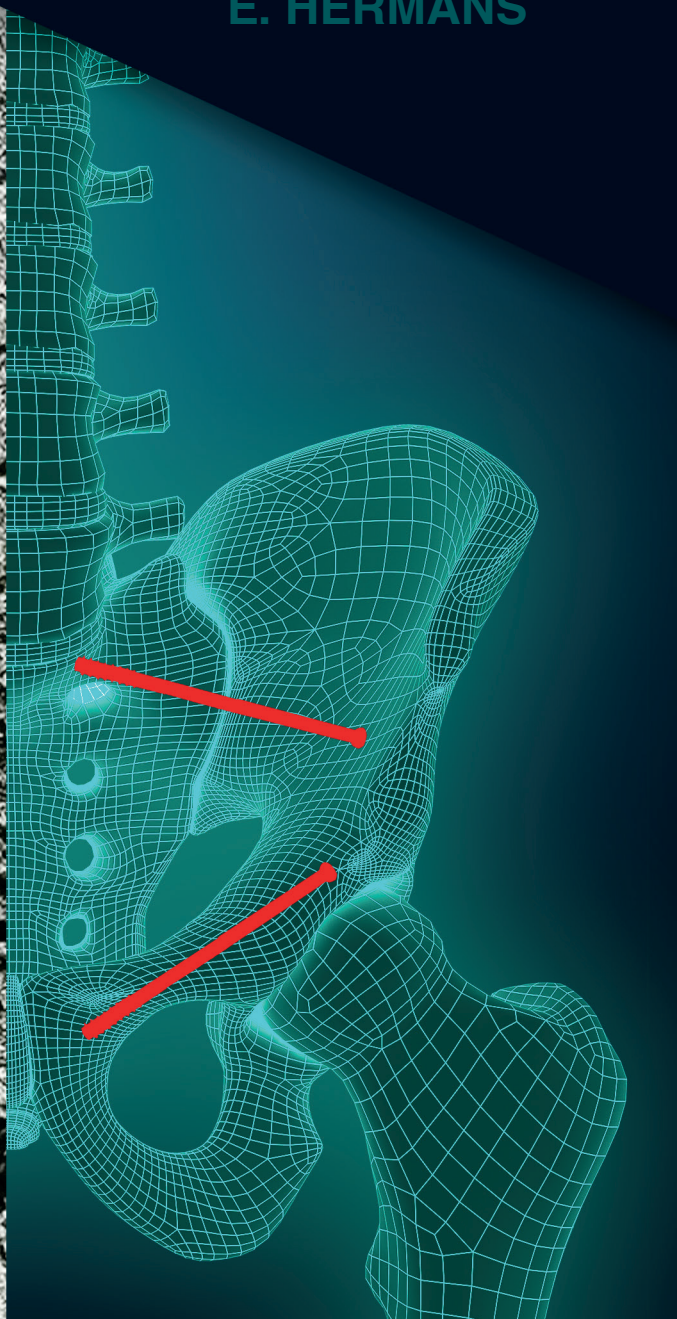
STUDIES ON TREATMENT AND OUTCOME OF PELVIC FRACTURES

E. HERMANS



STUDIES ON TREATMENT AND OUTCOME OF PELVIC FRACTURES

COLOFON

Author:	E. Hermans
Cover design en lay-out:	Miranda Dood, Mirakels Ontwerp
Printing:	Gildeprint - The Netherlands
ISBN:	978-90-9031602-4

STUDIES ON TREATMENT AND OUTCOME OF PELVIC FRACTURES

Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. dr. J.H.J.M. van Krieken,
volgens besluit van het college van decanen
in het openbaar te verdedigen op donderdag 18 april 2019
om 14.30 uur precies

door

Erik Hermans
geboren 20 juni 1983
te Waalwijk

PROMOTOREN:

Prof. dr. M.J.R. Edwards

Prof. dr. J.C. Goslings (Universiteit van Amsterdam)

COPROMOTOREN:

Dr. J. Biert

Dr. K.W.W. Lansink (Elisabeth-Twee Steden Ziekenhuis, Tilburg)

MANUSCRIPTCOMMISSIE:

