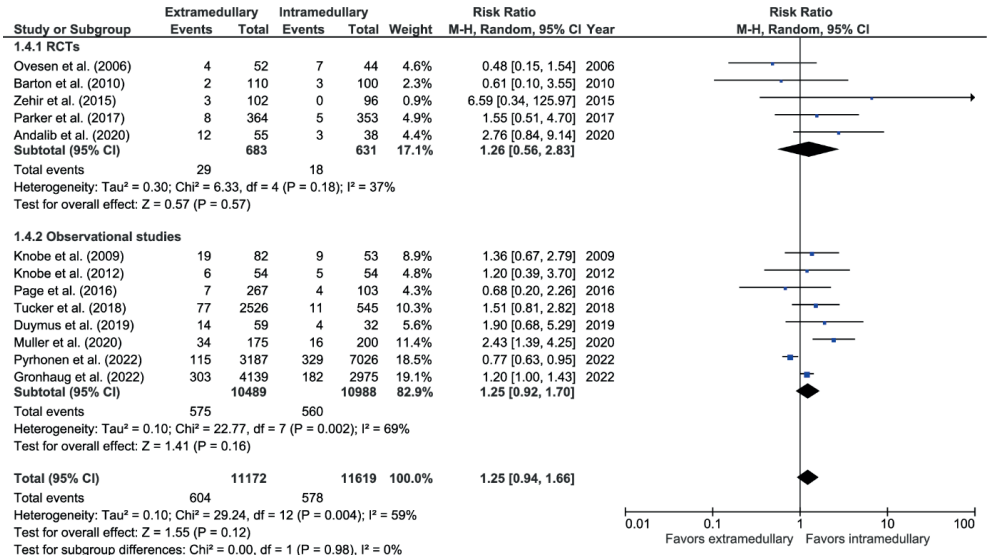


Figure 4: Forest plots of reoperations after extramedullary versus intramedullary fixation of AO 31-A2 fractures

M-H, Mantel-Haenszel; RCT, randomized controlled trial; SD, standard deviation

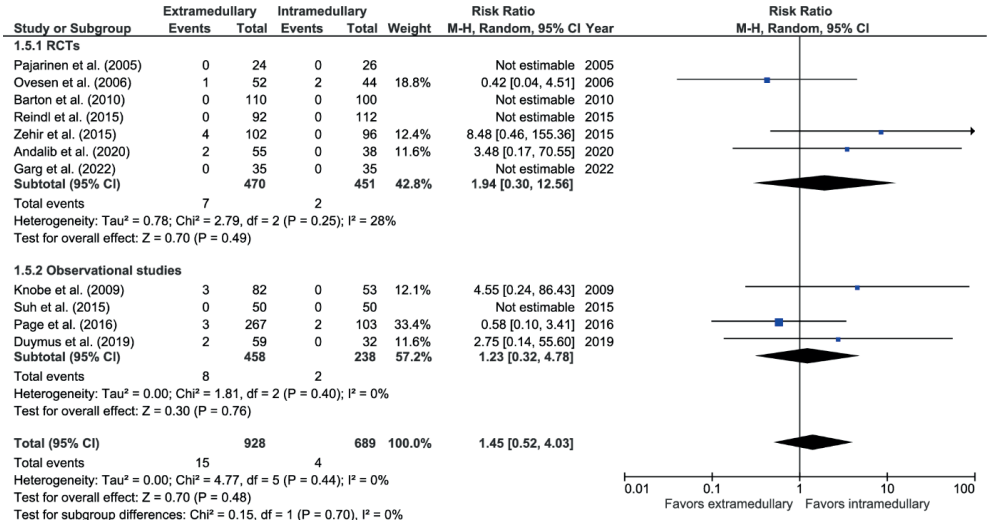


Figure 5: Forest plots of deep infections after extramedullary versus intramedullary fixation of AO 31-A2 fractures

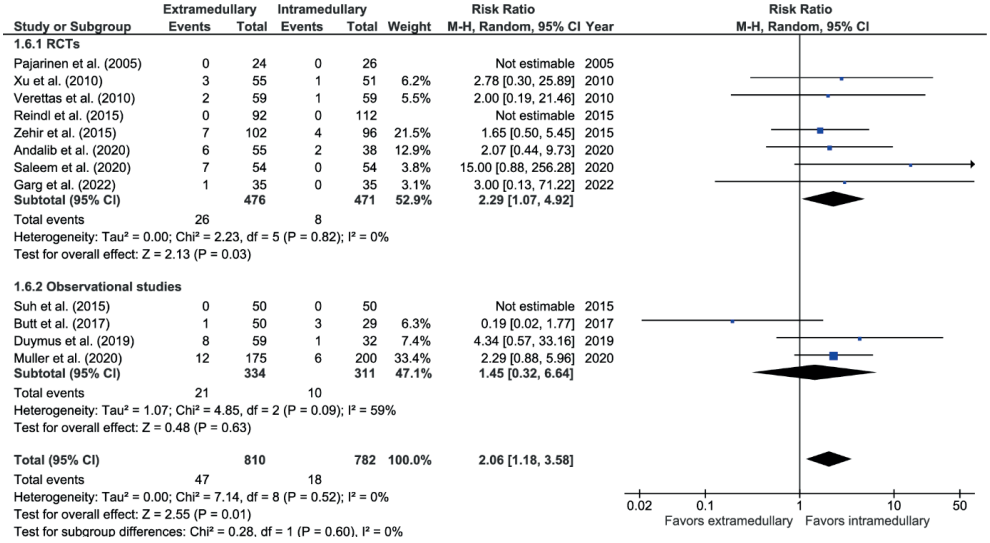


Figure 6: Forest plots of superficial infections after extramedullary versus intramedullary fixation of AO 31-A2 fractures

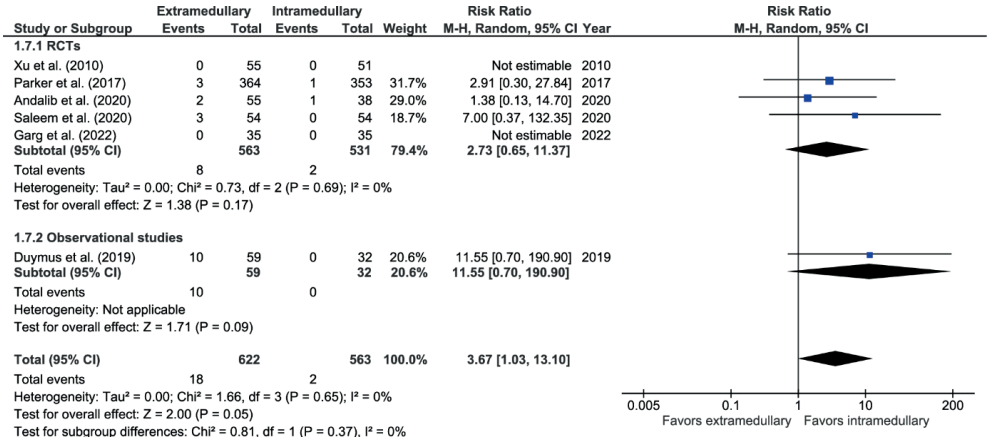


Figure 7: Forest plots of nonunion after extramedullary versus intramedullary fixation of AO 31-A2 fractures

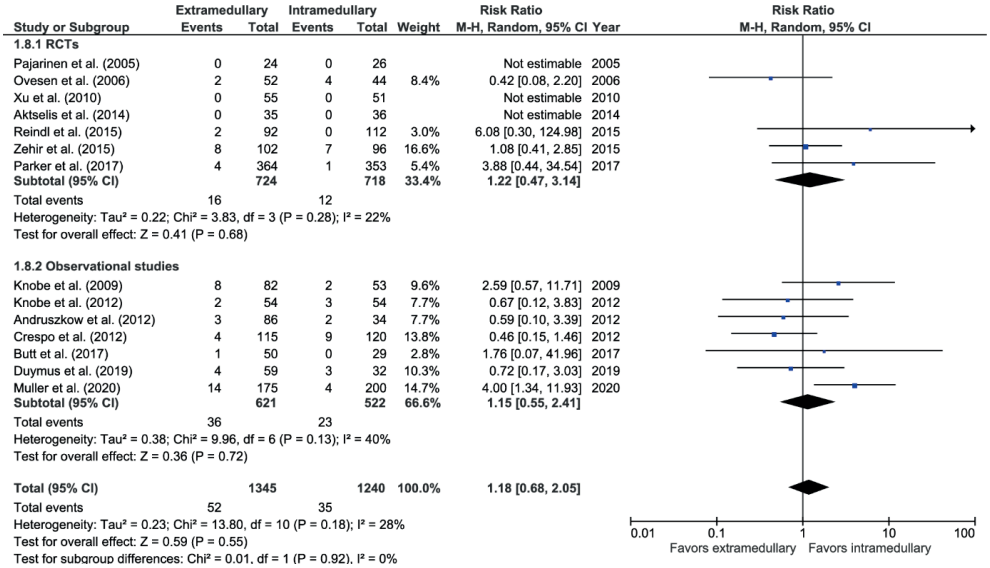


Figure 8: Forest plots of cut-out after extramedullary versus intramedullary fixation of AO 31-A2 fractures

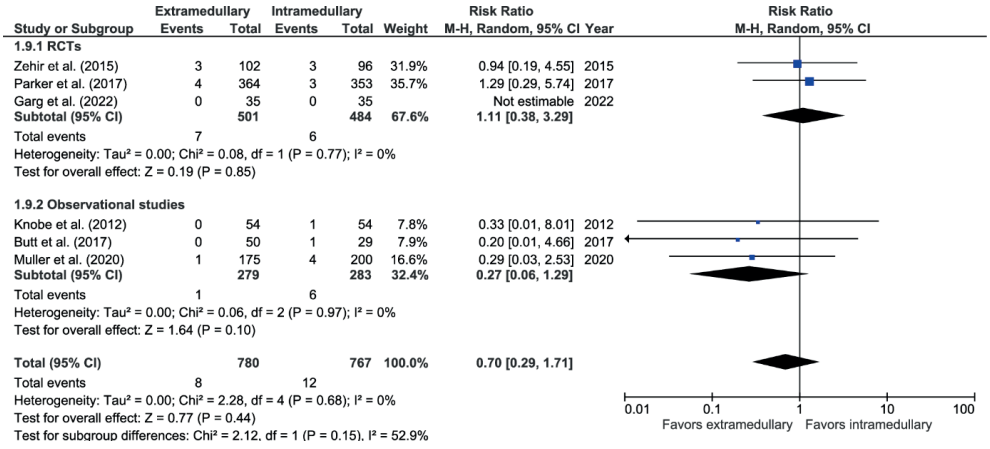


Figure 9: Forest plots of peri-implant fractures after extramedullary versus intramedullary fixation of AO 31-A2 fractures

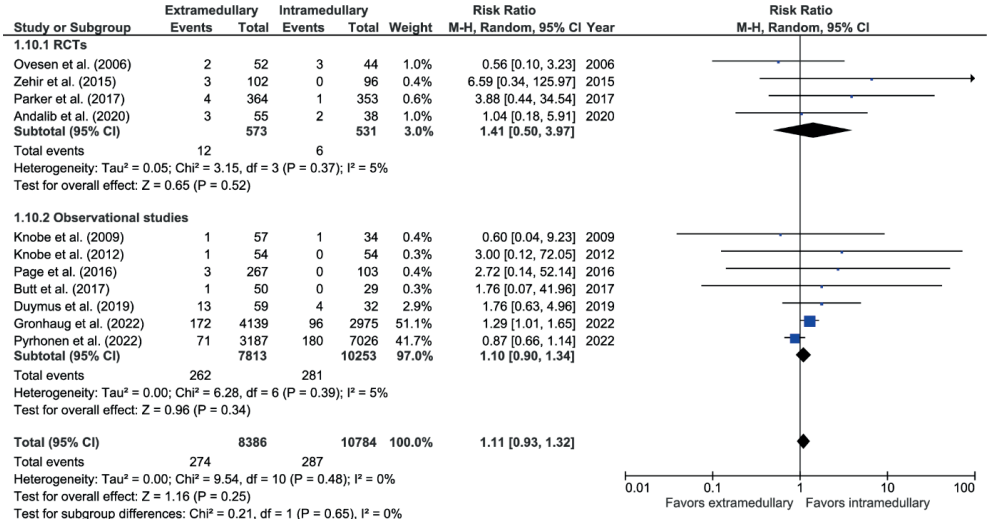


Figure 10: Forest plots of conversion to prosthesis after extramedullary versus intramedullary fixation of AO 31-A2 fractures

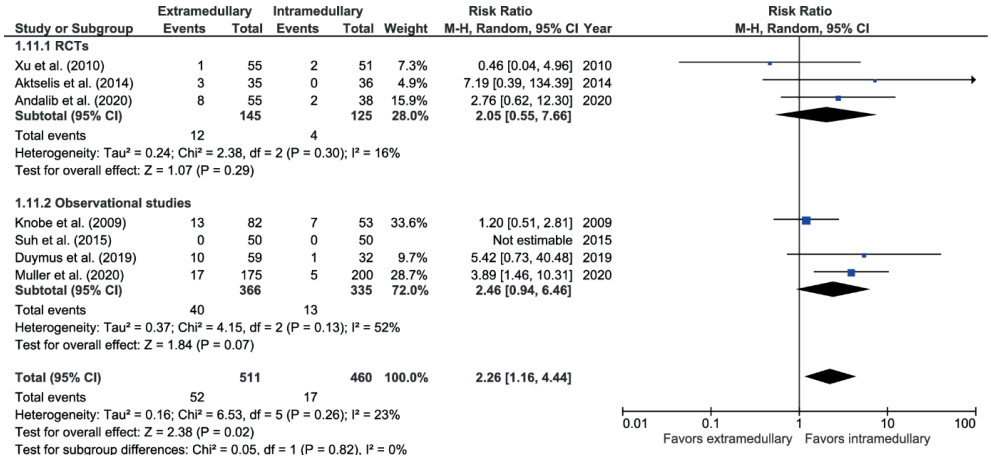


Figure 11: Forest plot of implant/fixation failure after extramedullary versus intramedullary fixation of AO 31-A2 fractures

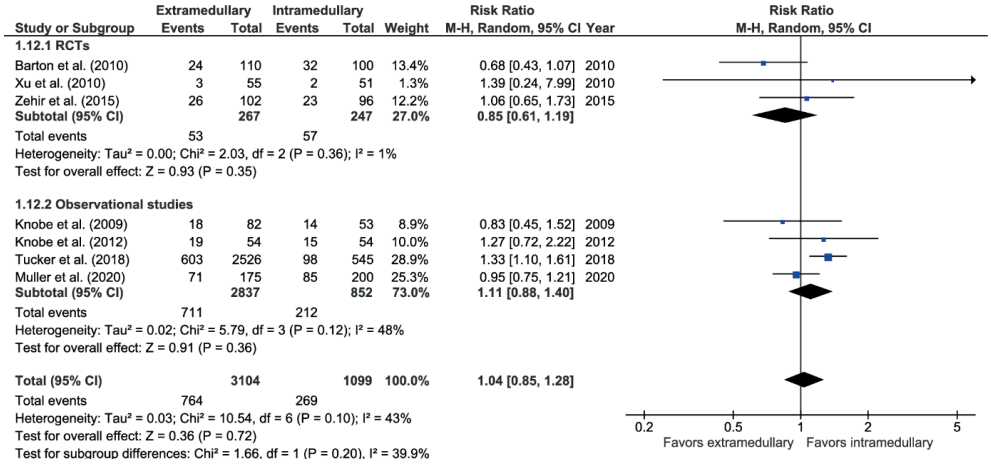


Figure 12: Forest plot of mortality at minimum one-year follow-up after extramedullary versus intramedullary fixation of AO 31-A2 fractures

Table 3: Overview of complications

Outcome	Study type	References	OM	Total population EMF	Total population IMF	Mean/cases		Pooled effect (95% CI), p-value	I^2
						EMF	IMF		
Reoperation	5 RCTs 8 OS	(19, 20, 26, 27, 33, 37, 38, 40, 46-49, 51)	RR	11,172	11,619	604[2] (4.8%)	578[2] (4.1%)	1.25 (0.94 to 1.66) p=0.12	59%
Deep infection	7 RCTs 4 OS	(26-28, 33, 37-39, 46, 49, 50)	RR	928	689	15[2] (1.6%)	4[2] (0.6%)	1.45 (0.52 to 4.03), p=0.48	0%
Superficial infection	8 RCTs 4 OS	(28, 30, 33, 34, 36, 37, 39, 42, 44, 46, 48, 50)	RR	810	782	47[2] (5.8%)	18[2] (2.3%)	2.06 (1.18 to 3.58) **p=0.01**	0%
Nonunion	5 RCTs, 1 OS	(33, 34, 36, 40, 42, 46)	RR	622	563	18[2] (2.9%)	2[2] (0.4%)	3.67 (1.03 to 13.10) **p=0.05**	0%
Cut-out	7 RCTs, 7 OS	(27, 28, 32, 36-40, 43-48)	RR	1,345	1,240	52[2] (3.9%)	35[2] (2.8%)	1.18 (0.68 to 2.05) p=0.55	28%
Peri-impant fracture	2 RCTs 3 OS	(37, 40, 44, 47, 48)	RR	780	767	8[2] (1.0%)	12[2] (1.6%)	0.70 (0.29 to 1.71) p=0.44	0%
Conversion to prosthesis	4 RCTs 7 OS	(19, 20, 27, 33, 37, 38, 40, 44, 46, 47, 49)	RR	8,386	10,784	274[2] (3.3%)	287[2] (2.7%)	1.11 (0.93 to 1.32) p=0.25	0%
Fixation failure	3 RCTs 4 OS	(27, 32, 33, 36, 46, 48, 50)	RR	511	460	52[2] (10.2%)	17[2] (3.7%)	2.26 (1.16 to 4.44), **p=0.02**	23%
Heterotopic ossification	2 RCT 1 OS	(28, 42, 50)	N.A.	167	172	23[2] (13.8%)	49[2] (28.5%)	N.A.	N.A.
Leg shortening (mm)	2 RCTs 2 OS	(34, 36, 47, 50)	MD	194	194	4.3[1]	2.3[1]	2.23 (0.81 to 3.65) **p=0.002**	65%
Screw migration	2 RCTs 1 OS	(37, 46, 47)	RR	215	182	10[2] (4.7%)	10[2] (5.5%)	0.76 (0.11 to 5.08) p=0.77	55%
Femoral shaft fracture	2 RCTs	(36, 37)	RR	157	147	1[2] (0.6%)	4[2] (2.7%)	0.38 (0.05 to 2.81) p=0.34	0%
Mortality	3 RCTs 4 OS	(26, 27, 36, 37, 47, 48, 51)	RR	3,104	1,099	764[2] (24.6%)	269[2] (24.5%)	1.04 (0.85 to 1.28) p=0.72	43%

[1]Subgroup mean [2]Cases reported in subgroup

OM, Outcome measurement; EMF, Extramedullary fixation; IMF, Intramedullary fixation; TAD, Tip-apex distance; RCT, Randomized Controlled Trial; OS, Observational Studies; RR, Relative Risk; MD, Mean Difference; N.A., Not available

Surgical outcomes and operation characteristics

Mean time to bone healing (weeks)

Mean time to radiological bone healing was reported in five studies; four RCTs (34, 37, 41, 42) and one observational study (Figure 13) (46), with 271 patients treated with EM devices and 238 patients with IM devices. Mean time to bone healing was 19.6 weeks for EM devices and 17.8 weeks for IM devices. Bone healing time was significantly longer in EM fixation (MD 2.19 weeks, 95% CI 0.56 to 3.83, p=0.009, I^2=89%).

Poor radiological quality of reduction

Poor radiological quality of reduction using the classification by was reported in three studies; one RCT (41) and two observational studies (OR3, Figure S8) (46, 48). Poor quality of reduction was reported in 23 out of 255 (9.0%) patients treated with an EM device and in 7 out of 253 (2.8%) patients treated with an IM. Tao et al. (41) reported zero cases. There was no significant difference between fixation groups (RR 2.52, 95% CI 0.71 to 8.93, p=0.15, I^2=56%).

Operation time (min)

Operation time was reported in nine studies; Six RCTs (32, 34, 36, 37, 41, 42) and four observational studies (Figure 14) (27, 46-48), with 672 patients treated with EM devices and 632 patients treated with IM devices. The mean surgery duration was 71 min for EM fixation and 58 min for IM fixation. Operation time was significantly longer for EM fixation (MD 11.63 min, 95% CI 2.63 to 20.62, p=0.01, I^2=97%).

Hospital stay (days)

Hospital stay was reported in seven studies; three RCTs (36, 41, 42) and five observational studies (OR3, Figure S9) (27, 46-49), with 748 patients treated with EM devices and 549 patients treated with IM devices. The mean hospital stay was 11 days in EM fixation and 12 days in IM fixation. There was no significant difference between fixation groups (MD 0.63, 95% CI -0.36 to 1.62, p=0.21, I^2=68%).

Blood loss and transfusion

The mean blood loss was 312 mL for EM fixation and 150 mL for IM fixation (34, 36, 37, 41, 42). Blood loss was significantly higher in EM fixation (MD 134.5 mL, 95% CI 51.00 to 217.95, p<0.001, I^2=98%, OR3, Figure S10). There was no significant difference in transfusion rate (26, 36) (27, 47) (RR 1.09, 95% CI 0.68 to 1.74, p=0.72, I^2=87%, OR4 Figure S11) or number of number of blood replacement units (27, 46-48) (MD 0.23 units, 95% CI -0.89 to 1.35, p=0.69, I^2=97%, OR4, Figure S12).

Fluoroscopy time (sec)

Fluoroscopy time was reported in five studies; three RCTs (36, 37, 41) and two observational study (OR3, Figure S13) (27, 47), with 314 patients treated with EM fixation and 275 patients treated with IM fixation. The mean fluoroscopy time was 122 sec for EM fixation and 166 sec for IM fixation. There was no significant difference between fixation groups (MD -47.32 sec, 95% CI -142.63 to 47.99, p=0.33, I^2=99%).

Tip apex distance (TAD) (mm) and TAD>25mm

The mean TAD was 23 mm in EM fixation and 21 mm in IM fixation (OR3, Figure S14) (29, 33, 37, 47, 48). There was no significant difference between fixation groups (MD 1.19 mm, 95% CI -1.06 to 3.45, p=0.30, I^2=77%). Increased TAD>25mm was reported in two studies (OR4, Figure S15), with 60 cases out of 285 (21.1%) patients treated with an EM device and in 37 cases out of 300 (12.3%) patients treated with an IM device (26, 48). The rate of TAD larger than 25 mm was significantly lower in the IM group (RR 1.73, 95% CI 1.10 to 2.74, p=0.02, I^2=18%).

Femoral neck shortening (mm)

Femoral neck shortening was reported in two studies; one RCT (28) and one observational study (OR3, Figure S16) (47), with 134 patients in the EM fixation group and 141 patients in the IM fixation group. The mean shortening distance was 8.0 mm for EM fixation and 3.1 mm for IM fixation. There was no significant difference between fixation groups (MD 4.00 mm, 95% CI -3.84 to 11.84, p=0.32, I^2=96%).

Neck shaft angle (NSA) (°)

NSA was reported in two observational studies (OR3, Figure S17) (42, 46, 47). The extramedullary fixation group consisted of 129 patients with a mean of 129.9° and the intramedullary fixation group consisted of 106 patients with a mean of 123.7°. There was no difference between fixation groups (MD 4.67, 95% CI -2.58 to 11.92, p=0.21, I^2=90%).

Costs

Costs and cost-effectiveness

No comparable data on costs or cost-effectiveness could be extracted from any of the included articles.

An overview of all surgical outcomes can be found in Table 4.

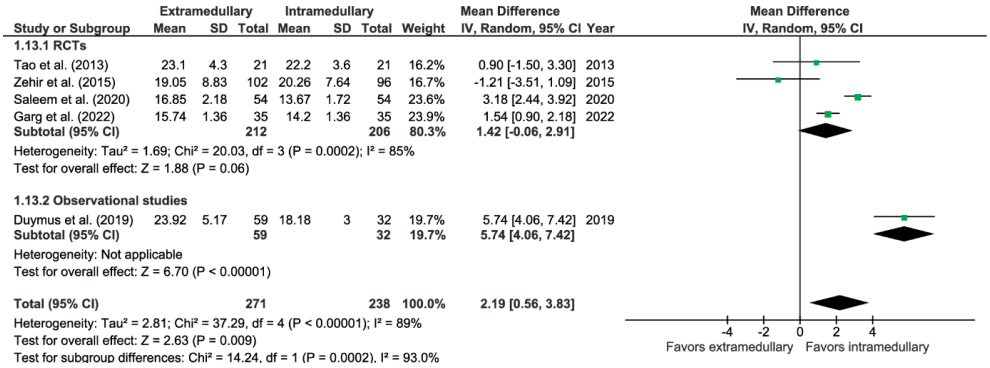


Figure 13: Forest plot of mean time to bone healing (weeks) after extramedullary versus intramedullary fixation of AO 31-A2 fractures

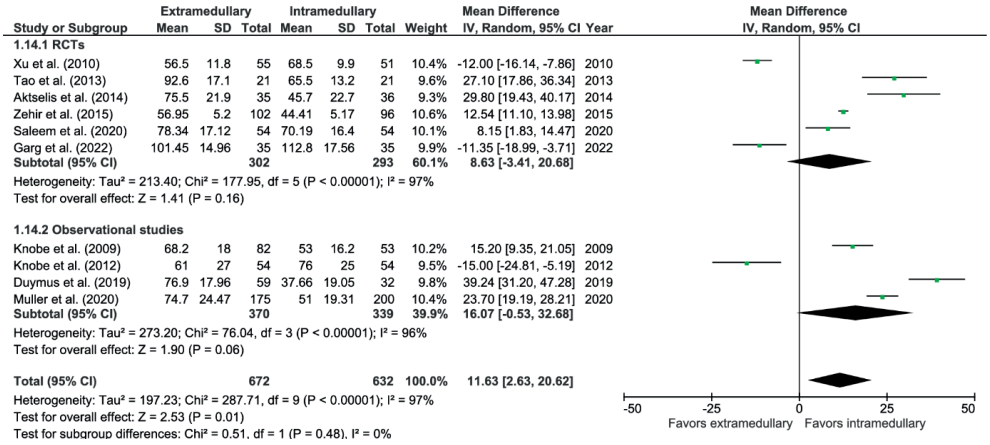


Figure 14: Forest plot of surgery duration (min) in extramedullary versus intramedullary fixation of AO 31-A2 fractures

Standard deviations for Knobe *et al.* (2009) (27) were imputed.

Table 4: Overview of surgical outcomes and operation characteristics

Outcome	Study type	References	OM	Total population EMF	Total population IMF	Mean/cases		Pooled effect (95% CI), p-value	I^2
						EMF	IMF		
Mean time to bone healing (weeks)	4 RCTs 1 OS	(34, 37, 41, 46)	MD	271	238	19.6[1]	17.8[1]	2.19 (0.56 to 3.83) **p=0.009**	89%
Poor radiological quality of reduction	1 RCT 2 OS	(41, 46, 48)	RR	255	253	23[2] (9.0%)	7[2] (2.8%)	2.52 (0.71 to 8.93) p=0.15	56%
Surgery duration (min)	6 RCTs 4 OS	(27, 32, 34, 36, 37, 41, 46-48)	MD	672	632	71[1]	58[1]	11.63 (2.63 to 20.62) **p=0.01**	97%
Hospital stay (days)	3 RCTs 5 OS	(27, 36, 41, 46-49)	MD	748	549	11[1]	12[1]	0.63 (-0.36 to 1.62) p=0.21	68%
Blood loss (mL)	5 RCTs	(34, 36, 37, 41)	MD	267	257	312[1]	150[1]	134.5 (51.0 to 218) **P=0.002**	98%
Patients receiving blood transfusion	2 RCTs 2 OS	(26, 27, 36, 47)	RR	301	258	162[2] (53.8%)	129[2] (50.0%)	1.09 (0.68 to 1.74) p=0.72	87%
Blood replacement units	4 OS	(27, 46-48)	MD	288	286	1.69[1]	1.3[1]	0.54 (0.67 to 1.75) p=0.38	97%
Fluoroscopy time (sec)	3 RCTs 2 OS	(27, 36, 37, 41, 47)	MD	314	275	122[1]	166[1]	-47.32 (-142.63 to 47.99) p=0.33	99%
TAD (mm)	2 RCTs 3 OS	(29, 33, 37, 47, 48)	MD	404	428	23[1]	21[1]	1.19 (-1.06 to 3.45) p=0.30	77%
TAD >25 mm	1 RCT 1 OS	(26, 48)	RR	285	300	60[2] (21.1%)	37[2] (12.3%)	1.73 (1.10 to 2.74) **p=0.02**	18%
Femoral neck shortening (mm)	1 RCT 1 OS	(28, 47)	MD	134	141	8.0[1]	3.1[1]	4.00 (-3.84 to 11.84) p=0.32	96%
NSA (°)	1 RCT 2 OS	(42, 46, 47)	MD	129	106	129.9[1]	123.7[1]	4.67 (-2.58 to 11.92) p=0.21	90%

[1]Subgroup mean [2]Cases reported in subgroup

OM, Outcome measurement; EMF, Extramedullary fixation; IMF, Intramedullary fixation; TAD, Tip-apex distance; NSA, neck-shaft angle; RCT, Randomized Controlled Trial; OS, Observational Studies; RR, Relative Risk; MD, Mean Difference.

Discussion

This systematic review and meta-analysis compared functional outcomes, complications, and surgical outcomes for EM versus IM fixation in elderly patients with an AO type 31-A2 fracture. Statistically superior results in favor of IM fixation were found for several outcomes including: Harris Hip Score, Parker mobility score, lower extremity measure, time to full-weight bearing, superficial infection, nonunion, fixation failure, leg shortening, time to bone-healing, and surgery duration.

The most recent Cochrane review, by Lewis *et al.* (53), on RCTs and 'RCT-like' cohort studies published up to July 2020 compared EM and IM fixation for a combination of AO A1, A2, and A3 fractures. In correspondence with the current review it found an increased risk of several complications including nonunion and implant failure in patients treated with an EM device. However, it found no difference in functional outcomes and found that IM devices were associated with an increased intra- and post-operative peri-implant fracture and shorter HLOS. Differences found in comparison with this meta-analysis can be partly explained by its combination of A1, A2, and A3 fractures and inclusion of older studies (before 2005) with a relatively higher rate of complications. The Cochrane review only performed a stratified analysis for stable versus unstable fractures for reoperation (no significant difference) and did not assess surgical outcomes and operation characteristics.

Another recent meta-analysis by Wessels *et al.* (54) comparing IM nailing with sliding hip screws (SHS) for all combined AO 31-A fractures reported no significant differences between both fixation options for the 31-A2 subgroup in combined major complication rate, infections (superficial and deep infections combined), nonunion, and mortality. Wessels *et al.* included several articles also included in this analysis, but chose to combine major complications, while the current study explores a wider range of adverse events, biomechanical outcomes, and patient reported outcomes. Contrary to the current study, they did not find a significant difference for nonunion rate. This review includes nonunion rate from two more recent RCT's not included by Wessels *et al.*, shifting the effect towards IM fixation. A meta-analysis of RCT's published by Zhu *et al.* (2017) (55), compared IM nails with SHS for AO 31-A2 fractures. They also showed statistical superiority of IM nails for intraoperative blood loss, leg shortening, superficial infections, length of hospital stay, days to mobilization and the Parker mobility score. These results are similar to those found in this meta-analysis.

Results found by older reviews and meta-analyses, demonstrating inferiority of IM fixation based on older studies, featuring mainly first and second generation IM implants, should be considered obsolete nowadays (16, 56). A change in paradigm that was

already predicted by Bhandari *et al* (57). Future meta-analyses should only incorporate implants that are still clinically used.

Interpretation of results

Several points should be considered when interpreting the differences found between EM and IM fixation. In contrast to the meta-analysis of several of the major complications (e.g. to prosthesis, mortality and infections) and their sequelae (e.g reoperation, conversion to prosthesis), a relative lack of data on functional outcomes in both the number of (prospective) studies and the number of included patients was observed. This study showed a significant mean difference of 4.1 points on the Harris Hip Score, on a scale of 0-100 points, in favor of intramedullary fixation. This number should be considered in the light of the minimally clinical important difference, which is established at 15 points for the HHS (52). While statistically significant, this difference is not expected to be clinically relevant. Similar arguments could be made for the small differences found in the Parker mobility score (MD -0.67, on 0-9 scale) and LEM (MD -4.07 on 0-100 scale), although no minimal important change/difference values have been published for these measures. The difference to full-weight bearing (MD 1.04 weeks in favor of IM fixation) could in theory be clinically relevant. However, this outcome was reported in only two studies which used radiological union as a starting point for full weight bearing, making this outcome similar to the outcome radiological union mentioned in other studies (favoring IM fixation). Relevant would be a difference in patient-reported time to full weight bearing without restrictions given by the treating surgeon that exceeds the MICD.

With regards to complications and operation characteristics several considerations should be taken into account. Most fracture- and implant related complications are rare and occur at rates under 5% or even 2%. In the two complications with the largest number of included patients, reoperation, and conversion to prosthesis, no significant differences were found. Although reoperation or conversion can be expected to be a result of other complications such as nonunion, infection, or fixation failure, statistically significant differences were found for these three complications. These effects might be exaggerated due to several (randomized) studies with 0 cases in both study arms, that could not be included in a pooled effect measure. The mean follow-up was 12 months, however the rate of biomechanical complications increases with a longer follow-up time. Therefore, comparing studies with varying follow-up durations, might have influenced the meta-analysis. Nearly all operation characteristics or surgical outcomes suffer from very high heterogeneity and variables such as surgery time or measurement of blood loss are often poorly defined by studies. In combination with their relatively low patient numbers and the possible influence of retrospective data these results should be interpreted with care.

While this review demonstrates that IM fixation for AO 31-A2 trochanteric fractures is no longer inferior to EM fixation, superiority remains questionable as many differences are below clinically relevant thresholds, hold low quality of evidence or analyses are underpowered to adequately compare functional outcomes or rare complications. Where clear superiority is missing, costs-effectiveness should also be considered when selecting an EM or IM fixation approach. Currently, EM fixation is considered the most cost-effective approach by the few studies that were conducted on this topic (15, 26). This conclusion is also emphasized by the Dutch and U.K. guidelines for treatment of proximal femoral fractures (13, 14). This is mainly due to the generally higher IM device cost. However, extensive cost-effectiveness analyses, including broad health care and rehabilitation costs, quality of life, and functional outcomes do not exist at the time of writing. Such an analysis would provide critical data for updating current guidelines. Because of the shifting trend of effectiveness towards IM fixation, due to newer implants and operative strategies, these conclusions may have become outdated. Therefore, this study reaffirms the need for properly powered, large scale comparisons of both fixation strategies, including costs and costs-effectivity. Additionally, due to the relative rarity of major complications and relative lack of functional or patient reported data, future research should primarily focus on functional outcomes and quality of life, instead of primarily focusing on number of complications.

Limitations

This is the most extensive systematic review and meta-analysis that is restricted to the treatment of only AO 31-A2 proximal femoral fractures, including both observational and RCT data on currently available implants, to date. It includes a substantially larger population than all previous meta-analyses. However, the meta-analysis does have several limitations: There was high heterogeneity for many analyzed variables due to differences in studied implants, study designs, international differences and duration of studies. In addition to this, many studies can be considered underpowered for often rare outcomes. Large (observational) studies can strongly impact the overall effect. This, together with a high heterogeneity could have resulted in missing or overstated differences between IM and EM fixation. Multiple functional scores and pain measurements were used by the included studies and SDs were often not reported. This made calculation of pooled effects impossible for several functional outcome scores. In addition, not all studies reporting functional scores also included baseline scores, making it difficult to observe potential selection bias. There are sparse data on many of the included variables, as many studies included all three of the subtypes of trochanteric fractures and were only adequately powered for the complete population. While the AO type A2 fracture subgroups could be extracted and included in the meta-analysis, this could result in a lower generalizability and lower quality of evidence for these limited results. Lastly, data for all specific outcomes was included as described by the original articles.

Most studies did not provide extensive definitions or definitions of outcomes differed slightly between studies. While articles were reviewed extensively and only comparable data was included, this might have introduced bias, especially in the case of retrospective data.

Conclusion

This review and meta-analysis showed that several functional outcomes, complications and surgical outcomes were in favor of intramedullary fixation when compared with extramedullary fixation of AO type 31-A2 fractures. Results indicate significantly higher Harris Hip Score, Parker mobility score, lower extremity measure and recovery to preoperative walking ability. No difference was found in reoperation rate or conversion to prosthesis but studies show a decrease in superficial infections, nonunion, fixation failure, leg shortening, surgery duration, operative blood loss and increased tip-apex distance, all in favor of intramedullary fixation. Previous meta-analyses describing inferiority of IM fixation in AO type 31-A2 fractures should now be considered obsolete. However, a true superiority of IM fixation for AO type 31-A2 fractures remains questionable as several differences in functional outcomes appear not clinically relevant, data on many outcomes remains sparse or heterogeneous, and a detailed cost(-effectiveness) evaluation of modern IM nails is missing in the literature. As major complications are rare and there is a relative lack of functional-, patient reported-, and cost data, future research should primarily focus on functional outcomes, quality of life and costs-effectiveness, instead of primarily focusing on the number of complications.

References

1. Bergström U, Jonsson H, Gustafson Y, Pettersson U, Stenlund H, Svensson O. The hip fracture incidence curve is shifting to the right. Acta orthopaedica. 2009;80(5):520-4. https://doi.org/10.3109/17453670903278282.
2. Cooper C, Campion G, Melton LJ, 3rd. Hip fractures in the elderly: a world-wide projection. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 1992;2(6):285-9. https://doi.org/10.1007/BF01623184.
3. Schürch MA, Rizzoli R, Mermillod B, Vasey H, Michel JP, Bonjour JP. A prospective study on socioeconomic aspects of fracture of the proximal femur. Journal of bone and mineral research : the official journal of the American Society for Bone and Mineral Research. 1996;11(12):1935-42. https://doi.org/10.1002/jbmr.5650111215.
4. Johnell O, Kanis JA. An estimate of the worldwide prevalence, mortality and disability associated with hip fracture. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2004;15(11):897-902. https://doi.org/10.1007/s00198-004-1627-0.
5. Keene GS, Parker MJ, Pryor GA. Mortality and morbidity after hip fractures. BMJ (Clinical research ed). 1993;307(6914):1248-50. https://doi.org/10.1136/bmj.307.6914.1248.
6. Leibson CL, Tosteson AN, Gabriel SE, Ransom JE, Melton LJ. Mortality, disability, and nursing home use for persons with and without hip fracture: a population-based study. Journal of the American Geriatrics Society. 2002;50(10):1644-50. https://doi.org/jgs50455.
7. Valizadeh M, Mazloomzadeh S, Golmohammadi S, Larijani B. Mortality after low trauma hip fracture: a prospective cohort study. BMC musculoskeletal disorders. 2012;13:143-. https://doi.org/10.1186/1471-2474-13-143
8. Vestergaard P, Rejnmark L, Mosekilde L. Increased mortality in patients with a hip fracture-effect of pre-morbid conditions and post-fracture complications. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2007;18(12):1583-93. https://doi.org/10.1007/s00198-007-0403-3.
9. Adeyemi A, Delhougne G. Incidence and Economic Burden of Intertrochanteric Fracture: A Medicare Claims Database Analysis. JB JS Open Access. 2019;4(1):e0045. https://doi.org/10.2106/JBJS.OA.18.00045.
10. Werner M, Macke C, Gogol M, Krettek C, Liodakis E. Differences in hip fracture care in Europe: a systematic review of recent annual reports of hip fracture registries. Eur J Trauma Emerg Surg. 2022;48(3):1625-38. https://doi.org/10.1007/s00068-021-01797-8.
11. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and Dislocation Classification Compendium-2018. Journal of orthopaedic trauma. 2018;32 Suppl 1:S1-S170. https://doi.org/10.1097/BOT.0000000000001063.
12. Jaarrapportage 2019 DHFA 2019 [Available from: https://dica.nl/jaarrapportage-2019/dhfa.
13. (NICE) NIfHaCE. National Institute for Health and Care Excellence: Guidelines, Hip fracture management. 2017 https://doi.org/NBK553768 [bookaccession].
14. Heelkunde MwNOVNVv. Behandeling pertrochantere fracturen: Federatie Medisch Specialisten; 2016 [updated 1 september 2016. Available from: https://richtlijnendatabase.nl/richtlijn/proximale_femurfracturen/pertrochantere_femurfractuur/behandeling_pertrochantere_fracturen.html.

15. Swart E, Makhni EC, Macaulay W, Rosenwasser MP, Bozic KJ. Cost-effectiveness analysis of fixation options for intertrochanteric hip fractures. J Bone Joint Surg Am. 2014;96(19):1612-20. https://doi.org/10.2106/jbjs.M.00603.
16. Jones HW, Johnston P, Parker M. Are short femoral nails superior to the sliding hip screw? A meta-analysis of 24 studies involving 3,279 fractures. Int Orthop. 2006;30(2):69-78. https://doi.org/10.1007/s00264-005-0028-0.
17. Anglen JO, Weinstein JN, American Board of Orthopaedic Surgery Research C. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database. The Journal of bone and joint surgeryAmerican volume. 2008;90(4):700-7. https://doi.org/10.2106/JBJS.G.00517.
18. Mellema JJ, Janssen S, Schouten T, Haverkamp D, van den Bekerom MPJ, Ring D, et al. Intramedullary nailing versus sliding hip screw for A1 and A2 trochanteric hip fractures. Bone Joint J. 2021;103-B(4):775-81. https://doi.org/10.1302/0301-620X.103B.BJJ-2020-1490.R1.
19. Pyrhonen HS, Lagergren J, Wolf O, Bojan A, Mukka S, Moller M, et al. No Difference in Conversion Rate to Hip Arthroplasty After Intramedullary Nail or Sliding Hip Screw for Extracapsular Hip Fractures: An Observational Cohort Study of 19,604 Individuals. 2022 https://doi.org/10.2106/jbjs.22.00316.
20. Gronhaug KML, Dybvik E, Matre K, Ostman B, Gjertsen JE. Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures : 17,341 patients from the Norwegian Hip Fracture Register. Bone Joint J. 2022;104-B(2):274-82. https://doi.org/10.1302/0301-620x.104b2.Bjj-2021-1078.R1.
21. Forte ML, Virnig BA, Eberly LE, Swiontkowski MF, Feldman R, Bhandari M, et al. Provider factors associated with intramedullary nail use for intertrochanteric hip fractures. The Journal of bone and joint surgeryAmerican volume. 2010;92(5):1105-14. https://doi.org/10.2106/JBJS.I.00295.
22. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71.
23. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg. 2003;73(9):712-6. https://doi.org/10.1046/j.1445-2197.2003.02748.x.
24. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ. 2019;366:l4898. https://doi.org/10.1136/bmj.l4898.
25. Jaglal S, Lakhani Z, Schatzker J. Reliability, validity, and responsiveness of the lower extremity measure for patients with a hip fracture. J Bone Joint Surg Am. 2000;82-A(7):955-62. https://doi.org/10.2106/00004623-200007000-00007.
26. Barton TM, Gleeson R, Topliss C, Greenwood R, Harries WJ, Chesser TJS. A comparison of the long gamma nail with the sliding hip screw for the treatment of AO/OTA 31-A2 fractures of the proximal part of the femur: A prospective randomized trial. J Bone Jt Surg Ser A. 2010;92(4):792-8. https://doi.org/10.2106/jbjs.I.00508.
27. Knobe M, Münker R, Sellei RM, Schmidt-Rohlfing B, Erli HJ, Strobl CS, et al. Unstable pertrochanteric femur fractures. Failure rate, lag screw sliding and outcome with extra- and intramedullary devices (PCCP, DHS and PFN). Z Orthop Unfall. 2009;147(3):306-13. https://doi.org/10.1055/s-0029-1185349.
28. Reindl R, Harvey EJ, Berry GK, Rahme E. Intramedullary Versus Extramedullary Fixation for Unstable Intertrochanteric Fractures: A Prospective Randomized Controlled Trial. J Bone Jt Surg Am Vol. 2015;97(23):1905-12. https://doi.org/10.2106/jbjs.N.01007.

29. Sevinç HF, Çırpar M, Canbeyli İD, Dağlar B, Oktaş B, Durusoy S. Comparison of functional outcomes in patients fixed with dynamic hip screw and proximal femur nail-anti-rotation in a1 and a2 type intertrochanteric femur fractures. Ulusal Travma Acil Cerrahi Derg. 2020;26(5):811-7. https://doi.org/10.14744/tjtes.2020.39888.
30. Verettas DAJ, Ifantidis P, Chatzipapas CN, Drosos GI, Xarchas KC, Chloropoulou P, et al. Systematic effects of surgical treatment of hip fractures: Gliding screw-plating vs intramedullary nailing. Injury. 2010;41(3):279-84. https://doi.org/10.1016/j.injury.2009.09.012.
31. Higgins JPT TJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA. Cochrane Handbook for Systematic Reviews of Interventions; Chapter 10: Analysing data and undertaking meta-analyses. 2022. Available from: www.training.cochrane.org/handbook.
32. Aktselis I, Kokoroghiannis C, Fragkomichalos E, Koundis G, Deligeorgis A, Daskalakis E, et al. Prospective randomised controlled trial of an intramedullary nail versus a sliding hip screw for intertrochanteric fractures of the femur. Int Orthop. 2014;38(1):155-61. https://doi.org/10.1007/s00264-013-2196-7.
33. Andalib A, Etemadifar M, Yavari P. Clinical outcomes of intramedullary and extramedullary fixation in unstable intertrochanteric fractures: A randomized clinical trial. Arch Bone Jt Surg. 2020;8(2):190-7. https://doi.org/10.22038/abjs.2019.34942.1919.
34. Saleem M, Ahmed M, Kumar M, Sahar K, Hussain G, Bux M. Comparison of unstable intertrochanteric femur fracture treated with dynamic hip screw and proximal femur nail. Rawal Med J. 2020;45(3):648-51.
35. Singh AK, Narsaria N, G R A, Srivastava V. Treatment of Unstable Trochanteric Femur Fractures: Proximal Femur Nail Versus Proximal Femur Locking Compression Plate. Am J Orthop. 2017;46(2):E116-E23.
36. Xu YZ, Geng DC, Mao HQ, Zhu XS, Yang HL. A comparison of the proximal femoral nail antirotation device and dynamic hip screw in the treatment of unstable pertrochanteric fracture. J Int Med Res. 2010;38(4):1266-75. https://doi.org/10.1177/147323001003800408.
37. Zehir S, Zehir R, Zehir S, Azboy İ, Haykir N. Proximal femoral nail antirotation against dynamic hip screw for unstable trochanteric fractures; a prospective randomized comparison. Eur J Trauma Emerg Surg. 2015;41(4):393-400. https://doi.org/10.1007/s00068-014-0463-y.
38. Ovesen O, Andersen M, Poulsen T, Nymark T, Overgaard S, Röck ND. The trochanteric gamma nail versus the dynamic hip screw: A prospective randomised study. One-year follow-up of 146 intertrochanteric fractures. HIP Int. 2006;16(4):293-8. https://doi.org/10.5301/hip.2008.2820.
39. Pajarinen J, Lindahl J, Michelsson O, Savolainen V, Hirvensalo E. Pertrochanteric femoral fractures treated with a dynamic hip screw or a proximal femoral nail. A randomised study comparing post-operative rehabilitation. J Bone Jt Surg Ser B. 2005;87(1):76-81. https://doi.org/10.2106/jbjs.C.01323.
40. Parker MJ. Sliding hip screw versus intramedullary nail for trochanteric hip fractures; a randomised trial of 1000 patients with presentation of results related to fracture stability. Injury. 2017;48(12):2762-7. https://doi.org/10.1016/j.injury.2017.10.029.
41. Tao R, Lu Y, Xu H, Zhou ZY, Wang YH, Liu F. Internal fixation of intertrochanteric hip fractures: A clinical comparison of two implant designs. Sci World J. 2013;2013 https://doi.org/10.1155/2013/834825.
42. Garg A, Kamboj P, Sharma PK, Yadav U, Siwach RC, Kadyan V. Evaluation of functional outcome and comparison of three different surgical modalities for management of intertrochanteric fractures in elderly population. Int j burns trauma. 2022;12(1):13-22.
43. Andruszkow H, Frink M, Frömke C, Matityahu A, Zeckey C, Mommsen P, et al. Tip apex distance, hip screw placement, and neck shaft angle as potential risk factors for cut-out failure of hip screws

after surgical treatment of intertrochanteric fractures. Int Orthop. 2012;36(11):2347-54. https://doi.org/10.1007/s00264-012-1636-0.
44. Butt FF, Hussain AS, Khan AM, Sultan M. Implants For Extracapsular Neck Of Femur Fracture Dynamic Hip Screw Versus Intramedullary Nailing. J Ayub Med Coll Abbottabad. 2017;29(4):697-701.
45. Crespo E, Galvez J, Tenias JM, Cano I, Crespo R, Palacios V. A comparative study between gamma nail and percutaneous compression plating for the treatment of intertrochanteric hip fractures. Eur j trauma emerg surg. 2012;38(4):443-9.
46. Duymus TM, Aydogmus S, Ulusoy İ, Kececi T, Adiyeke L, Dernek B, et al. Comparison of Intra- and Extramedullary Implants in Treatment of Unstable Intertrochanteric Fractures. J Clin Orthop Traum. 2019;10(2):290-5. https://doi.org/10.1016/j.jcot.2018.04.003.
47. Knobe M, Drescher W, Heussen N, Sellei RM, Pape HC. Is helical blade nailing superior to locked minimally invasive plating in unstable pertrochanteric fractures? Hip. Clin Orthop Relat Res. 2012;470(8):2302-12. https://doi.org/10.1007/s11999-012-2268-9.
48. Müller F, Doblinger M, Kottmann T, Füchtmeier B. PFNA and DHS for AO/OTA 31-A2 fractures: radiographic measurements, morbidity and mortality. Eur J Trauma Emerg Surg. 2020;46(5):947-53. https://doi.org/10.1007/s00068-019-01251-w.
49. Page PRJ, Lord R, Jawad A, Dawe E, Stott P, Rogers B, et al. Changing trends in the management of intertrochanteric hip fractures - A single centre experience. Injury. 2016;47(7):1525-9. https://doi.org/10.1016/j.injury.2016.05.002.
50. Suh YS, Nho JH, Kim SM, Hong S, Choi HS, Park JS. Clinical and Radiologic Outcomes among Bipolar Hemiarthroplasty, Compression Hip Screw and Proximal Femur Nail Antirotation in Treating Comminuted Intertrochanteric Fractures. Hip Pelvis. 2015;27(1):30-5.
51. Tucker A, Donnelly KJ, Rowan C, McDonald S, Foster AP. Is the Best Plate a Nail? A Review of 3230 Unstable Intertrochanteric Fractures of the Proximal Femur. J Orthop Trauma. 2018;32(2):53-60. https://doi.org/10.1097/bot.0000000000001038.
52. Singh JA, Schleck C, Harmsen S, Lewallen D. Clinically important improvement thresholds for Harris Hip Score and its ability to predict revision risk after primary total hip arthroplasty. BMC musculoskeletal disorders. 2016;17:256-. https://doi.org/10.1186/s12891-016-1106-8.
53. Lewis SR, Macey R, Gill JR, Parker MJ, Griffin XL. Cephalomedullary nails versus extramedullary implants for extracapsular hip fractures in older adults. Cochrane Database Syst Rev. 2022;1:CD000093. https://doi.org/10.1002/14651858.CD000093.pub6.
54. Wessels JO, Bjarnesen MP, Erichsen JL, Palm H, Gundtoft PH, Viberg B. Sliding hip screw vs intramedullary nail for AO/OTA31A1-A3: a systematic review and meta-analysis. Injury. 2022;53(3):1149-59. https://doi.org/https://doi.org/10.1016/j.injury.2021.12.034.
55. Zhu Q, Xu X, Yang X, Chen X, Wang L, Liu C, et al. Intramedullary nails versus sliding hip screws for AO/OTA 31-A2 trochanteric fractures in adults: A meta-analysis. Int J Surg. 2017;43:67-74. https://doi.org/10.1016/j.ijsu.2017.05.042.
56. Parker MJ, Handoll HHG. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. Cochrane Database of Systematic Reviews. 2010(9) https://doi.org/10.1002/14651858.CD000093.pub5.
57. Bhandari M, Schemitsch E, Jonsson A, Zlowodzki M, Haidukewych GJ. Gamma nails revisited: gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: a meta-analysis. J Orthop Trauma. 2009;23(6):460-4. https://doi.org/10.1097/BOT.0b013e318162f67f.