Prof. dr. H.W.B. Schreuder

Prof. dr. M. de Kleuver

Prof. dr. A.B. van Vugt (Medisch Spectrum Twente)

Prof. dr. V.A. de Ridder (Universiteit Utrecht)

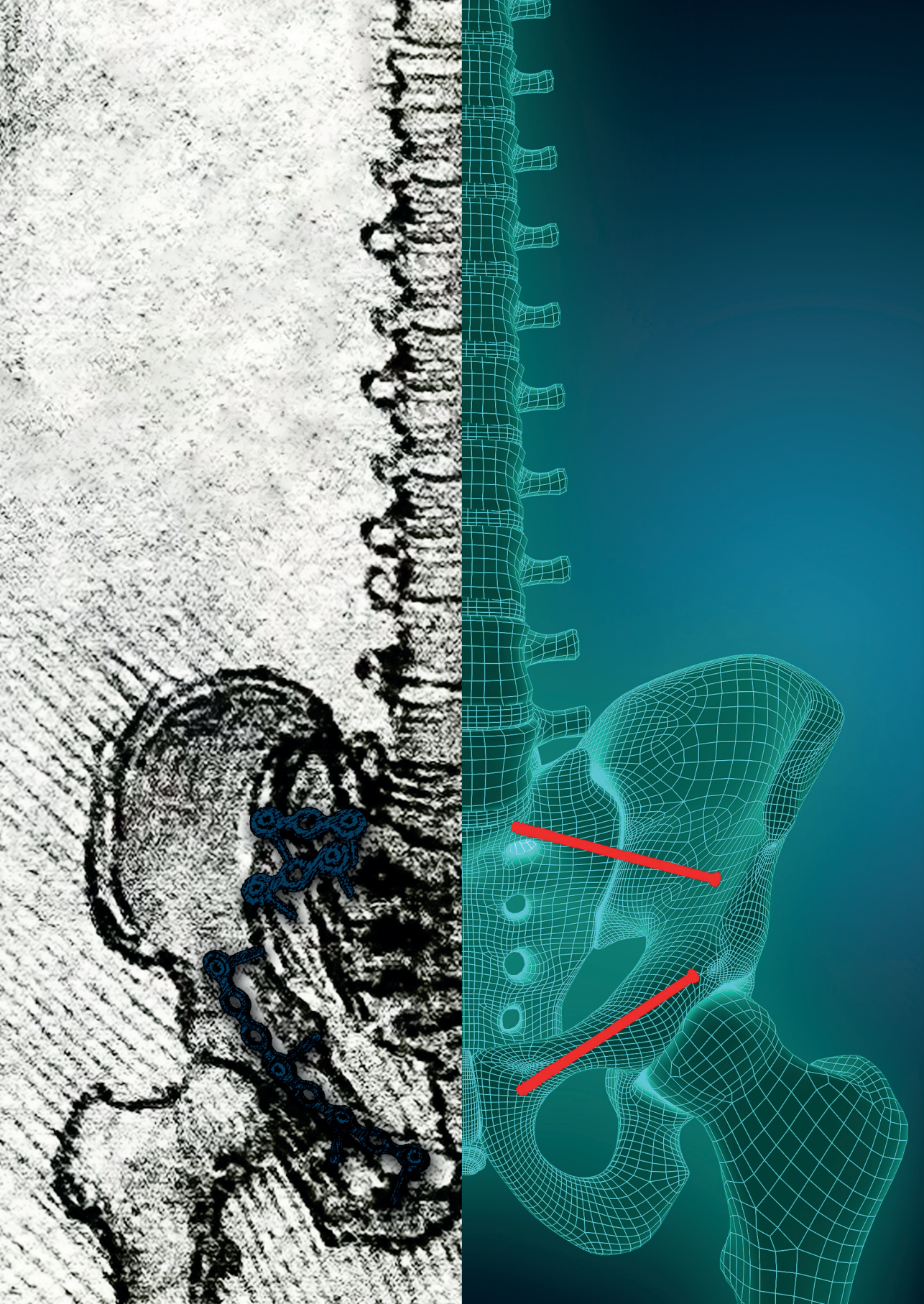
Prof. dr. M. Poeze (Maastricht University)

PARANIMFEN:

R.G. Stelt

J.P.C.M. van Kempen

TABLE OF CONTENTS



INTRODUCTION AND OUTLINE OF THIS THESIS

1

GENERAL INTRODUCTION

Pelvic fractures consist of 3%-8% of all fractures of the human skeleton[1]. Although this is a small percentage, pelvic ring fractures remain a subject of interest for the modern trauma surgeon. Pelvic ring fractures are different type of fractures than acetabular fractures. Acetabular fractures are injuries to a joint and patients often present with this fracture as an isolated injury. They normally are hemodynamically stable and treatment is focused on anatomic restoration of the hip joint in order to regain full range of motion and to prevent secondary osteoarthritis. Pelvic ring fractures often present with signs of severe hemorrhagic shock and multiple concomitant injuries. Focus on treatment is directed at control of hemorrhage and prevention of early death from exsanguinations and late sequelae as Adult Respiratory Distress Syndrome (ARDS) and Multiple Organ Failure (MOF). This presentation and difficult anatomy represents a serious clinical problem and treating these patients is a challenge, even for experienced trauma surgeons. In order to understand this injury, knowledge of the anatomy is of vital importance.

ANATOMY

The bony pelvis is strong and transmits the weight of the upper body to the lower limbs. It also withstands great forces of compression and protects vital structures in the abdominal and pelvic cavities. The bony pelvis consist of two innominate bones which are formed by the ilium, ischium and pubis. These 3 bones fuse at the age of 14-18 years[2]. The innominate bones attach in the back to the sacrum. The connection to the sacrum is formed by the sacroiliac joints. In the front the ossis pubis are connected by the pubic symphysis. The pubic symphysis is a fibrocartilageous structure which allows small movements between both pubic bones. Because of the attachments of both innominate bones in the front and the bridging by the sacrum in the back, the pelvis can be seen as a ring structure.

The acetabulum is a cup shaped socket that articulates with the femoral head to form the hip joint. It is formed by the pubis, which contributes to the anterior part, the ischium which forms the posteroinferior part and the ilium which forms the superior part. Fusion of these bones begins at the age of 15-18 years[3]. Before that, these bones are separated through the triradiate cartilage.

The main stability of the pelvis is not created through these joints but through many ligamentous structures. Because of these ligamentous structures, a high intrinsic stability is

created. In the back, the main stability is formed by the iliolumbar, the anterior and posterior sacroiliac, the sacrospinous and the sacrotuberous ligaments. The iliolumbar ligament attaches from the ilium to the transverse process of L5. When a pelvic fracture is seen on a X-ray and there is a fracture of the transverse process, this is due to an avulsion caused by the iliolumbar ligament and is a tell-tale sign for vertical instability[4]. The stability of the anterior ring is created by the pubic symphysis, and the superior and inferior pubic ligaments.

The anatomical pelvis can be divided in the false and true pelvis. The false (or greater) pelvis is the area above the pelvic brim and is part of the abdominal cavity. It contains for example the sigmoid colon and the ileum. The true (or lesser) pelvis lies below the pelvic rim and contains the rectum, female reproductive organs and the urinary bladder. It is bounded inferiorly to the musculofascial pelvic diaphragm. The levator ani muscle forms the largest part of this diaphragm. It forms a muscular sling supporting the intrapelvic viscera and assists the anterolateral abdominal wall in compressing the abdominal and pelvic viscera, which is important for containment of the viscera when the intraabdominal pressure rises, for example in coughing and sneezing. It also is an important muscle for the voluntary control of urination, defecation and fecal incontinence[5,6].