Appendix 1: Devices used in AO type 31-A2 fracture fixation

Table S1: Extramedullary and intramedullary devices used per study (as described in article)

Study	Extramedullary device	Intramedullary device
Aktselis *et al.* (2014) (31)	AMBI sliding hip screw[1] (SHS)	(Short) Gamma Nail[2] (GN)
Andalib *et al.* (2020) (32)	Dynamic hip screw (DHS) or dynamic condylar screw (DCS)*	Cephalomedullary nail* (CMN)
Andruszkow *et al.* (2012) (42)	Dynamic hip screw[3] (DHS)	Gamma 3 nail[2] (GN)
Barton *et al.* (2010) (25)	Sliding hip screw (SHS)*	Gamma nail (GN)*
Butt *et al.* (2017) (43)	Dynamic hip screw (DHS) with or without locking plate*	Intramedullary nail (IMN)*
Crespo *et al.* (2012) (44)	Percutaneus compression plate[4] (PCCP)	Gamma nail[2] (GN)
Duymus *et al.* (2019) (45)	Dynamic hip screw[3] (DHS) or Proximal femoral locking compression plate (PF-LCP)[3]	Trigen Intertan[2]
Garg *et al.* (2022) (41)	Dynamic hip screw[3] (DHS)	Proximal femoral nail[3] (PFN)
Grønhaug *et al.* (2022) (52)	SHS with or without a trochanteric support plate (TSP)*	Intramedullary nail (IMN) short or long*
Knobe *et al.* (2009) (26)	Percutaneus compression plate[4] (PCCP) or Dynamic hip screw[5] (DHS)	Proximal femoral nail[5] (PFN)
Knobe *et al.* (2012) (46)	Percutaneus compression plate[4] (PCCP)	Proximal femoral nail antirotation[3] (PFNA)
Müller *et al.* (2020) (47)	Dynamic hip screw[3] (DHS) with or without trochanteric fixation plate (TFP)	Proximal femoral nail antirotation[3] (PFNA)
Ovesen *et al.* (2006) (37)	Dynamic hip screw[3] (DHS), with or without stabilizing plate	Trochanteric gamma nail (GN)[2], second generation
Page *et al.* (2016) (48)	Dynamic hip screw[3] (DHS)	Intramedullary nail* (IMN)
Pajarinen *et al.* (2005) (38)	Dynamic hip screw[3] (DHS)	Proximal femoral nail[3] (PFN)
Parker *et al.* (2017) (39)	Sliding hip screw* (SHS)	Targon proximal femoral (TPF) nail[7] + Targon proximal femoral telescrew (TPFT) nail[7]
Pyrhönen *et al.* (2022) (51)	Sliding hip screw* (SHS)	Intramedullary nail* (IMN), short and long
Reindl *et al.* (2015) (27)	Dynamic hip screw[3] (DHS)	Trochanteric fixation nail[3] (TFN) or Gamma nail[2] (GN), or Trigen INTERTAN nail[1]
Saleem *et al.* (2020) (33)	Dynamic hip screw[3] (DHS)	Proximal femoral nail[3] (PFN)
Sevinç *et al.* (2020) (28)	Dynamic hip screw[3] (DHS)	Proximal femoral nail antirotation[3] (PFNA)
Singh *et al.* (2017) (34)	Proximal femoral locking compression plate (PFLCP)*	Proximal femoral nail[3] (PFN)
Suh *et al.* (2015) (49)	Compression hip screw[8] (CHS)	Proximal femoral nail antirotation[3] (PFNA)
Tao *et al.* (2013) (40)	Reverse less invasive stabilization system (LISS)[3]	Proximal femoral nail antirotation[3] (PFNA)

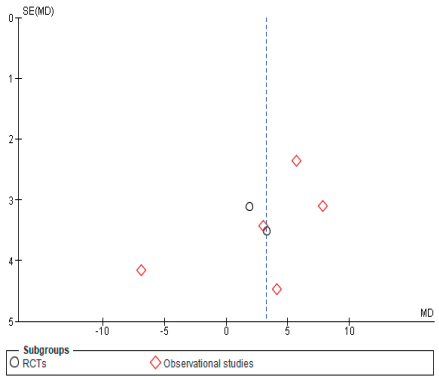
Tucker *et al.* (2018) (50)	Sliding hip screws[3,9] (SHS)	Cephalomedullary nails[1,3] (CMN)
Verettas *et al*. (2010) (29)	Dynamic hip screw[3] (DHS)	Gamma nail[2] (GN) or Endovis BA[6] (EBA)
Xu *et al*. (2010) (35)	Dynamic hip screw[3] (DHS)	Proximal femoral nail antirotation[3] (PFNA)
Zehir *et al.* (2015) (36)	Dynamic hip screw[3] (DHS)	Proximal femoral nail antirotation[3] (PFNA)

[1] Smith & Nephew, Memphis, TN, USA [2] Stryker, Schönkirchen, Germany/Mahwha, New Jersey, USA [3] Depuy-Synthes, Westchester, PA,USA/Umkirch, Germany/Oberdorf, Switserland [4] Orthofix, Bussolengo, Italy/Mckinney, TX, USA [5] Clinical house GmBh, Bochum, Germany [6] Citieffe, Bolongna, Italy [7] B. Braun, Tuttlingen, Germany[8] Corentec, Seoul, Korea [9] AO, Dubendorf, Switserland [*] Device manufacturer not mentioned in article

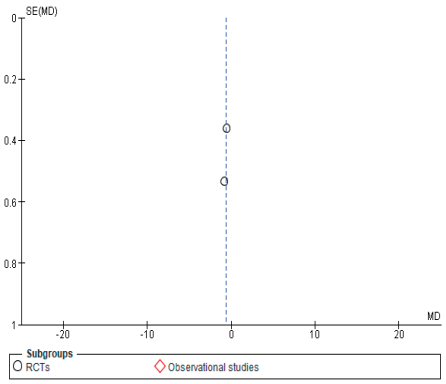
Appendix 2: Funnel plots for included outcomes

Supplemental Figure S1: Funnel plots for included outcomes after extramedullary versus intramedullary fixation of AO 31-A2 fractures

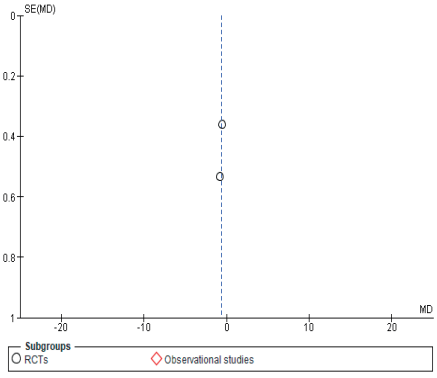
A: Harris Hip Score



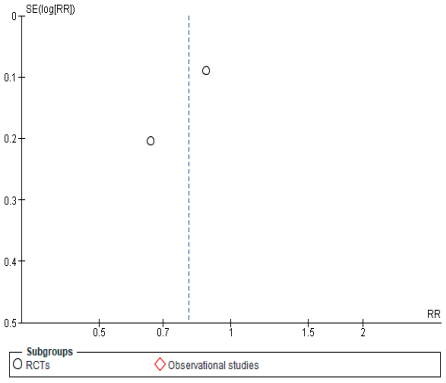
B: Parker mobility score



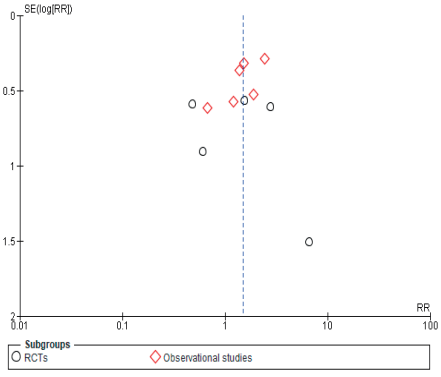
C: Lower extremity measure



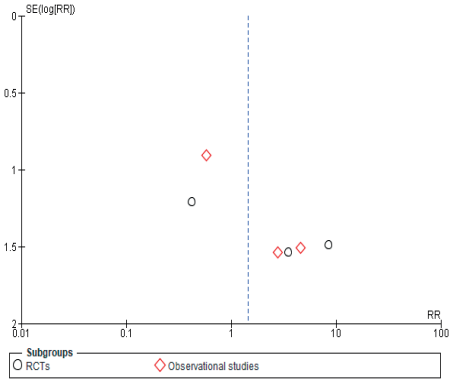
D: Recovery to pre-operative walking ability



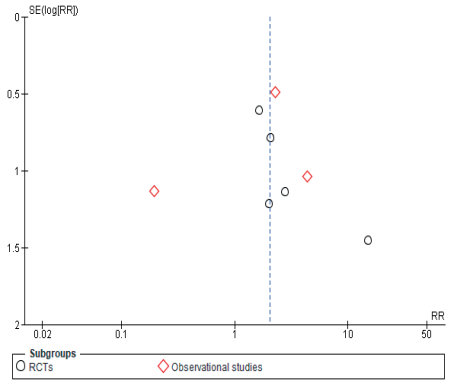
E: Reoperations



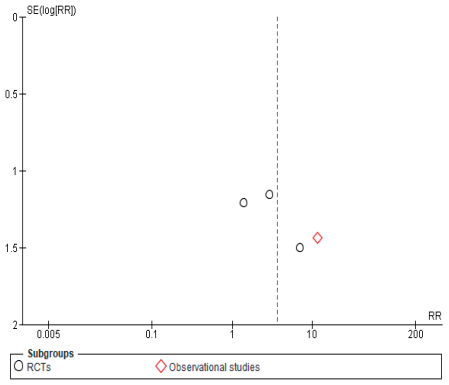
F: Deep infections



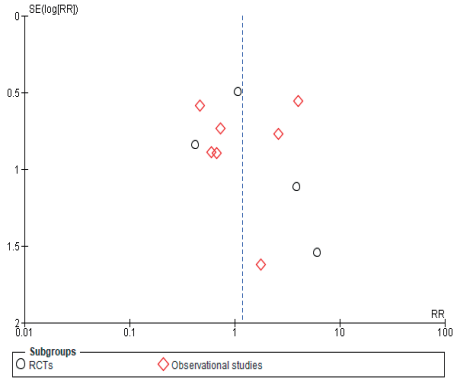
G: Superficial infections



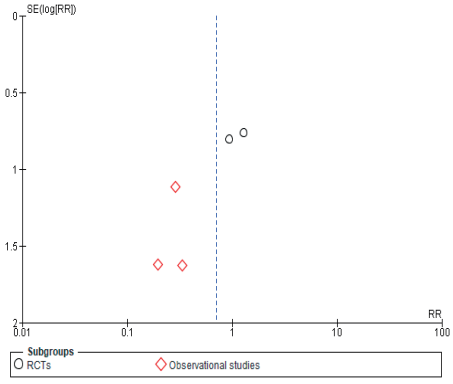
H: Nonunion



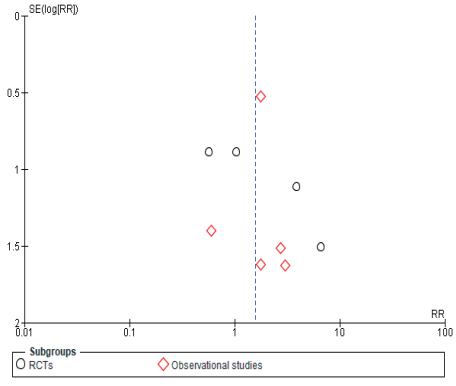
I: Cut-out



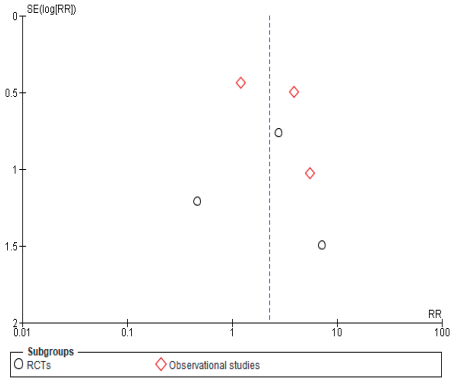
J: Peri-implant fracture



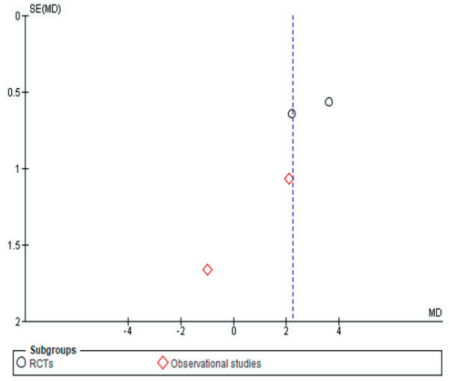
K: Conversion to prosthesis



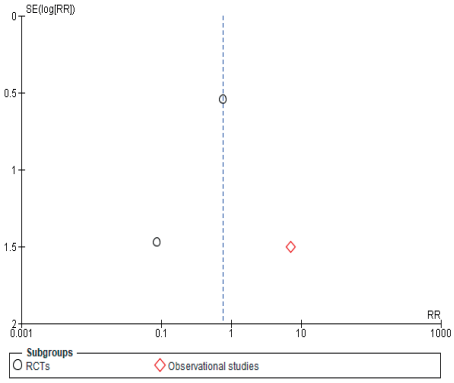
L: Implant/fixation failure



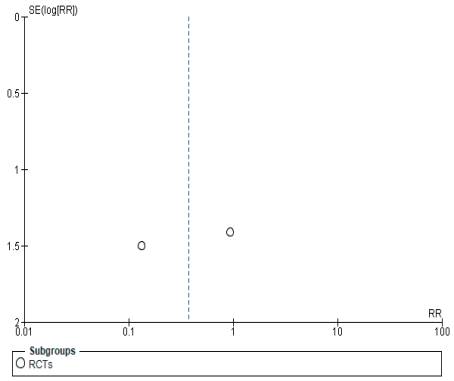
M: Leg shortening



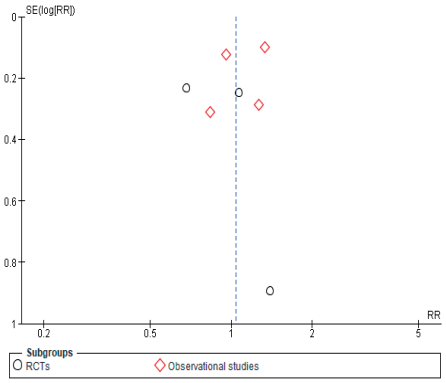
N: Screw Migration



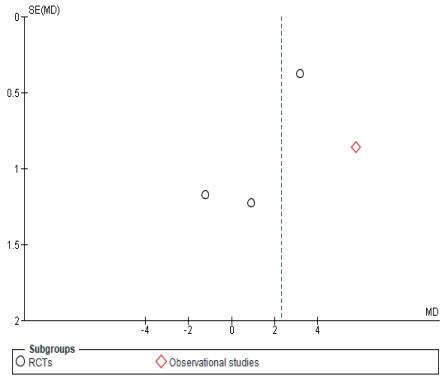
O: Femoral shaft fracture



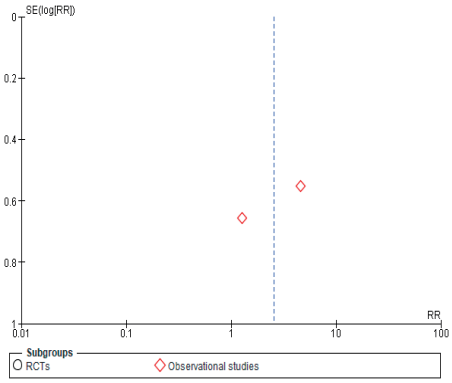
P: Mortality



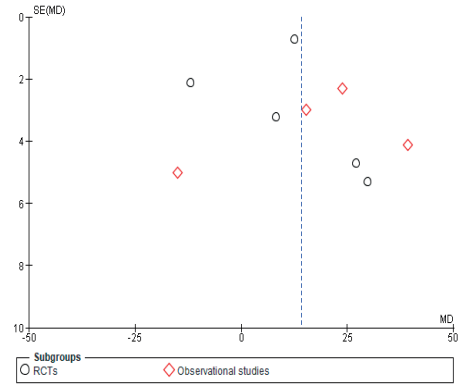
Q: Time to bone healing



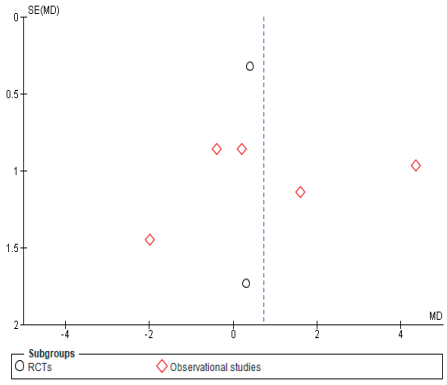
R: Poor quality of reduction



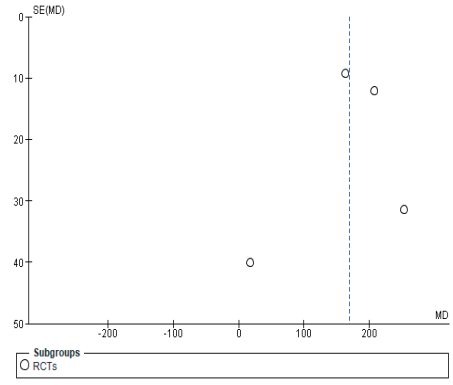
S: Surgery duration



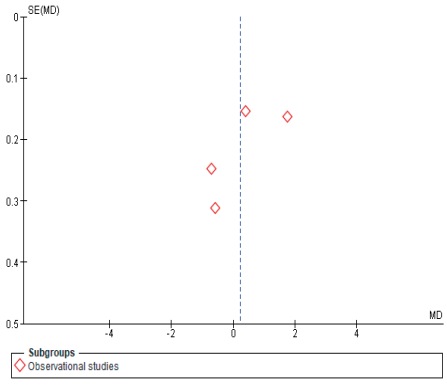
T: Hospital stay



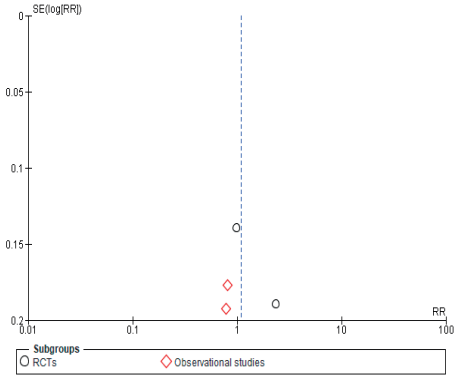
U: Blood loss



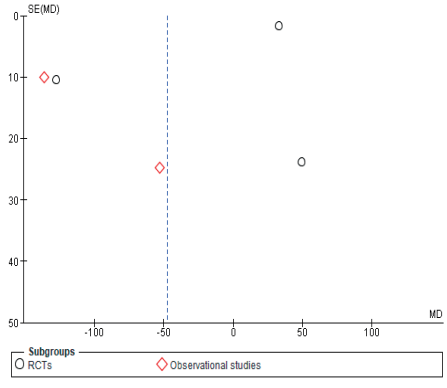
V: Blood replacement units



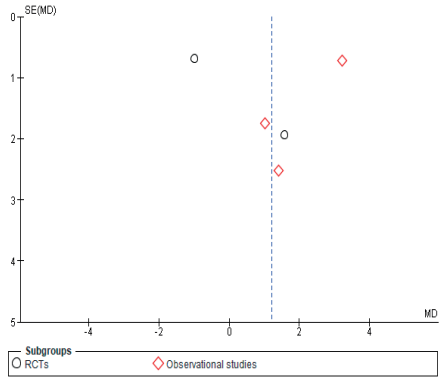
W: Blood transfusions



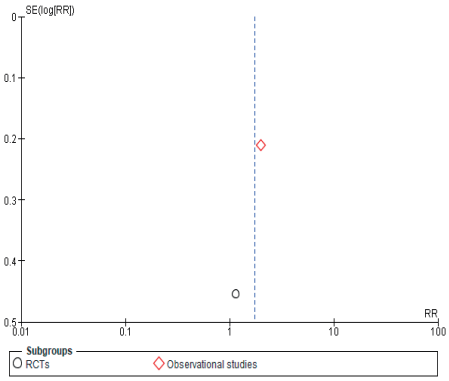
X: Fluoroscopy time



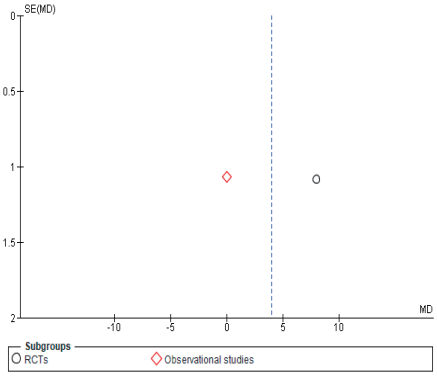
Y: Tip apex distance



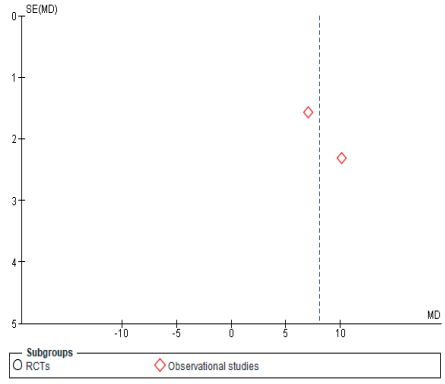
Z: Tip apex distance >25 mm



AA: Femoral neck shortening



BB: Neck shaft angle



Appendix 3: Additional tables and figures.

Table S2: Outcomes measured reported in the included studies

Outcome	Corresponding figure	Aktselis *et al.* (2014) [32]	Andalib *et al.* (2020) [33]	Andruszkow *et al.* (2012) [43]	Barton *et al.* (2010) [26]	Butt *et al.* (2017) [44]	Crespo *et al.* (2012) [45]	Duymus *et al.* (2019) [46]	Garg *et al.* (2022) [42]	Grønhaug *et al.* (2022) [20]	Knobe *et al.* (2009) [27]	Knobe *et al.* (2012) [47]	Müller *et al.* (2020) [48]	Oveson *et al.* (2006) [38]	Page *et al.* (2016) [49]	Pajarinen *et al.* (2005) [39]	Parker *et al.* (2017) [40]	Pyrhönen *et al.* (2022) [19]	Reindl *et al.* (2015) [28]	Saleem *et al.* (2020) [34]	Sevinç *et al.* (2020) [29]	Singh *et al.* (2017) [35]	Suh *et al.* (2015) [50]	Tao *et al.* (2013) [41]	Tucker *et al.* (2018) [51]	Verettas *et al.* (2010) [30]	Xu *et al.* (2010) [36]	Zehir *et al.* (2015) [37]
Harris Hip score	2	-	-	-	-	-	-	+	+	-	+	+	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-
Parker mobility score	3	+	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Lower extremity measure	S2	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Pain scores	N.A.	+	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-	-
Other functional scores and QoL	N.A.	+	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-
Recovery to pre-operative walking ability	S3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Time to full weight bearing	S4	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reoperation	4	-	+	-	+	-	-	+	-	+	+	+	-	+	+	+	-	+	-	-	+	-	+	+	-	+	-	+	+
Deep infection	5	-	+	-	-	-	-	+	+	-	+	-	-	+	+	+	+	-	+	+	-	-	-	+	-	-	-	-	+
Superficial infection	6	-	+	-	-	+	-	+	+	-	-	-	+	-	-	+	+	-	+	+	+	+	-	+	-	-	+	+	-
Nonunion	7	-	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Cut-out	8	+	-	+	-	+	+	+	-	-	+	+	+	+	-	+	+	+	+	+	+	-	-	-	-	-	-	+	-
Peri-implant fracture	9	-	-	-	-	+	-	-	+	-	-	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+
Conversion to prosthesis	10	-	+	-	-	+	-	+	-	+	+	+	-	+	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Implant/fixation failure	11	+	+	-	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-
Heterotopic ossification	N.A.	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-
Leg shortening	S5	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	+	-

Table S2: Outcomes measured reported in the included studies (*continued*)

Outcome	Corresponding figure	Aktselis *et al.* (2014) [32]	Andalib *et al.* (2020) [33]	Andruszkow *et al.* (2012) [43]	Barton *et al.* (2010) [26]	Butt *et al.* (2017) [44]	Crespo *et al.* (2012) [45]	Duymus *et al.* (2019) [46]	Garg *et al.* (2022) [42]	Grønhaug *et al.* (2022) [20]	Knobe *et al.* (2009) [27]	Knobe *et al.* (2012) [47]	Müller *et al.* (2020) [48]	Ovesen *et al.* (2006) [38]	Page *et al.* (2016) [49]	Pajarinen *et al.* (2005) [39]	Parker *et al.* (2017) [40]	Pyrhönen *et al.* (2022) [19]	Reindl *et al.* (2015) [28]	Saleem *et al.* (2020) [34]	Sevinç *et al.* (2020) [29]	Singh *et al.* (2017) [35]	Suh *et al.* (2015) [50]	Tao *et al.* (2013) [41]	Tucker *et al.* (2018) [51]	Verettas *et al.* (2010) [30]	Xu *et al.* (2010) [36]	Zehir *et al.* (2015) [37]
Screw migration	S6	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Femur shaft fracture	S7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Mortality	12	-	-	-	+	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+
Mean time to bone healing	13	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+
Radiologic quality of reduction	S8	-	+	-	-	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Surgery duration	14	+	-	-	-	-	-	+	+	-	+	+	+	-	-	-	-	-	-	+	-	-	-	+	-	+	+	+
Hospital stay	S9	-	-	-	+	-	-	+	+	-	+	+	+	-	+	-	-	-	-	-	-	-	-	+	-	+	+	-
Blood loss	S10	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	+	+	+
Blood transfusion (patients)	S11	-	-	-	+	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Blood transfusion (units per patient)	S12	-	-	-	-	-	-	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Fluoroscopy time	S13	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+
TAD	S14	-	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	-	+	-	-	-	-	-	-	+
TAD>25mm	S15	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Femoral neck shortening	S16	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+
NSA	S17	-	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-

+, reported in article; -, not reported in article; TAD, Tip-Apex Distance; mm, millimeter; NSA, Neck-shaft angle; AMS, Abductor Muscle Strength; N.A., Not available; QoL, Quality of life.

Table S3: Quality assessment of the included RCT's using the Cochrane RoB 2 tool

Study	D1	D2	D3	D4	D5	Overall
Aktselis *et al.* (2014) [32]	+	x	+	+	+	-
Andalib *et al.* (2020) [33]	x	x	x	+	+	x
Barton *et al.* (2010) [26]	+	+	+	+	+	+
Garg *et al.* (2022) [42]	+	-	+	+	+	-
Ovesen et al. (2006) [38]	+	+	+	+	+	+
Pajarinen et al. (2005) [39]	+	x	-	+	+	x
Parker et al. (2017) [40]	+	+	-	+	+	-
Reindl *et al.* (2015) [28]	-	+	+	+	-	-
Saleem *et al.* (2020) [34]	+	+	+	+	+	+
Singh *et al.* (2017) [35]	+	-	+	+	+	-
Tao et al. (2013) [41]	+	+	+	+	+	+
Verettas *et al.* (2010) [30]	x	+	+	+	+	x
Xu *et al.* (2010) [36]	+	-	+	+	+	-
Zehir *et al.* (2015) [37]	+	+	+	+	+	+

+ Low risk of bias; **-** Some concerns of bias; **x** High risk of bias

Domains: D1, Randomization process; D2, Deviations from intended interventions; D3, Missing outcome data; D4, Measurement of the outcome; D5, Selection of the reported result

Table S4: Quality assessment of the included observational studies using the MINORS criteria

Study	Aim	Inclusion	Collection	Endpoints	Assessment	Follow-up period	Loss of Follow-up	Study size calculation	Control group	Contemporary group	Baseline equivalence	Statistics	Total
Andruszkow *et al.* (2012) [43]	2	2	0	2	0	1	2	0	1	2	1	2	**15**
Butt et al. (2017) [44]	1	2	0	1	0	0	2	0	2	2	1	2	**13**
Crespo *et al.* (2012) [45]	1	2	0	2	0	2	1	0	2	2	1	2	**15**
Duymus *et al.* (2019) [46]	2	2	0	2	0	2	2	0	2	2	1	2	**17**
Grønhaug *et al.* (2022) [20]	2	2	2	2	0	2	1	0	2	2	2	2	**19**
Knobe *et al.* (2009) [27]	1	2	0	2	2	2	0	0	2	2	1	2	**16**
Knobe *et al.* (2012) [47]	2	2	2	2	1	2	2	1	2	2	2	2	**22**
Müller *et al.* (2020) [48]	1	2	1	2	0	2	2	0	2	2	2	2	**18**
Page *et al.* (2016) [49]	2	2	0	1	0	0	2	0	2	2	1	2	**14**
Pyrhönen *et al.* (2022) [19]	2	2	2	2	0	2	2	0	2	2	2	2	**20**
Sevinç *et al.* (2020) [29]	2	0	2	2	0	2	2	0	2	0	1	2	**15**
Suh *et al.* (2015) [50]	2	1	2	2	0	2	1	0	2	2	1	2	**17**
Tucker *et al.* (2018) [51]	2	2	1	2	0	2	2	0	2	2	1	2	**18**

Total scores range from 0 to 24 points, with lower scores indicating a higher risk of bias.

0, not reported; 1, reported but inadequate; 2, reported and adequate

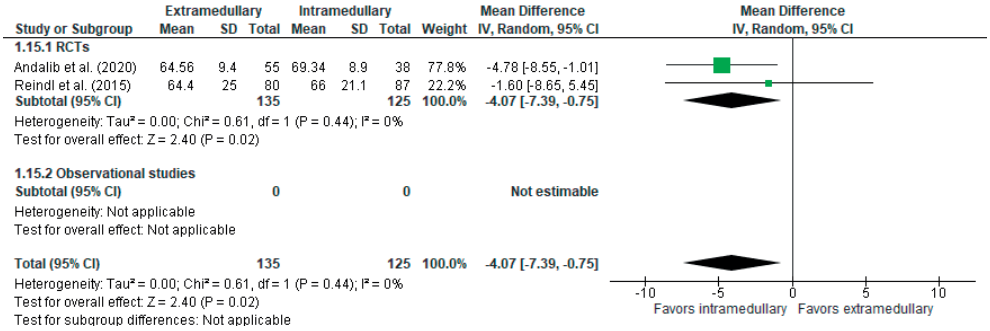


Figure S2: Forest plot of Lower Extremity Measure after extramedullary versus intramedullary fixation of AO 31-A2 fractures

IV, inverse variance; RCT, randomized controlled trial; SD, standard deviation

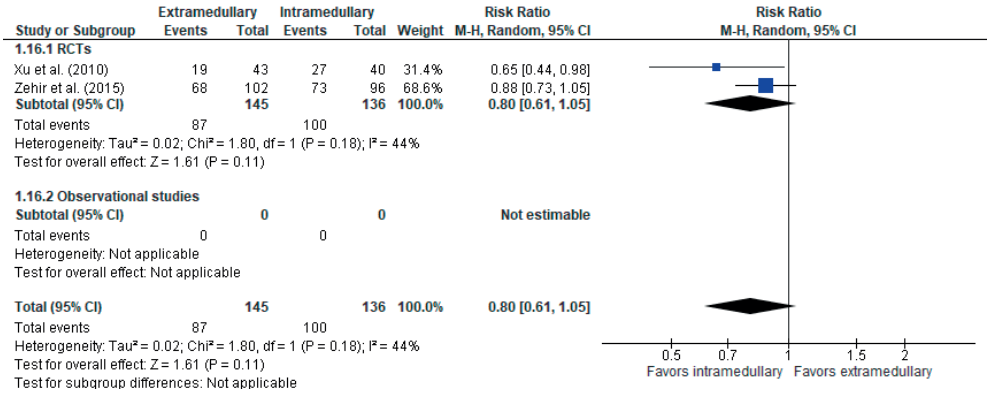


Figure S3: Forest plot of recovery to pre-operative walking ability after extramedullary versus intramedullary fixation of AO 31-A2 fractures

M-H, Mantel-Haenszel; RCT, randomized controlled trial; SD, standard deviation

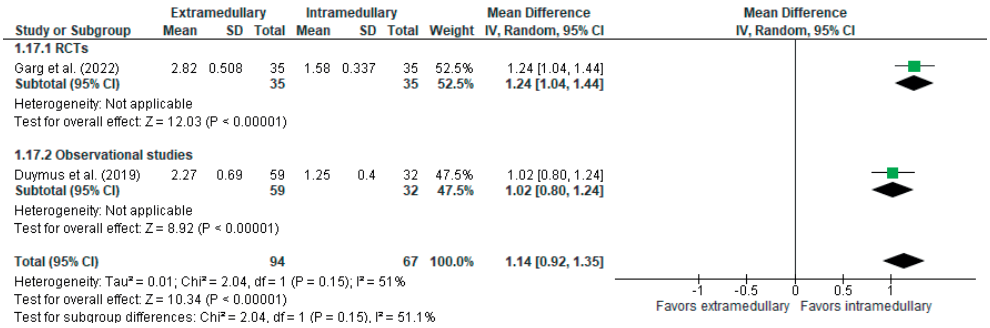


Figure S4: Forest plot of time to full weight bearing (months) after extramedullary versus intramedullary fixation of AO 31-A2 fractures

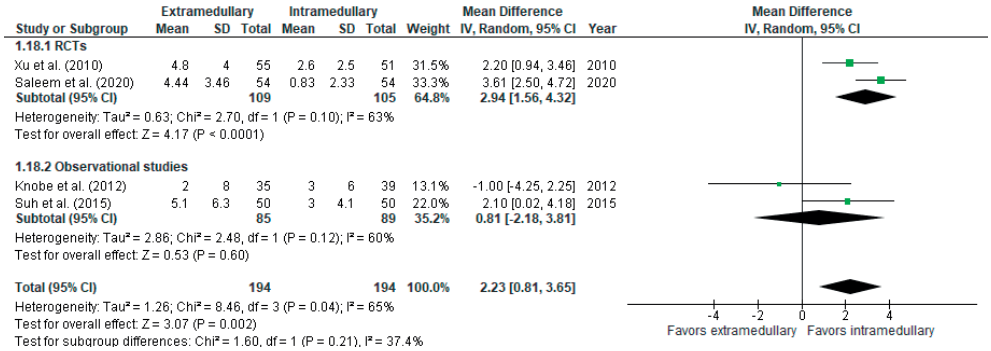


Figure S5: Forest plot of leg shortening (mm) after extramedullary versus intramedullary fixation of AO 31-A2 fractures

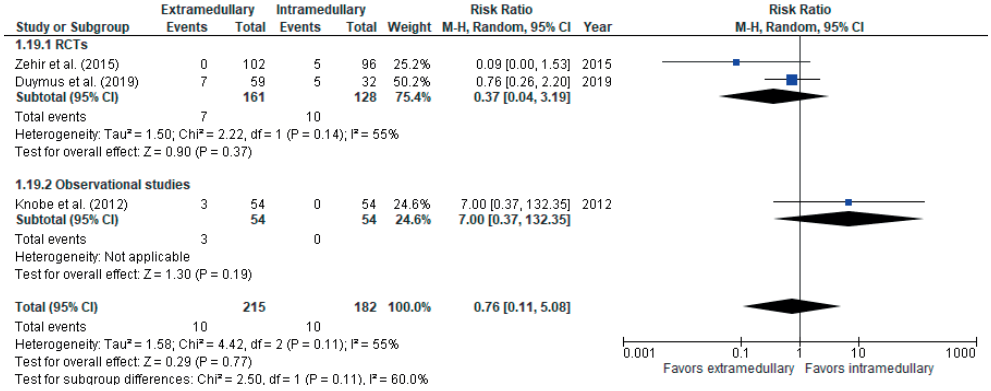


Figure S6: Forest plot of screw migration after extramedullary versus intramedullary fixation of AO 31-A2 fractures

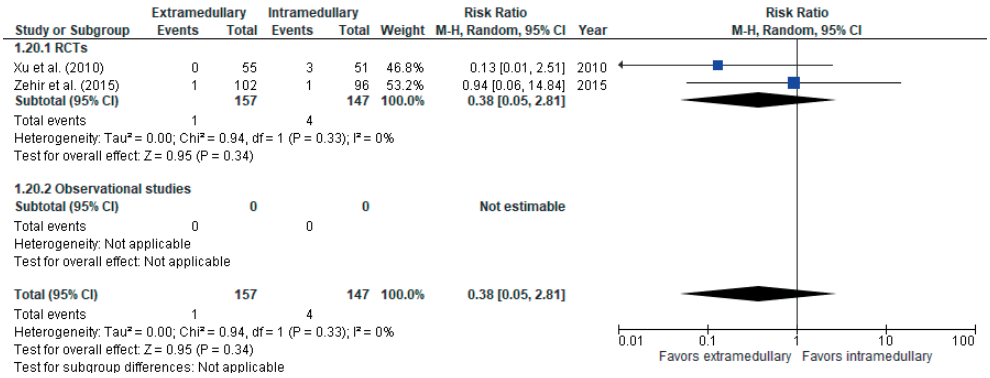


Figure S7: Forest plot of femoral shaft fractures after extramedullary versus intramedullary fixation of AO 31-A2 fractures

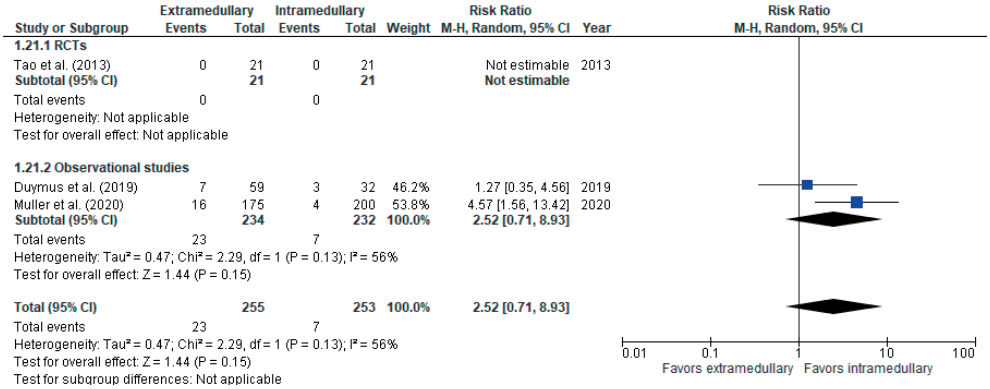


Figure S8: Forest plot of poor quality of reduction after extramedullary versus intramedullary fixation of AO 31-A2 fractures

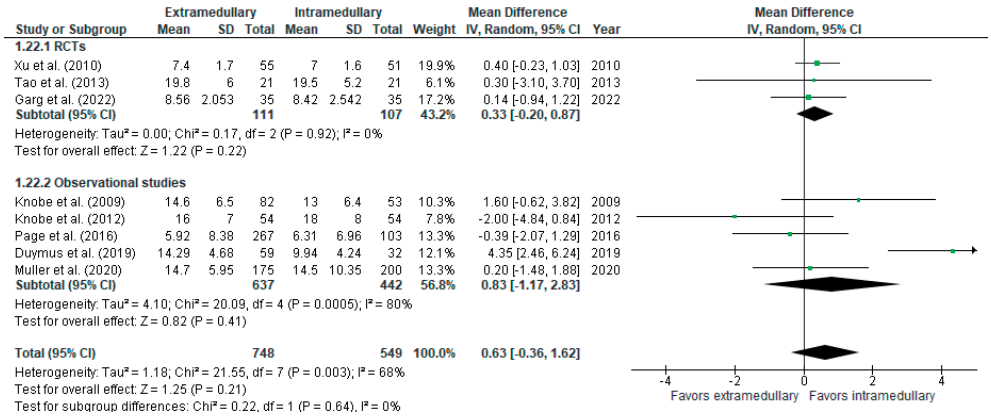


Figure S9: Forest plot of hospital stay (days) after extramedullary versus intramedullary fixation of AO 31-A2 fractures

Standard deviations for Knobe *et al.* (2009) [27] were imputed.

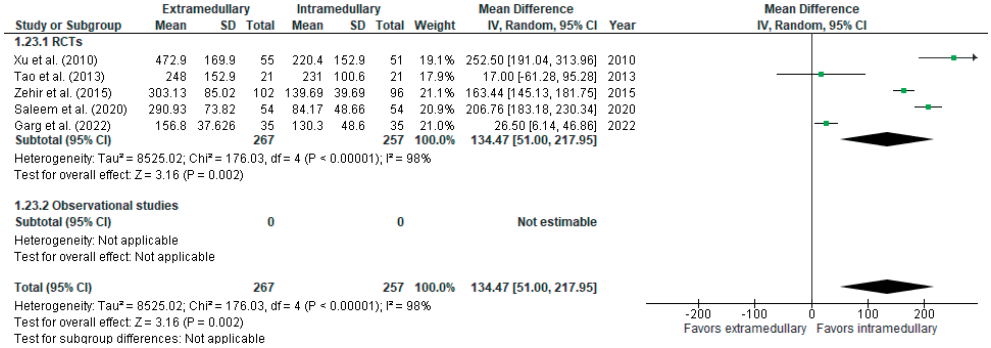


Figure S10: Forest plot of blood loss (mL) in extramedullary versus intramedullary fixation of AO 31-A2 fractures

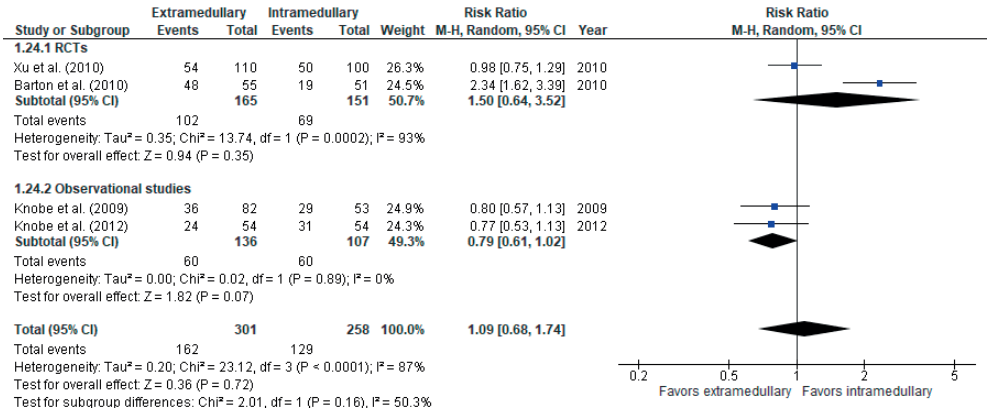


Figure S11: Forest plot of patients receiving blood transfusion after extramedullary versus intramedullary fixation of AO 31-A2 fractures

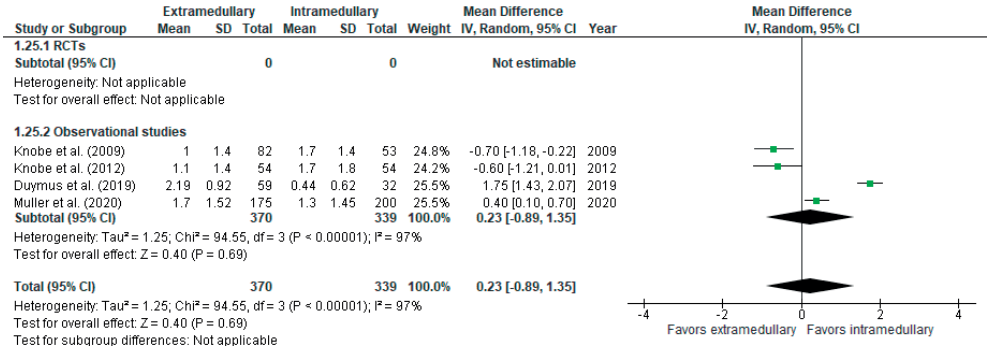


Figure S12: Forest plot of blood replacement units after extramedullary versus intramedullary fixation of AO 31-A2 fractures

Standard deviations for Knobe *et al.* [27] were imputed.



Figure S13: Forest plot of fluoroscopy time (sec) in extramedullary versus intramedullary fixation of AO 31-A2 fractures

Standard deviations for Knobe *et al.* (2009) [27] were imputed.

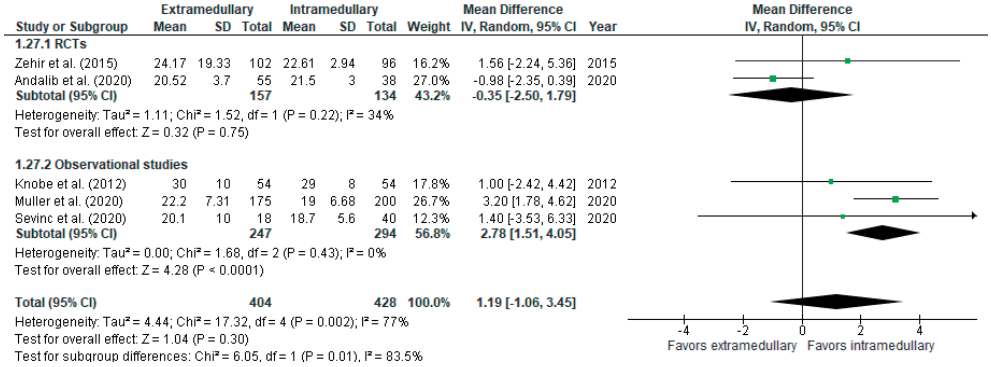


Figure S14: Forest plot of TAD after extramedullary versus intramedullary fixation of AO 31-A2 fractures

Standard deviations for Sevinc *et al.* (2009) [29] were imputed.

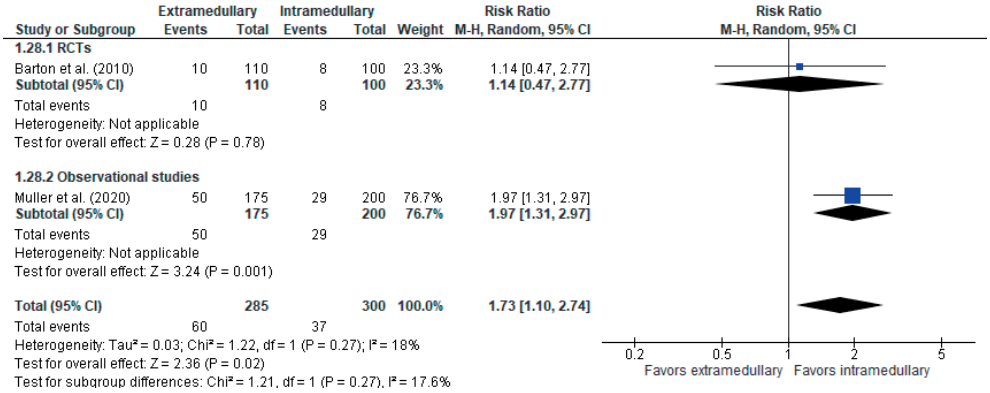


Figure S15: Forest plot of TAD > 25mm after extramedullary versus intramedullary fixation of AO 31-A2 fractures

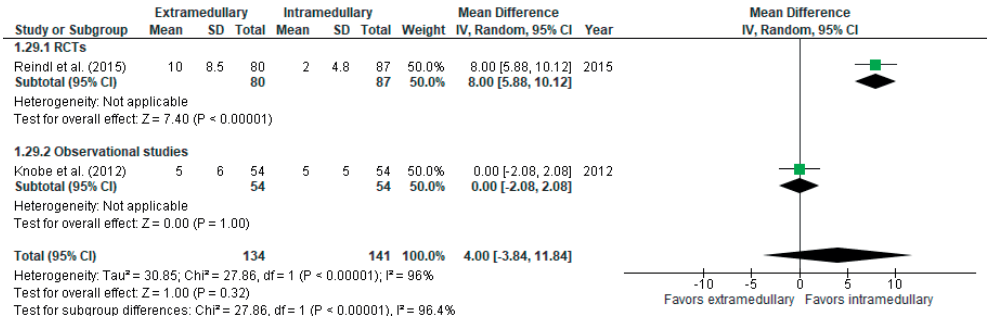


Figure S16: Forest plot of femoral neck shortening (mm) after extramedullary versus intramedullary fixation of AO 31-A2 fractures

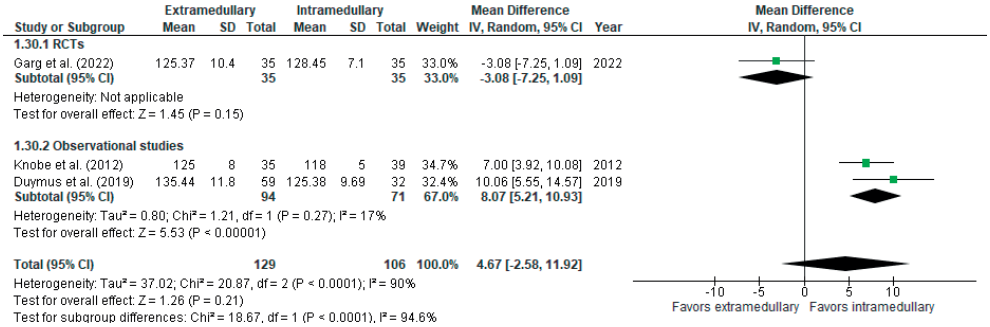


Figure S17: Forest plot of neck shaft angle (NSA) (degrees) after extramedullary versus intramedullary fixation of AO 31-A2 fractures



6

Mobility and living status at discharge and after three-months for extramedullary versus intramedullary fixation of AO type 31-A1 trochanteric fractures; an analysis of Dutch Hip Fracture Audit data

Miliaan L. Zeelenberg, Esther M.M. Van Lieshout, Taco Gosens, Johannes H. Hegeman, Dennis Den Hartog, Michiel H.J. Verhofstad, on behalf of the Stable-HIP Study Group and the Dutch Hip Fracture Audit indicator Taskforce

European Journal of Trauma and Emergency Surgery 2025, Volume 51, Article number 6

Abstract

Purpose

The use of intramedullary fixation of AO type 31-A1 fractures is rising, despite evidence of non-superiority when compared with extramedullary fixation. The aim of this study was to evaluate mobility and living status for extramedullary fixation (EMF) versus intramedullary fixation (IMF) in Dutch hospitals during the initial hospital stay and until three-months after trauma.