The pelvis has a vast amount of arteries and veins. The main arteries that lie in the pelvis are the common, internal and external iliac artery. The internal iliac artery arises from the common iliac artery at the level of L5-S1 and crosses the psoas muscle in the false pelvis. It splits into an anterior and posterior branch. The superior gluteal artery is the largest branch of the posterior division and is at risk in posterior ring injuries. Of the anterior branch the obturator artery and the interal pudendal artery are the main vessels at risk. The obturator artery runs along the pelvic wall to the obturator foramen, where it exits the pelvis. It also split in an anterior and posterior branch, where the anterior branch supplies the adductor muscles, pectineus, gracilis and obturator externus muscle and it forms an anastomosis with the medial femoral circumflex artery. The posterior branch supplies blood to muscles attached to the ischial tuberosity and it has a branch that provides blood to the femoral head through the ligament of the head of the femur. The internal pudendal artery runs on the lateral pelvic wall, exits the pelvis through the greater sciatic foramen, then curves around the sacrospinous ligament to enter the perineal region through the lesser sciatic foramen through the pudendal canal with the pudendal vein and nerve. It supplies the penis and scrotum in males and the labia and clitoris in women[7]. The corona mortis is another important vascular structure which can be at risk in open internal fixation of pelvic and

acetabular fractures. It is an anastomosis of branches of the inferior epigastric artery and the obturator artery or in 25% of the cases an aberrant obturator artery[8,9] which passes Coopers ligament and runs at the inner side of the pelvic wall near the anterior column of the acetabulum.

The venous structures correspond with branches of the internal iliac artery. Also, there are extensive venous plexus anterior to the sacrum, which is particularly prone to injury when there's a posterior injury. Massive bleeding can occur from this plexus after trauma[10,11].

The most important nervous structures in the pelvis arise from the lumbar and sacral plexus. The lumbar plexus originates from the twelth thoracic to the fourth lumbar vertebra. The lateral femorocutaneous nerve arises from L2 and L3 runs anterior and medial to the anterior superior iliac spine and is a sensory nerve to the anterolateral surface of the thigh[12]. The obturator nerve arises from the 2nd, 3rd and 4th lumbar root and runs from the psoas muscle vertically along the pelvic brim and exits the pelvis through the obturator foramen and innervates the medial side of the thigh. The femoral nerve is the largest nerve from the lumbar plexus and also arises from the 2nd, 3rd and 4th lumbar root and runs along the psoas muscle. It exits the pelvis beneath the inguinal ligament and has motor and sensory function. It supplies the pectineus and sartorius muscle and the sensory of the anteromedial thigh. The sciatic nerve is the largest nerve arising from the sacral plexus (roots L4-S2) and is in fact the largest nerve in the human body. All fibers unite in front of the piriformis muscle, leave the pelvis as a single bundle through the major sciatic foramen and passes down the posterior thigh to the popliteal canal, where it divides in the tibial nerve and the peroneal nerve. They are the main motor and sensory branches for the lower leg and foot. The sacral and pudendal plexuses arise from the roots of L4 to S3 and innervate the external genital organs, the gluteal area and the intrapelvic organs[13].

CLASSIFICATION OF PELVIC FRACTURES

Historically, pelvic fractures were classified as stable or unstable[14], mainly due to the fact that treatment consisted of non-operative management. This changed when the external fixation was introduced.

In 1958 Pennal and Sutherland proposed a classification system based upon the review of 354 pelvic disruptions[15]. In 1980, Pennal and Tile extended this classification system based on the stability of the pelvic ring[16]. This system was adopted by the AO[17] and divides the pelvic fractures into three fracture types; type A: stable fractures in which the ring

structure of the pelvis remains intact; type B, in which the pelvic ring is horizontally unstable but vertically stable; and type C, where there is horizontal and vertical instability. These fracture types can be subdivided in 3 subcategories (figure 1). Type A1 fractures are avulsion fractures. These avulsions are typically seen in adolescent athletes[18]. Type A2 fractures are isolated pubic rami fractures or iliac wing fractures without impairment of the posterior ring. They are often caused by direct force. A3 fractures are isolated sacral fractures.

In type B fractures the ring is horizontally unstable. In B1 fractures, the pubic symphysis is dislocated or pubic rami are fractured. Also on 1 side, the sacrospinous, sacrotuberous and anterior sacroiliac ligaments can be damaged. The posterior ligaments of the SI joint remain intact. If it occurs bilaterally, than it is a type B3 fracture. The B2 type fracture is a fracture which is caused by lateral compression. The ligaments often remain intact and therefore this fracture can be regarded as intrinsic stable.