Methods

Data on patient characteristics, mobility, living status, complications, reoperation, and mortality were extracted from the Dutch Hip Fracture Audit Indicator Taskforce. Data were collected for patients (>65 years) at baseline, at discharge, and at three-months follow-up. Univariate analysis was used for comparing the EMF versus IMF group.

Results

A total of 836 patients were included; 138 (16%) were treated with EMF and 698 (84%) with IMF. No significant differences were found between groups for the overall complication rate during the initial hospital stay (EMF: n=55 (40%) versus IMF: n=270 (39%)). Patients treated with EMF showed better mobility at discharge (mobility with frame/2 supports or better, EMF 77% versus IMF 50%), but otherwise no significant difference was found after a three-month follow-up (EMF 80% versus IMF 82%), suggesting faster improved mobility for IMF. However, matched subgroup analysis showed no meaningful differences in rates of deteriorated mobility or living status after three months.

Conclusion

This study showed no meaningful differences between EMF and IMF of type 31-A1 trochanteric fractures during hospital stay and until three-month follow-up. Despite little differences in outcome and EMF being the treatment option of first choice by the Dutch Hip fracture guideline, IMF is used in the vast majority of patients.

Introduction

A hip fracture is one of the leading causes of mortality and disability in the elderly population worldwide (1, 2). Current global incidence rate was estimated at 182.5 per 100,000 person-years, and these numbers are projected to increase even further in the upcoming decades (3). Trochanteric fractures constitute roughly 40-50% of the total number of hip fractures (3, 4). They were subdivided by the Arbeitsgemeinschaft für Osteosynthesefragen (AO) 2018 classification (5) into three main subcategories: 31-A1 simple (stable) pertrochanteric fractures; 31-A2 multi-fragmentary pertrochanteric, lateral wall incompetent (<20.5mm) fractures; and 31-A3 intertrochanteric (reverse obliquity) fractures. These fractures are usually fixated using either an extramedullary technique (*i.e.,* a type of sliding hip screw) or an intramedullary technique (*i.e.,* a type of intramedullary nail). The ideal fixation technique varies per type of fracture. While the American Academy of Orthopaedic Surgeons advises the usage of both intramedullary and extramedullary devices for A1 trochanteric fractures, several international guidelines advise extramedullary fixation for A1 fractures and consider both extra- and intramedullary fixation as a viable option in A2 fractures (6-8).

Despite these guidelines, the use of intramedullary fixation in all fracture types, and specifically A1 fractures, has risen in the past decades (9-12). Recent studies show increasing effectiveness of intramedullary devices but superiority in A1 fractures remains questionable (13-15). Factors that are attributed to their increased usage are surgeons' training, treatment volume of hospitals, and geographical differences, and the change does not seem to correlate with only patient-specific differences (11, 16). The Dutch hip fracture guideline also advises extramedullary fixation for the stable A1 subgroup due to lack of superiority for either treatment approach and lower implant costs for extramedullary devices (7). Despite this, but in line with previously mentioned international changes, a large majority of patients is treated using intramedullary devices (17). Due to the evolution of implants or improved operation techniques, and decreased usage of extramedullary devices, the results of intramedullary fixation may have improved further. The question is whether this trend of increasing intramedullary nailing has persisted in stable trochanteric fractures and if patient outcomes and complication rates have remained similar or have surpassed the outcomes of extramedullary devices.

As no recent large-scale outcome comparison for both devices exists for the Dutch population, this study aimed to compare the use of extramedullary versus intramedullary fixation of stable trochanteric fractures (AO type 31-A1) in older adults and compare mobility and living status at discharge and three months after trauma.

Methods

This retrospective cohort study was performed using data from the Dutch Hip Fracture Audit (DHFA) of the period January 1, 2018 to December 31, 2020 (18). These data are collected annually by the Dutch Institute for Clinical Auditing (DICA) (19). The DHFA has national coverage, and includes all hip fracture patients, but not all data, especially data regarding follow-up, is completed to a satisfactory level by the participating hospitals. Because of this, the DHFA Indicator Taskforce was created: a group consisting of six mid-to-large-sized Dutch hospitals (see list in acknowledgments) committed to adequate registration of treatment specific- and follow-up data. To ensure comparison of adequate data with a well completed follow-up this analysis was restricted to the data provided by the DHFA Indicator Taskforce.

Patients were included if they were ≥ 65 years and were admitted with an acute AO type 31-A1 trochanteric proximal femoral fracture. Data were collected on baseline characteristics (age, sex, ASA classification, pre-fracture mobility, pre-fracture Parker mobility score (PMS), pre-fracture Katz-ADL score, and pre-fracture living status), operation characteristics (implant type, time-to-surgery, type of anesthesia), hospital stay, complications as classified by hospital in DHFA, mobility at discharge, and discharge location. Additional data was collected after a three-month follow-up (reoperation, living status, mobility, Katz-ADL score, and mortality). Primary outcomes were (changes in) mobility and living status at discharge and at three-months after trauma. Secondary outcomes were mortality, in-hospital complications, HLOS, Katz-ADL at discharge and three months, and reoperation rate until three months.

Mobility was classified as either independent, mobility with 1 or 2 supports, mobility only within own home, or no functional mobility. Living status was classified as: at home with, or without supportive care, care home, nursing home, or rehabilitation institution. The latter three were seen as institutionalized and the first two as community-dwelling. The Katz-ADL score provides an indication of the ability to perform basic activities of daily life (ADL) (20). A score of zero indicates independent function and six indicates total dependance in ADL tasks.

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 28.0 (SPSS, Chicago, Ill., USA). Normality for continuous data was assessed using the Shapiro-Wilk test. Missing data were not imputed. The analyses were done stratified for extramedullary fixation (EMF) versus intramedullary fixation (IMF). To correct for possible confounders in the main analysis a matched complete case analysis was performed for all three month outcomes. This included only patients with complete base-

line characteristics and three-month outcomes. Cases (EMF) were matched 1:2 without replacement with controls (IMF), on age (within 10 years), sex, ASA classification, and pre-fracture mobility. In addition, a sensitivity analysis comparing EMF and IMF was performed for the total population, stratified on living status (institutionalized versus community dwelling).

Continuous data were reported as median with first quartile and third quartile and categorical data as numbers with percentages. Univariate comparison between groups in the unmatched analysis was performed using a Mann-Whitney or χ^2 test. For the matched analysis, the Mantel-Haenszel statistic was used to calculate odds ratios for outcomes after three months. A 2-sided P-value <0.05 was used as the threshold for statistical significance.

Results

Out of a total population of 2,717 patients with trochanteric fractures, 913 patients were treated for a stable trochanteric femoral fracture in the participating hospitals (Figure 1). Seventy-seven additional patients were excluded as they did not match the inclusion criteria (age ≥65). A total of 836 patients were included; 138 (16%) were treated with EMF and 698 (84%) with IMF (Table 1). These rates were similar during the three included years. The population had a median age of 84 (P_{25}-P_{75} 76-89), and 71% was female. There were no significant differences in age, sex, ASA classification, PMS, or pre-fracture Katz ADL score between the EMF and IMF group. There was a significant difference in pre-fracture mobility, with a notably higher proportion of patients in the EMF group who were mobile with two supports or a frame (EMF 44% versus IMF 32%, p=0.012). Another statistically significant difference was found for the pre-operative living status (p=0.038). EMF patients were more likely to live unassisted at home (EMF 56% versus IMF 50%) and less likely to live in a care or nursing home (EMF 19% versus IMF 23%).

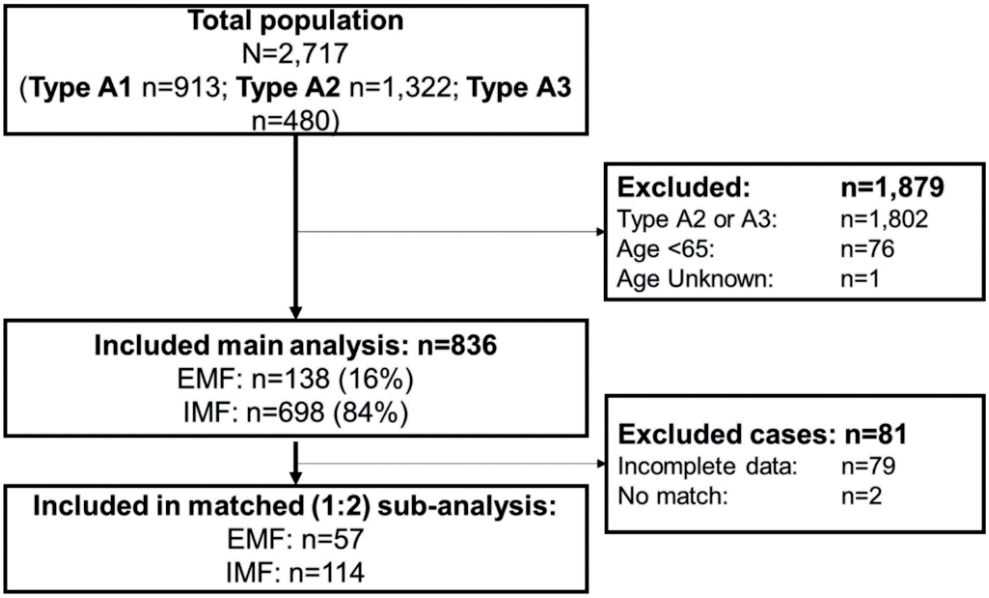


Figure 1: Flowchart of included and excluded patients

Operation and hospital stay

The median time to operation was 21 hours (P_{25}-P_{75} 14.9-27.6); Table 2). Median HLOS was similar for both groups (EMF 7 days (5-10) versus IMF 7 days (5-10), p=0.717). During hospital stay EMF (55 patients, 40%) and (270 patients, 39%) IMF patients suffered a similar rate of complications (p=0.849). The most common complications in both groups were anemia (19% versus 21%), delirium (11% versus 13%), urinary tract infection (7% versus 6%), and pneumonia (7% versus 5%). There were no significant differences between groups for all reported complications and in-hospital mortality.

Despite differences before trauma, discharge location was not significantly different between groups. When comparing differences in living status pre-trauma and living status at discharge, no significant difference was found (p=0.186, Supplemental Table S1) But similar to the pre-trauma situation, a larger proportion of EMF patients mobilized with two supports or a frame at discharge in comparison with IMF patients (EMF 71% versus IMF 46%) and IMF patients had a higher proportion of restricted mobility within their own homes (EMF 14% versus IMF 28%) or no functional mobility (EMF 10% versus IMF 22%). The proportion of patients with no functional mobility or only functional mobility within their own home increased more at discharge after surgery for the IMF group (EMF 9% increase versus IMF 28% increase).

Three-month follow-up

Living status, mobility, and Katz-ADL score at three months were all similar between groups, despite differences in mobility at discharge (Table 3). In the EMF group, 29 (40.8%) patients were fully independent in ADL (Katz 0) versus 148 (43%) patients in the IMF group (p=0.793). The total mortality rate was 16% in the EMF group versus 15% in the IMF group (p=0.876). There was no statistically significant difference in reoperation rate between EMF (6 patients, 7%) and IMF (45 patients, 10%, p=0.433). When comparing changes (from the pre-trauma situation to three months follow-up) in mobility, living status, and Katz-ADL score no significant differences between groups were found (Table 4). 43% of the EMF group and 46% of the IMF group returned to the previous level of mobility within three months (OR 0.9, 95% CI 0.5-1.5, p=0.612). Specific changes in living status can be found in the supplemental tables.

In the matched complete-case analysis 57 EMF patients were included and matched 1:2 to 114 IMF patients. After matched comparison, no significant differences were found in changes in mobility, living status, or Katz-ADL score (Table 4). For EMF 20/43 (46%) patients versus 39/79 (49%) IMF patients had decreased mobility after three months (OR 1.2, 95%CI 0.6-2.6, p=0.615) and 8/43 (19%) EMF patients versus 12/79 (15%) IMF patients changed from community dwelling to institutionalized from baseline to three-months follow-up (OR 0.8, 95%CI 0.3-2.1, p=0.649).

A sensitivity analysis stratified on pre-trauma living conditions (community-dwelling versus institutionalized) found similar results as the main analysis (Supplemental Tables S3-S5). With no differences between the groups in all three-month outcomes and only a significant difference between groups for mobility at discharge in favor of EMF.

Table 1: Baseline characteristics of patients with a stable trochanter fracture treated with extramedullary or intramedullary fixation

Characteristic		EMF n=138		IMF n=698		
		n *		n*		P-value
Age		138	83 (76-89)	698	84 (76-89)	0.648
Female		138	95 (69%)	698	493 (71%)	0.683
Year injury	2018	138	52 (38%)	698	253 (36%)	0.802
	2019		44 (32%)		243 (35%)	
	2020		42 (30%)		202 (29%)	
Injured side	Right	138	73 (53%)	697	330 (47%)	0.227
ASA	1 or 2	136	51 (38%)	693	247 (36%)	0.696
	≥3		85 (63%)		446 (64%)	
Pre-fracture mobility	Independent mobility	131	59 (45%)	660	306 (46%)	**0.012**
	Mobile with 1 support		3 (2%)		30 (5%)	
	Mobile with 2 supports or frame		58 (44%)		210 (32%)	
	Mobile with support within own home		8 (6%)		100 (15%)	
	No functional mobility		3 (2%)		14 (2%)	
Pre-fracture Katz ADL score	0	134	75 (56%)	670	305 (46%)	0.083
	1		13 (10%)		61 (9%)	
	2		17 (13%)		71 (11%)	
	3		3 (2%)		48 (7%)	
	4		9 (7%)		57 (9%)	
	5		6 (5%)		63 (9%)	
	6		11 (8%)		65 (10%)	
Pre-fracture living status	Home, no supportive care	123	69 (56%)	683	340 (50%)	**0.049**
	Home, with supportive care		28 (23%)		148 (22%)	
	Care home		7 (7%)		57 (8%)	
	Nursing home		15 (12%)		104 (15%)	
	Rehabilitation institution		4 (3%)		7 (1%)	
	Other		0 (0%)		27 (4%)	

Data are shown as median (P_{25}-P_{75}) or as n (%). n*, number of patients for whom data were available. Bold values indicate statistical significance. EMF, extramedullary fixation; IMF, intramedullary fixation.

Table 2: Outcomes for operation and initial hospital stay for extramedullary versus intramedullary fixation of stable trochanteric fractures

Outcome		EMF n=138		IMF n=698		
		n *		n*		P-value
Time to operation	Time (hours)	138	22 (17-27)	698	21 (14-28)	0.113
	<24 hours		84 (61%)		461 (66%)	0.402
	24-48 hours		46 (33%)		193 (28%)	
	>48 hours		8 (46%)		44 (6%)	
Complication rate		138	55 (40%)	697	270 (39%)	0.796
Complication type	Anemia	138	26 (19%)	697	143 (21%)	0.717
	Cardiac decompensation	138	5 (4%)	697	22 (3%)	0.752
	Delirium	138	15 (11%)	697	88 (13%)	0.609
	Fall	138	2 (2%)	697	3 (<1%)	0.150
	Infected wound	138	1 (1%)	697	1 (<1%)	0.197
	Kidney failure	138	2 (1%)	697	8 (1%)	0.766
	Pneumonia	138	9 (7%)	697	32 (5%)	0.315
	Pressure ulcer	138	2 (1%)	697	12 (2%)	0.837
	Pulmonary embolism	138	1 (1%)	697	1 (<1%)	0.202
	UTI	138	9 (7%)	697	41 (6%)	0.772
In-hospital mortality		138	6 (4%)	698	12 (2%)	0.052
HLOS (days)		132	7 (5-10)	685	7 (5-10)	0.717
Discharge location	Home, no supportive care	120	15 (13%)	680	53 (8%)	0.054
	Home with supportive care		12 (10%)		83 (12%)	
	Care home		7 (6%)		64 (10%)	
	Nursing home		18 (15%)		166 (24%)	
	Rehabilitation institution		64 (53%)		294 (43%)	
	Other		4 (3%)		20 (3%)	
Mobility at discharge	Independent mobility	132	1 (1%)	643	4 (1%)	**<0.001**
	Mobile with 1 support		6 (5%)		22 (3%)	
	Mobile with 2 supports or frame		93 (71%)		295 (46%)	
	Mobile with support within own home		19 (14%)		181 (28%)	
	No functional mobility		13 (10%)		141 (22%)	

Data are shown as median (P_{25}-P_{75}) or as n (%). n*, number of patients for whom data were available. Bold values indicate statistical significance. EMF, extramedullary fixation; HLOS, hospital length-of-stay; IMF, intramedullary fixation; UTI, urinary tract infection.

Table 3: Three-month outcomes and mortality for extramedullary versus intramedullary fixation of stable trochanteric fractures

			EMF n=138		**IMF** n=698	
Outcome		n*	n (%)	n*	n (%)	P-value
Living status at 3 months	Home, no supportive care	51	18 (35%)	323	157 (49%)	0.222
	Home with supportive care		16 (31%)		63 (20%)	
	Care home		2 (4%)		19 (6%)	
	Nursing home		9 (18%)		58 (18%)	
	Rehabilitation institution		6 (12%)		22 (7%)	
	Other		0 (0%)		4 (1%)	
Mobility at 3 months	Independent mobility	75	10 (13%)	362	51 (14%)	0.990
	Mobile with 1 support		8 (11%)		46 (13%)	
	Mobile with 2 supports or frame		42 (56%)		195 (54%)	
	Mobile with support within own home		9 (12%)		42 (11%)	
	No functional mobility		6 (8%)		28 (8%)	
Katz-ADL at 3 months	0	71	29 (41%)	343	147 (43%)	0.694
	1		13 (18 %)		42 (12%)	
	2		10 (14%)		39 (11%)	
	3		3 (4%)		30 (9%)	
	4		4 (6%)		19 (6%)	
	5		8 (11%)		40 (12%)	
	6		4 (6%)		26 (8%)	
Reoperation <3 months		89	6 (7%)	476	45 (10%)	0.546
Mortality at 3 months		96	15 (16%)	498	74 (15%)	0.876

Data are shown as median (P25-P75) or as n (%). n*, number of patients for whom data were available. EMF, extramedullary fixation; IMF, intramedullary fixation.

Table 4: Changes in mobility, living situation, and KATZ-ADL score between pre-trauma and three-months after trauma; Crude analysis and Matched subgroup-analysis

		EMF n=138		IMF n=698			
Unmatched analysis		**n***		**n***		**OR (95% CI)**	**P-value**
Mobility	Decreased mobility	75	43 (57%)	350	189 (54%)	0.9 (9.5-1.5)	0.612
Living situation	From living at home to institution*	51	10 (20%)	312	48 (15%)	1.4 (0.6-2.9)	0.416
Katz-ADL	Decrease in 1 domain or more	70	27 (39%)	341	127 (37%)	1.0 (0.6-1.6)	0.892
Mortality		96	15 (16%)	498	74 (15%)	0.9 (0.5-1.7)	0.847
		EMF N=57		**IMF N=114**			
Matched complete case analysis#		**n***		**n***		**OR (95% CI)**	**P-value**
Mobility	Decreased mobility	43	20 (46%)	79	39 (49%)	1.2 (0.6-2.6)	0.615
Living situation	From living at home to institution*	43	8 (19%)	79	12 (15%)	0.8 (0.3-2.1)	0.649
Katz-ADL	Decrease in 1 domain or more	43	18 (41%)	79	28 (35%)	1.3 (0.6-2.8)	0.485
Mortality		57	14 (25%)	114	35 (30%)	0.7 (0.4-1.5)	0.403

Data are shown as n (%). n*, number of patients for whom data were available. *Return to home environment (with or without support) or return to any type of institution. #Patients matched 1:2 case:control on age, sex, pre-fracture mobility, and ASA classification. EMF, extramedullary fixation; IMF, intramedullary fixation.

Discussion

This study showed that the vast majority of stable (AO type 31-A1) trochanteric fractures is treated with intramedullary fixation. No statistically significant differences were found in HLOS and in-hospital complications. At three months after trauma, no differences between groups were found in the reoperation rate, living status, mobility, and mortality when comparing EMF with IMF. Matched comparison of complete cases and sensitivity analysis in institutionalized or community-dwelling patients showed similar results after three months follow-up.

The main analysis of this study suggested a small indication for a faster recovery of patients' mobility in the three months after surgery for the IMF group. Despite a higher proportion of IMF patients having no functional mobility or only functional mobility within the home environment at baseline/pre-trauma and at discharge, there was no statistically significant difference in mobility at the three-month follow-up. A similar effect was found in the subgroup analysis for both institutionalized and community-dwelling patients. However, due to loss to follow-up at three months, these findings must be interpreted with care. These findings might indicate that while EMF patients

leave the hospital with better (or with a smaller decrease in) mobility, they make a slower functional recovery than IMF patients after three months. Although, when comparing changes in mobility before trauma and after three months, no significant differences were found in both the unmatched and matched analysis. Another recent registry study from Sweden, on both stable and unstable trochanteric fractures in independently living patients found no significant difference in return to independent living or mortality for stable trochanteric fractures (21). Van der Sijp *et al.* did not specifically study mobility but found, in agreement with the current study's results, no significant differences in Katz ADL score at three months and at one year follow-up (15). Additionally, a previous randomized trial that combined both stable and unstable trochanteric fractures reported a significantly faster improvement of mobility (using the Parker mobility score) at three months for IMF in the A1 subgroup (22). This trend continued up to one year follow-up. This might indicate that IMF has advantageous effects on mobilization of patients in the months after surgery, which may have beneficial effects on both fracture healing and quality of life.

A recent review comparing EMF and IMF for stable trochanteric fractures also found no meaningful differences in functional outcomes, complications, and surgical outcomes/operation characteristics (23). It showed lower rates of reoperation for both fixation groups than the current study (EMF 3.1% versus IMF 3.6%) but found no significant difference between the groups, as well. The lower reoperation rate might be due to inclusion of, often more selective, and younger randomized trial populations in this study. As specific reasons for reoperation were poorly reported in the DHFA dataset, these could not be adequately compared. With respect to in-hospital outcomes and complications, the current study reported similar results to previous literature, with no significant differences in HLOS, in-hospital mortality, and complications at discharge (15, 22, 24, 25).

The proportion of IMF versus EMF in this study was similar to data published for the full national coverage of the Dutch Hip Fracture Audit data in 2018-2019 (the current study also included data for the year 2020) (17). This was also visualized in DHFA data for all Dutch hospitals, including the six centers studied in this analysis, in Figure 2. This figure shows that the DHFA Indicator Taskforce is a representative sample of the national DHFA coverage and again confirms a low guideline adherence by Dutch (orthopedic) surgeons in the treatment of stable trochanteric fractures (7, 17). International studies show that reasons for choosing a particular device are often not motivated by patient specific factors but by surgeon specific training or preferences (11, 16). The difference in costs between both devices is significant and can range from around €300 to well over €2000 depending on the specific intramedullary device used, although specific costs per device are highly health system and also individual hospital

dependent (26, 27). If treatment of trochanteric fractures continues to shift towards only intramedullary nailing and EMF becomes a more obscure treatment, future generations of surgeons and surgical teams will lose the necessary training and experience. Future superiority of, the more expensive implant, IMF, will then become a self-fulfilling prophecy. As both devices are still used with relative frequency throughout the Netherlands, this might be a tipping point for a meaningful cost-effectiveness analysis. If extramedullary fixation proves to be more cost-effective, de-implementation studies and education aimed at increasing the use of EMF and decreasing the use of IMF for stable trochanteric fractures could potentially reverse the current trend.

Limitations

Although the DHFA should include all (31-A1) hip fracture patients, due to the often retrospective completion of the DHFA follow-up using patient medical files, there is a risk of selection bias through asymmetry in missing data. Differences found in baseline characteristics indicate the possibility of indication bias, as patients in the EMF group had a statistically significant better mobility and living status at baseline. However, after sensitivity analysis, stratified on pre-fracture living status and matched complete case analysis, we found similar results after 3 month follow-up as in the main analysis. Due to the nature of the DHFA registration, we could not provide data for a longer follow-up period than three months. While this would not influence data concerning the initial hospital stay, outcomes like reoperation rate may increase further in the period after the three month follow-up. Due to the anonymized nature of the DHFA data, we could not compare the results of individual hospitals. Hospitals with lower usage of a specific device could have worse results. Data on specific causes for reoperation, surgical outcomes, specific nail subtypes or augmentation are not included in the DHFA and could therefore not be included in this analysis. Due to the limitations of the DHFA for the included years, data on interdisciplinary orthogeriatric treatment, an important factor in rehabilitation could not be included in this manuscript. However, orthogeriatric treatment is the standard of care in the Netherlands for older hip fracture patients and most of the included hospitals in this analysis operate a geriatric trauma unit (7).

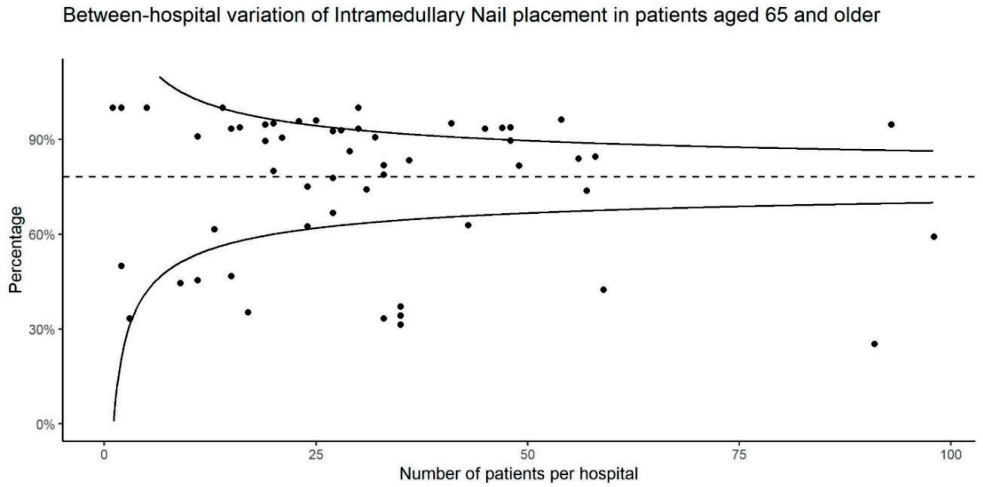


Figure 2: Between-hospital variation of intramedullary nail use for type 31-A1 trochanteric fractures in patients ≥ 65 years in 2018-2020 across the Netherlands

Each data point represents one Dutch hospital. This figure was provided by the Dutch Institute for Clinical Auditing and based on the complete national Dutch Hip Fracture Audit.

Conclusion

This study showed no meaningful differences between extramedullary and intramedullary fixation of stable (AO type 31-A1) trochanteric fractures during hospital stay and until three month follow-up. There were no significant differences between the groups for (deterioration of) mobility or living status after three months follow-up. Despite little differences in outcomes and extramedullary fixation being the treatment option of first choice by the Dutch Hip fracture guideline, intramedullary fixation was used in the vast majority of patients. Future efforts should focus more on cost-effectiveness analysis of both implant types.

References

1. Dong Y, Zhang Y, Song K, Kang H, Ye D, Li F. What was the Epidemiology and Global Burden of Disease of Hip Fractures From 1990 to 2019? Results From and Additional Analysis of the Global Burden of Disease Study 2019. Clin Orthop Relat Res. 2022.
2. Katsoulis M, Benetou V, Karapetyan T, Feskanich D, Grodstein F, Pettersson-Kymmer U, et al. Excess mortality after hip fracture in elderly persons from Europe and the USA: the CHANCES project. J Intern Med. 2017;281(3):300-10.
3. Collaborators GBDF. Global, regional, and national burden of bone fractures in 204 countries and territories, 1990-2019: a systematic analysis from the Global Burden of Disease Study 2019. Lancet Healthy Longev. 2021;2(9):e580-e92.
4. Zeelenberg ML, Den Hartog D, Panneman MJM, Polinder S, Verhofstad MHJ, Van Lieshout EMM. Trends in incidence, health care consumption, and costs for proximal femoral fractures in the Netherlands between 2000 and 2019: a nationwide study. Osteoporos Int. 2023.
5. AO. AO classification proximal femur fractures: Arbeitsgemeinschaft für Osteosynthesefragen (AO); 2023 [updated 2020. Available from: https://surgeryreference.aofoundation.org/orthopedic-trauma/adult-trauma/proximal-femur.
6. NICE Guidelines. National Institute for Health and Care Excellence: Guidelines, Hip fracture management. 2020/02/20 ed2017.
7. Multidiciplinaire werkgroep Nederlandse Orthopaedische Vereniging & Nederlandse Vereniging voor Heelkunde Behandeling pertrochantere fracturen (Dutch Hip Fracture Guideline): Federatie Medisch Specialisten; 2016 [updated 1 september 2016. Available from: https://richtlijnendatabase.nl/richtlijn/proximale_femurfracturen/pertrochantere_femurfractuur/behandeling_pertrochantere_fracturen.html.
8. American Academy of Orthopaedic Surgeons Management of Hip Fractures in Older Adults Evidence-Based Clinical Practice Guideline. : American Academy of Orthopaedic Surgeons 2021 [updated December 2021. Available from: https://www.aaos.org/hipfxcpg.pdf
9. Rogmark C, Spetz CL, Garellick G. More intramedullary nails and arthroplasties for treatment of hip fractures in Sweden. Acta Orthop. 2010;81(5):588-92.
10. Anglen JO, Weinstein JN, American Board of Orthopaedic Surgery Research C. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database. J Bone Joint Surg Am. 2008;90(4):700-7.
11. Forte ML, Virnig BA, Eberly LE, Swiontkowski MF, Feldman R, Bhandari M, Kane RL. Provider factors associated with intramedullary nail use for intertrochanteric hip fractures. J Bone Joint Surg Am. 2010;92(5):1105-14.
12. Page PR, Lord R, Jawad A, Dawe E, Stott P, Rogers B, Gill R. Changing trends in the management of intertrochanteric hip fractures - A single centre experience. Injury. 2016;47(7):1525-9.
13. Pyrhonen HS, Lagergren J, Wolf O, Bojan A, Mukka S, Moller M, Rogmark C. No Difference in Conversion Rate to Hip Arthroplasty After Intramedullary Nail or Sliding Hip Screw for Extracapsular Hip Fractures: An Observational Cohort Study of 19,604 Individuals. 2022.
14. Gronhaug KML, Dybvik E, Matre K, Ostman B, Gjertsen JE. Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures : 17,341 patients from the Norwegian Hip Fracture Register. Bone Joint J. 2022;104-B(2):274-82.
15. Van der Sijp MPL, de Groot M, Meylaerts SA, du Pre KJ, Verhage SM, Schipper IB, Niggebrugge AHP. High risks of failure observed for A1 trochanteric femoral fractures treated with a DHS compared to the PFNA in a prospective observational cohort study. Arch Orthop Trauma Surg. 2022;142(7):1459-67.

16. Mellema JJ, Janssen S, Schouten T, Haverkamp D, van den Bekerom MPJ, Ring D, et al. Intramedullary nailing versus sliding hip screw for A1 and A2 trochanteric hip fractures. Bone Joint J. 2021;103-B(4):775-81.
17. Wurdemann FS, Voeten SC, Krijnen P, Schipper IB. Variation in treatment of hip fractures and guideline adherence amongst surgeons with different training backgrounds in the Netherlands. Injury. 2022;53(3):1122-30.
18. Voeten SC, Arends AJ, Wouters M, Blom BJ, Heetveld MJ, Slee-Valentijn MS, et al. The Dutch Hip Fracture Audit: evaluation of the quality of multidisciplinary hip fracture care in the Netherlands. Arch Osteoporos. 2019;14(1):28.
19. Beck N, van Bommel AC, Eddes EH, van Leersum NJ, Tollenaar RA, Wouters MW, Dutch Clinical Auditing Group. The Dutch Institute for Clinical Auditing: Achieving Codman's Dream on a Nationwide Basis. Ann Surg. 2020;271(4):627-31.
20. Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of Illness in the Aged. The Index of Adl: A Standardized Measure of Biological and Psychosocial Function. JAMA. 1963;185:914-9.
21. Greve K, Ek S, Bartha E, Modig K, Hedstrom M. Sliding hip screw versus intramedullary nail for trochanteric hip fracture regarding death within 120 days and ability to return to independent living. Bone Jt Open. 2024;5(10):843-50.
22. Parker MJ. Sliding hip screw versus intramedullary nail for trochanteric hip fractures; a randomised trial of 1000 patients with presentation of results related to fracture stability. Injury. 2017;48(12):2762-7.
23. Zeelenberg ML, Nugteren LHT, Plaisier AC, Loggers SAI, Joosse P, Den Hartog D, et al. Extramedullary versus intramedullary fixation of stable trochanteric femoral fractures: a systematic review and meta-analysis. Arch Orthop Trauma Surg. 2023.
24. Alessio-Mazzola M, Traverso G, Coccarello F, Sanguineti F, Formica M. Dynamic hip screw versus intramedullary nailing for the treatment of A1 intertrochanteric fractures: A retrospective, comparative study and cost analysis. Jt dis relat surg. 2022;33(2):314-22.
25. Yu W, Zhang X, Zhu X, Yu Z, Xu Y, Zha G, et al. Proximal femoral nails anti-rotation versus dynamic hip screws for treatment of stable intertrochanteric femur fractures: an outcome analyses with a minimum 4 years of follow-up. BMC Musculoskelet Disord. 2016;17:222.
26. Baldock TE, Dixon JR, Koubaesh C, Johansen A, Eardley WGP. Variation of implant use in A1 and A2 trochanteric hip fractures : a study from the National Hip Fracture Database of England and Wales. Bone Jt Open. 2022;3(10):741-5.
27. Casnovsky L, Blaschke BL, Parikh HR, Flagstad I, Wise K, McMilan LJ, et al. Does Implant Selection Affect the Inpatient Cost of Care for Geriatric Intertrochanteric Femur Fractures? Geriatr Orthop Surg Rehabil. 2020;11:2151459320959005.

Supplemental Materials 1: Changes in living status at discharge and follow-up

Table S1: Changes in living status at discharge compared with the pre-trauma situation for extramedullary versus intramedullary fixation of stable trochanteric fractures

Living status		EMF n=138		IMF n=698		
Pre-fracture	**At discharge**	**n ***		**n***		**P-value**
-	Discharge to pre-fracture location	115	35 (30%)	623	209 (34%)	0.186
No supportive care	Supportive care at home		11 (10%)		54 (9%)	
No supportive care	Care home		4 (4%)		12 (2%)	
No supportive care	Nursing home		2 (2%)		23 (4%)	
No supportive care	Rehabilitation institution		34 (30%)		183 (29%)	
Supportive care at home	Care home		0 (0%)		9 (1%)	
Supportive care at home	Nursing home		2 (2%)		20 (3%)	
Supportive care at home	Rehabilitation institution		24 (21%)		84 (14%)	
Care home	Nursing home		0 (0%)		12 (2%)	
Care home	Rehabilitation institution		3 (3%)		6 (1%)	
Nursing home	Rehabilitation institution		0 (0%)		4 (1%)	
Other or unknown	Other or unknown		0 (0%)		7 (1%)	

Data are shown as n (%). n*, number of patients for whom data were available. EMF, extramedullary fixation; IMF, intramedullary fixation.

Table S2: Changes in living status at three-month follow-up compared with pre-trauma for extramedullary versus intramedullary fixation of stable trochanteric fractures

Living status		EMF n=138		IMF n=698		
Pre-fracture	**Three-month follow-up**	**n ***		**n***		**P-value**
-	Living at pre-fracture location	51	27 (53%)	302	201 (67%)	0.133
No supportive care	Supportive care at home		12 (24%)		34 (11%)	
No supportive care	Care home		0 (0.0%)		4 (1%)	
No supportive care	Nursing home		4 (8%)		11 (4%)	
No supportive care	Rehabilitation institution		4 (8%)		8 (3%)	
Supportive care at home	No supportive care		0 (0%)		10 (3%)	
Supportive care at home	Care home		1 (2%)		4 (1%)	
Supportive care at home	Rehabilitation institution		1 (2%)		12 (4%)	
Care home	Nursing home		1 (2%)		7 (2%)	
Care home	Rehabilitation institution		0 (0%)		1 (0.3%)	
Other or unknown	Other or unknown		1 (2%)		10 (3%)	

Data are shown as n (%). n*, number of patients for whom data were available. EMF, extramedullary fixation; IMF, intramedullary fixation

Supplemental Materials 2: Subgroup analysis institutionalized and community-dwelling patients

Table S3: Baseline characteristics of institutionalized and community-dwelling patients with a stable (A1) trochanteric fracture treated with extramedullary or intramedullary fixation

Characteristic		Institutionalized					Community dwelling				
			EMF n=26		IMF n=168			EMF n=100		IMF n=497	
		n*		n*		P-value	n*		n*		P-value
Age		26	89 (83-92)	168	88 (82-92)	0.581	100	81 (74-87)	497	82 (74-89)	0.407
Female		26	18 (69%)	168	129 (77%)	0.403	100	66 (66%)	496	342 (69%)	0.562
Year injury	2018	26	12 (46%)	168	65 (39%)	0.093	100	40 (40%)	497	175 (35%)	0.642
	2019		13 (50%)		66 (39%)			31 (31%)		172 (35%)	
	2020		1 (4%)		37 (22%)			29 (29%)		150 (30%)	
Injured side	Right	26	12 (46%)	168	88 (52%)	0.674[a]	100	54 (54%)	496	222 (45%)	0.100
ASA	1 or 2	25	3 (12%)	166	33 (20%)	0.424[a]	99	45 (46%)	494	205 (42%)	0.504
	≥3		22 (88%)		133 (80%)			54 (55%)		289 (59%)	
Pre-fracture mobility	Independent mobility	21	2 (10%)	154	21 (14%)	0.341	99	55 (56%)	481	277 (58%)	0.073
	Mobile with 1 support		0 (0%)		5 (3%)			3 (3%)		23 (5%)	
	Mobile with 2 supports		15 (71%)		74 (48%)			36 (36%)		130 (27%)	
	Mobile with support within own home		3 (14%)		46 (30%)			3 (3%)		47 (10%)	
	No functional mobility		1 (5%)		8 (5%)			2 (2%)		4 (1%)	
Parker mobility score		24	2 (2-4)	140	4 (2-6)	0.122	89	9 (6-9)	448	9 (6-9)	0.152
Pre-fracture KATZ ADL	Independent (KATZ 0)	23	7 (30%)	157	12 (8%)	**0.004**[a]	100	68 (68%)	483	285 (59%)	0.115
	Dependent (KATZ>0)		16 (70%)		145 (92%)			32 (32%)		198 (41%)	

Data are shown as median (P25-P75) or as n (%). n*, number of patients for whom data were available. Bold values indicate statistical significance. EMF, extramedullary fixation; IMF, intramedullary fixation.

Table S4: Outcomes for operation and initial hospital stay for institutionalized and community dwelling patients with stable (A1) trochanteric fractures

Outcome		Institutionalized					Community-dwelling				
		EMF n=26		IMF n=168			EMF n=100		IMF n=497		
		n*		n*		P-value	n*		n*		P-value
Time to operation	Time (hours)	26	23 (17-29)	167	21 (13-29)	0.393	100	22 (17-25)	496	20 (15-27)	0.333
	<24 hours	26	14 (53%)	167	101 (61%)	0.090	100	65 (65%)	496	336 (68%)	0.814
	24-48 hours		12 (46%)		49 (29%)			28 (28%)		132 (27%)	
	>48 hours		0		17 (10%)			7 (7%)		28 (6%)	
Complication rate		26	15 (58%)	168	69 (41%)	0.137[a]	100	35 (35%)	496	190 (38%)	0.573
Complication type	Anemia	26	8 (31%)	168	37 (22%)	0.326[a]	100	16 (16%)	496	100 (20%)	0.406
	Cardiac decompensation	26	2 (8%)	168	8 (5%)	0.626[a]	100	1 (1%)	496	14 (3%)	0.486
	Delirium	26	5 (20%)	168	20 (12%)	0.342[a]	100	9 (9%)	496	63 (13%)	0.400
	Fall	26	1 (4%)	168	1 (1%)	0.251[a]	100	1 (1%)	496	2 (<1%)	0.424
	Infected wound	26	0	168	0	N.A.	100	1 (1%)	496	1 (<1%)	0.308
	Kidney failure	26	0	168	2 (1%)	1.000[a]	100	2 (2%)	496	6 (1%)	0.627
	Pneumonia	26	2 (8%)	168	11 (7%)	0.687[a]	100	6 (6%)	496	21 (4%)	0.431
	Pressure ulcer	26	0	168	3 (2%)	1.000[a]	100	2 (2%)	496	9 (2%)	1.000
	Pulmonary embolism	26	0	168	0	N.A.	100	1 (1%)	496	1 (<1%)	0.308
	UTI	26	3 (12%)	168	6 (4%)	0.104[a]	100	5 (5%)	496	34 (7%)	0.658
In-hospital mortality		26	5 (20%)	168	4 (2%)	**0.003**[a]	100	0	497	8 (2%)	0.364
HLOS (days)		21	4 (4-6)	163	5 (4-7)	0.429	100	7 (5-12)	489	8 (6-11)	0.375
Discharge to	Institution	21	21 (100%)	163	163 (100%)	1.000[a]	98	71 (72%)	485	349 (72%)	1.000
Mobility at discharge	Independent mobility	21	0	153	2 (1%)	**0.017**	100	1 (1%)	465	2 (<1%)	**0.006**
	Mobile with 1 support		0		3 (2%)			6 (6%)		18 (4%)	
	Mobile with 2 supports or frame		12 (57%)		34 (22%)			72 (72%)		255 (55%)	

Table S4: Outcomes for operation and initial hospital stay for institutionalized and community dwelling patients with stable (A1) trochanteric fractures (*continued*)

Outcome		Institutionalized		Community-dwelling	
		EMF n=26	**IMF n=168**	**EMF n=100**	**IMF n=497**
	Mobile within home	3 (14%)	48 (31%)	15 (15%)	125 (27%)
	No functional mobility	6 (29%)	66 (43%)	6 (6%)	65 (14%)

Data are shown as median (P_{25}-P_{75}) or as n (%). n*, number of patients for whom data were available. Bold values indicate statistical significance. EMF, extramedullary fixation; HLOS, hospital length-of-stay; IMF, intramedullary fixation; UTI, urinary tract infection.

Table S5: Subgroup analysis of the three-month outcomes of institutionalized and community-dwelling patients comparing extramedullary versus intramedullary fixation

Outcome		Institutionalized					Community-dwelling				
			EMF n=26		IMF n=168			EMF n=100		IMF n=489	
		n*		n*		P-value	n*		n*		P-value
Reoperation <3 months		12	1 (8%)	102	12 (12%)	1.000[a]	68	5 (7%)	358	33 (9%)	0.817
Living status at 3 months	Home, no supportive care	7	0	55	2 (4%)	0.808	44	18 (41%)	256	154 (60%)	0.145
	Home with supportive care		0		2 (4%)			16 (36%)		61 (24%)	
	Care home		1 (14%)		6 (11%)			1 (2%)		9 (4%)	
	Nursing home		5 (71%)		41 (75%)			4 (9%)		12 (5%)	
	Rehabilitation institution		1 (14%)		2 (4%)			5 (11%)		20 (8%)	
	Other		0		2 (4%)			0		0	
Mobility at 3 months	Independent mobility	9	1 (11%)	62	1 (2%)	0.183	61	8 (13%)	465	50 (18%)	0.621
	Mobile with 1 support		0		2 (3%)			8 (13%)		43 (15%)	
	Mobile with 2 supports		3 (33%)		34 (55%)			36 (59%)		154 (54%)	
	Mobile within own home		5 (56%)		18 (29%)			3 (5%)		22 (8%)	
	No functional mobility		0		7 (11%)			6 (10%)		17 (6%)	
Katz-ADL at 3 months	Independent (Katz 0)	9	0	62	2 (3%)	1.000[a]	57	28 (49%)	270	142 (53%)	0.664
	Dependent (Katz>0)		9 (100%)		60 (97%)			29 (51%)		128 (47%)	
Mortality at 3 months		17	6 (35%)	107	25 (23%)	0.365[a]	71	6 (8.5%)	374	47 (13%)	0.425

Data are shown as median (P25-P75) or as n (%). n*, number of patients for whom data were available. EMF, extramedullary fixation; IMF, intramedullary fixation.

PART

III

PART III

Hip fractures in very frail older patients

Chapter 7: Satisfaction and quality of dying with nonoperative end-of-life care for hospitalized and non-hospitalized frail older patients with (suspected) hip fractures: a combined cohort study

Chapter 8: The value of preoperative diagnostic testing and geriatric assessment in frail institutionalized elderly with a hip fracture; a secondary analysis of the FRAIL-HIP study

Chapter 9: Shared decision making for nonoperative management versus operative management of hip fractures in selected frail older adults with a limited life expectancy; a protocol for a nationwide implementation study

Chapter 10: Patient and proxy satisfaction in shared decision-making for operative and nonoperative hip fracture treatment in frail older adults: A mixed methods study



7

Satisfaction and quality of dying with nonoperative end-of-life care for hospitalized and non-hospitalized frail older patients with (suspected) hip fractures: a combined cohort study

Miliaan L. Zeelenberg, Sverre A.I. Loggers, Pieter Joosse, Esther M.M. Van Lieshout, Taco Gosens, on behalf of the FRAIL-HIP Study Group and NONU-HIP Study Group

Acta Orthopaedica 2025, Volume 96, Pages 167–173.

Abstract

Purpose

For frail institutionalized hip fracture patients who opt for nonoperative management (NOM), the additional treatment benefits of hospital admission and in-hospital diagnostics are not well evaluated. We aimed to describe and compare treatment satisfaction and quality of dying, for patients who refrained from hospitalization after a hip fracture and patients who were treated nonoperatively after a short period of hospitalization.

Methods

Both cohorts included very frail institutionalized hip fracture patients. The first group directly started supportive care in their own nursing home after a suspected hip fracture. The second opted for NOM during shared decision making after admission and diagnostics at the hospital. Primary outcomes were treatment satisfaction and quality of dying measured by the Quality of Dying and Death Questionnaire (QODD). Secondary outcomes included health-related quality of life (EuroQoL-5D-5L and Qualidem), pain, and medication.

Results

20 non-hospitalized and 88 hospitalized patients were included. Overall treatment satisfaction by proxies was high for both non-hospitalized 9 (interquartile range [IQR] 8–10) and hospitalized patients 8 (IQR 4–9). Quality of dying was rated higher in the non-hospitalized group with QODD 8.3, IQR 6.9–8.6 versus 7.0, IQR 5.7–7.8, and median difference 1.0 (95% confidence interval [CI] 0.1–1.8). HRQoL, measured by the EQ-5D-5L utility score, was low in both groups but higher in non-hospitalized patients (0.30, IQR 0.15–0.32) than in hospitalized patients (0.25, IQR 0.03–0.32, median difference: 0.03, CI –0.03- 0.09)..Both groups reported similar pain levels, but hospitalized patients used higher standardized daily doses of opiates (39 mg versus 68 mg, median difference –24 mg, CI –42 to –7).

Conclusion

Proxies of hospitalized and non-hospitalized patients report a high treatment satisfaction after opting for NOM. Non-hospitalization may have beneficial effect on quality of dying in selected patients who have pre-recorded do-not-hospitalize directives or shared decision making after a suspected hip fracture.

Introduction

Hip fractures are related with morbidity and mortality in older adults, especially in those with extensive frailty (1, 2). A patient with a hip fracture is associated with limited return to pre-existing mobility and deteriorated health-related quality of life (HRQoL). While effective at reducing pain, operative treatment in frail older adults will increase the risk of surgically associated adverse events and may not always be beneficial to the patient (3, 4).

Nonoperative management (NOM) can be an appropriate option for selected frail older patients with poor life-expectancy and/or severely limited pre-trauma mobility (5, 6). In patients favoring palliative care focused on HRQoL and comfort, NOM may even be a more appropriate approach than operative management focused on return to function (7, 8). Currently, NOM is an increasingly used treatment option in the Netherlands, at around 3–5% of the total annual number of hip fractures in 2022 (9, 10).

In frail older patients with hip fractures, non-inferior HRQoL for NOM with a high treatment satisfaction and quality of dying has been reported (11). In a case series of nursing home patients with suspected hip fractures with do-not-hospitalize directives or advance care plans a high treatment satisfaction and quality of dying, reported by proxies and caregivers, was found (12).

Not hospitalizing patients (due to advance care plans or do-not-hospitalize directives) after a suspected hip fracture could potentially spare them from needless transfers, testing, and complications associated with hospital admissions, while also allowing them to directly receive care in a trusted environment. More comparative information can aid physicians and surgeons during advance care planning or decision making after suspected hip fractures and help them provide patients with more detailed expectations.

Therefore, we aimed to describe and compare treatment satisfaction and quality of dying in 2 cohorts of frail institutionalized patients with a (suspected) hip fracture, one group that was presented to the emergency department for diagnostics and decision making or underwent a short period of hospitalization and one that was not hospitalized due to pre-recorded do-not-hospitalize directives or pre-hospital decision making.