Type C fractures are horizontally and vertically unstable with disruption of the anterior and posterior ligaments. In Type C1 fractures the anterior ligaments are disrupted with fracture displacement of the hemipelvis in the vertical plane. In Type C2 one hemipelvis is displaced but the contralateral side is still attached to the posterior sacroiliac ligaments. In Type C3 injuries, both hemipelvis are displaced.

Young and Burgess developed a classification system[19,20] based on the vector of force applied to the pelvis. This should provide the surgeon with information needed to decide how correctional forces should be applied if the fracture is needed to be stabilized. They make a distinction in Lateral Compression (LC), AP compression (APC),Vertical Shear (VS), combined mechanism injuries (CMI) (fig 2). The LC and APC are subdivided in 3 groups, each based on fracture pattern and ligamentous injury.

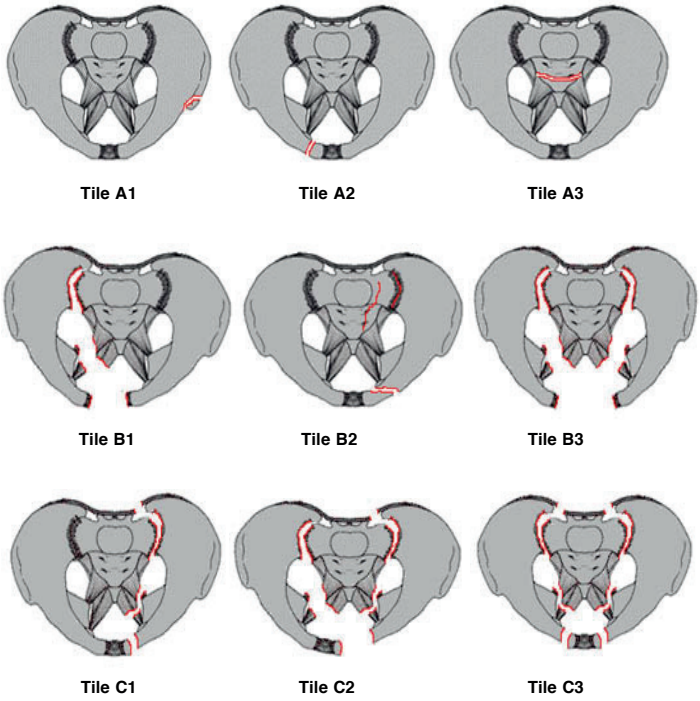


FIGURE 1 Tile classification

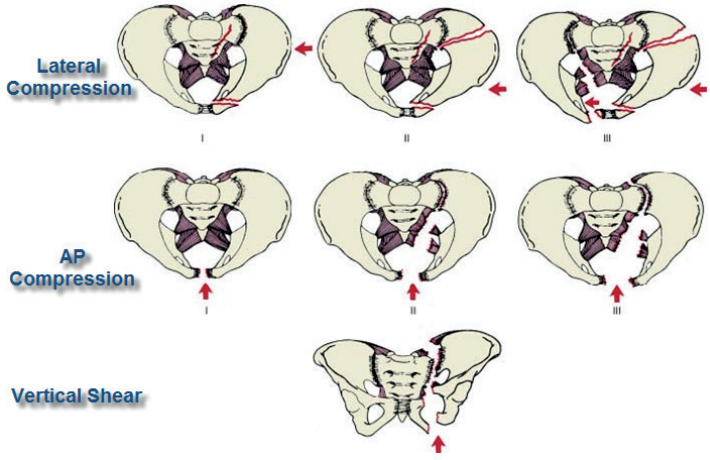


FIGURE 2 Young & Burgess classification

In the lateral compression injury, type I is an intrinsic stable, comparable to the Tile B2, in which there is a horizontal fracture of the pubic rami and an impacted fracture of the sacrum. The ligaments in the front and back are intact. In the LC type II, the fracture fragment anteriorly is rotated inwards, giving rise to either disruption of the posterior sacroiliac ligament or an oblique fracture of the posterior ilium which causes internal displacement of the hemipelvic fragment. In LC type III, the lateral force continues to the contralateral side, which causes external displacement of the contralateral iliac wing. These fractures are highly unstable.