Methods

Study design

A retrospective cohort study was conducted using data collected by the NONU-HIP (12) and FRAIL-HIP (11) studies. These studies were conducted, respectively, from November 1, 2019 to December 31, 2022 and from September 1, 2018 to April 25, 2020. They are reported using the STROBE guidelines.

Population

This study described and compared two groups of patients, a non-hospitalized group and a hospitalized group. The non-hospitalized group consisted out of patients included in the NONU-HIP study. This was a prospective case series in 3 nursing homes in the Netherlands. All permanently institutionalized nursing home patients aged over 65 years with a suspected hip fracture, as judged by the elderly care physicians or nurse practitioner, who underwent NOM without hospital admission were included. Treatment decisions for NOM were either made through shared decision making with patients and/or legal representatives with medical professionals in the hospital and for non-hospitalized patients, shared decision making in their institution of residence or because of pre-existing do-not-hospitalize directives from advance care plans.

The hospitalized group included patients from the FRAIL-HIP study. This was a 6-month prospective cohort study at 25 hospitals across the Netherlands. Eligible patients were aged 70 years or older, frail, institutionalized, and sustained a femoral neck or trochanteric fracture. The term frail implied that at least 1 of the following characteristics was present: malnutrition (body mass index <18.5) or cachexia, severe comorbidities (American Society of Anesthesiologists physical status class of IV or V), or mobility issues (Functional Ambulation Category ≤2). Only data from patients who chose NOM were included in this analysis. These patients either died during hospital stay or returned to an institution or hospice after opting for NOM.

Outcome measures and data collection

The primary outcome measures were treatment satisfaction and quality of dying, using the Quality of Dying and Death (QODD) questionnaire (13), both reported by proxies. Secondary outcome measures were HRQoL using by the EuroQol 5 Dimension 5 level (EQ-5D-5L) questionnaire and Qualidem questionnaire (14), pain assessed by the Pain Assessment Checklist for Seniors With Limited Ability to Communicate (PACSLAC) (15), and daily amount of narcotic drug administration (total used dose during follow-up was converted into equivalent doses of 1mg of oral morphine per day. Additional data collected was: age, sex, BMI, KATZ-ADL score, cognitive function, sedative medication use, and mortality.

Treatment satisfaction, reported by proxies, was measured on a numeric rating scale (0–10) after a patient had deceased or at the end of the 6-month follow-up. Herein, 0 was extremely dissatisfied and 10 extremely satisfied. Quality of death and dying was also assessed by proxies, after patients deaths, using the QODD questionnaire (13). Currently no minimal clinically important difference (MCID) has been calculated for the QODD.

This interview-based questionnaire explores 17 end-of-life priorities resulting in 3 corresponding categories of the quality of the final period of the decedent's life ('terrible-poor', 'intermediate', and 'good-almost perfect'). It also distinguishes 4 subdomains: symptom control, (death) preparation, connectedness (i.e., sharing physical expressions of affection, spending time with family/friends), and transcendence (i.e., being unafraid of- and at peace with dying). The EQ-5D-5L, also reported by proxies, is an instrument for measuring HRQoL, consisting of a utility score (EQ-US) and a visual analog scale (EQ-VAS) (16). It was converted into utility scores using the Dutch tariff (17). The Qualidem, a 37-item questionnaire completed by caregivers covering the last 7 days, measured the HRQoL on 9 domains in persons with dementia (14). The items are rated on a 4-point Likert scale. Higher scores indicate better HRQoL (minimum score 0, maximum scores between 6 and 21 per domain). The PACSLAC is a 24-item instrument for recognizing pain in patients with dementia and was completed by caregivers (15). The total score ranges from 0 to 24, resulting in a dichotomous outcome with a score of $\geq$4 points indicating significant pain. Because of the degree of cognitive impairment of both study groups, questionnaires completed by proxies and/or caregivers were inevitable

In this analysis, measurements on HRQoL and pain were compared for the follow-up moment within the 1st week post-trauma, around 3 days for the non-hospitalized group (NONU-HIP study) and 7 days for the hospitalized group (FRAIL-HIP study). As almost all patients in the non-hospitalized, and a large proportion of hospitalized patients died before or shortly after 7 days, follow-up calculation for other time-points was not possible.

Statistics

Descriptive analysis was performed using SPSS version 25.0 (IBM, Chicago, Ill., USA). Continuous data were reported as median and inter quartile ranges (IQR) (due to non-normal distributions), categorical data as number with percentages. For categorical data absolute differences with 95% confidence interval (CI) were calculated using MedCalc Statistical Software, version 18.2.1 (MedCalcSoftware Ltd). For continuous variables, the Hodges-Lehmann estimator was used to calculate median differences with corresponding 95% CIs.

Ethics, data sharing, funding, use of AI, and disclosures

Both the FRAIL-HIP study (ref.no 2018.208) and NONU hip study (ref.no 2019.343) were exempted by the Medical Research Ethics Committee of VUmc. Patients or proxies provided written consent for participation. No funding was received for this analysis. The data that support the findings of this study are available from the corresponding author upon reasonable request. AI was not used in the analysis or writing of this manuscript. The authors declare no conflicts of interest.

Results

108 patients were included in the analysis, 20 patients in the non-hospitalized group and 88 in the hospitalized group (Figure 1). The total population had a median age of 88 years (IQR 84-93) and 83 (77%) patients were female (Table 1). Both groups were similar in age, sex, BMI, and ASA score. None of the patients functioned without assistance in any measured activities of daily life, but a higher proportion of hospitalized patients had a KATZ of >4. Of hospitalized patients, 49 (55%) were admitted to the hospital for at least 1 day, with a median stay of 2 days (IQR 2–3). The others returned to their institution of residence after the diagnostic process and shared decision making at the emergency department. For non-hospitalized patients a predefined do-not-hospitalize directive was in place in 9 patients, and in the other 11 cases NOM was started after shared decision making with the patient and/or next-of-kin. 30-day mortality was 100% in non-hospitalized patients and 83% in hospitalized patients (absolute differ-

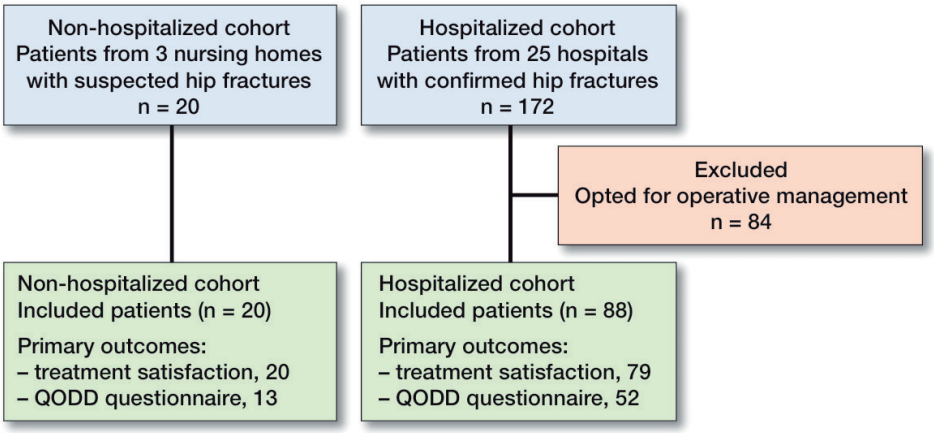


Figure 1. Flowchart of included patients for both included cohorts and the number of patients with data available for the primary outcomes.

QODD – Quality of dying and death questionnaire**.**

ence 17%, CI –0.3 to 27). Additional injury and treatment characteristics showed a median hospital stay of 2 days (IQR 2-3) for hospitalized patients. Of hospitalized patients, 54 (61%) suffered a femoral neck fracture and 30 (39%) a trochanteric hip fracture (Supplemental Table S1).

Overall treatment satisfaction, measured by proxies, was high for both groups, with a median NRS of 9 (IQR 8–10) in non-hospitalized patients and 8 (IQR 8–10) for hospitalized patients with a median difference of 1 (CI 0–1) (Table 2). Quality of dying, measured by the QODD total score, was rated better (median difference 1.0, CI 0.1–1.8) by proxies of non-hospitalized patients (8.3, IQR 6.9–8.6) than in hospitalized patients (7.0, IQR 5.7–7.8). 10 proxies (76%) of the non-hospitalized group and 26 proxies (50%) of the hospitalized group rated the quality of dying as 'good–almost

Table 1. Baseline characteristics. Data is shown as median (IQR) or as n (%).

	Non-hospitalized (n = 20)		Hospitalized (n = 88)		Absolute (in %) or median [a] difference
Characteristic	Total n	Median (IQR) / n (%)	Total n	Median (IQR) / n (%)	n/% (CI)
Age	20	87 (82–92)	88	89 (84–93)	–1 (–4 to 2)
Female sex	20	16 (80)	88	67 (76)	4 (–18 to 19)
BMI, median	12	21 (19–22)	68	21 (18–26)	0 (–2 to 3)
Nursing home resident	20	20 (100)	88	88 (100)	0 (–4 to 16)
Hospital admission after hip fracture diagnosis	20	NA	88	49 (56)	NA
Dementia diagnosis	20	17 (85)	88	83 (94)	9 (–3 to 30)
Katz ADL score 0	20	0 (0)	84	0 (0)	0 (–16 to 4)
1		2 (10)		0 (0)	10 (2 to 30)
2		1 (5)		4 (5)	0 (–18 to 8)
3		2 (10)		13 (16)	6 (–1 to 18)
4		7 (35)		12 (14)	21 (2 to 43)
5		5 (25)		23 (27)	2 (–21 to 19)
6		3 (15)		32 (38)	23 (–0.1 to 37)
ASA category II	20	2 (10)	88	4 (5)	5 (–4 to 25)
III		15 (75)		63 (60)	15 (–9 to 32)
IV		3 (15)		31 (35)	20 (–3 to 34)
Days to death	20	5 (3–6)	83	7 (5–12)	–3 (–5 to –1)
30-day mortality	20	20 (100)	88	73 (83)	17 (–0.3 to 26)

ADL – activities of daily living; BMI – body mass index; CCI – Charlton Comorbidity Index; FAC – Functional Ambulation Category

IQR – interquartile range [a] Median differences (and 95% confidence intervals) were calculated using the the Hodges-Lehmann estima

perfect' (Figure 2). The sub-scores for the domains symptom control, preparation, and transcendence were also rated higher in the non-hospitalized group. Symptom control was the worst rated subcategory for both groups, with more frequent "good to almost perfect" ratings for non-hospitalized patients across all 4 domains (Figure 2). For an overview of all questions per subcategory see Supplemental Figure S1.

HRQoL measured by the EQ-5D-5L through proxies was low for both groups (Table 2). While the VAS scores were similar, the utility score was higher in non-hospitalized patients (0.30, IQR 0.15–0.32) than in hospitalized patients (0.25, IQR 0.03–0.32, median difference: 0.03, CI –0.03 to 0.09). However, the magnitude of this difference does not seem clinically relevant, based on nonspecific MCID values (18). Proxies reported high disability with respect to mobility, self-care, and ADL tasks for both non-hospitalized and hospitalized patients (Figure 2). Extreme pain and anxiety/depression was uncommon in both groups. HRQoL measured by the domains of the Qualidem score registered high (positive) scores for both groups in the categories 'care relationships', 'feeling at home', and 'positive self-image', and lower (negative) scores in the categories 'having something to do', 'social relations', and 'restless tense behavior'.

Pain during care moments, measured using the PACSLAC was similar between the groups, with a median score of 5 (IQR 4–10) for non-hospitalized and 6 (IQR 4–9) for hospitalized patients (median difference 0, CI –2 to 2) (Table 2). Non-hospitalized patients received a lower median dose of morphine per day of follow-up, 39 mg (IQR 16–65) versus 68 mg (IQR 39–95) (median difference –24 mg, CI –42 to –7). In 17 (70%) of non-hospitalized and 41 (51%) of hospitalized patients, palliative sedation was started during the final phase of life (absolute difference 20% (CI –4-39)).

Table 2. Primary (treatment satisfaction and quality of dying) and secondary outcomes (health-related quality of life, pain and medication) for non-hospitalized and hospitalized patients. Data is shown as median (IQR) or as n (%)

		Non-hospitalized		Hospitalized		Absolute (in %) or median [b]
		n [a]		n [a]		difference (CI)
Primary						
Treatment satisfaction	NRS Proxy	20	9 (8–10)	79	8 (4–9)	1 (0 to 1)
QODD	Total score	13	8.3 (6.9–8.6)	52	7.0 (5.7–7.8)	1.0 (0.1 to 1.8)
	Symptom control	13	7.7 (6.7–8.3)	52	5.7 (3.1–6.7)	2.0 (1.0 to 3.3)
	Preparation	15	8.8 (8.0–9.2)	52	7.0 (6.0–8.0)	1.4 (0.6 to 2.1)
	Connectedness	15	8.5 (7.8–9.0)	52	7.5 (6.0–9.0)	1.0 (0.0 to 1.5)
	Transcendence	15	8.7 (7.7–9.0)	52	6.8 (4.8–8.0)	1.7 (0.7 to 2.7)
Secondary						
EQ–5D–5L	EQ–5D–5L Utility proxy	18	0.30 (0.15–0.32)	83	0.25 (0.03–0.32)	0.03 (–0.03 to 0.09)
	EQ–5D–5L VAS Proxy	18	25 (18–46)	83	40 (30–50)	–10 (–20 to 0)
Qualidem [c]	Care relationships (0–21)	14	20 (18–21)	84	19 (17–21)	1 (0 to 2)
	Positive affect (0–18)	14	10 (6–11)	84	9 (5–12)	1 (–1 to 4)
	Negative affect (0–9)	14	9 (7–9)	85	7 (5–9)	1 (0 to 2)
	Restless tense behavior (0–9)	14	5 (3–7)	85	4 (2–6)	0 (–1 to 2)
	Positive self–image (0–9)	14	9 (8–9)	85	9 (9–9)	0 (0 to 0)
	Social relations (0–18)	14	8 (6–10)	83	7 (5–9)	1 (–1 to 3)
	Social isolation (0–9)	14	6 (4–6)	85	6 (6–8)	0 (–1 to 0)
	Feeling at home (0–12)	14	12 (11–12)	84	12 (12–12)	0 (0 to 0)
	Having something to do (0–6)	14	0 (0–1)	84	0 (0–0)	0 (0 to 0)
Pain and medication [c]	PACSLAC during care (0–24)	19	5 (4–10)	85	6 (4–9)	0 (–2 to 2)
	PACSLAC ≥4 during care, n (%)	19	17 (90)	85	75 (88)	2 (–19 to 13)
	Daily morphine administration [d]	20	39 (16–65)	88	68 (39–95)	–24 (–42 to –7)
	Palliative sedation, n (%)	20	14 (70)	81	41 (50)	20 (–4 to 39)

IQR – interquartile range; NRS – numeric rating scale; QODD – quality of dying and death questionnaire; VAS – visual analog scale. PACSLAC – Pain assessed by the Pain Assessment Checklist for Seniors With Limited Ability to Communicate. [a] Number of patients for whom data were available. [b] Median differences (and 95% confidence intervals) were calculated using the the Hodges-Lehmann estimator [c] Both Qualidem and PACSLAC scores were completed by caregivers instead of proxies. [d] Total morphine administration was calculated by conversion of all administered opioid pain medication into 1 mg oral morphine per day for the first week after trauma

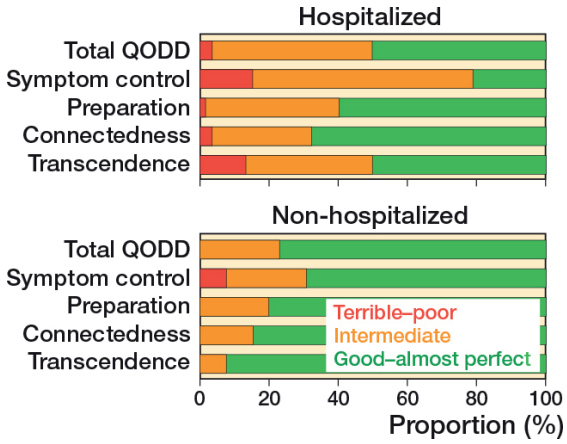


Figure 2. Quality of dying rated by proxies measured by the QODD questionnaire for non-hospitalized and hospitalized patients with ratings for the combined (total) QODD and the 4 subdomains.

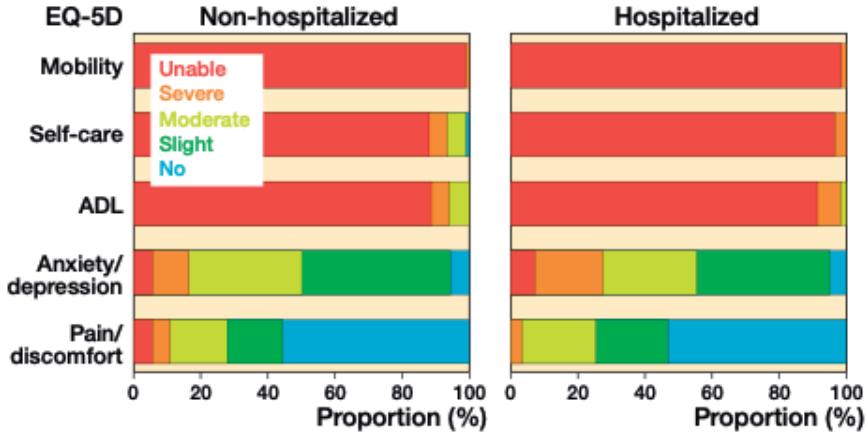


Figure 3. Quality of life for non-hospitalized versus hospitalized patients measured by the EQ-5D-5L for the 5 subdomains by proxies during the first week after trauma.

Discussion

We aimed to describe and compare treatment satisfaction and quality of dying, for patients who refrained from hospitalization after a (suspected) hip fracture and patients who were treated nonoperatively after a short period of hospitalization. We found that proxies of both hospitalized and non-hospitalized patients, who opt for NOM, report a high treatment satisfaction and high quality of dying for the majority of patients. Additionally, non-hospitalization may have beneficial effects on quality of life and dying in a select group of very frail older adults that opt for non-hospitalization after a

pre-recorded do-not-hospitalize directive or shared decision making after a suspected hip fracture.

This is the first study describing and comparing data from hospitalized and non-hospitalized patients after opting for NOM for a (suspected) hip fracture. These outcomes can aid physicians in shared decision making, advance care planning, and help them provide more realistic expectation management, or serve as a starting point for further study. However, due to the selection of both populations, the different moments patients opted for NOM, and differences in pre-existing expectations or preparedness of death or dying there is a high risk of selection bias, almost per definition. Interpretation and extrapolation of results should therefore be done with considerable care.

Proxies in both groups reported a high treatment satisfaction and quality of dying, comparable to results found in operatively managed patients (11). However, proxies of non-hospitalized patients reported better scores in the QODD total score and the subcategories symptom control, preparation, and transcendence. This can be interpreted as less observed pain, a sense of less strain on loved ones, and patients seeming more at peace with dying. The minimal important change for the QODD is unknown, making the clinical value of these differences, of a median 1–2 points per subcategory, unclear. Non-hospitalized patients did show a higher proportion of patients in "good–excellent quality of dying" and no proxies that rated the quality of dying below intermediate, suggesting that in this sample there were advantages for the non-hospitalized group. Previous qualitative studies reported that some of the most important aspects in comfortable palliative care after hip fracture are control of pain, easy access to and communication with loved ones, and a calm and peaceful moment of dying (19). Other studies also identified maintaining quality of life (over prolonging of life) and being with family as more important goals of care than hospital admission and intensive treatment for frail patients with dementia (20, 21). Transfers to and within the hospital, diagnostics, and care moments in an unfamiliar environment may all have contributed to the lower quality of dying of those who were hospitalized, as these will have placed more strain on both patients and next-of-kin, and potentially increases the risk of delirium. Alternatively, non-hospitalized patients and their next-of-kin may have been more at peace with dying or prepared for the consequences of NOM due to predetermined advance care plans or do-not-hospitalize directives. Dying within a short timespan would have been within the realm of expectation.

Pain during care was rated similar for both groups and is often one of the most challenging areas of NOM. Despite similar pain scores and a small proportion of patients receiving a local nerve block, hospitalized patients used higher mean doses of opiates per day. This might be due to differences in protocols, in availability of medication, and

means of administration between hospitals and nursing homes. It might also indicate that hospitalized patients experienced higher pain levels, therefore needing more analgesia. Conversely, some non-hospitalized patients may have benefitted from additional pain medication to further decrease pain levels. A larger proportion of non-hospitalized started palliative sedation, which may have reduced the need for or use of additional pain medication.

HRQoL during the first week after trauma was rated low in both groups by proxies or caregivers, with the small difference falling below most nonspecific MICD values (18). This can be expected as both groups included very frail patients in their final phase of life, often with pre-existing low HRQoL due to age, comorbidities, or mobility issues, worsened by the hip fracture (2, 19). The process of hospitalization seems not to have worsened these scores, although several patients in both groups scored near the absolute minimum of the EQ-5D-5L and several of the Qualidem subcategories.

This study shows a notably longer survival in the hospitalized group which most likely is explained by selection bias. The main reason for this difference might be that many in the non-hospitalized group had do-not-hospitalize directives based on other diagnoses or end-of-life preferences and consequently were treated earlier in a palliative matter. The longer survival combined with low HRQoL can have also negatively impacted quality of dying in this group, as judged by proxies, due to longer periods of ongoing perceived suffering (19). However, others may have valued the additional time with their loved ones. Is unlikely that the process of hospitalization will have significantly prolonged survival. For a large proportion of the hospitalized patients the decision for nonoperative palliative care had to be made after trauma in an acute hospital setting. This could possibly have led to a broader range of patients opting for NOM, with less specific advance care plans and wishes for end-of-life care and a less predictable short-term mortality.

When interpreting this study's results, basic differences between countries and their healthcare systems must be considered. NOM is starting to gain more international attention and acceptation but is still a small area of research (22, 23). Current projects in the Netherlands focus on implementation of standardized shared decision-making between operative management and NOM in the hospital setting for selected frail elderly with hip fractures (24). However, international views, culture and legislation on hip fracture care in the final phase of life differ greatly and not all will consider NOM a favorable alternative to surgery (23).

As it is unclear who out of all frail institutionalized patients benefits from either operative management or NOM, both approaches need to be discussed.

Limitations

We suspected selection bias as the major limitation. The sample size is small and the smaller group size of the non-hospitalized group may have affected the generalizability of results. The few data points for several outcomes hamper the possibility of matching or viability of regression analysis. However, both groups were similar in terms of age, sex, comorbidities, pre-trauma living situation, and mobility. While conducted within the first week for both groups, follow-up did not occur on the same day after fracture in the groups. Due to the nature of these patients, with high rates of dementia and/or sedative medication, the included studies were only able to assess HRQoL and quality of dying trough proxies or caregivers.

Conclusion

Proxies of hospitalized and non-hospitalized patients, who opt for NOM, reported a high treatment satisfaction and high quality of dying for a majority of the patients. In the situation of a suspected hip fracture, opting for non-hospitalization after a pre-recorded do-not-hospitalize directive or shared decision making may have benefits for quality of dying in selected very frail older adults when compared with patients who were hospitalized for diagnostics and in-hospital shared decision making.

In perspective, Future efforts should focus on studying and improving shared decision making and advance care planning in frail institutionalized older adults with a hip fracture so that hospitalization can be prevented for those patients who would prefer familiar care focused on comfort and quality of life in their final moment.

Refraining from hospitalization in selected patients who prefer nonoperative end-of-life care decreases the amount of unneeded in-hospital diagnostics and interventions which results in a cost-decrease for the health care system of approximately €2,200 per patient (25, 26). Therefore, it is important to improve identification of patients for whom hospitalization, diagnostics, and/or advanced pain treatment would be either beneficial or redundant after a suspected hip fracture. However, the cornerstone of both patient's satisfaction and quality of dying remains the thorough and timely discussion of expectations and wishes for the final phase of life, ideally conducted before a fracture occurs.

References

1. Berry SD, Rothbaum RR, Kiel DP, Lee Y, Mitchell SL. Association of Clinical Outcomes With Surgical Repair of Hip Fracture vs Nonsurgical Management in Nursing Home Residents With Advanced Dementia. JAMA Intern Med. 2018;178(6):774-80. doi: 10.1001/jamainternmed.2018.0743
2. Van de Ree CLP, Landers MJF, Kruithof N, de Munter L, Slaets JPJ, Gosens T, de Jongh MAC. Effect of frailty on quality of life in elderly patients after hip fracture: a longitudinal study. BMJ Open. 2019;9(7):e025941. doi: 10.1136/bmjopen-2018-025941
3. Hu F, Jiang C, Shen J, Tang P, Wang Y. Preoperative predictors for mortality following hip fracture surgery: a systematic review and meta-analysis. Injury. 2012;43(6):676-85. doi: 10.1016/j.injury.2011.05.017
4. De Joode S, Kalmet PHS, Fiddelers AAA, Poeze M, Blokhuis TJ. Long-term functional outcome after a low-energy hip fracture in elderly patients. J Orthop Traumatol. 2019;20(1):20. doi: 10.1186/s10195-019-0529-z
5. Loggers SAI, Van Lieshout EMM, Joosse P, Verhofstad MHJ, Willems HC. Prognosis of nonoperative treatment in elderly patients with a hip fracture: A systematic review and meta-analysis. Injury. 2020;51(11):2407-13. doi: 10.1016/j.injury.2020.08.027
6. Wijnen HH, Schmitz PP, Es-Safraouy H, Roovers LA, Taekema DG, Van Susante JLC. Nonoperative management of hip fractures in very frail elderly patients may lead to a predictable short survival as part of advance care planning. Acta Orthop. 2021;92(6):728-32. doi: 10.1080/17453674.2021.1959155
7. Van der Steen JT, Radbruch L, Hertogh CM, de Boer ME, Hughes JC, Larkin P, et al. White paper defining optimal palliative care in older people with dementia: a Delphi study and recommendations from the European Association for Palliative Care. Palliat Med. 2014;28(3):197-209. doi: 10.1177/0269216313493685
8. Hertogh CM. Advance care planning and the relevance of a palliative care approach in dementia. Age Ageing. 2006;35(6):553-5. doi: 10.1093/ageing/afl103
9. Van Bremen HE, Seppala LJ, Hegeman JH, van der Velde N, Willems HC, Dutch Hip Fracture Audit Group. Characteristics and Outcomes of Nonoperatively Managed Patients With Hip Fracture Using the Dutch Hip Fracture Audit. J Orthop Trauma. 2024;38(5):265-72. doi: 10.1097/BOT.0000000000002778
10. Dutch Hip Fracture Audit. DHFA annual report (In Dutch): Dutch Institute for clinical auditing; 2023 [Available from: https://dica.nl/wp-content/uploads/2024/05/DHFA-Jaarrapport-2022.pdf.
11. Loggers SAI, Willems HC, Van Balen R, Gosens T, Polinder S, Ponsen KJ, et al. Evaluation of Quality of Life After Nonoperative or Operative Management of Proximal Femoral Fractures in Frail Institutionalized Patients: The FRAIL-HIP Study. JAMA Surg. 2022;157(5):424-34. doi: 10.1001/jamasurg.2022.0089
12. Loggers SAI, Van Balen R, Steens J, Willems HC, Riezebos P, Wagenaar-Huisman A, et al. Treatment satisfaction with nonoperative management of suspected hip fractures in nursing home patients with a do not hospitalize directive; a prospective case series (NONU-HIP). Under submission. 2025.
13. Downey L, Curtis JR, Lafferty WE, Herting JR, Engelberg RA. The Quality of Dying and Death Questionnaire (QODD): empirical domains and theoretical perspectives. J Pain Symptom Manage. 2010;39(1):9-22. doi: 10.1016/j.jpainsymman.2009.05.012

14. Ettema TP, Droes RM, de Lange J, Mellenbergh GJ, Ribbe MW. QUALIDEM: development and evaluation of a dementia specific quality of life instrument--validation. Int J Geriatr Psychiatry. 2007;22(5):424-30. doi: 10.1002/gps.1692
15. Fuchs-Lacelle S, Hadjistavropoulos T. Development and preliminary validation of the pain assessment checklist for seniors with limited ability to communicate (PACSLAC). Pain Manag Nurs. 2004;5(1):37-49. doi: 10.1016/j.pmn.2003.10.001
16. Tol M, Kuipers JP, Willigenburg NW, Willems HC, Poolman RW. How are you doing in the eyes of your spouse? Level of agreement between the self-completed EQ-5D-5L and two proxy perspectives in an orthopaedic population: a randomized agreement study. Health Qual Life Outcomes. 2021;19(1):35. doi: 10.1186/s12955-021-01679-y
17. Versteegh M, Vermeulen MAA, Evers S, De Wit GA, Prenger RA, Stolk E. Dutch Tariff for the Five-Level Version of EQ-5D. Value Health. 2016;19(4):343-52. doi: 10.1016/j.jval.2016.01.003
18. Feng YS, Kohlmann T, Janssen MF, Buchholz I. Psychometric properties of the EQ-5D-5L: a systematic review of the literature. Qual Life Res. 2021;30(3):647-73. doi: 10.1007/s11136-020-02688-y
19. Nijdam TMP, Laane DWPM, Spierings JF, Schuijt HJ, Smeeing DPJ, Van der Velde D. Proxy-reported experiences of palliative, non-operative management of geriatric patients after a hip fracture: a qualitative study. BMJ Open. 2022;12(8):e063007. doi: 10.1136/bmjopen-2022-063007
20. Nijdam TMP, Laane DWPM, Schiepers TEE, Smeeing DPJ, Kempen DHR, Willems HC, et al. The goals of care in acute setting for geriatric patients in case of a hip fracture. Eur J Trauma Emerg Surg. 2023;49(4):1835-44. doi: 10.1007/s00068-023-02258-0
21. Mitchell SL, Palmer JA, Volandes AE, Hanson LC, Habtemariam D, Shaffer ML. Level of Care Preferences Among Nursing Home Residents With Advanced Dementia. J Pain Symptom Manage. 2017;54(3):340-5. doi: 10.1016/j.jpainsymman.2017.04.020
22. Boulet J, Belzile EL, Dion N, Morency C, Berube M, Tremblay A, Pelet S. Palliative care is a viable option for frail elderly patients with neurocognitive disorders admitted for hip fractures. BMC Musculoskelet Disord. 2024;25(1):635. doi: 10.1186/s12891-024-07739-w
23. Rogmark C, Lynoe N. How to play the final chess match-or at least lose with dignity. Acta Orthop. 2021;92(6):633-4. doi: 10.1080/17453674.2021.1959159
24. Zeelenberg ML, Oosterwijk PC, Willems HC, Gosens T, Den Hartog D, Joosse P, et al. Shared decision-making for non-operative management versus operative management of hip fractures in selected frail older adults with a limited life expectancy: a protocol for a nationwide implementation study. BMJ Open. 2024;14(4):e083429. doi: 10.1136/bmjopen-2023-083429
25. Zeelenberg ML, Den Hartog D, Van Lieshout EMM, Wijnen HH, Willems HC, Gosens T, et al. The value of preoperative diagnostic testing and geriatric assessment in frail institutionalized elderly with a hip fracture; a secondary analysis of the FRAIL-HIP study. Eur Geriatr Med. 2024. doi: 10.1007/s41999-024-00945-8
26. Loggers SAI, Geraerds A, Joosse P, Willems HC, Gosens T, Van Balen R, et al. Nonoperative versus operative management of frail institutionalized older patients with a proximal femoral fracture: a cost-utility analysis alongside a multicenter prospective cohort study. Osteoporos Int. 2023;34(3):515-25. doi: 10.1007/s00198-022-06638-x

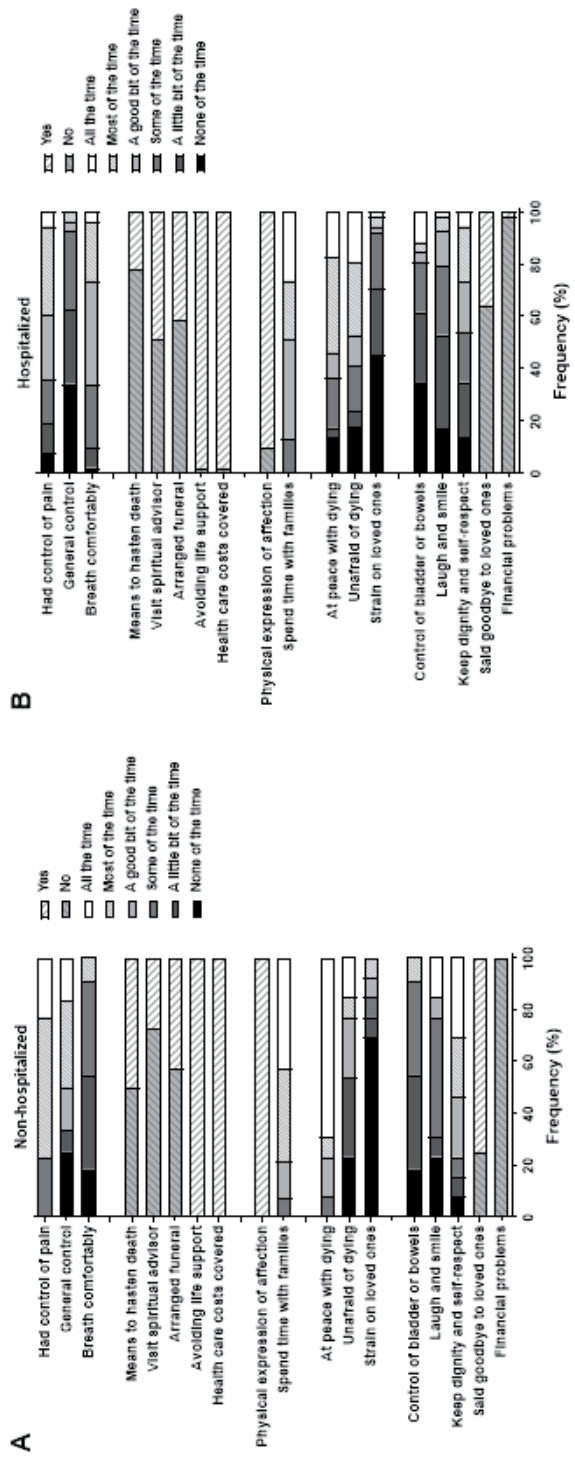
Supplemental tables and figures

Supplementary Table S1. Injury characteristics for hospitalized patient and additional treatment characteristics for both groups

	Non-hospitalized (n = 20)		Hospitalized (n = 88)	
Characteristic	n [a]	n	n [a]	median (IQR) or n (%)
Fracture type				
Femoral neck	Unknown	Unknown	54	54 (61)
Pertrochanteric	Unknown	Unknown	34	34 (39)
Days of hospital stay (IQR)	NA	NA	49	2 (2–3)
Consultations [b]				
Physical therapist	20	5	88	39 (44)
Occupational therapist	20	2	88	31 (35)
Dietician	20	1	88	8 (9.1)
Spiritual counselor	20	1	88	2 (2.3)
Antipsychotic medication [b]	20	2	88	29 (33)
Femoral nerve block	20	NA	88	14 (16)
PENG block	20	NA	88	1 (1.1)
Registered adverse events [b]	20	2	88	35 (40)
Pressure ulcers	20	0	88	20 (20)
Delirium	20	2	88	8 (9.1)
Heart failure	20	0	88	2 (2.3)
Urinary tract infection	20	0	88	4 (4.5)
Pneumonia	20	0	88	2 (2.3)
Fall	20	0	88	1 (1.1)
Morphine intoxication	20	0	88	1 (1.1)

[a] number of patients for whom data were available. [b] Up to 1 week follow-up

ED = emergency department; NA = not applicable; PENG = pericapsular nerve group**;** IQR = interquartile range



Supplemental Figure S1. Comparison of individual QODD questions for non-hospitalized (A) and hospitalized (B) patients



8

The value of preoperative diagnostic testing and geriatric assessment in frail institutionalized elderly with a hip fracture; a secondary analysis of the FRAIL-HIP study.

Miliaan L. Zeelenberg, Dennis Den Hartog, Esther Van Lieshout, Hugo H. Wijnen, Hanna C. Willems, Taco Gosens, Jeroen Steens, Romke Van Balen, Rutger G. Zuurmond, Sverre A.I. Loggers, Pieter Joosse, Michiel H.J. Verhofstad, on behalf of the FRAIL-HIP Study Group

European Geriatric Medicine 2024, Volume 15, Issue 3, Pages 753-763

Abstract

Purpose
The aim of this study was to provide a comprehensive overview of (preoperative and geriatric) diagnostic testing, abnormal diagnostic tests and their subsequent interventions, and clinical relevance in frail older adults with a hip fracture.

Methods
Data on clinical consultations, radiological, laboratory, and microbiological diagnostics were extracted from the medical files of all patients included in the FRAIL-HIP study (inclusion criteria: hip fracture, >70 years, living in a nursing home with malnourishment/cachexia and/or impaired mobility and/or severe co-morbidity). Data were evaluated until hospital discharge in nonoperatively treated patients and until surgery in operatively treated patients. 5 **Results**

A total of 172 patients (88 nonoperative and 84 operative) were included, of whom 156 (91%) underwent laboratory diagnostics, 126 (73%) chest X-rays, and 23 (13%) CT-scans. In 153/156 (98%) patients at least one abnormal result was found in laboratory diagnostics. In 82/153 (50%) patients this did not result in any additional diagnostics or (pharmacological) intervention. Abnormal test results were mentioned as one of the deciding arguments for operative delay (>24 hours) for 10/84 (12%) patients and as a factor in the decision between nonoperative and operative treatment in 7/172 (4%) patients.

Conclusion
A large number and variety of diagnostics were performed in this patient population. Abnormal test results in laboratory diagnostics were found for almost all patients and, in majority, appear to have no direct clinical consequences. To prevent unnecessary diagnostics, prospective research is required to evaluate the clinical consequences and added value of the separate elements of preoperative diagnostic testing and geriatric assessment in frail hip fracture patients.

Introduction

A proximal femoral fracture in frail institutionalized patients is associated with high mortality and significantly diminished health-related quality of life (1-4). The results of the FRAIL-HIP study suggested that nonoperative care is a viable option in the most frail older adults with a hip fracture (5). Patients who opted for nonoperative management showed a reduced life expectancy, but their quality of life was not inferior to operated patients and the dying process without surgery was judged humane (5, 6).

When these patients are admitted with a suspected hip fracture, an extensive diagnostic process is started. In addition to regular radiographs and physical examination, the Dutch guideline for surgical treatment of frail older adults recommends a geriatric assessment in addition to the general preoperative screening (7). In frail older adults with multiple pre-trauma comorbidities, many incidental abnormalities can be expected during the diagnostic process. Often clinical findings at arrival warrant additional laboratory diagnostics, chest X-rays, or cardiac ultrasound, and in some cases extensive routine testing is performed as standard care.

Questions could be raised about whether these abnormalities have consequences for patients. Many abnormalities found through routine preoperative diagnostic testing have little predictive value for outcomes in surgical patients (8-10). It is unknown what proportion of abnormal diagnostic tests requires additional interventions and whether these are performed. Also, the influence of preoperative assessment and diagnostic testing on the treatment choice (operative versus nonoperative) is unclear. Studies on preoperative cardiac testing show no changes in the perioperative management of older adults with a hip fracture, whereas testing significantly increases the costs of care and/or time to surgery (11-13). As less than one percent of routine preoperative chest radiographs in patients with hip fractures lead to a clinically significant finding, some authors advocate only selective use based on clinical indicators instead of routine testing (14, 15). Preventing unnecessary preoperative diagnostic testing could be vital in reducing the burden of care for admitted patients, delay of surgery, and general costs of care.

Few data exist on (preoperative) diagnostic testing and its associated interventions in frail older adults with a proximal femoral fracture. The aim of this study was to provide a comprehensive overview of (routine) preoperative and geriatric diagnostic testing, and the number of associated interventions with regards to frail institutionalized older adults with a proximal femoral fracture.

Methods

This retrospective cohort study conducted an additional analysis of patients who participated in the FRAIL-HIP study (5). These patients were enrolled between September 1, 2018 and April 25, 2020.

The FRAIL-HIP study was a prospective cohort study performed in 25 hospitals across the Netherlands. Eligible patients were aged 70 years or older, frail, institutionalized, and sustained a femoral neck or trochanteric fracture. The term frail implied that at least one of the following characteristics was present: malnutrition (body mass index <18.5 $kg.m^2$), severe comorbidities (American Society of Anesthesiologists physical status class of IV or V), or severe mobility issues (Functional Ambulation Category ≤2). The Functional Ambulation Categories (FAC) is a functional walking test that evaluates ambulation ability (16). This 6-point scale assesses ambulation status by determining how much human support the patient requires when walking, regardless of whether or not they use a personal assistive device. FAC ≤2 means that a patient at least has the need for (intermittent) help of another person to be able to ambulate (FAC 2) to no functional ambulatory capabilities (FAC 0).

Patients were either treated operatively or nonoperatively. Treatment decision was made by shared decision making based on the personal preference and treatment goals of patients and/or relatives. Patients were followed until six months after trauma or until death.

Outcome measures

The primary outcome of this post hoc analysis was the type and number of diagnostic tests performed as part of in-hospital (preoperative or geriatric) assessment. This was categorized into: consultations, radiological diagnostics and electrocardiograms (ECGs), laboratory (blood) and microbiological diagnostics. Secondary outcomes were: abnormal results found during testing, interventions or additional diagnostics initiated after abnormal results during diagnostic testing, postponement of surgery due to abnormal diagnostic test results, change in hip fracture treatment due to abnormal diagnostic test results, and adherence to the national guidelines with regards to diagnostic testing and preoperative assessment in frail older adults with a proximal femur fracture. Data on diagnostic procedures, test results, and subsequent interventions were either extracted from the FRAIL-HIP database or extracted from the patients' hospital records. For operatively treated patients, data were extracted until the moment of operation and for conservatively treated patients until discharge from the hospital. All data were collected as reported in hospital records; no new interpretations or test results were created based on available test data. Results were classified as an abnormal test result if

mentioned as such in the patients' records or classified as abnormal in the test registration. Abnormal diagnostic test results were classified as known if abnormal test results of similar magnitude were found in recent tests preceding the hip fracture admission, or if a related (chronic) disease was recorded in their recent medical history. Consequences of abnormal diagnostic tests were classified as no diagnostics or intervention (including expectant/conservative treatment or no mention of additional diagnostics or intervention), additional diagnostic testing (including all types of diagnostics related to the abnormal result or repeated measurement of the same test), pharmacological intervention (related starting, altering or stopping of medication), or invasive intervention (related surgical intervention or other non-diagnostic invasive procedures). Pain medication was not registered as additional intervention since all patients used analgesic medication in this study. Diagnostics were classified as indicated if they were performed after an explicit report of a complaint or clinical indication in the patient's file. In all other cases they were defined as screening diagnostics. Additional data on the patients' vital signs and physical state at admission were gathered, including heart rate, blood pressure, respiratory rate, oxygen saturation, neurological status, and abnormalities found during physical examination.

In addition, the proportion of conducted laboratory diagnostics in accordance with the advised laboratory tests by the Dutch guidelines was assessed (7, 17). The Dutch hip fracture guideline advises the minimum preoperative laboratory diagnostics to contain at least: hemoglobin, albumin, creatinine/eGFR, electrolytes (most likely represented by sodium, potassium, and calcium), and glucose (7). In addition, the Dutch guideline for the comprehensive geriatric assessment advises an assessment of: erythrocyte sedimentation rate (ESR), complete blood count, kidney function, glucose, thyroid assessment, electrolytes, liver enzymes, Vitamin B12, folic acid, total serum protein and albumin (17).

These data were combined with the pre-existing FRAIL-HIP database, including patient characteristics (age, sex, body mass index, ASA classification, Charlson comorbidity index), type of fracture, additional injuries, and treatment (operative versus nonoperative).

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 28.0 (SPSS, Chicago, Ill., USA). Normality for continuous data was assessed using the Shapiro-Wilk test. The analyses were done stratified for nonoperative treatment and operative treatment. Continuous data were reported as mean and SD (if normally distributed) or median and interquartile ranges (in case of non-normal distribution) and categorical data as numbers with percentages. Univariate comparison between groups

was performed using a Mann-Whitney, $\chi 2$, or Fischer exact tests. A 2-sided P-value <0.05 was used as threshold for statistical significance.

Results

A total of 172 patients with a hip fracture were included, of which 88 were treated nonoperatively, and 84 were treated operatively. No significant differences were found in baseline characteristics, physical parameters, or findings during physical examination between the two treatment groups (Table 1; Supplemental Table S1). Consultations, radiological diagnostics, laboratory diagnostics, and microbiological diagnostics were mainly requested at the emergency department (>90%; OR 1, Tables S2-S3). Radiological diagnostics were primarily performed after a clinical indication (*e.g.*. head trauma or painful wrist after a fall), whereas laboratory and microbiology diagnostics were mostly

Table 1: Baseline characteristics for non-operatively and operatively treated patients

	Nonoperative (n=88)		Operative (n=84)		
	N*		N*		**P-value**
Women	88	67 (76%)	84	68 (81%)	0.28
BMI (kg/m^2)	68	20.4 (18.0-25.2)	77	23.2 (18.4-26.3)	0.10
ASA classification					0.41
2	88	4 (5%)	84	1 (1%)	
3		53 (60%)		54 (64%)	
4		31 (35%)		29 (35%)	
CCI	88	3 (2-5)	84	3 (2-5)	0.44
Type of fracture					
Femoral neck	88	54 (61%)	84	45 (54%)	0.30
Trochanteric		34 (39%)		39 (46%)	0.94
Physical parameters at admission					
Temperature (ºC)	75	37.0 (SD 0.56)	79	36.9 (SD 0.66)	0.14
Heart rate (bpm)	81	81 (SD 15)	81	81 (SD 15)	0.14
SBP (mmHg)	81	149 (SD 30)	83	149 (SD 28)	0.94
DBP (mmHg)	81	78 (SD 15)	83	78 (SD 16)	0.90
O_2 saturation (%)	80	95 (94-97)	79	95 (93-97)	0.29
Respiratory rate	53	15 (14-19)	68	16 (14-16)	0.95
GCS	34	15 (14-15)	48	15 (15-15)	0.18

Data are shown as n (%), median (P_{25}-P_{75}) or mean (SD). N* refers to the number of patients for whom data were available. ASA, American school of Anesthesiologists; BMI, body mass index; bpm, beats per minute; CCI, Charlson comorbidity score; DBP, diastolic blood pressure; GCS, Glasgow coma scale**;** SBP, systolic blood pressure.

performed without mention of a specific clinical indication or related disease (OR 1, Tables S4-S5).

Clinical consultations

The most common clinical consultations (Table 2), excluding (orthopedic) surgery consultations (100% in both arms), were geriatric (59/88 nonoperative versus 77/84 operative) and cardiology (8/88 nonoperative versus 22/84 operative) consultations. No additional clinical consultations occurred in 28/88 nonoperative patients and in only 1/84 patients in the operative group (p<0.001). Seventeen of those 28 nonoperative patients without consultations also received no other diagnostics than a pelvic X-ray at the ER and directly returned to their nursing home after having chosen nonoperative treatment. Both geriatric and cardiology consultations occurred significantly more in the operative group. After geriatric consultations, 39/59 (66%) nonoperative and 19/77 (25%) operative patients had no (pharmacological) intervention or additional diagnostics (Supplemental Table S6). For cardiology consultations, this was 2/8 (25%) for nonoperative patients and 7/22 (32%) for operative patients. No patients received invasive interventions due to geriatric or cardiologic consultations.

Table 2: Clinical consultations for non-operatively and operatively treated patients

Consulted specialism	Nonoperative (n=88)	Operative (n=84)
(Orthopedic) Surgery	88 (100%)	84 (100%)
Geriatrics	59 (67%)*	77 (92%)
Cardiology	8 (9%)*	22 (26%)
Neurology	2 (2%)	4 (5%)
Internal medicine	1 (1%)	3 (3%)
Pulmonary medicine	2 (2%)	1 (1%)
Anesthesia[a]	2 (2%)	0 (0%)
Other[b]	1 (1%)	4 (5%)
No consultation[c]	28 (32%)*	1 (1%)

Data are shown as n (%). *Statistically significant difference (p<0.05) between nonoperative and operative groups [a] Not being regular preoperative screening consultation [b] Other including: Psychiatry, Microbiology, ophthalmology, urology [c] No consultations other than primary orthopedic or (trauma-)surgery consultation

Radiological diagnostics and electrocardiograms

As a radiologically proven cervical neck or trochanteric fracture was a requirement for inclusion, all patients received a form of radiological diagnostics (Table 3). Other than pelvic X-rays, chest X-rays were performed in 59/88 (67%) nonoperative patients and 67/84 (80%) operative patients. In 41/59 nonoperative and 32/67 operative patients, abnormal results were found on the chest X-ray. The most common abnormalities

found were cardiomegaly (18/59 versus 15/67) and pulmonary consolidation/suspected infection (8/59 versus 8/67) (OR 1, Table S7). In 18/59 nonoperative patients and 35/67 operative patients, no abnormal results were found in chest X-rays; this was significantly more in the operative group (p=0.011). Other types of X-rays were less common, with arm/wrist X-rays (six nonoperative and six operative) and knee X-rays (three nonoperative and five operative) being most frequent. CT-scans were made in nine nonoperative and 14 operative patients, with head and cervical spine as the most common categories.

Cardiac ultrasounds were performed significantly less (p=0.12) in nonoperative patients than in operative patients (4 with 4 abnormal test versus 14 with 10 abnormal tests). Electrocardiography was also performed more often in the operative group (47 versus 69, p<0.001), with 32 and 41 abnormal tests found, of which most were previously known abnormalities, respectively 21 and 26.

Regarding consequences (OR 1, Table S8), radiological diagnostics or ECGs rarely led to additional diagnostics or interventions in the nonoperative group, only six pharmacological or invasive interventions across all diagnostic tests. Likewise, in the operative group (besides hip fracture surgery) a total of 13 interventions were conducted related to performed radiological diagnostics.

Laboratory diagnostics

Laboratory diagnostics (Table 4) were performed in 72 (82%) of nonoperative patients and 84 (100%) of operative patients (p<0.001). All lab categories and microbiological tests, except for liver/pancreas and cardiac function, were performed significantly more in the operative group. In only one patient in the nonoperative group and two patients in the operative group, no abnormal test results were found in any of the laboratory diagnostics. Hematological diagnostics was the only subgroup with significantly more abnormal test results in the nonoperative group (64/72 versus 62/84, p=0.006). Most specific abnormal test results were found in hemoglobin (46/72 nonoperative and 36/84 operative), leukocyte count (45/71 nonoperative and 37/80 operative), Urea (37/65 nonoperative and 48/78 operative), and C-reactive protein (41/68 nonoperative and 48/80 operative). The most relevant tests and abnormalities, as described by the Dutch guideline for hip fracture treatment and guideline for CGA are shown in Table 5. Nonoperative patients had significantly lower values for hemoglobin (7.4 versus 7.8 mmol, p=0.009), hematocrit (0.36 versus 0.38 mmol, p=0.016), and serum albumin (34 versus 35 g/L, p=0.023), but had a higher glomerular filtration rate (eGFR) than operative patients (65 versus 60 mL/min/1,73m^2, p=0.026). All other specific laboratory diagnostic results can be found in Supplemental Table S9.

With regards to consequences for abnormal test results found during laboratory diagnostics (Table 6), for most abnormal test results, no additional diagnostics or interventions were reported. In the nonoperative group, no intervention or additional diagnostics rate was higher for all laboratory diagnostic subgroups, but a significant difference was only found for the hematological (55/64 versus 42/62, p=0.015) and vitamin status groups (8/9 versus 8/21, p=0.011). Abnormal test results in vitamins (1/9 versus 13/21, p=0.011) and inflammatory markers (3/42 versus 12/51, p=0.046) both showed an increased rate of pharmacological intervention in the operative group. Abnormal tests in kidney function were associated with an increased rate of additional diagnostics in the operative group (1/43 versus 11/56, p=0.036).

Laboratory diagnostics in guidelines

Adherence to the (Dutch) hip fracture guideline was investigated for the operative group. Hemoglobin was tested in all 84 patients, 82 (97.6%) patients received at least a sodium and potassium test, albumin was tested in 69 (82.1%) patients, kidney function was tested in 83 (98.8%) patients, and glucose was tested in 80 (95.2%) patients (also shown in Table 5).

Table 4: Laboratory diagnostics performed, abnormal test results found, and subsequent additional diagnostics or intervention performed per subcategory

	Nonoperative (n=88)			Operative (n=84)		
	Performed	Abnormal test results[a]	Additional diagnostics or Intervention	Performed	Abnormal test results[a]	Additional diagnostics or intervention
Laboratory testing						
Hematological	72 (82%)*	64 (89%)*	9 (14%)*	84 (100%)	62 (74%)	20 (32%)
Electrolytes	72 (82%)*	25 (65%)	4 (16%)	82 (98%)	32 (61%)	11 (34%)
Nutritional status	67 (76%)*	37 (55%)	2 (5%)	81 (96%)	46 (57%)	6 (13%)
Vitamin status	31 (35%)*	9 (29%)	1 (11%)*	49 (58%)	21 (43%)	13 (62%)
Inflammatory markers	69 (78%)*	42 (61%)	8 (19%)	80 (95%)	51 (64%)	18 (35%)
Kidney function	71 (81%)*	43 (61%)	3 (7%)	83 (99%)	56 (68%)	13 (23%)
Liver/pancreas function	61 (69%)*	37 (61%)	1 (3%)	68 (81%)	37 (54%)	2 (5%)
Cardiac function	2 (2%)	2 (100%)	1 (50%)	1 (1%)	1 (100%)	0 (0%)
(Para-)Thyroid function	37 (42%)*	10 (27%)	1 (10%)	54 (64%)	18 (33%)	0 (0%)
Coagulation	62 (71%)*	18 (29%)	10 (55%)	81 (96%)	19 (24%)	15 (79%)
Arterial blood gas	3 (3%)	2 (67%)	2 (100%)	1 (1.2%)	1 (100%)	0 (0%)
Urine sediment	22 (25%)*	6 (27%)	2 (33%)	46 (55%)	18 (39%)	14 (78%)
Microbiological testing	10 (11%)*			20 (24%)		
Blood culture	3	2	0	5	1	1
Urine culture	8	5	0	14	10	5
Viral PCR	1	0	N.A.	2	0	N.A.
MRSA culture	0	N.A.	N.A.	1	0	N.A.
Other						
D-dimer	0	N.A.	N.A.	1	1	1

Data are shown as n (%). *Statistically significant difference ($p<0.05$) between nonoperative and operative groups [a] At least one abnormal test result in the whole subcategory N.A., not applicable

Table 5: Number of patients receiving specific laboratory diagnostics and abnormal test results in the minimally required laboratory tests as described by Dutch hip fracture guideline and/or guideline for comprehensive geriatric assessment.

	Nonoperative (n=88)		Operative (n=84)	
	Performed	Abnormal test results	Performed	Abnormal test results
Hemoglobin	72 (82%)*	46 (64%)*	84 (100%)	36 (43%)
eGFR	71 (81%)*	26 (37%)	83 (99%)	34 (41%)
Sodium	72 (82%)*	9 (13%)	82 (98%)	8 (10%)
Potassium	72 (82%)*	9 (13%)	81 (96%)	11 (14%)
Calcium	58 (66%)*	6 (10%)	68 (81%)	3 (4%)
Albumin	58 (66%)*	28 (48%)*	69 (82%)	20 (29%)
Glucose	66 (75%)*	15 (23%)*	80 (95%)	33 (41%)
Additional tests mentioned in guideline for CGA				
ESR	24 (27%)	8 (33%)	27 (32%)	11 (41%)
Hematocrit	68 (77%)*	35 (52%)*	77 (92%)	21 (27%)
MCV	65 (74%)*	3 (5%)	78 (93%)	4 (5%)
Erythrocytes	58 (66%)	37 (64%)	59 (70%)	30 (51%)
Leukocytes	71 (81%)*	45 (63%)*	80 (95%)	36 (45%)
Leukocyte differentiation	35 (40%)	24 (69%)	37 (44%)	23 (62%)
Thrombocytes	68 (77%)*	6 (9%)	77 (92%)	6 (8%)
TSH	37 (42%)*	8 (22%)	54 (64%)	17 (32%)
AF	56 (64%)*	12 (21%)	66 (79%)	14 (21%)
ALAT	54 (61%)	2 (4%)	62 (74%)	2 (3%)
ASAT	44 (50%)*	5 (11%)	56 (67%)	3 (5%)
GGT	46 (52%)*	10 (22%)	59 (70%)	18 (31%)
LD	36 (41%)	18 (50%)	45 (54%)	17 (38%)
Vitamin B12	27 (31%)*	2 (7%)	42 (50%)	3 (7%)
Folic Acid	25 (28%)*	3 (12%)	38 (45%)	10 (26%)
Creatine	71 (81%)*	20 (28%)	83 (99%)	30 (36%)
Total protein	8 (9%)	2 (25%)	4 (5%)	0 (0%)
CRP[1]	68 (77%)*	41 (60%)	80 (95%)	48 (60%)

Data are shown as n (%). *Statistically significant difference ($p<0.05$) between nonoperative and operative groups [1]CRP was is not included as standard diagnostic test in both guidelines but was added to the table because of its frequency in testing and possible clinical significance.

AF, alkaline phosphatase; ALAT, alanine transaminase; ASAT, aspartate transaminase; CGA, comprehensive geriatric assessment; CRP, C-reactive protein; eGFR, estimated glomerular filtration rate; ESR, erythrocyte sedimentation rate; GGT, Gamma-glutamyltransferase; LD, lactate dehydrogenase; MCV, mean corpuscular volume; TSH, thyroid stimulating hormone

In addition to this, in accordance with the Dutch guideline for comprehensive geriatric assessment: In the total 84 operatively treated patients, in 27 (32%) patients ESR was tested, in 54 (64%) thyroid function was tested, in 68 (81%) at least one of the liver enzymes was tested, in 42 (50%) vitamin B12 was tested, in 38 (45%) folic acid was tested, and in four (5%) total serum protein was tested. A complete blood count was also advised. In addition to hemoglobin in all patients, for 77 (92%) patients hematocrit, for 78 (93%) mean corpuscular volume (93%), erythrocyte count 59 (70%), thrombocyte count 77 (92%), and leukocyte count 80 (95%) was determined, in the operative group. The number and proportion of performed diagnostics in the nonoperative group was generally lower (OR 1, Table S9).

Delay and change of intervention

Surgery was delayed for >24 hours in 31/84 (36.9%) patients (Table 7). This was most commonly due to logistical reasons (*e.g.*, admission in the early morning, no available timeslot in the surgical program, not possible to contact family in time). In 10/84 (11.0%) patients, new findings (*e.g.*, pneumonia, irregular antibodies, malignancy screening, initial nonoperative treatment changed to operative after increased fracture instability) during diagnostic testing were cited as a factor in delayed surgery (Table 7). In 5/172 (3.0%) patients, new findings were mentioned as one of the arguments for the decision to switch from operative treatment to nonoperative treatment. Specific arguments mentioned were a newly found severe aortic valve dysfunction (cardiac echography), increasing renal and cardiological dysfunction (laboratory diagnostics), liver metastasis (abdominal echography), and/or pulmonary infection/malignancy (thoracic X-ray). In all cases, these were only mentioned in a list of other arguments, such as low quality of life, worsening dementia, low mobility pre-trauma, and weariness of life. Changes from nonoperative to operative treatment in 2/172 (1%) patients were all due to increasing fracture displacement on an additional (secondary) X-ray or CT-scan because of increasing unmanageable pain after initial nonoperative management.

Table 6: Consequences of abnormal diagnostic test results found during laboratory diagnostics or microbiological testing

	Nonoperative				Operative			
	No diagnostics or intervention	Additional diagnostics	Pharmacological[a] intervention	Invasive intervention	No diagnostics or intervention	Additional diagnostics	Pharmacological[a] intervention	Invasive intervention
Laboratory diagnostics								
Hematological	55 (83%)*	9	4	0	42 (68%)	13	10	0
Electrolytes	21 (84%)	4	2	0	21 (66%)	7	8	0
Nutritional status	35 (95%)	2	0	0	40 (87%)	2	4	0
Vitamin status	8 (89%)*	0	1*	0	8 (38%)	0	13	0
Inflammatory markers	34 (81%)	6	3*	0	33 (65%)	14	12	0
Kidney function	40 (91%)	2*	2	0	47 (84%)	11	4	0
Liver and pancreatic function	36 (97%)	1	0	0	35 (95%)	2	0	0
Cardiac function	1 (33%)	1	1	0	1 (100%)	0	0	0
Thyroid function	9 (91%)	0	1	0	18 (100%)	0	0	0
Coagulation	8 (44%)	8	10	0	4 (21%)	14	14	0
Arterial blood gas	0 (0%)	2	2	0	1 (100%)	0	0	0
Urine	4 (67%)	0	2	0	6 (33%)	4	9	0
Microbiological diagnostics								
Blood culture	2 (100%)	0	0	0	0 (0%)	0	1	0
Urine culture	5 (100%)	0	0	0	5 (50%)	0	5	0

Data are shown as n (%) of total number of abnormal diagnostic tests per subcategory. *Statistically significant difference ($p<0.05$) between nonoperative and operative groups. A single patient could receive a combination of additional diagnostics and/or pharmacological- and/or invasive interventions. [a]Not being analgesics

Table 7: Reasons for postponement of surgery (>24 hours) and change of operative of nonoperative treatment (partly) due to abnormal diagnostic test results

	Operative (n=84)
Delayed surgery	31 (37%)
Reason delay[a]	
New finding	10 (32%)
Known finding	2 (6%)
Coagulation	11 (13%)
Logistical	20 (65%)
Change of treatment due to abnormal diagnostic test results	**Total population** (n=172)
Operative to nonoperative[b]	5 (3%)
Nonoperative to operative[c]	2 (1%)
Unknown reason	3 (2%)
New abnormal diagnostic tests not mentioned in treatment decision	162 (96%)

Data are shown as n (%). [a] A combination of multiple reasons was possible [b] Specific test results: Severe aortic valve dysfunction (cardiac echography), increasing renal and cardiological dysfunction (laboratory diagnostics), liver metastasis (abdominal echography), and/or pulmonary infection/malignancy (thoracic X-ray) [c] Increasing fracture displacement on an additional (secondary) X-ray or CT-scan

Discussion

This study evaluated (geriatric and preoperative) diagnostic testing in frail institutionalized patients with a hip fracture. The results showed that both a large variety and number of diagnostics were performed in this population, after presentation to the Emergency Department, both in the operative and nonoperative group. Operatively treated patients were tested more extensively in both radiological and laboratory diagnostics and the majority of tests (>90%) in both groups was requested at or by the Emergency Department. While many abnormal diagnostic tests did not result in (pharmacological) interventions or additional diagnostics, abnormal diagnostic tests were mentioned as a reason for surgery delay and as an argument in the decision between operative and nonoperative hip fracture care in several cases.

Both the operative and nonoperative groups showed large numbers of diagnostics. The rates of radiological diagnostics (not being pelvic X-rays) showed no differences between groups, except for the rate of cardiac ultrasound, which was performed more often in the operative group. Cardiac ultrasounds are often performed in the preoperative work-

up in patients with known or newly found signs of heart failure, abnormal ECGs, or cardiac murmurs during physical examination and would thus, logically, be performed more often in operative patients (18, 19). The number of (preoperative) chest X-rays was relatively high (67% nonoperative and 80% operative) and they were often used without clinical indication, while recent literature and guidelines recommend only indicated use of chest X-rays (14, 18-20). This study also showed that while abnormal results were found in many cases, only in a small group of patients (4/41 nonoperative and 5/32 operative patients) abnormal findings on chest X-rays were an argument for (pharmacological) intervention. This is in line with results found in previous research (14, 20).

Rates of laboratory and microbiological diagnostics were even higher, with 100% of operative patients and 82% of nonoperative patients undergoing blood tests. The significant differences between groups in performed diagnostics can be primarily explained by a group of 17 conservative patients in which nonoperative care was established before other diagnostics than pelvic X-rays were performed and were subsequently discharged without additional diagnostics.

In the patients who did receive laboratory diagnostics, this study found no significant differences in abnormal test results found per subgroup of laboratory diagnostics except for abnormalities in hematological diagnostics. In this subcategory, nonoperatively treated patients showed more abnormal test results than operatively treated patients. This is probably due to a worse (pre-trauma) condition and related to their choice for nonoperative care for their hip fracture. While there are differences between operative and nonoperative patients in the amount of diagnostic testing, these differences are remarkably small. As most tests were requested at or by the Emergency Department, they were conducted prior to or during the treatment decision. The treatment group might therefore have a limited effect on the number of requested tests.

This is the first study on the consequences of diagnostic testing in frail institutionalized older adults with hip fractures and to analyze this in both operative and nonoperative patients. Many previous prognostic studies have studied the influence of abnormal diagnostic tests in laboratory or radiological diagnostics on mortality after hip fracture surgery (21-24). They concluded that, despite the high predictive value of potential biomarkers, advanced age, minimal pre-trauma mobility and history of ischemic heart disease are the most important predictors for (in-hospital) mortality after a hip fracture (23-25). Prediction of in-hospital mortality may be an essential argument in the decision between operative and nonoperative care for patients with a hip fracture. As this was a retrospective analysis, the added value of specific tests in the treatment decision could not be studied.

(Trauma-)surgical guidelines on preoperative screening in older adults with a hip fracture advise restricting diagnostic testing and treatment to only acute correctable comorbidities or indicated diagnostics (7, 19, 26). According to surgical guidelines, operations should not be delayed due to abnormalities in the diagnostic process unless there is a severe condition preventing surgery. Because of this, the Dutch guideline advises only a limited blood analysis (7). In the operative subgroup only hemoglobin was tested in 100% of the patients, with the other tests (except for albumin) performed in 95% of the cases. No previous study evaluated adherence to this part of the guideline. The Dutch guideline also advises multidisciplinary care involving, ideally, a consulting geriatrician. A documented geriatric consultation was achieved in 67% of nonoperative patients and 92% of operative patients (in the period until respectively discharge or operation). In operative patients, this percentage could have increased further after the operation. However, this warrants attention in the nonoperative group as a geriatric opinion combined with the surgeon's view could be essential in deciding between operative and palliative hip fracture care. In both cases a geriatrician could provide advice and treatment for further recovery and rehabilitation or identify barriers and problems for palliative care.

Many of the laboratory diagnostics performed in this study, such as liver/pancreas function, vitamin status, or thyroid function, do not fit in the limited minimal surgical assessment. Many of those do, however, fit in the comprehensive geriatric assessment (CGA). This assessment is also advised by these same guidelines and plays a vital role in optimizing patients post-operatively for rehabilitation or prevention of complications and fracture recurrence (7, 17, 26-29). This guideline was met in lower percentages than the surgical guideline. However, additional tests can be expected to have been performed after surgery. It is important to note that a complete CGA was not common practice in all included hospitals and some items, like vitamin status, would play a marginal role in preoperative assessment.

As most test are requested at arrival, due to often standardized ER protocols, one could argue that some of these tests could be postponed until after surgery and could thus be omitted for patients opting for nonoperative/palliative care. These tests are associated with additional costs (*i.e.*, €47 for a thoracic X-ray and €46 for a vitamin status) and several seem to have limited direct value for both clinician and patient (30). On the other hand, grouping (blood) tests or applying standardized diagnostic protocols for whole patient groups can increase organizational efficiency and reduce the number of different diagnostic intervals during a patients hospital stay. This creates a dilemma: With on the one hand more extensive (standardized) diagnostics for an informed (nonoperative) treatment decision, and on the other hand doing only what is necessary to reduce the additional patient burden and associated costs. Either approach's effect has

yet to be studied but could be included in a future (cost-effectiveness) analysis. While diagnostic tests were mentioned as one of the reasons for change in treatment decisions between operative and nonoperative care, they were always mentioned in conjunction with other arguments about patients pre-existing health status or treatment wishes. Most tests were requested shortly after arrival at the ER, probably prior to an extensive treatment decision, however, the exact timing of a treatment decision is hard to establish and the role of specific (normal or abnormal) test results is often not described. Previous research on the shared decision making process identified co-morbidities as an important argument for palliative care after hip fracture but did not identify specific test results (31). The weight of abnormal diagnostic test results, as an argument, is unclear and would probably vary between patients.

This study was a secondary retrospective analysis, and thus results should be interpreted with care. In many cases, the clinical thought process remains unclear as reasons for performed tests were often not documented and consequences of abnormal diagnostic tests may have been considered but not performed or documented. A clear clinical indication is often absent when retrospectively accessing a medical file and clinical advice may have been given by other specialists but not officially documented as consultation. Additionally, this study only analyzed test outcomes as described in the medical files. Test results (*e.g.*, X-rays or electrocardiograms) were not interpreted by the researchers. Abnormal findings could have been missed, especially if found irrelevant at the time by the initial observer. Findings corresponding with chronic conditions such as arthrosis or cardiomegaly may not have been reported when a test's indication was to find acute diseases (*e.g.*, hip fracture or pneumonia) and new abnormal findings might be a result of existing disease not registered in the hospital of admission. As a result of these limitations, the results of this study should primarily be used as a basis for further prospective diagnostic and medical decision-making research. As nonoperative, palliative treatment for hip fractures in the frail older adults is becoming a viable and more accepted treatment option, it becomes crucial to define what additional diagnostics and consultations are necessary (or redundant) in deciding between operative and nonoperative care.

Conclusion

When frail older adults are admitted with a hip fracture, an extensive diagnostic process is started including a large number and variety of laboratory and radiological diagnostics. Operatively treated patients are tested more extensively than nonoperatively treated patients. Abnormal test results in laboratory diagnostics are found for almost all patients, however many abnormal findings seem to have no clinical consequences. In few cases, diagnostic tests seem to influence treatment decisions and in a proportion of

patients diagnostics are an argument for delay in the time till operation. However, the exact importance of diagnostic testing in these decisions remains unclear. As nonoperative hip fracture care is becoming a more viable palliative treatment option, prospective research is required to evaluate the timing and added value of the separate elements of preoperative diagnostic testing and geriatric assessment in older adults with hip fractures.

References

1. De Joode S, Kalmet PHS, Fiddelers AAA, Poeze M, Blokhuis TJ. Long-term functional outcome after a low-energy hip fracture in elderly patients. J Orthop Traumatol. 2019;20(1):20. https://doi.org/10.1186/s10195-019-0529-z
2. Lin JC, Liang WM. Mortality, readmission, and reoperation after hip fracture in nonagenarians. BMC Musculoskelet Disord. 2017;18(1):144. https://doi.org/10.1186/s12891-017-1493-5.
3. Loggers SAI, Nijdam TMP, Folbert EC, Hegeman JHH, Van der Velde D, Verhofstad MHJ, et al. Prognosis and institutionalization of frail community-dwelling older patients following a proximal femoral fracture: a multicenter retrospective cohort study. Osteoporos Int. 2022;33(7):1465-75. https://doi.org/10.1007/s00198-022-06394-y10.1007/s00198-022-06394-y [pii].
4. Loggers SAI, Van Lieshout EMM, Joosse P, Verhofstad MHJ, Willems HC. Prognosis of nonoperative treatment in elderly patients with a hip fracture: A systematic review and meta-analysis. Injury. 2020;51(11):2407-13. https://doi.org/10.1016/j.injury.2020.08.027.
5. Loggers SAI, Willems HC, Van Balen R, Gosens T, Polinder S, Ponsen KJ, et al. Evaluation of Quality of Life After Nonoperative or Operative Management of Proximal Femoral Fractures in Frail Institutionalized Patients: The FRAIL-HIP Study. JAMA Surg. 2022;157(5):424-34. https://doi.org/10.1001/jamasurg.2022.0089.
6. Loggers SAI, Geraerds A, Joosse P, Willems HC, Gosens T, Van Balen R, et al. Nonoperative versus operative management of frail institutionalized older patients with a proximal femoral fracture: a cost-utility analysis alongside a multicenter prospective cohort study. Osteoporos Int. 2023;34(3):515-25. https://doi.org/10.1007/s00198-022-06638-x.
7. Nederlandse Vereniging voor Klinische Geriatrie (NVKG). Behandeling kwetsbare ouderen bij chirurgie (Surgical treatment of frail elderly patients): Federatie Medisch Specialisten; 2016 [Available from: https://richtlijnendatabase.nl/richtlijn/behandeling_kwetsbare_ouderen_bij_chirurgie/generieke_zorgpad.html.
8. Dauny V, Thietart S, Cohen-Bittan J, Riou B, Khiami F, Meziere A, et al. Association between Vitamin D Deficiency and Prognosis after Hip Fracture Surgery in Older Patients in a Dedicated Orthogeriatric Care Pathway. J Nutr Health Aging. 2022;26(4):324-31. https://doi.org/10.1007/s12603-022-1762-3.
9. Dzankic S, Pastor D, Gonzalez C, Leung JM. The prevalence and predictive value of abnormal preoperative laboratory tests in elderly surgical patients. Anesth Analg. 2001;93(2):301-8, 2nd contents page. https://doi.org/10.1097/00000539-200108000-00013.
10. Ramesh B, Pillai VS, Koshy RC, Jagathnath Krishna KM. Role of preoperative investigations in elderly patients undergoing oncosurgical procedures - A retrospective review audit. J Anaesthesiol Clin Pharmacol. 2018;34(4):535-9. https://doi.org/10.4103/joacp.JOACP_147_17.
11. O'Heireamhoin S, Beyer T, Ahmed M, Mulhall KJ. The role of preoperative cardiac investigation in emergency hip surgery. J Trauma. 2011;71(5):1345-7. https://doi.org/10.1097/TA.0b013e318224cfa3.
12. Ricci WM, Della Rocca GJ, Combs C, Borrelli J. The medical and economic impact of preoperative cardiac testing in elderly patients with hip fractures. Injury. 2007;38 Suppl 3:S49-52. https://doi.org/10.1016/j.injury.2007.08.011.
13. Sinvani L, Mendelson DA, Sharma A, Nouryan CN, Fishbein JS, Qiu MG, et al. Preoperative Noninvasive Cardiac Testing in Older Adults with Hip Fracture: A Multi-Site Study. J Am Geriatr Soc. 2020;68(8):1690-7. https://doi.org/10.1111/jgs.16555.

14. Loggers SAI, Giannakopoulos GF, Vandewalle E, Erwteman M, Berger F, Zuidema WP. Preoperative chest radiographs in hip fracture patients: is there any additional value? Eur J Orthop Surg Traumatol. 2017;27(7):953-9. https://doi.org/10.1007/s00590-017-1971-3.
15. Joo HS, Wong J, Naik VN, Savoldelli GL. The value of screening preoperative chest x-rays: a systematic review. Can J Anaesth. 2005;52(6):568-74. https://doi.org/10.1007/BF03015764.
16. Holden MK, Gill KM, Magliozzi MR. Gait assessment for neurologically impaired patients. Standards for outcome assessment. Phys Ther. 1986;66(10):1530-9. https://doi.org/10.1093/ptj/66.10.1530.
17. Nederlandse Vereniging voor Klinische Geriatrie (NVKG). Comprehensive geriatric assessment (CGA): Federatie Medisch Specialisten; 2010 [updated 01-11-2010. Available from: https://richtlijnendatabase.nl/richtlijn/comprehensive_geriatric_assessment_cga/onderdelen_van_het_cga/laboratoriumonderzoek_bij_cga.html.
18. De Hert S, Imberger G, Carlisle J, Diemunsch P, Fritsch G, Moppett I, et al. Preoperative evaluation of the adult patient undergoing non-cardiac surgery: guidelines from the European Society of Anaesthesiology. Eur J Anaesthesiol. 2011;28(10):684-722. https://doi.org/10.1097/EJA.0b013e3283499e3b.
19. O'Neill F, Carter E, Pink N, Smith I. Routine preoperative tests for elective surgery: summary of updated NICE guidance. BMJ. 2016;354:i3292. https://doi.org/10.1136/bmj.i3292.
20. Den Harder AM, De Heer LM, De Jong PA, Suyker WJ, Leiner T, Budde RPJ. Frequency of abnormal findings on routine chest radiography before cardiac surgery. J Thorac Cardiovasc Surg. 2018;155(5):2035-40. https://doi.org/10.1016/j.jtcvs.2017.12.124.
21. Mosfeldt M, Pedersen OB, Riis T, Worm HO, Mark S, Jorgensen HL, et al. Value of routine blood tests for prediction of mortality risk in hip fracture patients. Acta Orthop. 2012;83(1):31-5. https://doi.org/10.3109/17453674.2011.652883.
22. Laulund AS, Lauritzen JB, Duus BR, Mosfeldt M, Jorgensen HL. Routine blood tests as predictors of mortality in hip fracture patients. Injury. 2012;43(7):1014-20. https://doi.org/10.1016/j.injury.2011.12.008.
23. Fisher A, Srikusalanukul W, Fisher L, Smith PN. Comparison of Prognostic Value of 10 Biochemical Indices at Admission for Prediction Postoperative Myocardial Injury and Hospital Mortality in Patients with Osteoporotic Hip Fracture. J Clin Med. 2022;11(22) https://doi.org/10.3390/jcm11226784.
24. Endo A, Baer HJ, Nagao M, Weaver MJ. Prediction Model of In-Hospital Mortality After Hip Fracture Surgery. J Orthop Trauma. 2018;32(1):34-8. https://doi.org/10.1097/BOT.0000000000001026.
25. Wiedl A, Forch S, Fenwick A, Mayr E. Prognostic value of orthogeriatric assessment parameters on mortality: a 2-year follow-up. Eur J Trauma Emerg Surg. 2022;48(4):2905-14. https://doi.org/10.1007/s00068-021-01727-8.
26. Chesser TJ, Handley R, Swift C. New NICE guideline to improve outcomes for hip fracture patients. Injury. 2011;42(8):727-9. https://doi.org/10.1016/j.injury.2011.06.002.
27. De Rui M, Veronese N, Manzato E, Sergi G. Role of comprehensive geriatric assessment in the management of osteoporotic hip fracture in the elderly: an overview. Disabil Rehabil. 2013;35(9):758-65. https://doi.org/10.3109/09638288.2012.707747.
28. Grigoryan KV, Javedan H, Rudolph JL. Orthogeriatric care models and outcomes in hip fracture patients: a systematic review and meta-analysis. J Orthop Trauma. 2014;28(3):e49-55. https://doi.org/10.1097/BOT.0b013e3182a5a045.

29. Van Heghe A, Mordant G, Dupont J, Dejaeger M, Laurent MR, Gielen E. Effects of Orthogeriatric Care Models on Outcomes of Hip Fracture Patients: A Systematic Review and Meta-Analysis. Calcif Tissue Int. 2022;110(2):162-84. https://doi.org/10.1007/s00223-021-00913-5.
30. Nederlandse Zorgautoriteit (Dutch Healthcare Authority). Tarievenlijst Eerstelijnsdiagnostiek: Nederlandse Zorgautoriteit; 2014 [updated 2017. Available from: https://puc.overheid.nl/nza/doc/PUC_11854_22/.
31. Spronk I, Loggers SAI, Joosse P, Willems HC, Van Balen R, Gosens T, et al. Shared decision-making for the treatment of proximal femoral fractures in frail institutionalised older patients: healthcare providers' perceived barriers and facilitators. Age Ageing. 2022;51(8) https://doi.org/10.1093/ageing/afac174.

Supplemental tables

Table S1: Findings reported during physical examination at admission

		Nonoperative		Operative	
		Total patients with measurement	n	Total patients with measurement	n
Cardiovascular abnormalities					
Cardiac souffle		70	20	67	16
Arrhythmia			4		5
No abnormalities			47		47
Pulmonary abnormalities					
Crepitations			7		5
Rhonchi		71	1	73	5
Decreased auscultation	volume		1		0
No abnormalities			62		64
Abdominal abnormalities		56		60	
No abnormalities			56		60
Neurological abnormalities					
Reduced consciousness		45	3	55	1
Pin-point pupils			2		1
None			40		55

Table S2: Screening versus indicated reason for radiological diagnostics and electrocardiograms

	Nonoperative (n=88)		Operative (n=84)	
	Screening n	Indicated n	Screening n	Indicated n
X-rays				
Pelvis	0	88	0	84
Thorax	57	2	65	2
Shoulder/clavicle	N.A.	N.A.	0	3
Arm/wrist	0	6	0	6
Hand	N.A.	N.A.	1	0
Upper leg	0	2	N.A.	N.A.
Knee	1	2	0	5
Lower leg	0	1	0	1
CT-scans				
Pelvis	0	2	0	6
Thorax	0	1	0	1
Cervical spine	0	4	0	6
Head	0	8	1	7
Face	0	1	N.A.	N.A.
Ultrasound				
Cardiac	0	4	3	11
Abdominal	1	0	N.A.	N.A.
Electrocardiograms	46	1	68	1

N.A., not applicable

Table S3: Screening versus indicated reason for laboratory and microbiological diagnostics

	Nonoperative (n=72)		Operative (n=84)	
	Screening n	Indicated n	Screening n	Indicated n
Laboratory testing				
Hematological lab	72	0	84	0
Electrolytes and vitamins	72	1	82	3
Nutritional status	67	0	81	0
Inflammatory markers	69	0	80	0
Kidney function	71	0	83	0
Liver and pancreatic function	61	0	68	0
Cardiac function	1	1	1	0
Thyroid function	37	0	52	2
Coagulation	58	4	77	5
Arterial blood gas	2	1	1	0
Urine sediment	22	0	43	3
Microbiological testing				
Blood culture	1	2	1	5
Urine culture	5	4	7	8
MRSA culture	1	0	1	1
Viral PCR	0	0	0	1

Table S4: Requesting departments for radiological diagnostics and electrocardiograms

	Nonoperative n=88	Operative n=84
X-Pelvis		
Emergency department	81	71
Surgery	5	9
Orthopedics	2	4
X-Thorax		
Emergency department	54	54
Surgery	2	8
Orthopedics	2	4
Geriatrics	0	1
ICU	1	0
X-Shoulder		
Emergency department	0	3
X-Arm/wrist		
Emergency department	6	5
Surgery	0	1
X-Hand		
Emergency department	0	1
X-Upper leg		
Emergency department	2	0
X-Knee		
Emergency department	1	3
Surgery	2	1
Orthopedics	0	1
X-Lower leg		
Emergency department	1	1
CT-Pelvis		
Emergency department	2	3
Surgery	0	2
Radiology	0	1
CT-Thorax		
Emergency department	0	1
Pulmonary medicine	1	0
CT-Cervical spine		
Emergency department	3	5
Surgery	1	0
Neurology	0	1

Table S4: Requesting departments for radiological diagnostics and electrocardiograms (*continued*)

	Nonoperative n=88	**Operative** n=84
CT-Head		
Emergency department	5	6
Surgery	1	0
Neurology	2	1
Geriatrics	0	1
CT-Face		
Emergency department	0	1
Cardiac ultra-sound		
Surgery	0	3
Orthopedics	0	2
Geriatrics	0	1
Cardiology	4	7
Anesthesiology	0	1
Abdominal ultrasound		
Internal medicine	1	0
Electrocardiogram		
Emergency medicine	40	55
Surgery	4	6
Orthopedics	0	4
Geriatrics	1	1
Cardiology	2	3

ICU, intensive care unit

Table S5: Requesting departments for laboratory diagnostics

	Nonoperative (n=72)	Operative (n=84)
Hematological lab		
Emergency medicine	71	79
Surgery	5	11
Orthopedics	4	5
Geriatrics	1	1
Electrolytes and vitamins		
Emergency medicine	71	77
Surgery	5	11
Orthopedics	4	5
Geriatrics	4	11
ICU	1	0
Nutritional status		
Emergency medicine	66	77
Surgery	4	10
Orthopedics	4	5
Geriatrics	2	3
Inflammatory markers		
Emergency medicine	68	76
Surgery	4	10
Orthopedics	4	5
Geriatrics	1	0
Kidney function		
Emergency medicine	70	78
Surgery	5	11
Orthopedics	4	5
Geriatrics	1	2
Liver and pancreatic function		
Emergency medicine	59	63
Surgery	4	9
Orthopedics	4	5
Geriatrics	1	3
ICU	1	0
Cardiac function		
Cardiology	2	1
Thyroid function		
Emergency medicine	35	44
Surgery	3	6
Orthopedics	0	2
Geriatrics	1	6

Table S5: Requesting departments for laboratory diagnostics (*continued*)

	Nonoperative (n=72)	**Operative** (n=84)
Coagulation		
Emergency medicine	60	77
Surgery	5	10
Orthopedics	4	5
Geriatrics	1	0
Arterial blood gas		
Emergency medicine	2	0
Geriatrics	0	1
ICU	1	0
Urine sediment		
Emergency medicine	20	41
Surgery	2	7
Orthopedics	3	6
Geriatrics	1	2
ICU	1	0
D-dimer		
Emergency medicine	0	1

Table S6: Consequences of (non-surgical) clinical consultations

		Nonoperative (n=88)					Operative (n=84)			
Consultation	n	No diagnostics or intervention	Additional diagnostics	Pharmacological[a] intervention	Invasive intervention	n	No diagnostics or intervention	Additional diagnostics	Pharmacological[a] intervention	Invasive intervention
Geriatrics	59	39 (66%)	7 (12%)	18 (31%)	0	77	19 (25%)	28 (36%)	50 (65%)	0
Cardiology	8	2 (25%)	6 (75%)	1 (13%)	0	22	7 (32%)	13 (59%)	3 (14%)	0
Neurology	2	1	1	0	0	4	2	1	1	0
Internal medicine	1	0	1	0	0	3	0	1	2	0
Pulmonary medicine	2	0	2	2	0	1	1	0	0	0
Anesthesia	2	2	0	0	0	0	-	-	-	-
Other[b]	1	1	0	0	0	4	1	2	0	1[c]

Data are shown as n (%).[a] Not being only analgesics [b] Other including: Psychiatry, Microbiology, ophthalmology, urology [c] The single invasive intervention after consultation was a cystoscopic catheter placement by the urology department

Table S7: Abnormal findings found during radiological diagnostics and electrocardiograms

	Nonoperative (n=88)		Operative (n=84)	
	New finding	Known finding	New finding	Known finding
X-Pelvis				
Fracture	87	0	84	0
Arthrosis	14	3	14	5
Other[a]	0	N.A.	2	0
No abnormal findings	1	N.A.	0	N.A.
X-thorax				
Fracture	2	1	5	0
Cardiomegaly	18	9	15	10
Consolidation	8	1	8	0
Nodule/mass	4	0	1	0
Hilar enlargement	4	0	2	0
Atelectasis	0	N.A.	3	0
Fibrosis/interstitial pattern	8	1	5	1
Pulmonary edema	3	0	3	2
Pleural effusion	7	1	4	0
Other[b]	4	1	3	3
No abnormal findings	18	N.A.	35	N.A.
X-shoulder				
Fracture	N.A.	N.A.	2	0
No abnormal findings	N.A.	N.A.	1	0
X-arm				
Fracture	5	0	4	0
No abnormal findings	1	N.A.	2	N.A.
X-hand				
Arthrosis	N.A.	N.A.	1	1
X-upper leg				
No abnormal findings	0	N.A.	N.A.	N.A.
X-knee				
Arthrosis	0	N.A.	3	2
No abnormal findings	3	N.A.	2	N.A.
X-lower leg				
Fracture	1	0	0	N.A.
No abnormal findings	0	N.A.	1	N.A.
CT-pelvis				
Fracture	2	0	6	0
Arthrosis	0	N.A.	2	0
CT-thorax				

Table S7: Abnormal findings found during radiological diagnostics and electrocardiograms (*continued*)

	Nonoperative (n=88)		Operative (n=84)	
Aortic aneurysm	1	0	0	N.A.
Atelectasis	1	0	0	N.A.
Pulmonary embolism	0	N.A.	1	0
Diaphragm herniation	0	N.A.	1	0
CT-cervical spine				
Arthrosis	3	1	4	0
Thyroid nodule	1	0	0	N.A.
No abnormal findings	1	N.A.	2	N.A.
CT-head				
Cerebral atrophy	5	4	5	3
Cerebral infarction	1	0	2	2
White matter lesion	1	1	1	1
No abnormal findings	3	N.A.	2	N.A.
CT-face				
No abnormal findings	1	N.A.	N.A.	N.A.
Cardiac ultrasound				
Valve dysfunction	4	1	8	1
Left dysfunction	0	N.A.	2	2
Pulmonary hypertension	0	N.A.	2	0
No abnormal findings	0	N.A.	4	N.A.
Abdominal ultrasound				
Liver metastasis	1	0	N.A.	N.A.
Electrocardiograms				
Conduction disorder[c]	31	21	39	24
STEMI	1	0	0	N.A.
Non-STEMI	0	N.A.	1	0
Heart failure	0	N.A.	1	0
No abnormal findings	15	N.A.	28	N.A.

[a]Includes a myoma and myositis ossificans [b]Includes one trachea deviation, two diaphragm herniations, two aortic enlargements, one scoliosis and one shoulder arthrosis [c]Including atrium fibrillation N.A., not applicable

Table S8: Consequences of abnormalities found during radiological diagnostics and electrocardiograms

	Nonoperative (n=88)					Operative (n=84)				
	n	No diagnostics or intervention	Additional diagnostics	Pharmacological[a] intervention	Invasive intervention	n	No diagnostics or intervention	Additional diagnostics	Pharmacological[a] intervention	Invasive intervention
X-rays										
Pelvis	87	85	1	1	0	84	0	5	0	82
Thorax	41	37	1	4	0	32	27	3	5	0
Shoulder/clavicle	0	N.A.	N.A.	N.A.	N.A.	2	2	0	0	0
Arm/wrist	5	4	0	0	1	4	2	0	0	2
Hand	0	N.A.	N.A.	N.A.	N.A.	1	1	0	0	0
Upper leg	0	N.A.	N.A.	N.A.	N.A.	0	N.A.	N.A.	N.A.	N.A.
Knee	0	N.A.	N.A.	N.A.	N.A.	3	3	0	0	0
Lower leg	1	1	0	0	0	0	N.A.	N.A.	N.A.	N.A.
CT-scan										
Pelvis	2	2	0	0	0	6	1	0	0	5
Thorax	1	1	0	0	0	1	0	0	1	0
Cervical spine	3	3	0	0	0	4	4	0	0	0
Head	5	5	0	0	0	6	6	0	0	0
Face	0	N.A.	N.A.	N.A.	N.A.	0	N.A.	N.A.	N.A.	N.A.
Ultrasound										
Cardiac	4	4	0	0	0	10	10	0	0	0
Abdomen	1	1	0	0	0	0	N.A.	N.A.	N.A.	N.A.
ECGs	32	30	1	0	0	41	38	2	1	0

[a]Not being analgesics N.A., not applicable

Table S9: Specific laboratory diagnostic outcomes for nonoperative and operative patients

	Nonoperative n=88		Operative n=84		
	n	Mean (SD)/ Median (P25-P75)	n	Mean (SD)/ Median (P25-P75)	P-value
Hematological	**72 (82%)**	**-**	**84 (100%)**		
Hemoglobin (mmol/L)	72	7.4 (SD 1.1)	84	7.8 (SD 0.87)	**0.009**
Hematocrit (mmol/L)	68	0.36 (SD 0.052)	77	0.38 (SD 0.040)	**0.016**
MCV (fL)	65	92 (89-96)	78	93 (89-96)	0.765
Erythrocytes (10^{12}/L)	58	4.0 (SD 0.63)	59	4.0 (SD 0.53)	0.459
Thrombocytes (10^{9}/L)	68	244 (204-296)	77	239 (199-293)	0.387
Leukocytes (10^{9}/L)	71	10.8 (9.1-13.3)	80	9.9 (7.7-13.0)	0.066
Leukocyte differentiation	35	-	37	-	N.A.
Electrolytes	**72 (82%)**		**82 (98%)**		
Sodium (mmol/L)	72	139 (137-141)	82	139 (137-141)	0.561
Chlorine (mmol/L)	17	104 (SD 5.1)	15	105 (SD 2.9)	0.289
Potassium (mmol/L)	72	4.1 (SD 0.50)	81	4.3 (SD 0.50)	0.11
Calcium (mmol/L)	58	2.29 (SD 0.14)	68	2.30 (SD 0.12)	0.768
Magnesium (mmol/L)	4	0.82 (SD 0.10)	7	0.88 (SD 0.090)	0.274
Phosphate (mmol/L)	11	0.99 (SD 0.23)	10	1.06 (SD 0.19)	0.448
Bicarbonate (mmol/L)	2	20.1 (N.A)	3	25.0 (N.A.)	0.248
Anion gap (meq/L)	1	10 (N.A.)	2	9.5 (N.A.)	1
Iron (mmol/L)	5	9.3 (SD 4.9)	13	6.5 (SD 3.2)	0.173
Ferritin (ug/L)	7	128 (SD 101)	15	190 (SD 142)	0.316
Transferrin (g/L)	2	2.1 (N.A.)	12	2.1 (2.0-2.5)	0.703
Iron saturation (%)	0	N.A.	2	16 (N.A.)	N.A.
Nutritional status	**67 (76%)**		**81 (96%)**		
Glucose (mmol/L)	66	7.0 (6.3-7.7)	80	7.4 (6.4-8.6)	0.060
Total protein (g/L)	8	65 (SD 5.3)	4	74 (SD 4.2)	**0.015**
Albumin (g/L)	58	34 (29-36)	69	35 (32-39)	**0.023**
Vitamin status					
Vitamin D (nmol/L)	60	74 (SD 30)	46	76 (SD 26)	0.765
Vitamin B1 (nmol/L)	3	141 (SD 16)	10	103 (SD 27)	**0.041**
Vitamin B6 (nmol/L)	3	68 (SD 43)	8	41 (SD 19)	0.175
Folic acid (nmol/L)	25	18 (SD 13)	38	17 (SD 13)	0.603
Vitamin B12 (pmol/L)	27	225 (169-437)	42	240 (96-415)	0.796
Inflammatory markers	**69 (78%)**		**80 (95%)**		
CRP (mg/L)	68	10 (5-36)	80	11 (4.3-32)	0.998
ESR (mm/hour)	24	23 (12-34)	27	26 (20-44)	0.138
Venous lactate (mmol/L)	2	2.2 (N.A.)	0	N.A.	N.A.
Kidney function	**71 (81%)**		**83 (99%)**		
eGFR (mL/min/1,73m^2)	71	65 (49-78)	83	60 (42-73)	**0.026**
Creatine (µmol/L)	71	72 (58-99)	83	84 (65-104)	0.074
Ureum (mmol/L)	65	7.7 (6.4-9.8)	78	8.5 (6.6-10.6)	0.236
Liver/pancreas function	**61 (69%)**		**68 (81%)**		
ALAT (U/L)	54	17 (12-23)	62	16 (13-20)	0.286
ASAT (U/L)	44	21 (18-28)	56	21 (17-25)	0.377
AF (U/L)	56	86 (76-109)	66	87 (71-101)	0.442
GGT (U/L)	46	22 (12-43)	59	29 (17-59)	0.128

Table S9: Specific laboratory diagnostic outcomes for nonoperative and operative patients (*continued*)

	Nonoperative n=88		Operative n=84		
	n	Mean (SD)/ Median (P25-P75)	n	Mean (SD)/ Median (P25-P75)	P-value
LD (U/L)	36	246 (200-297)	45	223 (201-276)	0.500
CK (U/L)	29	66 (39-109)	25	59 (46-94)	0.658
Total bilirubin (µmol/L)	30	9.2 (6.1-14)	36	9.0 (6.1-16)	0.985
Conjugated bilirubin (µmol/L)	1	23 (N.A.)	4	5.3 (3.3-8.4)	0.157
Amylase (U/L)	12	61 (SD 22)	5	94 (SD 40)	0.149
Lipase (U/L)	15	25 (11-139)	15	34 (24-48)	0.852
Cardiac function	**2 (2%)**		**1 (1%)**		
NT-proBNP (pmol/L)	2	5928 (N.A.)	1	5472 (N.A.)	1
Troponin T (µg/L)	1	0.064	0	N.A.	N.A.
(Para-)Thyroid function	**37 (42%)**		**54 (64%)**		
TSH (mU/L)	37	1.6 (0.85-2.8)	54	2.4 (1.5-5.4)	**0.005**
T4 (pmol/L)	11	17 (12-20)	23	15 (12-17)	0.146
PTH (pmol/L)	2	7.1 (N.A.)	0	N.A.	N.A.
Coagulation	**62 (71%)**		**81 (96%)**		
Type & screen	59	-	80	-	N.A.
INR	27	2.2 (1.0-2.8)	30	1.2 (1.0-2.3)	0.641
PT (seconds)	6	16 (13-29)	7	15 (12-17)	0.475
APTT (seconds)	1	43 (N.A.)	5	28 (26-32)	0.143
Arterial blood gas	**3 (3%)**		**1 (1%)**		
pH	3	7.41 (7.37-7.41)	1	7.32 (N.A.)	0.180
PO2 (kPa)	3	7.0 (5.0-7.0)	1	3.9 (N.A.)	0.180
PCO2 (kPa)	3	5.4 (3.2-5.4)	1	5.6 (N.A.)	0.655
Bicarbonate (mmol/L)	3	25.0 (15.4-25.0)	1	22.0 (N.A.)	0.655
Base-excess	2	1.2 (N.A.)	0	N.A.	N.A.
Lactate (mmol/L)	1	8.5 (N.A.)	0	N.A.	N.A.
Other					
D-dimer	0	N.A.	1	25000 (N.A.)	N.A.

Data are shown as n (%), mean (SD) or median (P_{25}-P_{75}). **Bold numbers** represent numbers and percentages for the whole subgroup of laboratory diagnostics AF, alkaline phosphatase; ALAT, alanine transaminase; APTT, Activated partial thromboplastin time; ASAT, aspartate transaminase; CK, creatine kinase; CRP, C-reactive protein; eGFR, estimated glomerular filtration rate; fL, femtoliter; ESR, erythrocyte sedimentation rate; GGT, Gamma-glutamyltransferase; INR, international normalized ratio; kPa, kilopascal; LD, lactate dehydrogenase; L, liter; m, meter; MCV, mean corpuscular volume; mg, milligram; mm, millimeter; mmol, millimol; µg, microgram; µmol, micromol; NT-proBNP, N-terminal prohormone of brain natriuretic peptide; PCO_2, partial pressure of carbondioxide; pmol, picomol; PO_2, partial pressure of oxygen; PT, prothrombin time; PTH, parathyroid hormone; P25, 25th percentile; P75, 75th percentile; SD, standard deviation; TSH, thyroid stimulating hormone; T4, thyroxine; U, units



9

Shared decision-making for non-operative management versus operative management of hip fractures in selected frail older adults with a limited life expectancy: a protocol for a nationwide implementation study.

Miliaan L. Zeelenberg*, Paulieke C. Oosterwijk*, Hanna C. Willems, Taco Gosens, Dennis Den Hartog, Pieter Joosse, Sverre A.I. Loggers, Thomas M. Nijdam, Ruth E. Pel-Littel, Suzanne Polinder, Henk Jan Schuijt, Hugo H. Wijnen, Detlef Van der Velde, Esther M.M. Van Lieshout, Michiel H.J. Verhofstad, on behalf of the NOM-Implementation Study Group.

*Authors contributed equally

BMJ Open 2024, Volume 14, Issue 4, Pages e083429

Abstract

Background and purpose

Recent research has highlighted nonoperative management (NOM) as a viable alternative for frail older adults with hip fractures in the final phase of life. This study aims to guide Dutch physicians and hospitals nationwide in a standardized implementation of shared decision making (SDM) regarding surgery or NOM in selected frail older adults with a hip fracture.

Methods and analysis

The patient population for implementation includes frail older adults aged ≥70 years with an acute proximal femoral fracture, nursing home care or a similar level of care elsewhere, and at least one additional criterion (i.e. malnutrition, severe mobility impairment, or ASA ≥4). The two-year implementation study will be conducted in four phases. In phases 1 and 2, barriers and facilitators for implementation will be identified and an implementation protocol, educational materials, and patient information will be developed. Phase 3 will involve an implementation pilot in 14 hospitals across the Netherlands. The protocol and educational material will be improved based on healthcare provider and patient experiences gathered through interviews. Phase 4 will focus on upscaling to nationwide implementation and the effect of the implementation on NOM rate will be measured using data from the Dutch Hip Fracture Audit.

Strengths and limitations of this study

This study builds on an existing foundation of recent well-received (inter)national publications, countrywide initiatives involving shared-decision making, and recent demands for assistance in the implementation of nonoperative management of hip fractures in selected frail older adults with a limited life-expectancy. The study will employ a staged approach in four phases, involving implementation strategies at the individual, local, and national level, that range from local educational sessions to nationwide distribution at conferences and proposed guideline changes. The study design allows for regular adjustment of its implementation protocols and educational materials based on patient and health care provider feedback from interviews from 14 different hospitals throughout the Netherlands. While the study has an ambitious 2-year time scheme to achieve nationwide implementation in the hospital setting, it will provide an important foundation for further initiatives.