In the APC injury, type I the force disrupts the anterior pelvis, either by fracturing the pubi rami or disrupting the pubic symphysis. The posterior ligaments remain intact. Therefore, the displacement of the symphysis is not greater than 2,5cm[21]. In type II injuries, the applied force causes external rotation of the iliac wing which causes disruption of the sacrospinous and/or sacrospinous ligaments. Displacement of the symphysis is therefore more than 2,5cm. In type III injuries the ligamentous injuries extend to the sacroiliac ligaments and creates complete instability.

Vertical shear injuries usually result from a fall from height. It is characterized by a vertically oriented fracture through the anterior and posterior pelvis with superior displacement of the hemipelvis. There is a complete disruption of the posterior SI-ligaments and the iliolumbar ligament.

The last group is the group of combined or mixed injuries, which consist of approximately 23% of the pelvic fractures. Fracture patterns of both APC and LC injuries are seen in this type of fractures.

Sacral fractures are classified according to Denis[22]into three zones; zone 1 are transalar fractures, zone 2 transforaminal fractures and zone 3 central fractures(fig 3). These zones are predictive for nerve injury; fractures in zone 1 can cause injury to the fifth lumbar root, fractures in zone 2 to the sciatic nerve and fractures in zone 3 injury to the autonomous nerves controlling bladder, rectal and sexual function[23]. In 56% of the zone 3 injuries, a cauda equina syndrome is found[24], however new studies suggest that the incidence of nerve root injury is lower than in earlier reports[25]. The fractures in zone 3 can be further divided in In H-, and U-shaped fractures, transverse fractures and a combination of these fracture patterns. Especially in U-shaped and transverse fractures, the attachment of the spine to the pelvis is damaged (spinopelvic dissociation). It is extremely important to detect these injuries because of the high risk of progression and dislocation, with further compromise of the nerve roots.

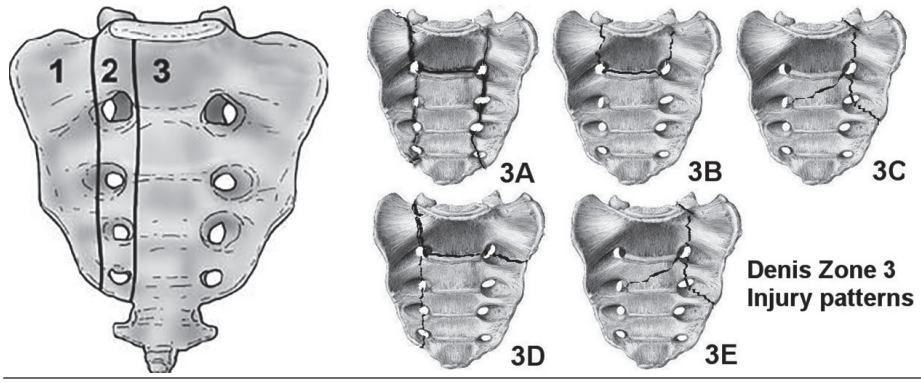


FIGURE 3 Denis classification and subdivision of zone 3 injuries

EPIDEMIOLOGY

Of all fractures, 3%-8% consist of fractures of the pelvis[1]. These fractures vary from isolated fractures of the pubic rami in elderly patients after a domestic fall to high energy impact fractures with complete disruption of the pelvic ring. In the Netherlands, the incidence of all pelvic fractures is estimated to be around 2400 fractures per year, of which about 30% is due to a high energy trauma[26]. Although this is a relatively small number, the mortality of these fractures are high and is reported to be around 14%[27]. When there's an open fracture, mortality can be as high as 50%, however due to improved surgical and resuscitation techniques and improvement in ICU care mortality has dropped in this type of fracture to 10-20%[28-30].

Exsanguination or late sequelae from hemorrhage are the main reasons for mortality in these patients. Exsanguination is caused by bleeding from the fracture surface, the forenamed venous plexus and arterial bleeding, mainly the internal obturator artery, the pudendal artery and the inferior gluteal artery, all branches of the internal iliac artery. In study conducted by Huittinen[31], 75% of bleeding originated from venous injury, 15% from the fracture site and 10% from arterial injury. It is of vital importance to identify those patients with a pelvic fracture that are in extremis during the primary survey and early control of hemorrhage is therefore mandatory.