Introduction

A hip fracture in frail older adults can indicate an approaching end of life. Advanced age, multiple comorbidities, and severe mobility limitations are important risk factors for early post-operative mortality after a hip fracture (1, 2). Studies show that >30% of patients die within one year post hip fracture, with six-month mortality rates in older adults with dementia exceeding 55%, often with low quality of life in the months preceding death (3-5). These patients, in their final phase of life, often do not benefit from an operative treatment that aims to restore mobility. Operations are often conducted in this population as a palliative treatment option, focused primarily on pain reduction. Based on these insights, a paradigm shift is occurring in clinical approach, emphasizing the importance of individualized care plans focused on optimal quality of life (6, 7).

The FRAIL-HIP study has confirmed that nonoperative management (NOM) can be a good alternative to operative management in select frail older adults with a limited life-expectancy (5, 8-10). Quality of life after NOM was valued non-inferiorly and the majority of the next of kin rated the quality of dying of their relative as very good (5, 8). Despite higher mortality rates in patients opting for NOM, the option to allow patients to pass away in a familiar environment was a compelling factor in favor of NOM in this select population (11). Both operative and nonoperative management can thus be effective treatment options as part of palliative care in selected frail older adults with a limited life-expectancy. Following these results, multiple Dutch hospitals have asked for guidance on implementing NOM in their institutions.

Central to NOM is the shared decision making (SDM) process, involving patients and their families in treatment decisions aligned with the patients' preferences and needs. Based on the results of the FRAIL-HIP study and other literature, an implementation protocol has been drafted, piloted, and refined based on experiences of healthcare professionals (7, 9, 12). This protocol version will serve as the starting point for the iterative process towards nationwide implementation.

The aim of this study is nationwide implementation of SDM on treatment of hip fractures, involving both NOM and operative treatment, to ensure that frail older adults receive optimal, patient-centered care in the final phase of their lives.

Methods and analysis

Study design and aims

This two-year implementation study will consist of four phases (Figure 1); development of the implementation protocol and educational material (Phase 1 & 2), implementation across a subset of hospitals across the Netherlands and process evaluation and optimization of the protocol based on healthcare provider/patient experiences (Phase 3), and upscaling towards nationwide implementation and project evaluation (Phase 4). The study design of phases 3 and 4 entails a multicenter prospective cohort study. Overall, the project will cover all activities as recommended in the ImpRes Guide, which mentions four implementation phases (*i.e.*, exploration, installation, initial implementation, and full implementation) and should efficiently translate local knowledge into general knowledge (13). The 'Consolidated Framework for Implementation Research' (CFIR) was used for designing this project (14, 15). With education being a critical part of the implementation, elements of the education strategy from Wensing *et al.* (16) were added. The CFIR domains that the four phases of this project will cover are mentioned in Table 1.

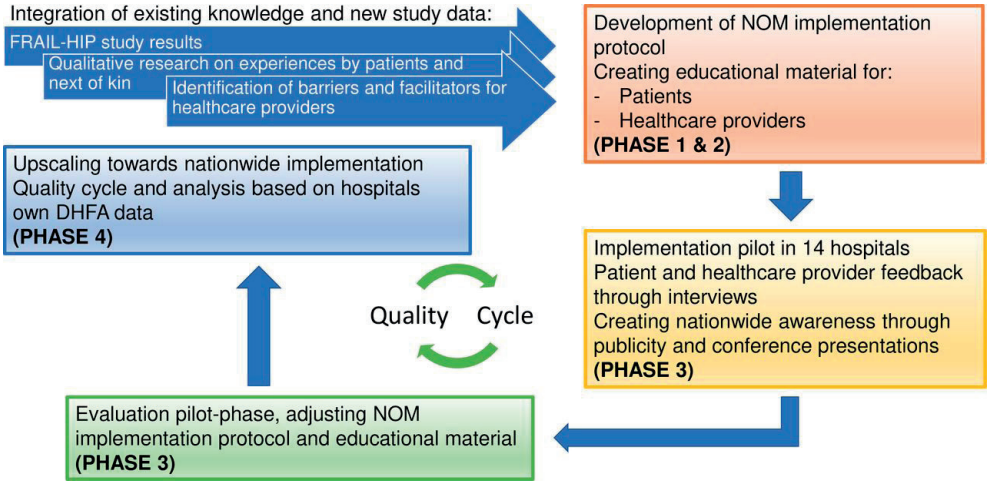


Figure 1: Schematic overview of the implementation process in 4 phases
DHFA, Dutch Hip Fracture Audit; NOM, nonoperative management

To achieve the primary aim, this study will use a staged approach in four phases that involves three levels: The healthcare provider specific/local hospital level (micro) in phases 1-3, the level of a limited number of hospitals (meso) in phase 3, and the national level (macro) in phase 4. The four consecutive phases of the project have phase-specific aims with corresponding target populations and points of action, that are de-

scribed in Table 2. To ensure nationwide implementation many parties and interest groups are or will be involved in the project (Table 3).

Table 1: CFIR domains and their role in the implementation project

CFIR Domain	Role in project
Inner setting	Gain insight into the hospital/implementation location, including internal network and communication, culture (norms and values), knowledge, current use of the intervention, and implementation climate (tension for change, feedback, learning climate)
Outer setting	Gain insight into the needs of patients/proxies and pressure from peers (need for hospitals to use the same protocol).
Characteristics of individuals	Gain insight into the confidence/preparedness to discuss and apply NOM through SDM with the intended target group
Characteristics of the intervention	Gain insight into the SDM conversation as part of NOM, the needs of healthcare providers on how to conduct SDM and who participates in it, and what they need to apply NOM.

CFIR, Consolidated Framework for Implementation Research; NOM, nonoperative management; SDM, shared decision making

Table 2: Study aims with specific action points per targeted group for the four study phases

Points of action per phase	Targeted group	Aim/outcome
Phase 1		
Qualitative research on patient experiences and perceived barriers and facilitators for SDM on NOM	Patients, next-of-kin and healthcare providers*	Enriching the implementation protocol with recent research on patient/healthcare provider experiences regarding SDM on NOM versus operative treatment. Providing insight into barriers and facilitators on the local and individual level
Phase 2		
Development of educational material on SDM with frail older adults with hip fractures for patients and healthcare providers Implementing SDM on NOM in the curriculum for (orthopedic) surgeons in training	Patients, next-of-kin and healthcare providers*	Increasing (practical) knowledge on performing SDM on NOM in healthcare providers. Providing healthcare providers with tools to prepare patients and next-of-kin for SDM on NOM versus operative treatment
Phase 3		
Presentations of the Implementation protocol and included tools at annual meetings of the involved scientific associations	Healthcare providers*, members of associated scientific associations	Creating awareness and a sense of urgency for SDM implementation and identifying local drivers of change for future implementation
Implementation of the NOM implementation protocol and evaluation through interviews with patients and healthcare providers in 14 selected Dutch hospitals	Local project teams and drivers of change in 14 Dutch hospitals and patients/next-of-kin	Evaluating and improving the implementation protocol and educational modules based on local experiences, barriers and facilitators through patient- and healthcare provider interviews
Phase 4		
Maintaining and improving awareness through conference- and regional trauma network presentations Identification of local ambassadors/drivers of change Dissemination of the implementation protocol/educational tools through a dedicated website, scientific publications and media coverage	Health care providers*, and specifically, local drivers of change, in all Dutch hospitals treating frail older adults with hip fractures	Upscaling of the implementation to all hospitals in the Netherlands that treat the targeted patient group
Measuring the effect of implementation, changes in NOM rate, through the DHFA database	Dutch patients and hospitals through the DHFA database	Evaluating changes in practice after implementation

*Healthcare providers include (orthopedic) trauma surgeons, geriatricians, acute care physicians, anesthesiologists, residents, and physician assistants directly involved in (acute) care for frail older adults with a hip fracture in Dutch hospitals. DHFA, Dutch Hip Fracture Audit; NOM, nonoperative management; SDM, shared decision making

Table 3: Participating parties and their roles and responsibilities

Participator(s)	Roles and responsibilities
Central project group/steering committee	The project group is responsible for the general oversight of the entire project.
Participating hospitals	They will implement the NOM protocol locally, and will provide data needed to evaluate the effect of the implementation. They will need to allow local training, and participate in interviews to gain insight into their experience with NOM implementation.
Patients and/or proxies	Will be asked to voluntarily participate in interviews and provide feedback on the chosen treatment and SDM process.
Dutch Hip Fracture Audit (DHFA) and Dutch Institute for Clinical Auditing (DICA)	They will provide the data so the hospitals can use it as mirror information. The DHFA data (which are existing data) will be used as pre and post implementation data, and will thus allow accurate monitoring of the impact of NOM implementation.
Scientific associations (Dutch Trauma Society (NVT), Dutch Association of Surgeons of the Netherlands (NVvH), Dutch Orthopedic Association (NOV), and Dutch Association of Clinical Geriatrics (NVKG))	The scientific associations are responsible for education for medical specialists and residents-in-training. They will play a key role in the education sessions, and in forwarding information on our project to their members.
Members of the National Association of General Practitioners (LHV) and the Association for Older Adult Care Physicians (Verenso)	Will be kept informed about this project through mailings and presentations during their annual conferences.

DHFA, Dutch Hip Fracture Audit; DICA, Dutch Institute Clinical Auditing; LHV, Landelijke Huisartsen Vereniging; NVKG, Nederlandse Vereniging voor Klinische Geriatrie; NVT, Nederlandse Vereniging voor Traumachirurgie; NVvH, Nederlandse Vereniging voor Heelkunde; NOV, Nederlandse Vereniging voor Orthopedie; NOM, nonoperative management; SDM, shared decision making;

Study population

Phases 1 and 2 will not include patients or patient data but will include healthcare provider and patient association perspectives. Phases 3 and 4 will also include frail older adults with a limited life expectancy who sustained a proximal femoral fracture. Patients will be included and receive SDM on NOM and operation if they meet the following criteria:

1. Acute proximal femoral fracture (AO type 31), confirmed on X-ray or CT-scan
2. 70 years or older
3. Living in a nursing home or receiving similar care at home
4. And at least one of the following characteristics:
    - Malnutrition (cachexia or BMI <18.5 kg/m2)
    - Functional ambulation category* (FAC) 2 or lower
    - Severe comorbidities (ASA category 4 or 5)

Patients and/or proxies that do not have sufficient comprehension of the Dutch language will be excluded from the interviews during phase 3.

*The Functional Ambulation Categories (FAC) is a functional walking test that evaluates ambulation ability (17). This 6-point scale assesses ambulation status by determining how much human support the patient requires when walking, regardless of whether or not they use a personal assistive device. FAC ≤2 means that a patients at least has the need for (intermittent) help of another person to be able to ambulate (FAC 2) to no functional ambulatory capabilities (FAC 0).

Implementation in four phases

Phase 1 (exploration): evaluate current practice and identify facilitators and barriers of NOM implementation

Based on the evidence-based 'Measurement Instrument for Determinants of Innovations' (MIDI) (18, 19) and the 'Barriers and Facilitators Assessment Instrument' (BFAI) (20) a survey has been developed, aimed to identify the facilitators and barriers for applying SDM and NOM for selecting the best treatment for individual patients of the target population and identified five barriers and 23 facilitators (9). The patient perspective was not included in this study, but was explored in another study (11). A panel from older adults organizations, general practitioners and geriatric specialists will discuss and supplement the data from the aforementioned studies from their perspective.

Phase 2 (installation): developing an implementation strategy for NOM

A draft protocol for NOM implementation, with as focal point the SDM interview, has been written based on the experience and expertise of the project members, previous studies, and questionnaires. This protocol contains the central vision, the requirements for the implementation of NOM in selected frail older adults, and a recommendation for the composition of a local project team of stakeholders and drivers of change. To remove barriers, practical tools such as pocket cards, posters, factsheets, and local training options will be drafted or updated by the project team, based on the 'Expert Recommendations for Implementing Change strategies' (21). This should help drivers of change in achieving implementation goals and change day-to-day policies. The NOM implementation protocol will contain an overview of the data to be collected for NOM evaluation. A reporting tool will be developed in the Dutch Hip Fracture Audit (DHFA) for this purpose. In addition, educational modules for healthcare professionals will be developed using the NOM protocol in combination with existing educational modules on SDM (22-24). NOM as a treatment option for selected frail older adults will also be included in the obligatory curriculum for residents by the Association of

Surgeons of the Netherlands (in Dutch: Nederlandse Vereniging voor Heelkunde, NVvH), in order to incorporate NOM into the educational program of (orthopedic) trauma residents.

PHASE 3 (initial implementation): NOM-implementation in selected hospitals

NOM for selected frail older adults will be implemented in 14 selected hospitals (Figure 2, collaborators listed in Online supplementary materials 1). Based on the experience of these hospitals, the NOM implementation protocol and/or the educational material will be optimized. To safeguard implementation of NOM in the long term, the NOM protocol pays explicit attention to the involvement of all relevant healthcare providers by informing those involved before, during and after implementation, and by collecting data on relevant feasibility parameters as described in the Bowen model (25). To achieve this, the site principal investigator will be asked to establish a local project team. The team should represent all groups involved in NOM, including relevant physicians and, as applicable, residents of the involved departments, specialized nurses, physician assistants, and hospital management. Prior to implementation, this local team will meet with the researchers for an interview to train them in applying the SDM and the NOM implementation protocol, and to collect details on their specific needs for the implementation.

The local team will perform patient selection and apply SDM on NOM and operative treatment for all patients who meet the eligibility criteria. After the start of the implementation, during the first six months, patients, relatives, and/or next of kin will be approached once by telephone to ask about their satisfaction with the treatment decision process, and the chosen treatment. This will be done through a semi-structured interview. To provide more insight about their own patient population the interview results will be discussed with the participating centers on a quarterly basis. All collected data will be used to improve the NOM protocol and/or educational material prior to phase 4. Six months after start of implementation, the local team will be approached again for an interview to evaluate the process with the relevant parameters: adoption, integration, applicability, expansion, and early local effectiveness.

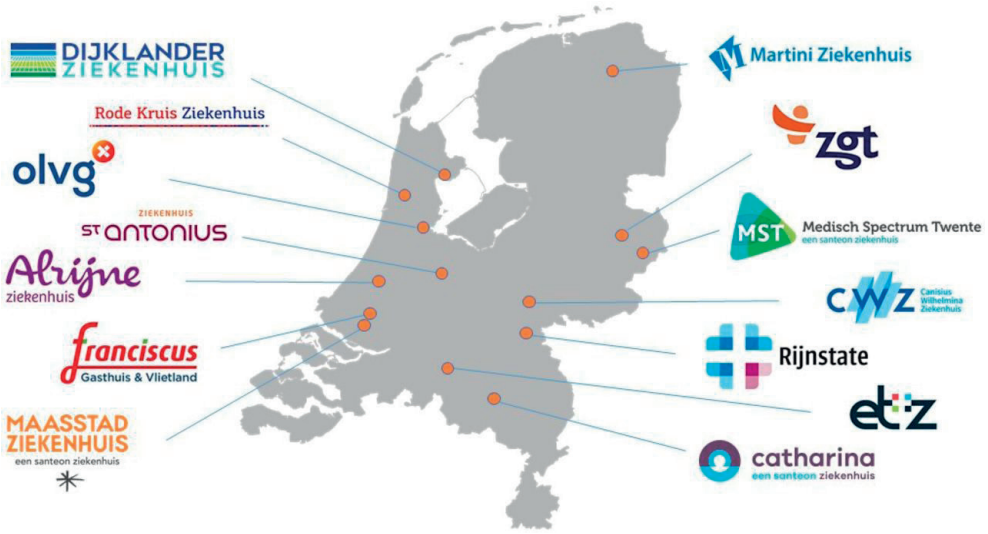


Figure 2: Map of participating hospitals during the initial implementation in selected hospitals (Phase 3)

PHASE 4 (nationwide implementation): NOM-implementation in all hospitals in the Netherlands and project analysis

Phase 4 is an expansion of phase 3 to reach nationwide implementation. The implementation strategy will essentially be the same as in phase 3. Due to the increase in number of hospitals, the supervision and contact with the researchers and steering committee will be less intensive than in phase 3. In practice, this means that the NOM protocol will be implemented, but the interviews with health care professionals in the hospitals (prior to start and six months after start) will be omitted. To ensure that all information on SDM and NOM implementation is available continuously to both patients and healthcare providers, a dedicated website will be developed and maintained. To effectively reach a broad audience of healthcare providers and keep them updated on the implementation process and learning experiences, our goal is to give presentations at the annual meetings of orthogeriatric scientific associations, as well as associations for general practitioners and elderly care physicians (Table 3). In addition, time slots for presentations will be requested at the meetings of the regional trauma networks. Ultimately, we aim to include SDM on NOM or operative treatment for proximal femoral fractures in select frail older adults in the National guidelines for hip fracture treatment and operative care in older adults.

Outcome measures and data collection

The primary outcome measure (for phase 3 and 4) is (change in) the NOM rate. Type of treatment (NOM versus operative treatment) will be extracted from the Dutch Hip Fracture Audit (DHFA). The DHFA is a national database, including over 95% of Hip fracture patients, and can provide automated anonymous patient data up to one year after hip fracture treatment. To evaluate the effect of the implementation, the change in NOM rate and operative rate for the targeted population will be evaluated and compared with the rate prior to implementation. This will be calculated using the annual national DHFA data from the two-years preceding implementation per hospital, as baseline. The post-implementation NOM rate will be collected immediately after completion of phase 4, as well as at the end of 2025. The secondary outcome measures (for phase 3 only) will be collected during semi-structured interviews with patients/proxy or next of kin, four to six weeks after inclusion. These are the satisfaction with the chosen treatment on a numeric rating scale (0-10), their valuation of the information received during the SDM process, and if the patient's needs were respected enough in the treatment decision. The interview sheets (in Dutch), used for patient or healthcare provider interviews in phases 1-3, are included in online supplementary materials 2.

The following patient data will be also collected in phases 3 and 4 from the DHFA at 3-months and one year after hip fracture treatment (emerging from the patients' medical records). Patient characteristics (age, sex, ASA, Functional Ambulation Category), pre-fracture situation (residence, mobility, KATZ Activities of Daily Living (ADL) score), fracture details (fracture classification, affected side), hospital details (hospital length of stay and intensive care length of stay), and outcome details (complications, revision surgeries, readmission, 30-day mortality, and time until death).

Data will be collected for each patient who meets the eligibility criteria. To reduce the administrative burden, the DHFA database will be used as much as possible. Data from the DHFA will be imported in a Castor EDC database, in which hospitals can only see their own data. The datasets of all hospitals will be combined for the final analysis.

Sample size calculation

A formal sample size calculation was not made as the primary aim is implementation on a national level. To give an idea of the total national population size the following estimate was made: In 2020 21,165 patients presented to a hospital in the Netherlands with a proximal femoral fracture (26). Of these 17,225 (81.5%) were aged 70 years or older. An approximate 25% of this population lived in a nursing home or other institution. Which projects to about 4,300 patients as the primary target population of this study. Approximately half of these patients will meet our inclusion criteria and thus not all patients will be eligible for NOM, but this gives a broad estimate of the annual

number of patients that should at least be considered for SDM on NOM and operative treatment.

Statistical analysis

Data will be analyzed using the Statistical Package for the Social Sciences (SPSS) version 28 or higher (SPSS, Chicago, Ill., USA). Normality of continuous data will be tested with the Shapiro-Wilk test, and homogeneity of variances will be tested using the Levene's test. A p-value <0.05 will be taken as threshold of statistical significance. Missing values will not be imputed.

The primary outcome, NOM rate, will be determined by dividing the number of patients treated with NOM by the total eligible number of patients (per participating center and for all participating centers combined).

All continuous data will be reported as mean with standard deviation (SD; if normally distributed based on Shapiro-Wilk test) or as median with quartiles (if not normally distributed). Categorical data will be reported as number with percentage. Pre- and post-implementation data will be compared with a Student T-test (continuous data, normally distributed), Mann-Whitney U-test (continuous data, non-normally distributed), or a Chi-square or Fisher's Exact test (categorical data), as applicable. The analysis will be stratified by NOM versus operative treatment, and further stratified as feasible depending on the final study population, e.g., by time since NOM implementation, pre-fracture mobility, ADL status, fracture classification, or bilateral fracture.

Project timeline

Phase 1 of the study started in June 2023 and ended in August 2023. Phase 2 started in June 2023 and ended in October 2023. Phase 3 started in September 2023 and will approximately end in October 2024. Phase 4 will start in June 2024 and will approximately be concluded in June 2025.

Patient and public involvement

A patient association representative was consulted during the drafting of the study protocol and could provide input for the study design and implementation tools. Through interviews, study participants (patients, next-of-kin and healthcare providers) will be directly involved in providing feedback on the SDM process and educational tools used during the project. In addition to general publication, a summary of the main results will be made available to study participants on request.

Ethics and dissemination

The study was exempted by the local Medical Research Ethics Committee (MEC-2023-0270, 10-05-2023) and Medical Ethics Committee United (W23.083, 26-04-2023) and is registered at ClinicalTrial.gov (NCT06079905, 11-10-2023). The study was approved by the board of directors of all hospitals participating in phase 3. There are no risks involved in this study. The only burden is the time needed for the interviews with health care providers and patients/next of kin in phase 3. The interviews will be performed by researchers following an opt-out design, participants can stop at any time. Participants will be asked to consent to share their contact details with the researchers and participation means interview data can be used (Online supplementary materials 3). Besides this, only already existing and routinely collected data will be collected. All treatments, chosen after SDM, will be performed following local standard care protocols. Based on the above, the overall burden and risks are considered negligible. The study will follow Good Clinical Practice (GCP) guidelines. The study's results will be submitted to an open access international peer-reviewed journal. As previously explained above, it's protocols, tools and results will be made publicly available and presented at several national and international academic conferences of relevant orthogeriatric (scientific) associations.

Data management, monitoring, and privacy

All data and information collected regarding this study will be treated confidentially by the researchers. Research data that can be traced to individual persons can only be viewed by authorized personnel (members of the research team and members of the health care inspection). Data will be encoded and stored in a Castor EDC database with password restricted access to the researchers at individual sites only. Regarding participants privacy, the Dutch 'General data protection regulation (GDPR) implementation act' will be applied.

Funding and disclosures

This project has been funded by the Netherlands Organization for Health Research and Development (ZonMw; project No. 10390162210008). The funder of the study has no role in study design, data collection, data analysis, data interpretation, or writing of the manuscript. All authors declare no conflicts of interest or competing interests for this project.

Discussion

Clinical impact

This project provides an important translation of recent scientific publications to clinical practice and its success could play an important role in (inter)national surgical and geriatric guideline changes. Successful implementation of NOM will change the way healthcare providers view acute hip fractures in frail older adults with a limited life-expectancy. Instead of primarily focusing on clinical possibility of hip fracture treatment, the focus will shift towards treatment concerning patients' quality of life, harm reduction, and effective palliative care in the final stages of life. Because of this shift, the NOM rate is expected to rise in this select group. However, the main goal is not to increase NOM rate, but to provide each patient with the clinical care that best suits their wishes, needs, and clinical reality. Nationwide implementation of SDM on NOM will also lead to a reduction of overtreatment and might reduce associated costs (10). Another important outcome is reduced practice variation between hospitals in both patient selection for (SDM on) NOM and nationwide implementation of a universal structured SDM protocol for frail older adults with a hip fracture.

Strengths and limitations

The strength of this study is that it builds on an existing foundation of recent well-received (inter)national publications, countrywide initiatives involving SDM and advance care planning, and recent demands for assistance in the implementation of NOM from several hospitals. The project group includes experienced professionals from (orthopedic-) trauma surgery, geriatrics, epidemiology, and implementation science from both university medical centers and general hospitals, supplemented with patient perspectives and experts in SDM and study methodology. A limitation of the project is the limited time period for the initial project. Achieving nationwide implementation within two years, which is the maximum allowed project duration of the grantor, might be an overoptimistic aim. However, the project will have developed a strong foundation on which future projects can build and will keep sharing its tools and information, even after completion. Another limitation is that the inclusion criteria might prove to be too narrow. There might be a larger group of patients for whom NOM could suit their preferences or goals of care. However, the project group has decided to keep strict criteria to prevent the pendulum swinging too far and causing undertreatment with long-term survival without functional recovery after opting for nonoperative treatment, which results in potential decreased quality of life and associated adverse events. Depending on the results of the initial implementation the inclusion criteria in the protocol might be adjusted to suit the needs of patients and health care providers. Finally, the NOM rate in the DHFA database might be an underestimation, as patients living in a nursing home might already have advance care plans preventing them from being transferred to

the hospital in the case of a hip fracture. As the NOM implementation gains national traction more attention to advance care planning around hip fractures might lead to an unmeasured increase of the NOM rate in the pre-hospital setting. While reducing DHFA registration for this project, improved communication on patients wishes and integration of hip fractures in advance care planning, between patients and (geriatric) medical practitioners within and outside the hospital, is a desired effect that will improve the quality of NOM and patients' treatment satisfaction.

Future perspective

The success of this project can be used as an international example for trauma care in selected frail older adults and lead to further changes in advance care planning within this older trauma population. The projects finished protocols and clinical tools may be used for updating the Dutch national 'Guideline for the treatment of proximal femoral fractures' and 'Guideline for multidisciplinary treatment of operative treatment of frail older adults' and may also help updating international treatment guidelines on proximal femoral fractures in selected frail older adults with a limited life-expectancy.

References

1. Nijmeijer WS, Folbert EC, Vermeer M, Slaets JP, Hegeman JH. Prediction of early mortality following hip fracture surgery in frail elderly: The Almelo Hip Fracture Score (AHFS). Injury. 2016;47(10):2138-43.
2. Van de Ree CL, Gosens T, Van der Veen AH, Oosterbos CJ, Heymans MW, De Jongh MA. Development and validation of the Brabant Hip Fracture Score for 30-day and 1-year mortality. Hip Int. 2020;30(3):354-62.
3. Hu F, Jiang C, Shen J, Tang P, Wang Y. Preoperative predictors for mortality following hip fracture surgery: a systematic review and meta-analysis. Injury. 2012;43(6):676-85.
4. Morrison RS, Siu AL. Survival in end-stage dementia following acute illness. JAMA. 2000;284(1):47-52.
5. Loggers SAI, Van Balen R, Willems HC, Gosens T, Polinder S, Ponsen KJ, et al. The Quality of Dying in Frail Institutionalized Older Patients After Nonoperative and Operative Management of a Proximal Femoral Fracture: An In-Depth Analysis. Am J Hosp Palliat Care. 2023:10499091231180556.
6. Schuijt HJ, Lehmann LS, Javedan H, von Keudell AG, Weaver MJ. A Culture Change in Geriatric Traumatology: Holistic and Patient-Tailored Care for Frail Patients with Fractures. J Bone Joint Surg Am. 2021;103(18):e72.
7. Nijdam TMP, Laane D, Schiepers TEE, Smeeing DPJ, Kempen DHR, Willems HC, et al. The goals of care in acute setting for geriatric patients in case of a hip fracture. Eur J Trauma Emerg Surg. 2023;49(4):1835-44.
8. Loggers SAI, Willems HC, Van Balen R, Gosens T, Polinder S, Ponsen KJ, et al. Evaluation of Quality of Life After Nonoperative or Operative Management of Proximal Femoral Fractures in Frail Institutionalized Patients: The FRAIL-HIP Study. JAMA Surg. 2022;157(5):424-34.
9. Spronk I, Loggers SAI, Joosse P, Willems HC, Van Balen R, Gosens T, et al. Shared decision making for the treatment of proximal femoral fractures in frail institutionalized older patients: healthcare providers' perceived barriers and facilitators. Age Ageing (in print). 2022.
10. Loggers SAI, Geraerds A, Joosse P, Willems HC, Gosens T, Van Balen R, et al. Nonoperative versus operative management of frail institutionalized older patients with a proximal femoral fracture: a cost-utility analysis alongside a multicenter prospective cohort study. Osteoporos Int. 2023;34(3):515-25.
11. Nijdam TMP, Laane D, Spierings JF, Schuijt HJ, Smeeing DPJ, van der Velde D. Proxy-reported experiences of palliative, non-operative management of geriatric patients after a hip fracture: a qualitative study. BMJ Open. 2022;12(8):e063007.
12. Palliatief niet-operatief management bij kwetsbare oudere patiënten met een heupfractuur. Implementatiehandleiding Versie 1.1.1., d.d. 20-06-2022.
13. Center for Implementation Science Research. Implementation science research development (ImpRes) tool 2018 [Available from: https://impsci.tracs.unc.edu/wp-content/uploads/ImpRes-Guide.pdf. .
14. Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implement Sci. 2009;4:50.
15. Birken SA, Powell BJ, Shea CM, Haines ER, Alexis Kirk M, Leeman J, et al. Criteria for selecting implementation science theories and frameworks: results from an international survey. Implement Sci. 2017;12(1):124.

16. Wensing M, Fluit C, Grimshaw J, Grol R. Educational Implementation Strategies. In Improving Patient Care (eds M. Wensing, R. Grol and J. Grimshaw. 2020.
17. Holden MK, Gill KM, Magliozzi MR, Nathan J, Piehl-Baker L. Clinical gait assessment in the neurologically impaired. Reliability and meaningfulness. Phys Ther. 1984;64(1):35-40.
18. Fleuren MA, Paulussen TG, Van Dommelen P, Van Buuren S. Towards a measurement instrument for determinants of innovations. Int J Qual Health Care. 2014;26(5):501-10.
19. Fleuren M, Paulussen T, Van Dommelen P, Van Buuren S. Measurement instrument for determinants of innovations (MIDI). Leiden: TNO. 2014.
20. Harmsen M, Peters M, Wensing M. Barriers and facilitators assessment instrument: Introduction, instructions and instrument. Nijmegen: IQ healthcare Scientific Institute for Quality of Healthcare. Radboud University Medical Center Nijmegen. 2005.
21. Powell BJ, Waltz TJ, Chinman MJ, Damschroder LJ, Smith JL, Matthieu MM, et al. A refined compilation of implementation strategies: results from the Expert Recommendations for Implementing Change (ERIC) project. Implement Sci. 2015;10:21.
22. Dialuge Trainer. Samen beslissen met ouderen met multimorbiditeit: Dialogue Trainer; [Available from: https://nl.dialoguetrainer.app/module/samenbeslissengeriatrie-open/.
23. FMS. Samen Beslissen (Shared decision making): Federatie Medisch Specialisten; 2023 [Available from: https://demedischspecialist.nl/themas/thema/samen-beslissen-0.
24. Kennisplatform Uitkomstgerichte Zorg. Samen beslissen: Kennisplatform Uitkomstgerichte Zorg; [Available from: https://www.platformuitkomstgerichtezorg.nl/themas/samen+beslissen/default.aspx.
25. Bowen DJ, Kreuter M, Spring B, Cofta-Woerpel L, Linnan L, Weiner D, et al. How we design feasibility studies. Am J Prev Med. 2009;36(5):452-7.
26. CBS. Hospital admissions and patient diagnosis (Ziekenhuisopnamen en -patiënten; diagnose-indeling): Centraal Bureau Statistiek (Dutch Central Bureau for Statistics) 2022 [updated 16-06-2022. Available from: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84069NED/table?ts=1670493690817



10

Patient and proxy satisfaction regarding Shared Decision Making for operative and nonoperative hip fracture treatment in frail older adults: A mixed methods study

Paulieke C. Oosterwijk*, Miliaan L. Zeelenberg*, Henk Jan Schuijt, Detlef Van der Velde, Johannes M. Van Delden, Taco Gosens, Dennis Den Hartog, Pieter Joosse, Sverre A.I. Loggers, Thomas M.P. Nijdam, Michael H.J. Verhofstad, Hugo H. Wijnen, Esther M.M. Van Lieshout, Hanna C. Willems, on behalf of the NOM-Implementation study group

*Authors contributed equally

Submitted for publication

Abstract

Objective

Shared decision making (SDM) is essential in hip fracture treatment, as operative and nonoperative management are viable options in a select group of frail older adults with a limited life expectancy. This study aims to assess the satisfaction of patients and their proxies on SDM and the definitive decision in operative or nonoperative management for hip fractures, to gain insights into patients and proxies experience after implementation of SDM and to give direction for improvement for healthcare professionals.

Methods

We conducted a multicenter study with a concurrent mixed methods design in 14 hospitals across the Netherlands for a select group of frail older adults with a hip fracture. Patients and treatment specific characteristics were collected from the national Dutch hip fracture database. Semi-structured interviews provided quantitative and qualitative data regarding rates and perspectives on satisfaction, information, and attention for patients wishes.

Results

172 patients engaged in SDM, a total of 80 participants consented for an interview. After SDM participants were satisfied with the final decision. The median age was 87 years , and 55(69%) was female. In 52 patients nonoperative management was the definitive decision. The median satisfaction score regarding the chosen treatment was 8 out of 10 (P_{25}-P_{75} 7-9). Contributing factors include acknowledging patients' frailty and ensuring treatment consistency. Access to adequate and honest information and sufficient time allocated was crucial. In 23/78 (30%) cases participants missed information on technical details and aftercare.

Conclusion

After SDM with frail older adults with a hip fracture and their proxies, participants are satisfied with the final decision. However there are several considerations to improve SDM, this study describes practical insights and recommendations to guide healthcare providers during SDM process.

Introduction

Shared decision-making (SDM) is crucial for aligning treatment options with patient preferences, facilitating more informed and well-understood decisions that contribute to personalized care [1,2]. Patients and proxies feel supported and empowered though effective communication in SDM [2]. The SDM approach is essential in hip fracture treatment in a select group of frail older adults with a limited life expectancy, as it emphasizes personalized, tailored care rather than solely focusing on the clinical aspects of hip fracture treatment [3,4]. While operative management (OM) is the cornerstone for management of hip fractures, nonoperative management (NOM) can be a viable option for frail older adults when end-of-life care aligns with patient's preferences [5,6].

Nevertheless, SDM in an acute setting can be challenging due to perceived practical barriers and uncertainty about the individual prognosis [7,8]. Previously described barriers include the time required for an SDM conversation and the inability to arrange multidisciplinary commitment [9]. Additional challenges include patient-related barriers, where individuals may be hindered by the emergency setting and pain or side effects from opioids which reduce their ability to take control of the situation [10].

When these barriers obstruct the process, SDM might be inadequately performed potentially leading to lower patient satisfaction and a higher incidence of decision regret [11,12]. Therefore, as in the Netherlands, the adoption of SDM is becoming more accepted in this select group of frail older adult with a hip fracture it is crucial to address and improve this process [4,10,13]. By implementing appropriate SDM strategies, the patient and proxy experiences regarding SDM for OM versus NOM could improve. However, it remains unclear what the satisfaction of frail older adults with a hip fracture with the SDM process is, and how this can be optimized.

Therefore, the aim of this study was to assess the satisfaction of patients and their proxies on SDM and the final decision on OM versus NOM for hip fracture treatment, and to gain insights into patient's and proxies experience after implementation of SDM. These insights will be used to provide practical insights and recommendations to guide healthcare providers throughout the SDM process.

Methods

Study design

A multicenter, mixed methods study was conducted among frail older adults with a hip fracture and their proxies, from January 1, 2024 to September 1, 2024, parallel to the

NOM-implementation project in 14 hospitals [14]. In a concurrent mixed methods design, quantitative and qualitative data were collected during a single semi structured interview (Figure 1). Additional data and baseline characteristics were extracted from the Dutch Hip Fracture Audit (DHFA), the national quality data registry of hip fracture patients [15]. Both quantitative and qualitative data were analyzed separately. Next, quantitative and qualitative data were concurrently triangulated [16]. This study is reported according to the Good Reporting on a Mixed Methods Study (GRAMMS) Guideline [17].

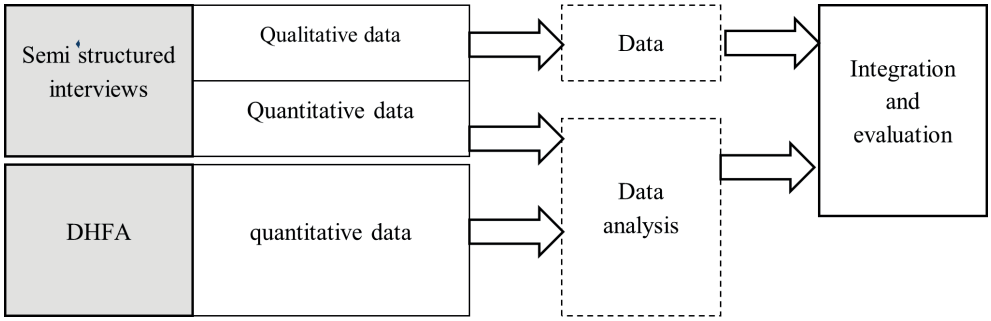


Figure 1: Concurrent mixed methods design
DHFA, Dutch Hip Fracture Audit

Context and study Setting

This study was conducted alongside the nationwide NOM-implementation project on SDM for OM and NOM of hip fractures in a selected group of frail older adults, see subheading participants for further details. SDM implementation was done following an implementation protocol, which was developed in a preparation phase [14]. During a pilot phase, 14 hospitals in the Netherlands implemented SDM on hip fracture treatment, all level 1 or 2 trauma centers. Educational materials were developed to support the local healthcare providers during the SDM process, following the four step SDM-strategy described by Stiggelbout et al [1,2]. Healthcare providers at each hospital received SDM education tailored to their needs in SDM by a certified SDM trainer (PCO or MLZ) [14]. Subsequently, the local teams performed patient selection and applied SDM on hip fracture treatment when patients met the inclusion criteria.

Participants

Participants were patients or their proxies who attended the SDM process. Patients were eligible if they met all of the following inclusion criteria, and were engaged in SDM for OM or NOM by the attending physician(s). Inclusion criteria were: patients being 70 years or older with an acute proximal femoral fracture (AO type 31), confirmed by X-ray or CT scan [18], who were either living in a nursing home, receiving equivalent

care at home, or qualifying for long-term care under the Dutch Long-Term Care Act [19]. Additionally, at least one of the following characteristics had to be present: either malnutrition (cachexia or body mass index<18.5 kg/m^2), a functional ambulation category* (FAC) 2 or lower, or severe comorbidities defined as American Society of Anesthesiologists (ASA) category 4 or 5 [20,21]. Patients and/or proxies with insufficient comprehension of the Dutch language were excluded. Participants were asked if they were willing to participate in interviews and provide feedback on the SDM process and the decision. Four to six weeks after the SDM process, participants were contacted by telephone, they could opt out if they no longer wished to participate at the time of the interview. Participants were also excluded after at least five unsuccessful contact attempts.

Data collection

Baseline characteristics were age, sex, living situation (institutional care facility or nursing home care at home), Katz Activities of Daily Living (ADL) score, diagnosis of dementia, and ASA score [21,22]. Furthermore, intervention characteristics of SDM were described, including what medical specialists were involved in the shared SDM process and what decision was made (OM or NOM).

Quantitative patient data including patient characteristics, fracture details and treatment characteristics were partly collected from the DHFA. Other quantitative data was collected through closed questions with numeric rating scales (NRS) during the interview including; satisfaction regarding the treatment decision (NRS 0-10), the valuation of the amount and content of information received (NRS 0-1 and NRS 0-5), and if there was enough attention for patient's needs/wishes (NRS 0-1). Questions are listed in Supplemental document S1. Quantitative data were pseudonymized and then captured using Castor Electronic Data Capture.

Qualitative data were collected through open ended questions following the closed questions, to gain a thorough understanding of experiences and perceptions of the participants on the SDM process. The interviews were recorded and stored on a secure server.

Data analysis

Quantitative data were analyzed using SPSS software version 28 (IBM, Chicago, Ill., USA). A descriptive analysis was performed for baseline characteristics and outcome measures. Variables were tested for normality using the Shapiro Wilk's test. Continuous data are reported as median with 1st and 3rd quartiles and categorical data are reported as numbers with percentages. Continuous data for the operative versus the nonoperative groups were compared using a Mann-Whitney U-test, and categorical data were

compared using a $\chi 2$ test or Fisher exact test, as applicable. Statistical significance was assumed at a 2-sided P value of <0.05.

Qualitative data were analyzed using ATLAS.ti (version 23.1.1.0). The semi-structured interviews were executed and transcribed *ad verbatim* either by PCO or MLZ. A thematic analysis following the six-step framework by Braun and Clark (2006) was conducted [23]. After independent familiarization with the data, initial coding, searching and identifying key themes was be done by PCO and MLZ. An inter coder agreement meeting was held until final inter coder agreement was reached [23,24].

Ethical Considerations

This study is a part of the NOM-implementation project, which was approved by the local Medical Research Ethics Committee Erasmus MC (MEC-2023–0270, approval data May 10, 2023 and Medical Ethics Committee United (W23.083, approval data April 26, 2023). The project is registered at ClinicalTrial.gov (NCT06079905, 11-10-2023). Patients and proxies were asked for informed consent to be contacted for the interview and could opt-out during the interview at any moment.

Results

Participants and baseline characteristics

A total of 172 frail older adults and/or their proxies, were engaged in SDM regarding OM or NOM for hip fracture treatment (Figure 2). Following SDM, 96 participants consented to being approached for an interview. Of these, 11 participants could not be reached despite repeated attempts and five withdrew consent. In total 80 participants were interviewed. All interviews were conducted with a proxy, except for one that was held with an operated patient. In 28 (35%) patients OM was chosen and in 52 (65%) patients NOM was.

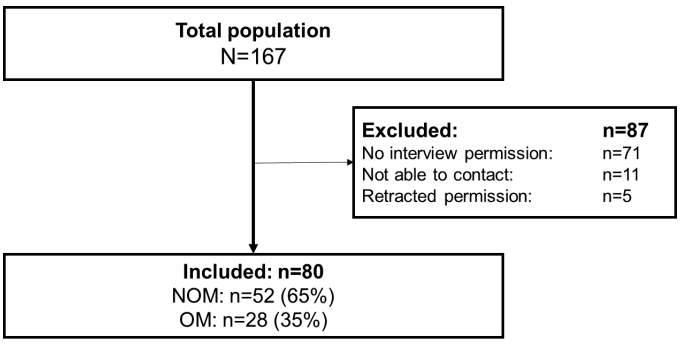


Figure 2: Flowchart of included patients

The median age was 87 (P_{25}-P_{75} 83-92) years and 55 (69%) of the patients were female (Table 1). Prior to the trauma, 49 (61%) patients resided in institution care, 22 (28%) were community-dwelling with daily ADL care. Nine (11%) patients were community-dwelling without daily ADL care but with a qualification for long-term care under the Dutch Long-Term Care Act. A significant difference (p=0.007) in pre-trauma mobility was observed between the OM group, with 3 (11%) patients being independent, and the NOM group, with 9 (18%) patients mobilizing independently. In the total population the median hospital length of stay was 4 days (P_{25}-P_{75} 1-8), with a significant difference (p<0.001) between the OM group (8 days; P_{25}-P_{75} 3-10) and the NOM group (2 days; P_{25}-P_{75} 1-5). Significantly fewer patients in the OM group had died at the time of the interview (3 patients; 11%), than patients in the NOM group (40 patients; 77%; p<0.001).

Table 1: Baseline characteristics

	Total population (n=80)		**Operative (n=28)**		**Nonoperative (n=52)**		P-value
	n*		n*		n*		
Age (years)	80	87 (82-92)	28	85 (82-92)	52	87 (83-92)	0.496
Females	80	55 (69%)	28	17 (61%)	52	38 (73%)	0.314
Pre-trauma living status	80		28		52		0.476
Community dwelling without daily ADL care		9 (11%)		3 (11%)		6 (12%)	
Community dwelling with daily ADL care		22 (28%)		10 (36%)		12 (23%)	
Institutionalized		49 (61%)		15 (54%)		34 (65%)	
Pre-trauma mobility	77		28		49		**0.007**
Independent		12 (16%)		3 (11%)		9 (18%)	
With 1 or 2 aids		38 (49%)		21 (75%)		17 (35%)	
Only within own home		20 (26%)		3 (11%)		17 (35%)	
Not functional		7 (9%)		1 (4%)		6 (12%)	
Dementia diagnosis	80	46 (58%)	28	13 (46%)	52	33 (64%)	0.161
HLOS (days)	80	4 (1-8)	28	8 (3-10)	52	2 (1-5)	**<0.001**
In-hospital mortality	80	6 (8%)	28	1 (4%)	52	5 (10%)	0.659
Discharge location	74		27		47		**<0.001**
Own home (with care)		5 (7%)		1 (4%)		4 (9%)	
Care home		49 (66%)		14 (52%)		35 (75%)	
Rehabilitation institution		12 (16%)		12 (44%)		0	
Hospice/other		8 (11%)		0		8 (17%)	
Mortality at time of interview	80	43 (54%)	28	3 (11%)	52	40 (77%)	**<0.001**

Data are shown as median (P_{25}-P_{75}) or as n (%). n* refers to the number of patients for whom data were available.

ADL, activities of daily-life; HLOS, hospital length-of-stay; MUST, malnutrition universal screening tool; SNAQ, short nutritional assessment questionnaire.

The SDM process often took place at multiple locations. SDM was at least partly conducted in the emergency department for 30/66 (46%) patients and/or at the in-patient ward for 50/66 (76%) patients (Supplemental Table S2). In addition, in two patients (3%) it was partially conducted in the preoperative holding department. Data was missing about the exact location of- and the specialties participating in SDM in respectively 14 and 3 patients.

Table 2: Outcomes of questionnaire on overall treatment satisfaction and SDM process

	Total population[#]		**Operative**		**Nonoperative**		
	n*		n*		n*		P-value
Overall satisfaction (NRS of 0-10)	80	8 (7-9)	28	9 (8-9)	52	8 (7-9)	0.111
Information amount							
Too little	78	15 (19%)	27	7 (26%)	51	8 (16%)	0.528
Sufficient		59 (76%)		19 (70%)		40 (78%)	
Too much		4 (5%)		1 (4%)		3 (6%)	
Missing information (Yes)	78	23 (30%)		10 (37%)		13 (26%)	0.308
Enough attention for patients wishes (Yes)	80	74 (93%)	28	27 (96%)	52	47 (90%)	0.659

[*] Data are shown as median (P_{25}-P_{75}) or as n (%). n* refers to the number of patients for whom data were available.

NRS, numerating rating scale

[#]All interviews were conducted with a proxy, except one operative case, in which the patient was interviewed.

Satisfaction regarding the chosen treatment after SDM

The overall satisfaction with the chosen treatment was scored with a median of 8 (P_{25}-P_{75} 7–9; Table 2). In the total population, 59/78 (76%) of the participants described the information as sufficient, 15 (19%) participants perceived the information as being too little and four (5%) as too much. Information was sufficient in 55 (71%) participants and 73 (91%) participants felt that healthcare providers adequately considered and respected the patient's wishes. Two proxies could not answer the questions regarding the content and volume of information as they were not present during the complete SDM process. The patient's wishes were adequately considered in 27 (96%) participants of the OM group and in 47 (90%) participants of the NOM group. No statistical significant differences between the satisfaction, amount and content of the information and the attention for patient's need/wishes were recorded between the OM and NOM groups.

Perceptions about the SDM process

Trough thematic analysis three themes were identified, describing underlying perceptions and contextual factors. The first two align with the quantitative questions; 'the SDM conversation techniques', comprising four subthemes (S1-S4), and 'the information content and volume' comprising three subthemes (I1-I3). Lastly, an additional theme 'logistics' was identified, with two subthemes (L1-L2). These themes and subthemes are presented as follows:

SDM conversation techniques

S1: Orchestrating SDM: creating space for a balanced dialogue

The way the SDM conversation was experienced played an acknowledgeable role in the satisfaction with the chosen treatment. Participants responded positively to the information and were satisfied when the advantages and disadvantages of the options were discussed in balanced dialogue. The availability of options was sometimes unexpected and deemed as a choice between "two evils" or "two unfavorable scenarios". When no choice was available, decisions framed as SDM were perceived as directive, especially if they felt pressuring, one-sided, or when it gave the impression that the patient was unvalued. In several cases healthcare providers acknowledged treatment options were not equivalent. For instance, when elevated surgical risks were identified and openly discussed, these risks often guided conversations towards choosing NOM as the definitive decision. Some proxies perceived this directedness as supportive and felt reassured and strengthened in the decision making process. However, others described a different experience, stating that the process was steered in a way that left other treatment options unknown to both patient and proxies.

S2: Conversation techniques: honest, open and personal discussions

Conversations perceived as blunt were linked to word choice, the impression of being dismissed, and the delivery style. Although avoiding sugar-coating was important, participants considered depersonalization—focusing on statistics rather than the individual—as harsh. Consequently, incorporating patient's perspective was found relevant, extending beyond the advantages and disadvantages of treatment. Additionally, involving patients actively in the conversation strengthened the participants perceived sense of engagement with the healthcare provider, even if the patient suffered from (partly) cognitive impairment due to dementia. Addressing the patient directly was perceived as respectful and contributed to overall satisfaction.

S3: Providing time to talk and time to think

Participants perceived that when enough time was allocated for a calm conversation, it helped both patients and proxies feel understood and supported. The demeanor of the

healthcare provider played a crucial role; standing during the conversation gave the impression that the healthcare provider was in a rush, adding pressure to make decisions quickly. The possibility to ask questions and seek clarification, both during and after the conversation was important. The emotional intensity of the acute situation and the sudden need for decisions often made it challenging to fully and instantly comprehend the information. Some participants initially focused on listening and engaged more actively at a later stage. This approach allowed time for reflection, facilitating meaningful conversations. Offering time to think and deferring decisions when possible, reduced feelings of overwhelm and increased confidence in the choices made.

S4: The 'Sharedness' in SDM, before and throughout the process

Providing an opportunity in the conversations for patients or their proxies, to discuss their preferences and considerations, played a key role in their involvement in the conversation. It gave them the experience of being an active partner in the SDM and they felt supported in this process. Understanding a loved one's wishes through prior end-of-life discussions or advance care planning, improved the experience of the conversation and enabled proxies to reflect on the SDM with greater satisfaction. This was also the case when patients could openly express their preferences themselves.

Information: content and volume

I1: Quality and completeness of information: facilitating understanding and engagement

In general, participants were satisfied with the content and quantity of the information provided. Effective communication was characterized by clear explanations and honest discussions. The opportunity to ask questions contributed to the completeness of the information. Simple, well-formulated points, presented in a manner that avoided overwhelming the recipients, were particularly appreciated. Gradual delivery of information allowed patients and/or proxies to process the details at their own pace. When information was deemed insufficient, it was often due to the absence of key details, which hindered a comprehensive understanding of the situation and could lead to a negative perception of the SDM process in hindsight.

I2: Missing or incomplete information: complications, aftercare and expectations

The most frequently missing information pertained to the aftercare trajectory, which was often incomplete or unclear. Accurate details about technical options for fracture management, the likelihood of pain block effectiveness, and mortality risks were considered essential. Furthermore, participants frequently noted a lack of detailed information about potential complications and their severity for both OM and NOM. They

also highlighted the absence of outcome information specifically tailored to the individual patient. The absence of information was often perceived as leading to unrealistic expectations. In a few cases, when NOM was chosen, end of life care and short survival times were at odds with initial expectations. If the outcomes after a decision fell short in what proxies anticipated on, it influenced their satisfaction or created doubt in hindsight. Some proxies expressed post-decision doubts. In OM complications and difficult rehabilitation outcomes contributed to these doubts. Overly optimistic expectations were perceived as mentally burdensome. In a few cases, survival after NOM exceeded expectations, and when comfort and pain relief were achieved, this was deemed acceptable. However, when adequate pain management was not achieved, it was distressing.

I3 The role of patient information materials in communication

Printed patient information materials were not often used. If they were used participants underlined it could not substitute for direct conversations, accessible explanations remained essential. Some participants expressed a desire for patient information materials, contrariwise a minority indicated they did not feel a need for this. However, written materials alone were not always sufficient, as some patients were unable to engage with text-based resources due to language skills or eyesight. Participants emphasized that supportive materials did help or could have helped align expectations regarding aftercare and the possibility of end-of-life outcomes.

SDM Logistics

L1: Location matters

SDM solely in the emergency department was often described as fast-paced, disorganized, hectic, or unsettling. The experiences were more positive when discussions took place in a private setting. SDM in the emergency department was frequently perceived as being communicated in a directive manner. In contrast, on the hospital ward, participants felt there was more time and space for discussion. In addition, information was perceived as more complete, expectations were better outlined, there was more openness and time for reflection.

L2: The importance of a multidisciplinary approach

A multidisciplinary perspective was perceived as valuable. Conversations that included input from multiple specialties were viewed as more thorough and complete. When collaboration was inadequate, proxies perceived the SDM process as incomplete and more often stated it was lacking attention to detail. The role of geriatricians and geriatric nurses was highlighted as beneficial. Effective communication between the hospital and care facilities, both before and after discharge, was deemed essential. Clear agreements made in advance contributed to more informed and deliberate decision-making.

Table 3: Quotes per theme

Themes	Quotes
Satisfaction in SDM	
Balanced dialogue	'I am, in principle, satisfied with the conversation, only at that moment, it was no longer a joint decision. So then it will come out lower than that generous 8, yes. Yes, I can honestly say, I was absolutely not dissatisfied with it. So yes, a 6 would be fine, and maybe even a bit higher. But look, as I just said, we were certainly aware that our father no longer had a strong body.'
	'But maybe it was a tactic, or maybe it was a way to test. I don't know, of course, but that surgeon was not very positive right from the start, so to speak. The surgeon clearly had a preference. And the geriatrician too...'
Honest and open discussions	'It came like a bolt from the blue, but they [the doctors] explained it very clearly. They didn't beat around the bush. They simply said, this is the choice you have, and my friend, based on that information—and it was brief but very clear—just made his decision and said, I don't want that.'
Time to talk and think	'There was just calmness in the conversation. It was explained calmly and then again to my mother, you know. It didn't happen in five minutes; they really took the time. I found that very pleasant. I.'
	'at that moment, it just happens to you. You're standing there, and you're not actively thinking about it, so you accept things. You don't really get the chance to think it through properly because, yes, the process starts immediately'.
	'there were silences where she was thinking, and there was patience for that. I really appreciated how much patience there was to listen to her.'
Information	
Quality and completeness	'that [the information] was exactly enough. It was very…. I also asked for very honest information. Like, don't beat around the bush, just honestly say what the advantages are for one option and what the advantages could be for the other. And, of course, also the disadvantages. And it was really, yes, very helpful in making a decision'
Missing or incomplete information	'That my mother could have ended up in a wheelchair or something similar—that we had talked about. But when I saw how things went, we hadn't realistically imagined it at all. The chances were extremely small. And that wasn't entirely clear to us.'
	'But they could have explained better what complications you can have at her age. Because I heard that if you're at this age and have dementia, then after an operation, you might pass away within a few days.'
Supportive materials	'That [patient information materials] could maybe be better in the future. Definitely a leaflet beforehand. Then you can calmly read what to expect and how it's going to proceed. Yes, that kind of information.'
	'Well, I don't know if the things we're discussing now would be included in such a booklet. The options, the consequences, and the risks. If that were included, it might be useful. Because we did sit around for a while or stayed with him, maybe you'd read it during that time.'

SDM logistics	
Location matters	'No, it really happened in the emergency room. In a separate room, so where my mother was lying, that's where it was communicated. Yes, no, that was fine. We all know they're busy, so he was being called in the meantime. But yes, you know, that's just how it is.'
	'We spoke with the attending doctor, or yes, the attending surgeon, in the ER. He didn't encourage surgery, so to speak. And then later also with the geriatrician, who eventually came to the ward, so to speak, with more time and opportunity to talk. For a more in-depth conversation.'
Multidisciplinary approach	'But if I may make a recommendation, I would say, have all the parties, all the people who are directly involved in care, be present during that conversation.'
	'It really are the medical specialists who don't listen to each other, don't even look at each other. And I think there's a lot to gain there. In healthcare in general, if people, especially medical specialists, share their knowledge and findings with each other.'

SDM, shared decision making

Practical implications and recommendations

The findings from the themes described above have been translated into practical implications and recommendations to guide healthcare providers with SDM for frail older adults with a hip fracture in daily practice. These recommendations are summarized and presented in Table 4 in the discussion section.

Discussion

SDM in frail older adults with a hip fracture is increasingly recognized, as both OM and NOM are viable treatment options in this select group of patients. Implementing SDM with frail older adults selected for OM or NOM could contribute to better experiences and higher satisfaction of both patients and proxies. This study showed that after SDM most participants were satisfied with the final decision. Acknowledging patient's frailty and ensuring consistency with their treatment were fundamental factors. Although decisions and the SDM process were challenging, access to adequate and honest information was fundamental to making informed choices. Key details including technical aspects of the fracture and treatment options, complications, and details regarding the aftercare were often missing, although these aspects are deemed vital in this conversation. A calm, open environment with sufficient time allocated was viewed as beneficial to the decision satisfaction. Practical implications and recommendations on preparing the SDM process, conducting SDM, and providing appropriate after care, are described in Table 4. These are intended to guide healthcare providers during the SDM process with frail older adults with a hip fracture and their proxies.

Several previous studies have described treatment satisfaction after OM and NOM for hip fractures in frail older adults [5,10]. However, this is the first study investigating proxy perspectives on specifically the SDM process. Previous research in other orthopedic/trauma patient populations have shown implementing SDM was associated with better treatment satisfaction and therapy adherence [25]. Nevertheless, limited access to information and preparation for both healthcare providers and patients is identified as a barrier to orchestrating SDM in frail older adults with a hip fracture [9]. Nationwide implementation efforts are in progress to address this issue, and the recommendations from this study could contribute to this progress and will be described in the national implementation guidelines. [14]. Despite high treatment satisfaction, not all participants in the current study found the SDM process satisfactory in term of information quantity, quality, or inclusion of patient's/proxy's preferences. Providing patients and proxies with complete, neutral information is crucial to help them understand treatment options and manage expectation. This study emphasized the need to share outcome information tailored to the individual, as outcome probabilities are calculated based on population data. Patient and proxies should be made aware that unexpected outcomes may occur and that predicting an individual's prognosis is challenging. Although decision aids can support this process, they are not always used or available [26,27]. If used, they should be readily available, for example a hip fracture decision aid could be a valuable tool to provide guidance for the SDM process [28]. A commonly cited challenge in SDM is achieving 'sharedness' in the decision process, which includes the belief that patients want healthcare providers to make decisions or that informed consent equates to SDM [29]. As, previous literature have described, a decision is rarely truly shared equally, but this sharedness can be seen as a spectrum from patient-driven decision-making to physician-driven decision-making [4,30]. Therefore, it is important to explore patient's goals of care together with what role they prefer in the decisions process.

This study provides clear objectives and recommendations for improving SDM for frail older adults with a hip fracture in clinical practice. There are, however, several limitations. The perspective of only one patient could be included in this study, due to early mortality or cognitive limitations proxies were interviewed in all other cases. While a frequent practice in research in this population, true patient reported data could provide further valuable insights in satisfaction and decision making among frail older patients.

Table 4: Shared decision making in frail older adults with a hip fracture: practical insights and recommendations

Steps to guide the SDM process
Prepare
Choose a multidisciplinary approach, include healthcare providers from trauma/orthopedic and geriatric care and additional relevant specialties.
If options are unclear or uncertain, first discuss the options with involved specialists before engaging in SDM.
If options are not equivalent, they should not be introduced as equivalent options in a shared decision making matter.
Orchestrate SDM in the inpatient ward as the ED is often to hectic.
Allocate enough time for the conversation, take time to sit down.
A balanced SDM conversation
Carefully introduce both options (availability of nonoperative management can be unexpected)
Direct and honest information is important.
Actively involve the cognitive impaired patient in the conversation.
Discus (dis)advantages of both options and including key details, be clear about technical options, complications and after care.
Give the possibility to ask (future) questions and plan a second conversation if needed.
Use patient information materials and provide them
Aftercare
Ensure that information is transferred accurate and efficient between the hospital and aftercare providers.

SDM, Shared decision making; ED, emergency department.

As numbers of included patients differed greatly between including hospitals and several participants could not be reached or declined, it is possible that patients have been missed. The authors limited the inclusion criteria to a very frail hip fracture population, similar to the nationwide implementation study and previous research [14,31]. However, to our knowledge SDM on OM and NOM is performed in a wider range of patients in several Dutch hospitals. This population may have different satisfaction rates or may encounter other problems in information needs or expectation management. Furthermore, although SDM followed a standardized format variations in the clinical setting, namely the high-pressure environment of the emergency department compared with a calmer ward, may have influenced the way SDM was conducted. These differences could have impacted the experiences of proxies, highlighting an important implication for daily practice. Moreover, individual experiences or developments following a decision may shape both treatment satisfaction and the perception of the SDM process. Data for some patients were not collected or missing due to incomplete data in the DHFA. Lastly, the personal experiences and professional background of the involved researchers may have introduced bias throughout (qualitative) data collection, analysis, and interpretation.

A substantial proportion of (Dutch) surgeons have shown gaps in their understanding of SDM and find it challenging to accomplish or implement without guidance [26,32,33]. Training healthcare providers in SDM and using a dedicated protocol for implementation, like the one related to this study, may help improve on these points [14]. In this SDM trained context, participants were satisfied with the SDM process and final decision but show several aspects that need improvement. The insights from this study, as described in table 4, wil be used to enhance clinical implementation of SDM for frail older adults with a hip fracture.

Conclusion

This study showed that after SDM frail older adults and their proxies were generally satisfied with the final decision on hip fracture treatment. Several important factors contributing to satisfaction in the SDM process were a balanced dialogue, enough allocated time, a multidisciplinary approach, and adequate sharedness of the decision. Healthcare providers should provide patients with neutral but realistic information on technical aspects, complications, and aftercare. This study's recommendations for daily practice could further enhance clinical implementation of SDM for operative and nonoperative hip fracture treatment in frail older adults.

References

1 Stiggelbout AM, Pieterse AH, De Haes JCJM. Shared decision making: Concepts, evidence, and practice. Patient Educ Couns 2015;98:1172–9. https://doi.org/10.1016/j.pec.2015.06.022.

2 Elwyn GJ, Edwards A, Kinnersley P, Grol R. Shared decision making and the concept of equipoise: The competences of involving patients in healthcare choices. Br J Gen Pract 2000;50:892–7.

3 Nijdam TMP, Laane DWPM, Schiepers TEE, Smeeing DPJ, Kempen DHR, Willems HC, et al. The goals of care in acute setting for geriatric patients in case of a hip fracture. Eur J Trauma Emerg Surg 2023;49:1835–44. https://doi.org/10.1007/s00068-023-02258-0.

4 Schuijt HJ, Smeeing DPJ, Verberne WR, Groenwold RHH, van Delden JJM, Leenen LPH, et al. Perspective; recommendations for improved patient participation in decision-making for geriatric patients in acute surgical settings. Injury 2023;54. https://doi.org/10.1016/j.injury.2023.05.054.

5 Loggers SAI, Willems HC, Van Balen R, Gosens T, Polinder S, Ponsen KJ, et al. Evaluation of Quality of Life After Nonoperative or Operative Management of Proximal Femoral Fractures in Frail Institutionalized Patients: The FRAIL-HIP Study. JAMA Surg 2022;157:424–34. https://doi.org/10.1001/jamasurg.2022.0089.

6 Tremblay A, Pelet S, Belzile É, Boulet J, Morency C, Dion N, et al. Strategies to improve end-of-life decision-making and palliative care following hip fracture in frail older adults: a scoping review. Age Ageing 2024;53. https://doi.org/10.1093/AGEING/AFAE134.

7 Sullivan NM, Blake LE, George M, Mears SC. Palliative Care in the Hip Fracture Patient. Geriatr Orthop Surg Rehabil 2019;10. https://doi.org/10.1177/2151459319849801.

8 Murray IR, Biant LC, Clement NC, Murray SA. Should a hip fracture in a frail older person be a trigger for assessment of palliative care needs? BMJ Support Palliat Care 2011;1:3–4. https://doi.org/10.1136/BMJSPCARE-2011-000027.

9 Spronk I, Loggers SAI, Joosse P, Willems HC, Van Balen R, Gosens T, et al. Shared decision-making for the treatment of proximal femoral fractures in frail institutionalised older patients: healthcare providers' perceived barriers and facilitators. Age Ageing 2022;51. https://doi.org/10.1093/ageing/afac174.

10 Nijdam TMP, Laane DWPM, Spierings JF, Schuijt HJ, Smeeing DPJ, Van Der Velde D. Proxy-reported experiences of palliative, non-operative management of geriatric patients after a hip fracture: a qualitative study. BMJ Open 2022;12. https://doi.org/10.1136/bmjopen-2022-063007.

11 Chichua M, Brivio E, Mazzoni D, Pravettoni G. Shared decision-making and the lessons learned about decision regret in cancer patients. Support Care Cancer 2022;30:4587. https://doi.org/10.1007/S00520-021-06725-5.

12 Altin SV, Stock S. The impact of health literacy, patient-centered communication and shared decision-making on patients' satisfaction with care received in German primary care practices 2016. https://doi.org/10.1186/s12913-016-1693-y.

13 Laane D, Kroes T, van den Berg A, de Jongh M, The R, Van der Velde D, et al. Patient and proxy perspectives in decision-making for geriatric hip fracture management in the Netherlands: a qualitative study. BMJ Open 2024;14. https://doi.org/10.1136/bmjopen-2023-082093.

14 Zeelenberg ML, Oosterwijk PC, Willems HC, Gosens T, Den Hartog D, Joosse P, et al. Shared decision-making for non-operative management versus operative management of hip fractures in selected frail older adults with a limited life expectancy: a protocol for a nationwide implementation study. BMJ Open 2024;14:e083429. https://doi.org/10.1136/BMJOPEN-2023-083429.

15 Würdemann FS, Krijnen P, van Zwet EW, Arends AJ, Heetveld MJ, Trappenburg MC, et al. Trends in data quality and quality indicators 5 years after implementation of the Dutch Hip Fracture Audit. Eur J Trauma Emerg Surg 2022;48:4783–96. https://doi.org/10.1007/s00068-022-02012-y.

16 Das MK. An Introduction to Qualitative and Mixed Methods Study Designs in Health Research. Indian Pediatr 2022;59:416–23. https://doi.org/10.1007/s13312-022-2523-4.
17 O'Cathain A, Murphy E, Nicholl J. The quality of mixed methods studies in health services research. J Heal Serv Res Policy 2008;13:92–8. https://doi.org/10.1258/jhsrp.2007.007074.
18 Baumgaertne M, Apivatthakakul T, Oh J-K. AO Classification: Proximal Femur. SurgeryreferenceAofoundationOrg 2022. https://surgeryreference.aofoundation.org/orthopedic-trauma/adult-trauma/proximal-femur/additional-credits#third-edition-2022- (accessed August 1, 2024).
19 Rijksoverheid. Wet langdurige zorg. 2015.
20 Holden MK, Gill KM, Magliozzi MR, Nathan J, Piehl-Baker L. Clinical Gait Assessment in the Neurologically Impaired: Reliability and Meaningfulness. Phys Ther 1984;64:35–40. https://doi.org/10.1093/PTJ/64.1.35.
21 Doyle DJ, Hendrix JM, Garmon EH. American Society of Anesthesiologists Classification. StatPearls 2023.
22 Laan W, Zuithoff NPA, Drubbel I, Bleijenberg N, Numans ME, De Wit NJ, et al. Validity and reliability of the Katz-15 scale to measure unfavorable health outcomes in community-dwelling older people. J Nutr Health Aging 2014;18:848–54. https://doi.org/10.1007/S12603-014-0558-5.
23 Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol 2006;3:77–101. https://doi.org/10.1191/1478088706QP063OA.
24 Byrne D. A worked example of Braun and Clarke's approach to reflexive thematic analysis 2022;56:1391–412. https://doi.org/10.1007/s11135-021-01182-y.
25 Wilson CD, Probe RA. Shared Decision-making in Orthopaedic Surgery. J Am Acad Orthop Surg 2020;28:E1032–41. https://doi.org/10.5435/JAAOS-D-20-00556.
26 Bossen JKJ, Jansen J, van der Weijden T, Heyligers IC. Disappointing evaluation of a shared decision-making intervention for residents and orthopaedic surgeons. Patient Educ Couns 2022;105:1066–74. https://doi.org/10.1016/J.PEC.2021.09.029.
27 Stacey D, Lewis KB, Smith M, Carley M, Volk R, Douglas EE, et al. Decision aids for people facing health treatment or screening decisions. Cochrane Database Syst Rev 2024;1. https://doi.org/10.1002/14651858.CD001431.PUB6.
28 Gans EA, Van Mun LAM, De Groot JF, Van Munster BC, Rake EA, Van Weert JCM, et al. Supporting older patients in making healthcare decisions: The effectiveness of decision aids; A systematic review and meta-analysis 2023. https://doi.org/10.1016/j.pec.2023.107981.
29 Baggett ND, Schulz K, Buffington A, Marka N, Hanlon BM, Zimmermann C, et al. Surgeon Use of Shared Decision-making for Older Adults Considering Major Surgery: A Secondary Analysis of a Randomized Clinical Trial. JAMA Surg 2022;157:406–13. https://doi.org/10.1001/JAMASURG.2022.0290.
30 Kon AA. The shared decision-making continuum. JAMA 2010;304:903–4. https://doi.org/10.1001/JAMA.2010.1208.
31 Loggers SAI, Geraerds AJLM, Joosse P, Willems HC, Gosens T, Van Balen R, et al. Nonoperative versus operative management of frail institutionalized older patients with a proximal femoral fracture: a cost-utility analysis alongside a multicenter prospective cohort study. Osteoporos Int 2023;34:515–25. https://doi.org/10.1007/s00198-022-06638-x.
32 Woltz S, Krijnen P, Pieterse AH, Schipper IB. Surgeons' perspective on shared decision making in trauma surgery. A national survey. Patient Educ Couns 2018;101:1748–52. https://doi.org/10.1016/J.PEC.2018.06.002.
33 Bozic KJ. Orthopaedic healthcare worldwide: Shared medical decision making in orthopaedics. Clin Orthop Relat Res 2013;471:1412–4. https://doi.org/10.1007/S11999-013-2838-5.

Supplemental tables

Supplemental Table S2: Location(s) of SDM and participating health care providers

	Total population		Operative		Nonoperative	
	n*		n*		n*	
Location of SDM[#]	66		24		42	
Emergency department		30 (46%)		5 (21%)		25 (60%)
Ward		50 (76%)		22 (92%)		28 (67%)
Preoperative holding		2 (3%)		0		2 (5%)
Specialties participating in SDM[#]	77		27		50	
Orthopedic- or trauma surgery		33 (43%)		15 (56%)		18 (36%)
(Orthopedic-) Surgery resident		29 (38%)		9 (33%)		20 (40%)
Geriatrician		42 (55%)		18 (66%)		24 (48%)
Emergency physician		2 (3%)		0		2 (4%)
Physician assistant GTU/trauma surgery		18 (23%)		4 (15%)		14 (28%)
Others[+]		7 (9%)		0		7 (14%)

Data are shown as median (P_{25}-P_{75}) or as n (%). n* refers to the number of patients for whom data were available.

[#]Participants can have had (part of the) SDM process at various locations with multiple healthcare providers from different specialties.

GTU, geriatric trauma unit; SDM, shared decision making

[+]Other specialties includes: Pulmonary medicine, cardiology, and/or intensive care medicine.

Supplemental Table S3: Additional patient characteristics, including fracture type, operation characteristics and in-hospital complications

	Total population		Operative		Nonoperative	
	n*		n*		n*	
Fracture type	74		28		46	
Femoral neck		46 (62%)		15 (54%)		31 (67%)
Trochanteric		27 (37%)		12 (43%)		15 (33%)
Subtrochanteric		1 (1%)		1 (4%)		0
ASA score	36		27		9	
2		3 (8%)		2 (7%)		1 (11%)
3		18 (50%)		15 (55%)		3 (33%)
4		15 (42%)		10 (37%)		5 (56%)
Operative fixation	28		28		NA	
Hemiarthroplasty		15 (54%)		15 (54%)		NA
Intramedullary nail		13 (46%)		13 (46%)		NA
In-hospital complications	80		28		52	
Any		14 (18%)		11 (39%)		3 (6%)
Anemia		3		3		0
Delirium		10		7		3
Fall		1		1		0
Heart failure		1		1		0
Kidney failure		1		1		0
Pneumonia		1		1		0
Pressure sores		1		1		0
UTI		2		1		1

Data are shown as median (P_{25}-P_{75}) or as n (%). n refers to the number of patients for whom data were available.

PART

IV

PART IV

General discussion and Conclusions

Chapter 11: General discussion and future perspectives

Chapter 12: Summary and conclusions in Dutch and English



11

Discussion and Future perspectives

In this chapter the answers to the research questions posed in the three parts of this thesis are discussed and situated within a broader scientific context. It details how the results of the included studies support these conclusions and how those align with existing knowledge on the relevant subjects. Additionally, it explores how the results can be applied to guide future research and to enhance the quality of care for hip fracture patients.

Part I: Epidemiology and burden to society

Hip fractures are not only a disease from the past but certainly one for the future. In the past decades several authors warned for a growing hip fracture epidemic (1-4). This prediction has come true. After the already significant increase in incidence rates of the previous decades, **Chapter 2** shows that crude numbers and population wide incidence rates of hip fractures have continued to increase. The overall incidence rate of femoral neck and trochanteric fractures increased by 22% between 2000 and 2019. However, among older adults (>65 years), a decreasing trend was found, of 37%, despite increasing crude numbers. This decrease was primarily pushed by a decrease in incidence in the female population and is in line with similar trends found in other ageing populations, such as Japan or other European countries (5-7). Reasons for this decrease can be found in the larger increase of the elderly population due to increased life expectancy and decreasing birthrates among younger generations. Many older adults reach higher ages with better mobility, cognitive function, and less functional impairment (8). Another part, outside of the scope of this thesis, might be due to active and effective osteoporosis prevention and fall prevention campaigns (9, 10). There are, however, specific populations of interest. Among older male patients the incidence remained relatively stable over the first two decades of the century and incidence among the oldest males (>90) has even surpassed the declining female incidence rates. With other literature describing that osteoporosis among older men is still under-screened, underdiagnosed, and undertreated, more attention on prevention and treatment of osteoporosis and fall risk in this population is warranted (11). In addition, the 'oldest old' population (>80 years) is expected to double in size among both males and females, a population with prevalent frailty and an increased risk of both hip fractures and associated complications (12). While the incidence may be decreasing, the wave of fractures has not passed and will continue to put further pressure on our healthcare system.

Subtrochanteric fractures, accounting for only about 5% of all hip fracture admissions and more often associated with pathological or atypical fractures, followed a different incidence pattern (13, 14). **Chapter 3** described a decreasing incidence rate of 15% over the whole Dutch populations but also a decrease of 42% for older adults over 65

years. This effect was again larger for female patients but both males and females showed a decreasing trend, contrary to previous international studies on the subject (15, 16). Previous studies linked their increasing incidence rates to increased bisphosphonate usage (15, 16). Specific medication was outside of the scope of our analysis but, since implementation in 2011, a new general practitioner guideline reduced the number of annual bisphosphonate subscriptions by 11% (17). However, the decreasing trend in fracture incidence was already clearly visible before 2011 and might be more related to a general increase in (hip) fracture and osteoporosis prevention campaigns, medication and awareness, than a decrease in bisphosphonate usage. While also often described as a fracture type with a bimodal age distribution, with a peak at young/early adult age and a peak al older age, the national trauma registration data, described in **Chapter 3,** found no such a pattern. Younger male patients did, however, show a higher incidence rates than female patients. These small differences between the sexes, all below 0.6 per 100,000 person years, are overshadowed by incidence rates well over 50 per 100,000 person years for older patients. Speaking of a true bimodal distribution would thus be an overstatement.

While **Chapter 2 and 3** show decreasing numbers for overall hospital length of stay (HLOS) from a mean 18 days in 2000-2004 to only seven days in 2015-2019. This is likely due to several developments, including the implementation of dedicated clinical pathways, new surgical techniques and rehabilitation, and changes the organization of healthcare that moved a large proportion of rehabilitation outside of the initial hospital stay (18, 19). Despite this reduction, the total impact on our health system is still high with a cumulative annual HLOS of 86,439 days for femoral neck, 56,363 days for trochanteric, and 5,410 days for subtrochanteric fractures. This is equivalent to a total of 406 hospital beds continuously occupied by hip fracture patients all year round, or about 1% of all available beds in the Netherlands. These fractures have more impact than hospital stay alone. The associated healthcare related costs are considerable with €17,723 for male patients and €23,351 for female patients. The costs per patient are higher than those of other fracture types, and hip fracture is the most costly fracture in total health care costs and poses a significant strain on national health care expenditure (20-22). The Dutch National Institute for Public Health and the Environment reported a total health care cost for hip fractures in 2007 of €378M (0.39% of the total yearly health care expenditure) (23). This increased to €461M in 2019 (0.48% of total expenditure). While secondary costs due to loss of productivity play only a marginal role due to the high age of the large majority of hip fracture patients, the studies described in **Chapter 2 and 3** could not calculate costs made by care provided by next-of-kin and possible work absence due to informal social care ("mantelzorg"). These costs might be substantial and put further strain on our already decreasing available workforce (24). In short, hip fractures are an epidemic both the current and next generations will have to

deal with, both as medical professionals, policy makers, and as informal caregivers for those around us.

Part II Fixation of (stable) trochanteric fractures

Treatment of trochanteric fractures has been an topic of debate for decades (25-27). While historically there was a clear advantage for extramedullary fixation, the introduction of new generations of intramedullary designs and fixation techniques have erased this gap (25, 28). However, the question of superiority for the most common subgroups (AO type A1 or A2) of trochanteric fractures remains ongoing. The systemic review of recent literature from **Chapter 4** showed that the differences between both fixation strategies for (stable) type A1 fractures are negligible. Only in terms of intra-operative blood loss (92 ml) and operation time (14 min), slight advantages for intramedullary fixation were found, although with very high heterogeneity between included studies, likely due to international differences and differences between specific implants. The similarly conducted meta-analysis from **Chapter 5** found different results for type A2 fractures. It found statistical advantages for intramedullary fixation on functional outcomes (Harris Hip score and Parker mobility score) after one year and an elevated risk of nonunion, fixation failure, and superficial infections for extramedullary fixation. However, the absolute differences in functional outcomes remained below clinical relevance thresholds and complications were rare in both groups. Both devices can thus be considered adequate treatment options for both fracture subtypes based on their clinical outcomes. Large randomized studies were found to be lacking in both reviews but their findings were again confirmed in a very recent large international multicenter RCT (29).

The most recent Dutch national guideline advises both extramedullary and intramedullary devices for AO type A2 fractures but favors extramedullary devices, or more specifically sliding hip screws, for type A1 fractures (30). The reason for this advice is the lower average unit cost of extramedullary devices, about 500-1000 euros, depending on specific retail contract (31-33). Because of the high volume in annual hip fracture surgeries this, seemingly modest, difference can make a significant impact on a national level. A cost reduction of 500 euros in about half of the approximate 8000 trochanteric fractures could save two million euros annually. Contrarily, **Chapter 6** shows that despite the guidelines advice, over 80% of patients with type A1 fractures in multiple high volume Dutch hospitals was treated using intramedullary devices. The subsequent analysis the outcomes of patients with type A1 fractures again confirmed little to no differences between the groups after three months. In concordance with previous Dutch and international publications and the meta-analysis of **Chapter 4**, it

also found no differences in in-hospital complications, HLOS, or mortality (34, 35). Comparative analysis of type A2 data even proved too difficult as >95% of patients was fixated using intramedullary devices. The study described in **Chapter 6**, comparing outcomes of extramedullary and intramedullary fixation, did find an indication for a possible advantageous effect in favor of intramedullary fixation for faster improvement of mobility up to three months. Other studies also reported this effect (31, 36). This might indicate that intramedullary fixation has advantageous effects on mobilization of patients in the months after surgery, which may have beneficial effects on both fracture healing and quality of life. We did, however, not see this (as a clinically relevant) effect in the meta-analysis described in **Chapter 4**. It may also have been affected by both selection or survival bias as follow-up data from the DHFA is often incomplete.

This all raises the question whether surgeons should care about device selection in future care? They should. The skewed device usage for trochanteric fractures in the Netherlands may start a self-fulfilling prophesy: As surgeons lose day-to-day experience with certain devices and provide less training opportunity to younger colleagues, future results may start to falter as well. Especially, as working in a teaching hospital is associated with intramedullary fixation (37). The decline in extramedullary fixation usage seems to be largely influenced by surgeons bias, rather than patient- or operation specific factors, including factors such as training, effective marketing of intramedullary fixation (in the US), lack of knowledge about device costs, and lack of consensus in international guidelines (37, 38). Although the clear advice of the Dutch guideline seems to have little effect on the device choice among Dutch surgeons.

To summarize, the chapters included in this thesis confirm that there are no meaningful differences between extramedullary and intramedullary fixation for stable (AO type A1) trochanteric fractures and find a few, often clinically irrelevant differences, in favor of the more costly intramedullary devices for AO type A2 fractures. As the costs of hip fracture treatment are rising within our national budget, clear decisions may be necessary to ensure cost-effectiveness of care (39). One of the area's for possible reduction of costs may be device choice for trochanteric fractures. However, before stronger arguments for reduction of intramedullary fixation are possible, a large scale cost-effectiveness analysis should be performed for both stable and unstable trochanteric fractures. Such a study should ideally be conducted within our own healthcare system, as the large international differences in how healthcare is organized and financed may have substantial effects on the results. To make this possible, participating surgeons would have to temporarily set aside their expert opinions. Additional efforts could also be made to make surgeons (in training) aware of the costs of implants used and their less costly alternatives. If physicians make cost-conscious decisions, it is easier for hospitals to negotiate prices with implant vendors and further reduce costs (40). As

many hospitals in the Netherlands operate in combined trauma units, both orthopedic- and trauma surgery teams would need to synchronize their approaches, the uniformity of instruments in the operating room for the supporting staff, and training of their residents. To safeguard value based care in the long term, it is adamant to not only evaluate the results of treatment options but also their cost-effectiveness on a national level and implement this in the current treatment guidelines. As many hospitals in the Netherlands operate in combined trauma units, both orthopedic and trauma surgery teams would need to synchronize their approaches, the uniformity of instruments in the operating room for the supporting staff, and training of their residents.

Part III Nonoperative treatment of frail older hip fracture patients

Cost- and outcome-sensitive device selection is only one of the areas we can improve our hip fracture care. As discussed in the introduction of this thesis, the way we view quality of care has changed over time. Other quality indicators have reached prominence such as patient reported outcome measures and societal costs in the narrow and wide sense. No longer is only prevention of mortality or complications the highest cause. As a consequence of this, care is becoming more individualized. Findings that are 'better' for a population are not necessarily true for individual patients and vice versa. This thinking can improve individual quality of life for patients but it also can also complicate the clinical practice. The old saying "If there is a fracture, fix it" is outdated, especially among frail older hip fracture patients, and a higher mortality rate can, paradoxically, be a desired consequence if patients opt for nonoperative management in the final phase of life.

Since the publication of the FRAIL-HIP study (41), there has been an increase of attention towards nonoperative management (NOM) for frail older hip fracture patients in the Netherlands. Related projects also showed that nonoperative management was viable, humane, and cost-effective (42, 43). In the years preceding this thesis the proportion of patients treated nonoperatively was around 3% in the years 2016-2021 based on Dutch Hip Fracture Audit data (44). A number that can be expected to rise due to the new evidence provided by the FRAIL-HIP study and related research (45, 46). However much is still unknown and there are many areas to be improved.

It is even questionable, for some patients whether the hospital is the right location to make the decision between nonoperative and operative management. As described in **Chapter 7**, there is a group of patients who could potentially benefit from forgoing admission and starting (palliative) nonoperative management in their familiar nurs-

ing home environment. When compared with hospitalized patients, their next-of-kin showed similar treatment satisfaction and better quality of dying for several aspects of the final phase of life, despite dying earlier than hospitalized patients. These results are heavily influenced by the selection of patients, as the non-hospitalized patients and/or proxies had pre-recorded do-not-hospitalize directives or advanced care plans for the occurrence of a hip fracture. This would have made them better prepared for the final phase of life and dying and have improved their preparedness and coping. Although this is a form of selection bias, it is also a desired effect of advance care planning. Maintaining quality of life (over prolonging of life) and being with family were previously identified as more important goals of care than hospital admission and intensive rehabilitation (47, 48). While advance care planning is often performed for nursing home residents, hip fractures are not always included specifically (49-51). Improving this may reduce unnecessary hospital admissions, diagnostics, and reduce their burden on the patients quality of life. It is easier to reaffirm or adjust a past decision than to make a new decision at an acute and unforeseen moment. This can relieve the burden for the elderly care specialist in the acute moments after the fracture, and allow them to earlier focus on palliative treatment and pain relieve.

To try to provide more tailored care and diagnostics for those patients who are admitted to a hospital, efforts could made to further reduce the number of diagnostic tests performed in this population. (Trauma-)surgical guidelines on preoperative screening in older adults with a hip fracture advise restricting diagnostic testing and treatment to only acute correctable comorbidities or indicated diagnostics (52, 53). However, as described in **Chapter 8** a large quantity and variety of diagnostic tests is performed in the frail older hip fracture population, both in nonoperatively and operatively treated patients. Diagnostics that are often, if not always, deviant but almost never result in additional interventions (e.g. thoracic x-rays without related symptoms or a liver/vitamin blood panel). Most diagnostics are performed at the Emergency Department, are often protocolized, and differ between individual hospitals. While there are logistical advantages of standardized and protocolized diagnostics for all patients, efforts could be made to implement patient group specific diagnostics and to exclude diagnostics that rarely have relevant outcomes or should only be performed after a clinical indication (54). This could reduce both the costs and the burden for patients, especially if they opt for nonoperative management shortly after admission.

Nonoperative management has become an accepted treatment option in the Netherlands and has recently gained also gained international interest in Spain, Canada and the Scandinavian countries (55-57). However, discussion of the option of nonoperative management was, and is, not implemented in all hospitals on a national scale. In **Chapter 9** of this thesis we proposed a nationwide implementation of shared-decision

making (SDM) on operative and nonoperative management for selected frail older patients. During this project an implementation guide was drafted, decision aids for both patients and medical professionals were created, and the subject was put on the agenda of the training curriculum for surgeons, and scientific associations. The projects finished protocol and clinical tools may be used to aid in the future for updating the Dutch national 'Guideline for the treatment of proximal femoral fractures' and 'Guideline for multidisciplinary treatment of operative treatment of frail older adults' and may also help updating international treatment guidelines on proximal femoral fractures in selected frail older adults with a limited life-expectancy. Although the project is not yet concluded, it is expected to reduce practice variation between hospitals in both patient selection for (SDM on) NOM and aid in implementation of a universal structured SDM protocol for frail older adults with a hip fracture (see example in Figure 1). The finished version of these resources can be found and downloaded through the website of the Dutch association for trauma surgery (Nederlandse Vereniging voor Traumachirurgie) (58).

During the implementation process interviews were conducted with next-of-kin of these patients after SDM in 14 hospitals. **Chapter 10** describes that, like in previous research, most proxies were content with the chosen treatment (41, 46, 59). What often seems the deciding factor in these decisions is a combination of the patients' pre-fracture frailty and their own wishes and expectations for the final-phase of life (43, 46). While most were also content with the decision making process and the information received, several areas of interest were identified. The decision process itself should ideally be conducted in a suitable quiet location, be conducted after multidisciplinary (*e.g.*, both surgical and geriatric) consultation, and provide an adequate picture of both the advantages and disadvantages of the treatment options. This can then be combined with a patients and/or proxy's wishes and expectations and lead to a shared decision. The use of factsheets, patient information documents, or videos can help in this effort but should not supplant a thorough discussion. Prolonged and badly controlled pain after nonoperative management was a prominent reason for dissatisfaction. This was also seen in other studies and is an important problem to tackle in future research and implementation (41, 43, 60).

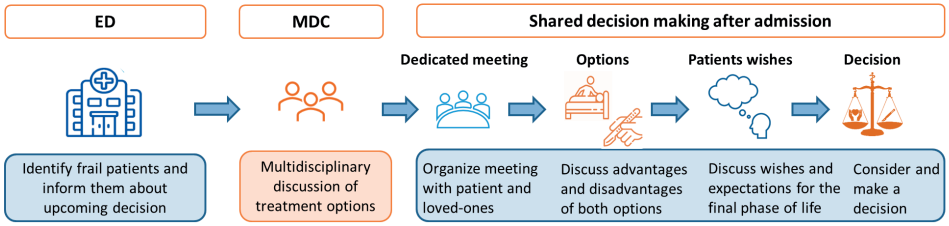


Figure 1: Overview of Shared decision making for frail older patients after admission at the emergency department. ED, emergency department; MDC, multidisciplinary consultation

However, new developments are on the horizon, with pericapsular nerve group (PENG) and spinal phenol in glycerol (SPING) blocks, to provide better management of pain after fractures and in the palliative phase (61, 62). PENG blocks are currently under evaluation in a nationwide prospective registration study (63). While providing extra options for pain treatment and the expectation of better quality of life and quality of dying for many hip fracture patients, these methods are likely not the holy grail. What is more important, is to accurately define with which patients nonoperative management should be discussed. As there is no mention of nonoperative management in the current guideline, future hip fractures guidelines may aid physicians by providing a target population. This should be done with caution and restraint. Current research only supports nonoperative management among the most frail patients in the final phase of life. If the nonoperative option gains increased interest and the pendulum swings too far towards the more healthy patients, unwanted complications and low quality of life due to a long survival in a bedridden state might be the result. Several mortality or complication prediction models for hip fracture patients have been created and researched and might help choosing the right population for nonoperative management (64-66). However, while an effective aid in treatment decisions or counseling, physicians seem to be able to independently identify high risk patients even more accurately (67). Improving and standardizing shared decision making (training) may provide a better improvement of care than trying to define hard cut-offs for operative or nonoperative care based on scores or patient characteristics. Ultimately while better patient selection and novel pain treatment options will improve the outcomes of nonoperative management in the future, I believe, the key to both patient's satisfaction and good quality of dying remains the thorough and timely discussion of expectations and wishes for the final phase of life, ideally conducted before a fracture occurs.

References

1. Collaborators GBDF. Global, regional, and national burden of bone fractures in 204 countries and territories, 1990-2019: a systematic analysis from the Global Burden of Disease Study 2019. Lancet Healthy Longev. 2021;2(9):e580-e92.
2. Hartholt KA, Oudshoorn C, Zielinski SM, Burgers PT, Panneman MJ, van Beeck EF, et al. The epidemic of hip fractures: are we on the right track? PLoS One. 2011;6(7):e22227.
3. Korhonen N, Niemi S, Parkkari J, Sievanen H, Palvanen M, Kannus P. Continuous decline in incidence of hip fracture: nationwide statistics from Finland between 1970 and 2010. Osteoporos Int. 2013;24(5):1599-603.
4. Rosengren BE, Karlsson MK. The annual number of hip fractures in Sweden will double from year 2002 to 2050: projections based on local and nationwide data. Acta Orthop. 2014;85(3):234-7.
5. Talbot S, Denton H, Dodds MK, Lynch D. Changing trends in hip fracture epidemiology in the Republic of Ireland: a follow-up study. Arch Osteoporos. 2022;17(1):79.
6. Imai N, Endo N, Shobugawa Y, Ibuchi S, Suzuki H, Miyasaka D, Sakuma M. A decrease in the number and incidence of osteoporotic hip fractures among elderly individuals in Niigata, Japan, from 2010 to 2015. J Bone Miner Metab. 2018;36(5):573-9.
7. Lippuner K, Rimmer G, Stuck AK, Schwab P, Bock O. Hospitalizations for major osteoporotic fractures in Switzerland: a long-term trend analysis between 1998 and 2018. Osteoporos Int. 2022;33(11):2327-35.
8. Timmermans EJ, Hoogendijk EO, Broese van Groenou MI, Comijs HC, van Schoor NM, Thomese FCF, et al. Trends across 20 years in multiple indicators of functioning among older adults in the Netherlands. Eur J Public Health. 2019;29(6):1096-102.
9. Nederlandse Vereniging voor Reumatologie. Dutch Guideline osteoporosis and fracture prevention (Richtlijn osteoporose en fractuurpreventie). Utrecht; 2011.
10. Gillespie LD, Robertson MC, Gillespie WJ, Sherrington C, Gates S, Clemson LM, Lamb SE. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2012(9):CD007146.
11. Rinonapoli G, Ruggiero C, Meccariello L, Bisaccia M, Ceccarini P, Caraffa A. Osteoporosis in Men: A Review of an Underestimated Bone Condition. Int J Mol Sci. 2021;22(4).
12. CBS. Prognose bevolking; geslacht, leeftijd, herkomstland, 2024-2070: Centraal Bureau voor Statistiek (CBS); 2024 [Available from: https://opendata.cbs.nl/#/CBS/nl/dataset/85743NED/table.
13. Dutch Hip fracture Audit (DHFA) DHFA report 2019: Dutch Instute for Clinical Auditing (DICA); 2019 [Available from: https://dica.nl/jaarrapportage-2019/dhfa.
14. Garrison I, Domingue G, Honeycutt MW. Subtrochanteric femur fractures: current review of management. EFORT Open Rev. 2021;6(2):145-51.
15. Maravic M, Ostertag A, Cohen-Solal M. Subtrochanteric/femoral shaft versus hip fractures: incidences and identification of risk factors. J Bone Miner Res. 2012;27(1):130-7.
16. Ng AC, Drake MT, Clarke BL, Sems SA, Atkinson EJ, Achenbach SJ, Melton LJ, 3rd. Trends in subtrochanteric, diaphyseal, and distal femur fractures, 1984-2007. Osteoporos Int. 2012;23(6):1721-6.
17. Zorginstituut Nederland. Open data usage of farmaceuticals: Zorginstituut Nederland (Dutch health care institute); 2023 [updated 09-05-2023. Available from: https://www.gipdatabank.nl/.
18. Burgers PTPW, Van Lieshout EMM, Verhelst J, Dawson I, de Rijcke PA. Implementing a clinical pathway for hip fractures; effects on hospital length of stay and complication rates in five hundred and twenty six patients. Int Orthop. 2014;38(5):1045-50.

19. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, et al. Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet. 2015;385(9978):1623-33.
20. Polinder S, Iordens GIT, Panneman MJM, Eygendaal D, Patka P, Den Hartog D, Van Lieshout EM. Trends in incidence and costs of injuries to the shoulder, arm and wrist in The Netherlands between 1986 and 2008. BMC Public Health. 2013;13:531.
21. Prins JTH, Wijffels MME, Wooldrik SM, Panneman MJM, Verhofstad MHJ, Van Lieshout EMM. Trends in incidence rate, health care use, and costs due to rib fractures in the Netherlands. Eur J Trauma Emerg Surg. 2021.
22. De Boer AS, Schepers T, Panneman MJ, Van Beeck EF, Van Lieshout EM. Health care consumption and costs due to foot and ankle injuries in the Netherlands, 1986-2010. BMC Musculoskelet Disord. 2014;15:128.
23. Kosten van ziekten in Nederland 2007. Trends in de Nederlandse zorguitgaven 1999–2010 [press release]. Bilthoven: RIVM2011.
24. Ipsen JA, Viberg B, Pedersen LT, Draborg E, Bruun IH. Informal care after hip fracture: prospective cohort. BMC Geriatr. 2024;24(1):436.
25. Bhandari M, Schemitsch E, Jonsson A, Zlowodzki M, Haidukewych GJ. Gamma nails revisited: gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: a meta-analysis. J Orthop Trauma. 2009;23(6):460-4.
26. Jones HW, Johnston P, Parker M. Are short femoral nails superior to the sliding hip screw? A meta-analysis of 24 studies involving 3,279 fractures. Int Orthop. 2006;30(2):69-78.
27. Schipper IB, Marti RK, van der Werken C. Unstable trochanteric femoral fractures: extramedullary or intramedullary fixation. Review of literature. Injury. 2004;35(2):142-51.
28. Parker MJ, Handoll HH. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. Cochrane Database Syst Rev. 2010(9):CD000093.
29. Schemitsch EH, Nowak LL, Schulz AP, Brink O, Poolman RW, Mehta S, et al. Intramedullary Nailing vs Sliding Hip Screw in Trochanteric Fracture Management: The INSITE Randomized Clinical Trial. JAMA Netw Open. 2023;6(6):e2317164.
30. Multidisciplinaire werkgroep NVvH en NOV. Behandeling pertrochantere fracturen: Federatie Medisch Specialisten; 2016 [updated 1 september 2016. Available from: https://richtlijnendatabase.nl/richtlijn/proximale_femurfracturen/pertrochantere_femurfractuur/behandeling_pertrochantere_fracturen.html.
31. Casnovsky L, Blaschke BL, Parikh HR, Flagstad I, Wise K, McMilan LJ, et al. Does Implant Selection Affect the Inpatient Cost of Care for Geriatric Intertrochanteric Femur Fractures? Geriatr Orthop Surg Rehabil. 2020;11:2151459320959005.
32. Swart E, Makhni EC, Macaulay W, Rosenwasser MP, Bozic KJ. Cost-effectiveness analysis of fixation options for intertrochanteric hip fractures. J Bone Joint Surg Am. 2014;96(19):1612-20.
33. Alessio-Mazzola M, Traverso G, Coccarello F, Sanguineti F, Formica M. Dynamic hip screw versus intramedullary nailing for the treatment of A1 intertrochanteric fractures: A retrospective, comparative study and cost analysis. Jt dis relat surg. 2022;33(2):314-22.
34. Wessels JO, Bjarnesen MP, Erichsen JL, Palm H, Gundtoft PH, Viberg B. Sliding hip screw vs intramedullary nail for AO/OTA31A1-A3: a systematic review and meta-analysis. Injury. 2022;53(3):1149-59.
35. Lewis SR, Macey R, Gill JR, Parker MJ, Griffin XL. Cephalomedullary nails versus extramedullary implants for extracapsular hip fractures in older adults. Cochrane Database Syst Rev. 2022;1:CD000093.

36. Parker MJ. Sliding hip screw versus intramedullary nail for trochanteric hip fractures; a randomised trial of 1000 patients with presentation of results related to fracture stability. Injury. 2017;48(12):2762-7.
37. Forte ML, Virnig BA, Eberly LE, Swiontkowski MF, Feldman R, Bhandari M, Kane RL. Provider factors associated with intramedullary nail use for intertrochanteric hip fractures. J Bone Joint Surg Am. 2010;92(5):1105-14.
38. Mellema JJ, Janssen S, Schouten T, Haverkamp D, van den Bekerom MPJ, Ring D, et al. Intramedullary nailing versus sliding hip screw for A1 and A2 trochanteric hip fractures. Bone Joint J. 2021;103-B(4):775-81.
39. Aalbers R, Roos A. Zorguitgaven, ons een zorg? Den Haag: Centraal Planbureau.; 2022.
40. Egol KA, Capriccioso CE, Konda SR, Tejwani NC, Liporace FA, Zuckerman JD, Davidovitch RI. Cost-effective trauma implant selection: AAOS exhibit selection. J Bone Joint Surg Am. 2014;96(22):e189.
41. Loggers SAI, Willems HC, Van Balen R, Gosens T, Polinder S, Ponsen KJ, et al. Evaluation of Quality of Life After Nonoperative or Operative Management of Proximal Femoral Fractures in Frail Institutionalized Patients: The FRAIL-HIP Study. JAMA Surg. 2022;157(5):424-34.
42. Loggers SAI, Geraerds A, Joosse P, Willems HC, Gosens T, Van Balen R, et al. Nonoperative versus operative management of frail institutionalized older patients with a proximal femoral fracture: a cost-utility analysis alongside a multicenter prospective cohort study. Osteoporos Int. 2023;34(3):515-25.
43. Loggers SAI, Van Balen R, Willems HC, Gosens T, Polinder S, Ponsen KJ, et al. The Quality of Dying in Frail Institutionalized Older Patients After Nonoperative and Operative Management of a Proximal Femoral Fracture: An In-Depth Analysis. Am J Hosp Palliat Care. 2023:10499091231180556.
44. Van Bremen HE, Seppala LJ, Hegeman JH, van der Velde N, Willems HC, Dutch Hip Fracture Audit G. Characteristics and Outcomes of Nonoperatively Managed Patients With Hip Fracture Using the Dutch Hip Fracture Audit. J Orthop Trauma. 2024;38(5):265-72.
45. Nijdam TMP, Laane D, Schiepers TEE, Smeeing DPJ, Kempen DHR, Willems HC, van der Velde D. The goals of care in acute setting for geriatric patients in case of a hip fracture. Eur J Trauma Emerg Surg. 2023.
46. Nijdam TMP, Laane DWPM, Spierings JF, Schuijt HJ, Smeeing DPJ, van der Velde D. Proxy-reported experiences of palliative, non-operative management of geriatric patients after a hip fracture: a qualitative study. BMJ Open. 2022;12(8):e063007.
47. Nijdam TMP, Laane DWPM, Schiepers TEE, Smeeing DPJ, Kempen DHR, Willems HC, van der Velde D. The goals of care in acute setting for geriatric patients in case of a hip fracture. Eur J Trauma Emerg Surg. 2023;49(4):1835-44.
48. Mitchell SL, Palmer JA, Volandes AE, Hanson LC, Habtemariam D, Shaffer ML. Level of Care Preferences Among Nursing Home Residents With Advanced Dementia. J Pain Symptom Manage. 2017;54(3):340-5.
49. Wijnen HH, Schmitz PP, Es-Safraouy H, Roovers LA, Taekema DG, Van Susante JLC. Nonoperative management of hip fractures in very frail elderly patients may lead to a predictable short survival as part of advance care planning. Acta Orthop. 2021;92(6):728-32.
50. Kata A, Cenzer I, Sudore RL, Covinsky KE, Tang VL. Advance Care Planning Prior to Death in Older Adults with Hip Fracture. J Gen Intern Med. 2020;35(7):1946-53.
51. Tanuseputro P, Hsu A, Chalifoux M, Talarico R, Kobewka D, Scott M, et al. Do-Not-Resuscitate and Do-Not-Hospitalize Orders in Nursing Homes: Who Gets Them and Do They Make a Difference? J Am Med Dir Assoc. 2019;20(9):1169-74 e1.