HISTORY OF PELVIC FRACTURE TREATMENT

Historically, treatment of pelvic fractures consisted of non-operative management. In the ancient Egypt, treatment was based on splinting the fracture with wooden sticks and application of roller bandages[32]. Many patients with this injury died because of the uncontrollable hemorrhage. It is even speculated that Tutankhamon died of a massive trauma (collision with a chariot), in which he sustained thoracic, pelvic and lower leg trauma, which ultimately led to gangrene of the lower limb and to his death[33]. During the 19th century, Joseph-Francois Malgaigne described a pelvic fracture with bilateral SI-joint dislocations and associated fractures of the pubic rami. There was displacement of the hemipelvis and shortening of the affected extremity. He advocated closed reduction followed by traction, bed rest and a pelvic sling for a period of 45-50 days[34]. He also noticed that most patients would not survive this type of injury. In the first half of the 20th century , and with the introduction of X-ray, Holdsworth described several pelvic fracture types (vertical shear, crescent fracture and open book fractures) and provided more technical refinement in skeletal traction and compression with a pelvic sling[35].

In the late 1950's, surgical treatment of pelvic fractures with external fixators was introduced and changed the acute management of patients with an unstable pelvic ring fracture, especially those patients with hemodynamic instability[36]. In the 1980's, Marvin Tile was a pioneer in the field of internal fixation, which allowed the patients early mobilization[37]. Early internal fixation is nowadays the standard treatment in the modern world[38,39].

PRE-HOSPITAL TREATMENT

In patients with stable fractures and normal hemodynamics, bleeding is confined to the pelvic compartment and is often self limiting. This changes when the pelvic fracture is unstable, the anatomic compartment of the pelvis is disrupted and the tamponade effect is lost. Therefore, the anatomic compartment of the pelvis has to be restored. Reduction and stabilization of a pelvic fracture should occur as soon as possible when this injury is suspected, and clotting mechanisms are still intact. One of the easiest ways to do so is manual traction of the affected limb and internal rotation of the legs to the reduce the pelvic volume. After this circumferential pressure should be given. Initially this was done by wrapping a bedsheet around the pelvis[40]. Since then, a lot of commercial devices have been developed. The Trauma Pelvic Orthotic Device (T-POD®) is a flexible pelvic binder

which is applied at the level of the greater trochanters (fig 4). A study done by Tan et al.[41], showed a decrease in diastasis of the symphysis and a good response on hemodynamics. Another device which can be used is the SAM sling, which is an equivalent of an autostop buckle, which reduces the chance of overcompression in case of internal rotation of the pelvis (fig 5). The effectiveness of this device was described several authors including Bottlang[42] and Simpson[43] and showed good reduction of the fracture on radiological examinations and no complications. Other commercial binders are available but not widely used in the Netherlands. No studies have been conducted which circumferential wrapping device is superior. It is important however that the device is remained in place during the resuscitation phase on the trauma room so that the clot that has formed in bleeding sites in the pelvis remains intact.

FIGURE 4 T-POD

FIGURE 5 SAM sling

Another device which has been advocated for the use in hemorrhage control in patients with a pelvic fracture is the Military Anti-Shock Trousers (MAST). This pneumatic device was developed during the Vietnam war and is inflated around the patients legs and pelvis creates a pelvic tamponade and reduces the inflow of blood in the lower extremities, thus increasing the availability of blood to the brains and the abdominal organs[44]. It's use however, has not demonstrated a benefit in hospital stay or patient survival[45] and several severe complications have been reported, such as compartment syndrome of the lower extremities.