52. Nederlandse Vereniging voor Klinische Geriatrie (NVKG). Behandeling kwetsbare ouderen bij chirurgie (Surgical treatment of frail elderly patients): Federatie Medisch Specialisten; 2016 [Available from: https://richtlijnendatabase.nl/richtlijn/behandeling_kwetsbare_ouderen_bij_chirurgie/generieke_zorgpad.html.
53. O'Neill F, Carter E, Pink N, Smith I. Routine preoperative tests for elective surgery: summary of updated NICE guidance. BMJ. 2016;354:i3292.
54. Loggers SAI, Giannakopoulos GF, Vandewalle E, Erwteman M, Berger F, Zuidema WP. Preoperative chest radiographs in hip fracture patients: is there any additional value? Eur J Orthop Surg Traumatol. 2017;27(7):953-9.
55. Boulet J, Belzile EL, Dion N, Morency C, Berube M, Tremblay A, Pelet S. Palliative care is a viable option for frail elderly patients with neurocognitive disorders admitted for hip fractures. BMC Musculoskelet Disord. 2024;25(1):635.
56. Marti-Garcia C, Fernandez-Ferez A, Fernandez-Sola C, Perez-Rodriguez R, Esteban-Burgos AA, Hernandez-Padilla JM, Granero-Molina J. Patients' experiences and perceptions of dignity in end-of-life care in emergency departments: A qualitative study. J Adv Nurs. 2023;79(1):269-80.
57. Rogmark C, Lynoe N. How to play the final chess match-or at least lose with dignity. Acta Orthop. 2021;92(6):633-4.
58. NVT. Niet operatieve behandeling bij heupfracturen; Samen beslissen over opereren of niet opereren bij kwetsbare ouderen met een heupfractuur: Nederlandse Vereniging voor Traumachirurgie; 2024 [Available from: https://www.trauma.nl/richtlijn/niet-operatieve-behandeling-bij-heupfracturen/.
59. Loggers SAI, Van Balen R, Steens J, Willems HC, Riezebos P, Wagenaar-Huisman A, et al. Treatment satisfaction with nonoperative management of suspected hip fractures in nursing home patients with a do not hospitalize directive; a prospective case series (NONU-HIP). Under submission. 2024.
60. Loggers SAI, Van Balen R, Willems HC, Gosens T, Polinder S, Ponsen KJ, et al. The quality of dying in frail institutionalized older patients after nonoperative and operative management of a proximal femoral fracture: an in-depth analysis of a prospective multicenter cohort study. Submitted.
61. Giron-Arango L, Peng PWH, Chin KJ, Brull R, Perlas A. Pericapsular Nerve Group (PENG) Block for Hip Fracture. Reg Anesth Pain Med. 2018;43(8):859-63.
62. Van der Velden MWA, Faes MC, de Loos PJF, Berende N, van den Beuken-van Everdingen MHJ, Suman A. [Palliative treatment of proximal femur fracture: results of intrathecal phenol (SPING block) in frail older patients]
Palliatieve pijnbehandeling bij proximale femurfractuur. Ned Tijdschr Geneeskd. 2023;168.
63. ZonMw. De PENG-studie: evaluatie en implementatie van pijnstilling middels PEricapsular Nerve Group blokkade (PENG) in de palliatieve zorg voor kwetsbare ouderen met een heupfractuur: ZonMw; 2023 [Available from: https://projecten.zonmw.nl/nl/project/de-peng-studie-evaluatie-en-implementatie-van-pijnstilling-middels-pericapsular-nerve-group.
64. Van de Ree CL, Gosens T, Van der Veen AH, Oosterbos CJ, Heymans MW, De Jongh MA. Development and validation of the Brabant Hip Fracture Score for 30-day and 1-year mortality. Hip Int. 2020;30(3):354-62.
65. Nijmeijer WS, Folbert EC, Vermeer M, Slaets JP, Hegeman JH. Prediction of early mortality following hip fracture surgery in frail elderly: The Almelo Hip Fracture Score (AHFS). Injury. 2016;47(10):2138-43.
66. Rushton PR, Reed MR, Pratt RK. Independent validation of the Nottingham Hip Fracture Score and identification of regional variation in patient risk within England. Bone Joint J. 2015;97-B(1):100-3.

67. Karres J, Zwiers R, Eerenberg JP, Vrouenraets BC, Kerkhoffs G. Mortality Prediction in Hip Fracture Patients: Physician Assessment Versus Prognostic Models. J Orthop Trauma. 2022;36(11):585-92.



12

Summary and Conclusions in English and Dutch

Summary

Chapter 1 provides a general introduction to the topic. It starts with a brief historical overview of hip fracture care and describes that hip fractures are one of the most prevalent injuries and reasons for morbidity and mortality in the elderly population. The most common subtypes are femoral neck fractures and trochanteric fractures. For the latter there is an ongoing discussion on extramedullary versus intramedullary fixation, especially for the stable intertrochanteric fractures, AO 31-A1 subtype. A recent development in hip fracture care is nonoperative treatment of very frail older adults with a hip fracture. While this seems a promising treatment option for hip fractures in the final phase of life, there are still many unknowns around decision-making, patient selection, and treatment. After discussion of these topics, this chapter also provides an overview of this thesis.

Part I focusses on the epidemiology and societal burden of hip fractures in the Netherlands. Due to an aging population the number of hip fractures is increasing. Therefore, **Chapter 2** evaluated population-based trends in incidence rate and societal burden due to femoral neck and trochanteric hip fractures between 2000 and 2019 in the Netherlands. A total of 357,073 patients were included over the twenty year period. The overall incidence rate increased by 22% from 16.4 to 27.1/100,000 person years during the 20-year study period. However, age-specific incidence rates in older patients ≥65 years decreased by 16% (from 649.1 to 547.6/100,000 person years). Hospital length of stay (HLOS) decreased in all age groups, both hip fracture subtypes, and sexes from a mean of 18.5 days to 7.2 days. Due to increasing crude numbers the annual cumulative costs reached and all time high amount of €425M. Although incidence rate in the elderly population is decreasing and HLOS is at an all-time low, the burden of medical costs and crude numbers of proximal femoral fractures is still rising in our aging population.

In **Chapter 3** population-based trends in incidence and societal burden were analyzed for a less common and less studied subtype of hip fracture, the subtrochanteric fracture. This analysis was again performed on a nationwide level between 2000 and 2019. A total of 14,399 patients sustained a subtrochanteric fracture in the 20-year study period and incidence rates dropped by 15.5% from 4.5 to 3.8 per 100,000 person years (py). Subtrochanteric fractures were associated with total annual costs of €15.5M. Increasing incidence rates and a bimodal age distribution, described in previous studies from other European countries, were not found in the Dutch population.

Part II focusses on the comparison of extramedullary versus intramedullary fixation of trochanteric femoral fractures. A systematic review and meta-analysis, described in **Chapter 4**, compared extramedullary fixation and intramedullary fixation for stable

two-part trochanteric femoral fractures (AO type 31-A1) with regards to functional outcomes, complications, and surgical outcomes. The review included comparative studies using only device types currently in use. Five RCTs (397 patients) and 14 observational studies (21,396 patients) were included. No significant differences in functional outcomes, complications, or surgical outcomes/operation characteristics were found between the extramedullary- and intramedullary fixation groups, except for a small difference in duration of surgery (mean difference 14.1 min, 95% CI 5.76-22.33) and intraoperative blood loss (mean difference 92.30 mL, 95% CI 13.49-171.12), favoring intramedullary fixation. This lead to the conclusion that, based on current literature there are no meaningful differences in complications, surgical, or functional outcomes between extramedullary and intramedullary fixation of stable two-part trochanteric femoral fractures. And both treatment options result in good outcomes. This implicates that, costs and cost-effectiveness should be taken into account when considering implants or comparing fixation methods in future research.

In **Chapter 5** a similar comparison was made between extramedullary versus intramedullary fixation of unstable (AO type A2) trochanteric femoral fractures. This systematic review and meta-analysis also only included comparative studies on current devices. Fourteen RCTs (2,039 patients) and 13 observational studies (22,123 patients) were included. The meta-analysis found statistically superior results for Harris Hip Score (mean difference 4.09, 95% CI 0.91-7.26), Parker mobility score (mean difference -0.67 95% CI -1.2 to -0.17), time to full-weight bearing (mean difference 1.14 weeks 95% CI 0.92-1.35), superficial infection, non-union, fixation failure, leg shortening, time to radiological bone healing, and several operation characteristics. While these outcomes point towards superiority for intramedullary fixation of type A2 fractures, most differences were below clinically important difference levels and complications were rare and heterogenous for both device types. Therefore, complete superiority of intramedullary fixation remains questionable. Additionally, data on patient reported outcomes or costs remained sparse.

Chapter 6 investigated outcomes of extramedullary versus intramedullary fixation of stable (AO type A1) trochanteric femoral fractures in the Netherlands, based on outcomes from the Dutch Hip Fracture Audit indicator group. This is a subgroup of six high volume hospitals within the national quality registry (the Dutch Hip Fracture Audit), dedicated to completeness and quality of data collection. A total of 836 patients were included; 138 (16%) were treated with extramedullary fixation and 698 (84%) with intramedullary fixation. While the extramedullary fixation group showed better mobility at discharge, no meaningful differences between groups were found after three-months in return to pre-trauma mobility, disability in activities of daily life, or return to pre-trauma living status. Similar results were found in a subgroup analysis of

only community dwelling patients. Despite little differences in outcomes and extramedullary fixation being the treatment option of first choice by the Dutch Hip fracture guideline, intramedullary fixation was used in the vast majority of patients.

Part III focusses on treatment decisions on operative versus nonoperative care for hip fractures in frail older adults. For frail institutionalized or intensive ADL-care dependent hip fracture patients who opt for nonoperative management (NOM), the additional treatment benefits of hospital admission and in-hospital diagnostics can be questionable. **Chapter 7** aimed to describe and compare treatment satisfaction and quality of dying, for patients who were treated nonoperatively after hospitalization and patients who refrained from hospitalization after a (suspected) hip fracture. It included data from two previous cohorts of frail institutionalized hip fracture patients. The first cohort opted for NOM during shared decision making (SDM) after admission and diagnostics at the hospital. The second directly started supportive care in their own nursing home after a suspected hip fracture. Twenty non-hospitalized and 88 hospitalized patients were included. Median overall treatment satisfaction by proxies was high for both non-hospitalized (Numeric rating scale 0-10 (NRS): 9) and hospitalized patients (NRS: 8). Quality of dying was rated higher in the non-hospitalized group (QODD 8.3 versus 7.0). Opting for non-hospitalization after a pre-recorded do-not-hospitalize directive or shared decision making after a suspected hip fracture may have benefits for quality of dying in selected very frail older adults when compared with patients who were hospitalized for diagnostics and in-hospital shared decision making. Hospitalization could be prevented for those patients who would prefer familiar care focused on comfort and quality of life in their final moments.

Chapter 8 evaluated (preoperative and geriatric) diagnostic testing and its consequences in operatively and nonoperatively treated frail older adults with an acute hip fracture. Data on clinical consultations, radiological, laboratory, and microbiological diagnostics were extracted from the medical files of all patients included in the FRAIL-HIP study. A total of 172 patients (88 nonoperative and 84 operative) were included. A large number and variety of diagnostics was performed in this patient population. In the whole group 156 (91%) underwent laboratory diagnostics, 126 (73%) chest X-rays, and 23 (13%) CT-scans. Abnormal test results in laboratory diagnostics or thoracic X-rays were found for almost all patients and, in majority, appeared to have no direct clinical consequences or influence on the treatment choice for the hip fracture. To prevent unnecessary diagnostics, further prospective research needs to evaluate the clinical consequences and added value of the separate elements of preoperative diagnostic testing and geriatric assessment in very frail hip fracture patients around (nonoperative) treatment decisions.

Recent research has highlighted NOM as a viable alternative for frail older adults with hip fractures in the final phase of life. **Chapter 9** describes a study protocol aimed to guide Dutch physicians and hospitals nationwide in a standardized implementation of shared decision making (SDM) regarding surgery or NOM in selected frail older adults with a hip fracture. The two-year implementation study is being conducted in four phases. In phases 1 and 2, barriers and facilitators for implementation were identified and an implementation protocol, educational materials, and patient information was developed. Phase 3 involved an implementation pilot in 14 hospitals across the Netherlands. The protocol and educational material were improved based on healthcare provider and patient experiences gathered through interviews. Currently Phase 4 focusses on upscaling to nationwide implementation and measuring the effect of the implementation on NOM rate using data from the Dutch Hip Fracture Audit.

As part of this implementation effort, interviews were conducted with patients and/or proxies about their treatment satisfaction and their views on the decision process. In **Chapter 10** qualitative data from a questionnaire on satisfaction and elements of the decision process was combined with qualitative data from the interviews. This study showed that while most proxies were satisfied with the chosen treatment, several areas were identified that are important for a high quality decision process. These included completeness of information, adequate conversation techniques, logistical considerations, and 'sharedness' of the decision process. It is important to not only provide patients with options but to also explain them, listen to what is important for the patient, and integrate this information in the shared decision making. To make this possible, adequate time and preparation for both the healthcare provider and the patient and their loved ones is important.

Finally, **Chapter 11** contains the general discussion, including future perspectives, of this thesis.

Samenvatting

Hoofdstuk 1 is een algemene introductie van het onderwerp. Het begint met een korte beschrijving van de geschiedenis van behandeling van de heupfractuur. Op dit moment zijn heupfracturen een van de meest voorkomende letsels en een belangrijke oorzaak zijn van morbiditeit en mortaliteit bij ouderen wereldwijd. De meest voorkomende subtypen zijn de femurhalsfracturen (ook collumfracturen genoemd) en trochantere fracturen. Voor het laatste subtype is er discussie over extramedullaire versus intramedullaire fixatie, met name bij het stabiele intertochantere AO 31-A1 subtype. Een recente ontwikkeling in de zorg rondom heupfracturen is de niet-operatieve behandeling bij zeer kwetsbare oudere patiënten. Hoewel dit een veelbelovende optie lijkt in de laatste levensfase, bestaan er nog veel onzekerheden over besluitvorming, patiëntselectie en behandeling. Dit hoofdstuk biedt vervolgens ook een overzicht van de opbouw van dit proefschrift.

Deel 1 richt zich op de epidemiologie en maatschappelijke last van heupfracturen in Nederland.

Door de vergrijzing neemt het aantal heupfracturen toe. In **Hoofdstuk 2** werden trends in incidentie en maatschappelijke impact van femurhals- en trochantere fracturen tussen 2000 en 2019 in Nederland geanalyseerd. In totaal werden 357.073 patiënten geïncludeerd. De incidentie steeg met 22%, van 16,4 naar 27,1/100.000 persoonsjaren, hoewel de leeftijdsspecifieke incidentie bij ouderen boven de 65 jaar met 16% afnam. Bij mannen ouder dan 90 jaar overtrof de incidentie die van vrouwen. De gemiddelde opnameduur daalde van 18,5 naar 7,2 dagen. De jaarlijkse kosten bereikten een piek van €425 miljoen. Hoewel de incidentie in de oudere populatie afneemt en de gemiddelde opnameduur een historisch dieptepunt heeft bereikt, blijft de last van medische kosten en het absolute aantal heupfracturen stijgen in onze vergrijzende populatie.

Hoofdstuk 3 beschreef populatietrends in incidentie en maatschappelijke belasting voor een minder vaak voorkomende en minder onderzochte subtype heupfractuur, de subtrochantere fractuur. Deze analyse werd op nationaal niveau uitgevoerd tussen 2000 en 2019. In totaal kregen 14.399 patiënten een subtrochantere fractuur in de 20-jarige studieperiode, waarbij de incidentiecijfers met 15,5% daalden van 4,5 naar 3,8 per 100.000 persoonsjaren (py). Subtrochantere fracturen waren geassocieerd met totale jaarlijkse kosten van €15,5 miljoen. Een, in eerdere studies in andere Europese landen beschreven, toenemende incidentie en bimodale leeftijdsverdeling werden niet waargenomen in de Nederlandse populatie.

Deel II richt zich op de vergelijking tussen extramedullaire en intramedullaire fixatie van trochantere femurfracturen. Een systematische review en meta-analyse, beschreven in **Hoofdstuk 4**, vergeleek extramedullaire en intramedullaire fixatie voor stabiele trochantere femurfracturen (AO type 31-A1) met betrekking tot functionele uitkomsten, complicaties en chirurgische uitkomsten. Het review omvatte alleen vergelijkende studies die gebruik maakten van huidige implantaten. Vijf RCT's (397 patiënten) en 14 observationele studies (21.396 patiënten) werden geïncludeerd. Er werden geen significante verschillen gevonden in functionele uitkomsten, complicaties of chirurgische uitkomsten tussen extramedullaire en intramedullaire fixatie, behalve kleine verschillen in operatieduur (gemiddeld verschil 14,1 minuten, CI 5,76-22,33) en intra-operatief bloedverlies (gemiddeld verschil 92,30 ml, CI 13,49-171,12), beide in het voordeel van intramedullaire fixatie. Hieruit werd geconcludeerd dat, op basis van de huidige literatuur, er geen belangrijke verschillen zijn in complicaties, chirurgische of functionele uitkomsten tussen extramedullaire en intramedullaire fixatie van stabiele trochantere femurfracturen. Beide behandelopties leveren goede resultaten op. Dit impliceert dat kosten(effectiviteit) een belangrijke factor zouden moeten zijn bij de keuze voor implantaten of bij vergelijkend onderzoek naar fixatiemethoden in de toekomst.

In **Hoofdstuk 5** werd een soortgelijke vergelijking gemaakt tussen extramedullaire en intramedullaire fixatie van instabiele (AO type A2) trochantere femurfracturen. Veertien RCT's (2.039 patiënten) en 13 observationele studies (22.123 patiënten) werden geïncludeerd. De meta-analyse vond statistisch superieure resultaten voor de Harris Hip Score (gemiddeld verschil 4,09, 95%CI 0,91-7,26), Parker mobiliteitsscore (gemiddeld verschil -0,67, 95%CI -1,2 tot -0,17), tijd tot volledige belasting (gemiddeld verschil 1,14 weken, 95%CI 0,92-1,35), en meerdere andere parameters in het voordeel van intramedullaire fixatie. Hoewel deze resultaten wijzen op een mogelijke superioriteit van intramedullaire fixatie bij type A2 fracturen, waren de gevonden verschillen meestal niet klinisch relevant, was data vaak heterogeen en waren complicaties zeldzaam voor beide fixatiemethoden. Complete superioriteit van intramedullaire fixatie blijft daarom discutabel. Tevens blijven gegevens over patiënt-gerapporteerde uitkomsten of kosten schaars.

Hoofdstuk 6 onderzocht de uitkomsten van extramedullaire versus intramedullaire fixatie van stabiele (AO type A1) trochantere femurfracturen in Nederland, gebaseerd op gegevens uit de Dutch Hip Fracture Audit (DHFA) indicatorgroep. Dit is een subgroep van zes hoogvolume ziekenhuizen binnen het landelijke kwaliteitsregister, gericht op de volledigheid en kwaliteit van gegevensverzameling in de DHFA. In totaal werden 836 patiënten geïncludeerd; 138 (16%) werden behandeld met extramedullaire fixatie en 698 (84%) met intramedullaire fixatie. Hoewel de groep met extramedullaire fixatie betere mobiliteit bij ontslag liet zien, werden na drie maanden geen significante

verschillen gevonden in terugkeer naar pretrauma-mobiliteit, beperkingen in dagelijkse activiteiten of woonsituatie. Ook een subgroep analyse bij thuiswonende patiënten vond vergelijkbare uitkomsten na drie maanden. Ondanks de minimale verschillen en het feit dat extramedullaire fixatie de voorkeursbehandeling is volgens de Nederlandse richtlijn, wordt intramedullaire fixatie in de meerderheid van de gevallen toegepast in de onderzochte ziekenhuizen.

Deel III richt zich op besluitvorming tussen operatief versus niet-operatief management bij kwetsbare ouderen met een heupfractuur. Voor kwetsbare geïnstitutionaliseerde patiënten die kiezen voor niet-operatieve behandeling (NOM), kan de toegevoegde waarde van ziekenhuisopname en -diagnostiek soms twijfelachtig zijn. **Hoofdstuk 7** had als doel behandeltevredenheid en kwaliteit van sterven te beschrijven en te vergelijken bij patiënten die niet-operatief werden behandeld na besluitvorming in het ziekenhuis en patiënten die afzagen van ziekenhuisopname na een (vermoedelijke) heupfractuur. Hiervoor werden gegevens uit twee eerdere cohorten van kwetsbare geïnstitutionaliseerde heupfractuurpatiënten gebruikt. Het eerste cohort koos voor NOM tijdens gezamenlijke besluitvorming, na opname en diagnostiek in het ziekenhuis. Het tweede cohort startte direct met ondersteunende zorg in hun eigen verpleeghuis na een vermoedelijke heupfractuur. In totaal werden 20 niet-gehospitaliseerde en 88 gehospitaliseerde patiënten geïncludeerd. De algemene behandeltevredenheid, gemeten bij proxies/naasten was hoog voor beide groepen: niet-gehospitaliseerde patiënten scoorden een mediane behandeltevredenheid van 9 op een schaal van 10 en gehospitaliseerde patiënten een 8. De kwaliteit van sterven werd hoger gewaardeerd in de niet-gehospitaliseerde groep (QODD 8,3 versus 7,0). Het vermijden van ziekenhuisopname na een vooraf vastgelegde 'niet-insturen' afspraak of gezamenlijke besluitvorming na een vermoedelijke heupfractuur kan voordelen hebben voor de kwaliteit van sterven bij geselecteerde zeer kwetsbare ouderen vergeleken met patiënten die in het ziekenhuis werden opgenomen voor diagnostiek en besluitvorming. Voor patiënten die de voorkeur geven aan vertrouwde zorg gericht op comfort en kwaliteit van leven in hun laatste momenten kan worden besloten om af te zien van ziekenhuisopname.

Hoofdstuk 8 evalueerde preoperatieve en geriatrische diagnostische tests en de gevolgen daarvan bij kwetsbare ouderen met een acute heupfractuur die operatief of niet-operatief werden behandeld. Gegevens over klinische consulten en radiologische, laboratorium- en microbiologische diagnostiek werden verzameld uit de medische dossiers van alle patiënten die waren opgenomen in de FRAIL-HIP-studie. In totaal werden 172 patiënten geïncludeerd (88 niet-operatief en 84 operatief). Er werden veel en diverse diagnostische tests uitgevoerd bij deze patiëntenpopulatie. Bij de gehele groep ondergingen 156 patiënten (91%) laboratoriumdiagnostiek, 126 (73%) een thoraxfoto en 23 (13%) een CT-scan. Abnormale testresultaten kwamen bij bijna alle patiënten voor,

en hadden vaak geen directe klinische consequenties of invloed op de behandelkeuze voor de heupfractuur. Om onnodige diagnostiek te voorkomen, is verder prospectief onderzoek nodig om de klinische gevolgen en toegevoegde waarde van afzonderlijke (preoperatieve) diagnostische tests bij kwetsbare heupfractuurpatiënten te beoordelen.

Recent onderzoek heeft aangetoond dat niet-operatief management een goed alternatief kan zijn voor kwetsbare ouderen met heupfracturen in de laatste levensfase. Daarom beschrijft **Hoofdstuk 9** een studieprotocol gericht op het begeleiden van artsen en ziekenhuizen in Nederland bij de landelijke implementatie van gestandaardiseerd samen beslissen over operatie of niet-operatief management bij deze selecte groep kwetsbare ouderen. Deze tweejarige implementatiestudie wordt uitgevoerd in vier fasen. In de eerste twee fasen werden barrières en facilitators voor implementatie geïdentificeerd en werden een implementatieprotocol, educatief materiaal en patiënteninformatie ontwikkeld. Fase 3 omvatte een implementatiepilot in 14 ziekenhuizen in Nederland. Het protocol en het educatief materiaal werden verbeterd op basis van ervaringen van zorgverleners en patiënten, verzameld via interviews. Fase 4 richt zich op landelijke opschaling en het meten van het effect van de implementatie op het percentage niet operatief behandelde patiënten.

Als onderdeel van dit implementatieproces werden interviews gehouden met patiënten en/of hun vertegenwoordigers over hun tevredenheid met de behandeling en hun visie op het besluitvormingsproces. In **Hoofdstuk 10** werden kwalitatieve gegevens uit een vragenlijst over tevredenheid en het besluitvormingsproces gecombineerd met kwalitatieve gegevens uit de interviews. Deze studie, waarbij 80 naasten werden geïncludeerd, liet zien dat, hoewel de meeste vertegenwoordigers tevreden waren met de gekozen behandeling, er verschillende aspecten zijn die belangrijk zijn voor een hoogwaardig besluitvormingsproces. Dit waren onder andere de volledigheid van de informatie, geschikte gesprekstechnieken, logistieke overwegingen en de 'gezamelijkheid' van het besluitvormingsproces. Het is essentieel om patiënten niet alleen opties te bieden, maar deze ook toe te lichten, te luisteren naar wat belangrijk is voor de patiënt en deze informatie te integreren in de gezamenlijke besluitvorming. Om dit mogelijk te maken, zijn voldoende tijd en voorbereiding belangrijk, zowel voor de zorgverlener als voor de patiënt en hun naasten.

Tot slot worden in **Hoofdstuk 11** de algemene discussie en toekomstperspectieven besproken.

APPENDIX



Contributing authors
List of publications
PhD portfolio
Dankwoord
About the author

Contributing Authors

Romke Van Balen
Department of Public Public Health and Primary Care, Leiden University Medical Center, Leiden, The Netherlands

Johannes M. Van Delden
Department of Bioethics and Health Humanities, Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht, The Netherlands

Taco Gosens
Department of Orthopedics, Elisabeth Hospital (ETZ), Tilburg, The Netherlands

Dennis Den Hartog
Trauma Research Unit Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands

Johannes H. Hegeman
Department of Trauma Surgery, Ziekenhuisgroep Twente, Almelo, The Netherlands

Pieter Joosse
Department of Surgery, Noordwest Ziekenhuisgroep, Alkmaar, The Netherlands

Esther M.M. Van Lieshout
Trauma Research Unit Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands

Sverre A.I. Loggers
Department of Surgery, Noordwest Ziekenhuisgroep, Alkmaar, The Netherlands

Thomas M.P. Nijdam
Department of Trauma surgery, St. Antonius Hospital, Utrecht, The Netherlands

Leendert H.T. Nugteren
Trauma Research Unit Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands

Paulieke C. Oosterwijk
Department of Trauma surgery, St. Antonius Hospital, Utrecht, The Netherlands

Ruth E. Pel-Littel
Vilans, Center of Expertise for Long-Term Care, Utrecht, The Netherlands

Martien J. M. Panneman
VeiligheidNL (Consumer Safety Institute), Amsterdam, The Netherlands

A. Cornelis Plaisier
Trauma Research Unit Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands

Suzanne Polinder
Department of Public Health, Erasmus MC, University Medical Center Rotterdam, Rotterdam, the Netherlands

Henk Jan Schuijt
Department of Trauma surgery, St. Antonius Hospital, Utrecht, The Netherlands

Jeroen Steens
Department of Surgery, Dijklander Hospital, Hoorn, The Netherlands

Detlef Van der Velde
Department of Trauma surgery, St. Antonius Hospital, Utrecht, The Netherlands

Michiel H.J. Verhofstad
Trauma Research Unit Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands

Hugo H. Wijnen
Department of Clinical Geriatrics, Rijnstate Hospital, Arnhem, The Netherlands

Hanna C. Willems
Department of Internal Medicine and Geriatrics, Amsterdam University Medical Center, Amsterdam, The Netherlands

Rutger G. Zuurmond
Department of Orthopedics, Isala Hospital, Zwolle, The Netherlands

Participating collaborator groups

The FRAIL-HIP Study Group also includes the following collaborators:
Lisanne Balemans, Frank W. Bloemers, Janneke Bos, Bart J. Burger, Judella O. Daal, Annemarieke De Jonghe, Matthea Dijkshoorn, Michael J.R. Edwards, Ellen A. Elbrecht, Miriam, C. Faes, Elvira R. Flikweert, Ellis C. Folbert, Robert D.A. Gaasbeek, Olivia C. Geraghty, J. Carel Goslings, Mischa M. Hindriks, Micha Holla, André Janse, Joris A. Jansen, Simone J.M. Jong, Paul J.C. Kapitein, Ydo V. Kleinlugtenbelt, Barbara E. Kreis, Rover Krips, Koen W.W. Lansink, Michiel Leijnen, Pieter H.W. Lubbert, Francesco U.S. Mattace-Raso, Marieke C. Meinardi, Joris J. Mellema, Roland M.H.G. Mollen, Majon Muller, Joost C. Peerbooms, Kornelis J. Ponsen, Rudolf W. Poolman, Miruna Popescu, Albert F. Pull ter Gunne, Bas J. Punt, Gert R. Roukema, Hilde I.F. Roijen, Jeanine Schukking, Josje Snoek, Charles T. Stevens, Dieneke Van Asselt, Esther Van de Glind, Cornelis L.P. Van de Ree, Alexander H. Van der Veen, Detlef Van der Velde, Bart A. Van Dijkman, Sven H. Van Helden, Paul J. Van Koperen, Job L.C. Van Susante, Romuald Van Velde, M. Remmelt Veen, Ralf W. Vingerhoets, Dagmar I. Vos, Judith Wilmer, Jasper Winkelhagen, Johan F.H. Wold, Robbert A. Zandbergen, G. (Bert) Ziere

The NOM-Implementation Study Group also includes the following collaborators:
Eelke Bosma, Janneke H. Duits, Henk A. Formijne Jonkers, Justus Jansen, Joris A. Jansen, Olivia C. Geraghty, Reinier De Groot, Johannes H. Hegeman, Diederik H.R. Kempen, Aafke M. Van der Knaap, Nick C. Leegwater, Michiel Leijnen, Huub A.A.M. Maas, Nikki M.F. Noorda, Marieke Peters-Kop, Albert F. Pull ter Gunne, Tom M. Van Raaij, E. Marlies Regtuijt, Gert R. Roukema, Niek C. Schepel, Dawi Van der Stap, William A.H. Van der Stappen, Evelien Sohl, Matthijs P. Somford, Jeroen Steens, Erik Tanis, Alexander H. Van der Veen, Vivianne Vis, Kerst De Vries, Olivier Wijers, Judith A.M. Wilmer, Jasper Winkelhagen, Robbert A. Zandbergen, Elgun V.C.M. Zeegers

The NONU Study Group also includes the following collaborators:
Pamela Riezebos and Anja Wagenaar-Huisman

The STABLE-HIP Study Group also includes the following collaborators:
Taco Gosens, Johannes H. Hegeman, Pieter Joosse, Suzanne Polinder; Rudolf W. Poolman, Hanna C. Willems, and Rutger G. Zuurmond

List of publications

In this thesis:

Trends in incidence, health care consumption, and costs for proximal femoral fractures in the Netherlands between 2000 and 2019: a nationwide study.
Zeelenberg ML, Den Hartog D, Panneman MJM, Polinder S, Verhofstad MHJ, Van Lieshout EMM. Osteoporos Int. 2023 Aug;34(8):1389-1399. doi: 10.1007/s00198-023-06774-y. Epub 2023 Apr 29. PMID: 37119329

Trends in incidence, health care use and costs for subtrochanteric femur fractures in the Netherlands 2000-2019.
Zeelenberg ML, Van Lieshout EMM, Polinder S, Panneman MJM, Verhofstad MHJ, Den Hartog D. Injury. 2024 Apr;55(4):111461. doi: 10.1016/j.injury.2024.111461. Epub 2024 Feb 28. PMID: 38457999.

Extramedullary versus intramedullary fixation of stable trochanteric femoral fractures: a systematic review and meta-analysis.
Zeelenberg ML[*], Nugteren LHT, Plaisier AC[*], Loggers SAI, Joosse P, Den Hartog D, Verhofstad MHJ, van Lieshout EMM; STABLE-HIP Study Group. Arch Orthop Trauma Surg. 2023 Aug;143(8):5065-5083. doi: 10.1007/s00402-023-04902-1. Epub 2023 May 2. PMID: 37129692
*Authors contributed equally

Extramedullary versus intramedullary fixation of unstable trochanteric femoral fractures (AO type 31-A2): a systematic review and meta-analysis.
Zeelenberg ML[*], Plaisier AC[*], Nugteren LHT, Loggers SAI, Joosse P, Verhofstad MHJ, Den Hartog D, Van Lieshout EMM; STABLE-HIP Study Group. Arch Orthop Trauma Surg. 2024 Mar;144(3):1189-1209. doi: 10.1007/s00402-023-05138-9. Epub 2024 Jan 4. PMID: 38175213
*Authors contributed equally

Mobility and living status at discharge and after three-months for extramedullary versus intramedullary fixation of AO type 31-A1 trochanteric fractures; an analysis of Dutch Hip Fracture Audit data
Zeelenberg ML, Van Lieshout EMM, Gosens T, Hegeman JH, Den Hartog D, Verhofstad MHJ, Stable-HIP group, Dutch Hip Fracture Audit indicator Taskforce. Eur J Trauma Emerg Surg. 2025 Jan 10;51(1):6. doi: 10.1007/s00068-024-02749-8. PMID: 39794605; PMCID: PMC11723844.

Satisfaction and quality of dying with nonoperative end-of-life care for hospitalized and non-hospitalized frail older patients with (suspected) hip fractures; A combined cohort study
Zeelenberg ML, Loggers SAI, Joosse P, Van Lieshout EMM, Gosens T, FRAIL-HIP study group, NONU-HIP study group. *Acta Orthop*. 2025 Feb 24;96:167-173. doi:10.2340/17453674.2025.42998. PMID: 39993173 PMCID: PMC11849162

The value of preoperative diagnostic testing and geriatric assessment in frail institutionalized elderly with a hip fracture; a secondary analysis of the FRAIL-HIP study.
Zeelenberg ML, Den Hartog D, Van Lieshout EMM, Wijnen HH, Willems HC, Gosens T, Steens J, Van Balen R, Zuurmond RG, Loggers SAI, Joosse P, Verhofstad MHJ; FRAIL-HIP Investigator Group. Eur Geriatr Med. 2024 Jun;15(3):753-763. doi: 10.1007/s41999-024-00945-8. Epub 2024 Feb 28. PMID: 38418712

Shared decision-making for non-operative management versus operative management of hip fractures in selected frail older adults with a limited life expectancy: a protocol for a nationwide implementation study.
Zeelenberg ML, Oosterwijk PC, Willems HC, Gosens T, Den Hartog D, Joosse P, Loggers SAI, Nijdam TM, Pel-Littel RE, Polinder S, Schuijt HJ, Wijnen HH, Van der Velde D, Van Lieshout EMM, Verhofstad MHJ; NOM-Implementation study group. BMJ Open. 2024 Apr 17;14(4):e083429. doi: 10.1136/bmjopen-2023-083429. PMID: 38631829

Patient and proxy satisfaction regarding Shared Decision Making for operative and nonoperative hip fracture treatment in frail older adults: A mixed methods study.
Oosterwijk PC*, *Zeelenberg ML**, Schuijt HJ, Van der Velde D, Den Hartog D, Gosens T, Joosse P, Loggers SAI, Nijdam TMP, Van Delden JM, Wijnen HH, Verhofstad MHJ, Van Lieshout EMM[A], Willems HC[A], NOM-Implementation study group
Under revision
*First authors contributed equally; [A]Last authors contributed equally

Other publications:

Classification, treatment, and outcome of humeral shaft fractures in polytraumatized patients (HSF-polytrauma): a retrospective case series
Van Bergen SH, Den Hartog D, *Zeelenberg ML*, Van Lieshout EMM, Verhofstad MHJ
Accepted for publication in Acta Orthopaedica Belgica 2025

The impact of upper-extremity injuries on polytrauma patients at a level 1 trauma center.
Zeelenberg ML, Den Hartog D, Halvachizadeh S, Pape HC, Verhofstad MHJ, Van Lieshout EMM. J Shoulder Elbow Surg. 2022 May;31(5):914-922. doi: 10.1016/j.jse.2021.10.005. Epub 2021 Oct 20. PMID: 34687916.

Proximal humerus fractures (PHFs): comparison of functional outcome 1 year after minimally invasive plate osteosynthesis (MIPO) versus open reduction internal fixation (ORIF).
Buchmann L, Van Lieshout EMM, *Zeelenberg ML*, Den Hartog D, Pfeifer R, Allemann F, Pape HC, Halvachizadeh S. Eur J Trauma Emerg Surg. 2022 Dec;48(6):4553-4558. doi: 10.1007/s00068-021-01733-w. Epub 2021 Jul 3. PMID: 34216222; PMCID: PMC9712325.

PhD Portfolio

Name PhD candidate:	Drs. Miliaan L. Zeelenberg
Erasmus MC department:	Trauma Research Unit Department of Surgery
PhD period:	March 2022-January 2025
Promotors:	Prof. dr. Michiel H.J. Verhofstad
	Prof. dr. Taco Gosens
Co-promotors:	Dr. Esther M.M. Van Lieshout
	Dr. Dennis Den Hartog

Summary of PhD training, activities, and teaching	Year	Workload (ECTS)
Courses during Netherlands Institute of Health Sciences (NIHES) Master 'Clinical Research'		
Erasmus Summer Program 2017 (several courses)	2017	3.5
CC01 Study design	2017	4.3
CE01 Clinical Translation of Epidemiology	2017	2.0
CE02 Clinical Epidemiology	2017	3.7
CC02 Biostatistical Methods I: Basic Principles	2017	5.7
EP03 Biostatistical Methods II: Classical Regression Models	2017	4.3
EWP02 Advance topics in Decision Making in Medicine	2018	2.4
BST01 Review of Mathematics and Introduction to Statistics	2018	1.4
EP01 Principles in Causal Inference	2018	1.4
EWP10 Advanced Clinical Trials	2018	1.9
HS11 Quality of life Measurement	2018	0.9
BST02 Intermediate course in R	2018	1.4
CE08 Repeated Measurements	2018	1.7
CE15 Advanced Decision Modelling	2018	1.0
EP16 Missing Values in Clinical Research	2018	1.7
ESP64 Erasmus Summer Lectures	2018	0.4
ESP75 Human Epigenomics	2018	0.7
EWP03 Pharmaco-epidemiology and Drug Safety	2019	1.9
SC07 Scientific Writing in English for Publication	2019	2.0
ESP01 Principles of Research in Medicine and Epidemiology	2019	0.7
EWP25 Principles of Epidemiologic Data-analysis	2019	0.7
EWP13 Advanced analysis of Prognosis Studies	2019	0.9
Other courses		
PhD introduction Session	2022	0.2
Basic course Rules and Organization for Clinical researchers (BROK)	2022	1.5

Scientific Integrity	2022	0.3
Shared-Decision Making Train-the-Trainer course	2023	1.0
Conference presentations		
Traumadagen 2022	2022	1.5
Chirurgendagen 2023	2023	2.5
Traumadagen 2023	2023	2.5
Wetenschapsdag Heelkunde Erasmus MC 2024	2024	0.5
NVT Assistentensymposium 2024	2024	0.5
Geriatriedagen 2024	2024	1.5
Symposium Dijklander ziekenhuis 'Kwetsbare ouderen met heupfractuur'	2024	0.5
European Conference for Trauma and Emergency Surgery (ECTES) Estoril	2024	1.5
Orthopedic Trauma Association (OTA) conference Montreal	2024	2.0
Conferences visited		
Traumadagen 2018	2018	1.0
Traumadagen 2021	2021	1.0
Wetenschapsdag Heelkunde Erasmus MC 2023	2023	0.25
NVT Assistenten-symposium 2023	2023	0.25
Lecturing & Supervision		
Supervising Bachelor student research Leendert H.T. Nugteren	2022	0.5
Supervising Bachelor student research A. Cornelis Plaisier	2022	0.5
Supervising Bachelor student research Noam Nieboer	2023	0.5
NOM-Implementation and/or SDM lectures in 7 hospitals	2023-2024	2.0
Lecturing: Clinical cases trauma surgery for medical master students	2022-2024	0.75
Other		
Board member PhD representative association Erasmus MC 'Promeras'	2022-2024	2.0

Dankwoord

Men zegt dat dit het best gelezen onderdeel is van een proefschrift. Dat legt natuurlijk wel enige druk op de auteur om ook hier een weloverwogen en compleet resultaat neer te zetten. In de jaren dat ik onderzoek heb gedaan zijn er veel mensen betrokken geweest, hebben mij ondersteund, advies gegeven of samengewerkt aan verschillende projecten en publicaties. Dit proefschrift is door jullie geduld, steun, vertrouwen, afleiding en enthousiasme mogelijk gemaakt. Ik wil jullie daar allemaal voor bedanken.

Geachte **professor dr. Verhofstad**, beste Michiel, uw kamerdeur stond altijd open op de momenten wanneer dat nodig was. Bedankt voor de scherpe zinsneden en analyses waarmee u altijd weer tot de kern van een probleem kwam. Na een bedachtzaam moment van stilte kwam daar altijd een antwoord waar ik weer mee verder kon. Of dit nu met een knipoog toestemming was om de halve wereld over te vliegen voor een congres, of toen de fondsen even dreigden op te drogen, de geruststelling dat er wel wat te regelen viel waardoor het onderzoek nog een paar maanden verder kon.

Geachte **professor dr. Gosens**, beste Taco, pas later sloot jij aan in mijn promotieteam maar vanaf het begin was je al betrokken bij het gros van de projecten. Bedankt voor alle adviezen en ideeën. Vanuit het Tilburgse kon ik altijd beroep doen op een extra hulplijn of nuttige contacten in binnen- en buitenland!

Geachte **dr. Van Lieshout**, beste Esther, jij hebt misschien wel de belangrijkste hand gehad in de totstandkoming van dit proefschrift, niet alleen als copromotor maar ook als directe begeleider en mentor door de jaren heen. Het is al heel wat jaar geleden dat ik via jou mijn eerste onderzoeks-stapjes zette bij de traumachirurgie. Sinds die tijd heb ik veel van jou geleerd en me verder kunnen ontwikkelen als onderzoeker, eerst als masterstudent en later als promovendus. Jouw oog voor detail is ongeëvenaard en heeft me op methodologisch en statistisch vlak ontzettend veel geleerd. Bedankt voor alle hulp, samenwerking en de kansen die je me hebt gegeven de afgelopen jaren, door jou ben ik een beter wetenschapper geworden.

Geachte **dr. Den Hartog**, beste Dennis, ook jij was er al bij vanaf het eerste uur toen mijn onderzoek zich nog richtte op de bovenste extremiteit. Via jouw ongeëvenaarde netwerk vonden we altijd weer de juiste persoon om de volgende stap mogelijk te maken. Inmiddels zijn we afgezakt naar de heup en was je mijn copromotor tijdens mijn promotietraject. Ondanks jouw drukke agenda maakte je altijd ruimte als dat nodig was. Ik bewonder nog steeds jouw tomeloze enthousiasme en humor binnen en buiten het onderzoek. Het was een feestje met jou samen te werken en ik hoop dat in de toekomst ook in de kliniek te doen!

Geachte promotiecommissie en opponenten, **prof. dr. Jutte, prof. dr. Schipper en dr. Van Bruchem**, ik ben u dankbaar voor de tijd die u genomen heeft voor de beoordeling van dit proefschrift en voor het opponeren in de promotiecommissie. Ook veel dank aan **prof. dr. Van der Laan, dr. Willems, prof dr. Rogmark** en **dr. Lagarde** voor het opponeren bij de verdediging van dit proefschrift.

Beste hoofdonderzoekers, chirurgen, orthopeden, geriaters, researchcoördinatoren, arts-assistenten, verpleegkundig specialisten en andere deelnemers aan het NOM-implementatie project, de FRAIL-Hip studie en de STABLE-HIP groep. Zonder jullie inzet en samenwerking waren deze projecten niet mogelijk geweest! In het bijzonder wil ik hiervoor **Pieter Joosse, Hanna Willems, Henk Jan Schuijt, Hugo Wijnen** en **Detlef van der Velde** bedanken. Jullie waren in wisselende formatie bij veel van de projecten betrokken, ik heb veel van jullie geleerd en hoop nog veel meer met jullie te blijven samenwerken!

Promoveren is ondanks alle vergaderingen en conferenties toch vaak een beetje eenzaam werk. Daarom waardeerde ik het extra als er fijne collega's op mijn pad kwamen. Beste **Paulieke**, ik vond het superleuk om in de tweede helft van mijn traject met jou aan de slag te gaan met het NOM-implementatie project. Het was fijn te kunnen sparren over nieuwe ideeën en ervaringen te kunnen delen. We vulden elkaar goed aan en hebben samen de brug gevormd in een vruchtbare samenwerking tussen het Anton en EMC. Ik wens jou veel succes met de afronding van jouw traject, dat komt zeker goed! Beste **Sverre**, jij was vanaf het begin al betrokken op verschillende vlakken. Samen hebben we aan meerdere stukken geschreven en jouw FRAIL-Hip was de basis voor aantal van mijn vervolgstappen. Bedankt voor je kennis en altijd kritische blik. Ik kijk er naar uit binnenkort ook jouw verdediging te aanschouwen.

Mijn collega's van Rg-2, lieve **Sas, Suus** en **Alex**, ik heb genoten van onze periode samen als collega's, alle congressen waar we zijn geweest en vooral ook de mooie belevenissen en vriendschap buiten het onderzoek om. Beste **Max, Lennard** en **Niels**, jullie horen voor mij inmiddels ook tot het vaste meubilair van de kantoortuin. Bedankt voor jullie enthousiasme, nieuwsgierigheid en inzet bij een aantal van mijn projecten. Ik zie jullie bij Robbie!

Beste **Promeras bestuur 2022-2024**, bedankt voor de leuke tijd samen waar we even konden uitzoomen van ons eigen onderzoek en ons konden inzetten voor het verbeteren van het algemene onderzoeksklimaat, maar voor al ook voor alle lol en de gezellige activiteiten die we samen hebben georganiseerd!

Lieve **Bobbie, Naftali, Patrick, Maurits, Özgür, Tim, Thijs, Thijs** en **Thijs,** de **Lowlands-groep,** de **familie Starrenburg** en alle andere vrienden die mijn leven gezelliger, vrolijker en mooier maken, bedankt voor alle steun, een luisterend oor, gezamenlijke avonturen en vooral de lol. Ik ben jullie ontzettend dankbaar!

Beste paranimfen **Marc** en **Niek,** alvast bedankt voor jullie ondersteuning tijdens en rondom de verdediging. Jullie hebben allebei al een belangrijke rol gespeeld als supporter tijdens dit traject. Niek, jouw (soms wat vaker dan) wekelijkse koffietjes in het midden tussen Rg en Ee zorgden altijd voor weer wat relativering en ontspanning. Het was fijn ervaringen te kunnen delen en te speculeren over onze toekomsten binnen en buiten het ziekenhuis. Marc, al meer dan 15 jaar kennen we elkaar, je was er altijd al bij als vriend en huisgenoot. Bedankt voor alles door de jaren heen, van preekendjes tot paranimfen. Ik vind het fantastisch dat jij ook straks weer achter mij staat bij de verdediging!

Lieve **mama, papa** en **Fee**, ik kan me geen fijner gezin wensen om in op te groeien. Bedankt voor jullie onophoudelijke steun en liefde bij alles wat ik doe. Met jullie onvoorwaardelijke vertrouwen, interesse en aanmoediging hebben jullie me altijd de ruimte gegeven om mijn dromen na te jagen. Fee jouw drive en buitenlandse avonturen waren ook voor mij een grote bron van inspiratie en ik vond het fijn dat we er ondanks de regelmatige afstand toch voor elkaar waren en zijn. Je gaat een prachtige toekomst tegemoet. Papa en mama, jullie zijn mijn grote voorbeeld, veilige haven en inspiratiebron. Ik ben ontzettend trots op jullie alledrie!

Lieve **Margot,** liefde van mijn leven en binnenkort ook mijn echtgenote! Bedankt voor jouw liefde, enthousiasme en positiviteit bij alles wat je doet. Je was er dit hele traject bij en zonder jou was alles anders geweest. Ik geniet van alles wat we samen doen en meemaken. Ik ben trots op jouw passie, levenslust en alles wat je al hebt bereikt en laat me daar graag door inspireren. We gaan nog veel mooie avonturen beleven. Ik hou ontzettend veel van jou en wil niets liever dan de rest van mijn leven met jou doorbrengen!

About the author



Miliaan Lorenzo Zeelenberg was born on October 9th, 1995 in Rotterdam, the Netherlands. Growing up in Ouddorp, he attended secondary school at CSG Jacob van Liesveldt in Hellevoetsluis from 2008 to 2014. During this period he also completed the Junior Medschool program at the Erasmus Medical Center and through this got his first tastes of (bio)medical research.

After graduation he returned to the Erasmus MC and Rotterdam to study medicine at the Erasmus University Medical School. During his studies he played rugby at the Rotterdam Student Rugby Club and pursued an interest in history and politics. In his first year of the medical bachelor he was selected for the Erasmus Querido Honours College. This program further enthused him to participate in medical research at the department of virology and endocrinology. This led him to pursue a double masters program and to also study Clinical Research at the Netherlands Institute of Health Sciences (NIHES) from 2017 to 2019. At this point he had also developed a keen interest in (trauma) surgery and, therefore, wrote his master thesis at the Erasmus MC department of trauma surgery on upper extremity injuries in polytrauma patients. He conducted an 18-month research project in collaboration with the UTZ in Zurich that also led to his first scientific publication.

After the conclusion of the research master program he continued his medical training in 2019. After his final clerkship ('oudste coschap') at the department of surgery in the Franciscus hospital in Rotterdam, he obtained his medical degree in 2022. He then started a PhD program at the department of trauma surgery at the Erasmus MC under supervision of Professor M.H.J Verhofstad. In his research he focused on hip fractures in older adults and extramedullary versus intramedullary fixation of trochanteric fractures. During this period he was also a board member of Promeras, the association representing PhD candidates at the Erasmus MC.

Starting in February 2025, he works as a senior house officer at the department of surgery at the Franciscus hospital in Rotterdam. In the upcoming years he aspires to start his surgical training and pursue a career as a surgeon.