Temporary arrest of arterial inflow may also be achieved by occlusion of the aorta. This can be done through an anterolateral thoracotomy and direct cross-clamping, and although it can be performed on scene, it is a highly invasive procedure usually performed in penetrating trauma, with poor outcome in blunt injury[46]. An alternative for this procedure is the percutaneous aortic balloon occlusion, which is inserted in the femoral artery and then inflated in the descending aorta. This was done for the first time in 1954 during the Korean war[47], and some results were published in 1989 by Buhren et al.[48]. During the 90's and early 00's this technique didn't gain much interest until the 10's with the advancements made in endovascular procedures. Nowadays, the resuscitative endovascular balloon occlusion of the aorta (REBOA), gains much interest in gaining control of non-compressable intratruncal hemorrhage. Although studies suggest that the REBOA is effective in temporary hemorrhage control[49], results in other studies vary widely and several major complications have been reported[50,51].

DAMAGE CONTROL RESUSCITATION (DCR)

A dramatic change in trauma resuscitation is seen in the last two decades. Due to an increased understanding of coagulopathy, hypothermia and acidosis (the lethal triad), resuscitation management has shifted. Initially, restoring blood pressure to normotension and early administration of crystalloids were advocated. If the patient was a non-reponder to fluid therapy, transfusion with blood products was given. Patients became therefore more coagulopathic due to hemodilution and hypothermia, increasing mortality[52]. Nowadays, limited crystalloid infusion but early transfusion with packed red blood cells (PRBC's), plasma and platelets according to a massive transfusion protocol, administration of tranexamic acid (TXA) and permissive hypotension are advocated[53]. The ratio for DCR is that limited transfusion with crystalloids and early administration of blood products which resembles the patient's own blood (ratio 1:1:1) limit acidosis and hypothermia and restores patients coagulation. Also, the use of TXA, an antifibrinolytic agent, in trauma was investigated in the CRASH-2 trial[54], and showed that early administration of TXA safely reduced the risk of death in bleeding trauma patients and is highly cost-effective. TXA is nowadays available for the first responders[55]. Finally, when aiming for a blood pressure that is high enough for organ perfusion, the ischemic-induced cellular damage is prevented and lactate production is limited. Also, there is no mechanical disruption of clot formation[56]. Multiple studies have shown an improved outcome after the implementation of DCR[57,58].

ACUTE OPERATIVE TREATMENT

Damage Control Surgery or Damage Control Orthopaedics are an adjunct to DCR. The surgical burden, in addition to the first insult of the trauma, should remain limited because prolonged operative interventions lead to hypothermia and coagulopathy and leads to adverse outcome[59]. Complex restorative surgery is delayed until the patient is stabilized and in a better physiological condition to withstand the additional surgical burden.

The application of an external fixator is an easy and relatively fast option to operatively stabilize a pelvic fracture. Its application can be done in the shock room. It relies on the placement of several pins in the iliac crest or just above the acetabulum and a bar or frame to connect the pins. It can be used as a temporary fixation method or definitive treatment. To increase the strength of the external fixators, a single bar construction is preferred over a frame[60]. Also, supra-acetabular placements of pins create a greater stiffness than pins in the iliac wing[61]. An example of a external fixator is shown in fig. 6.

The C-clamp (fig. 7) is an external fixator which was introduced by Ganz in the early 90's[62]. It consists of 2 pins that are placed on the posterior ilium at the level of the SI joints. It is then connected to a frame and allows to give compression of the posterior complex. Several studies[63-65] have shown the effectiveness of the C-clamp in stabilizing posterior fractures and thus creating pelvic tamponade. However, its use in contraindicated in comminuted sacral fractures and crescent fractures of the iliac wing. Complications that are described are iatrogenic nerve damage, overcompression of sacral fractures, pintract infections, pin loosening and malposition of the screws resulting in penetration of the small pelvis and iatrogenic damage to vessels or organs[66].

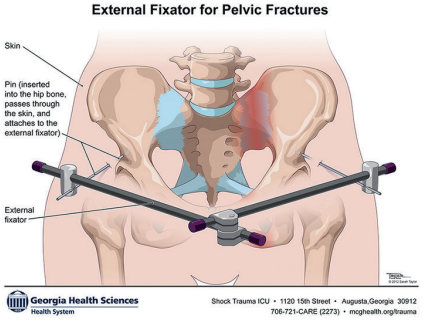


FIGURE 6 external fixator

FIGURE 7 C-clamp

Pelvic packing is a surgical technique in which the presacral spaces, Retzius space and the iliac wings are packed with gauzes in order to tamponade low-pressure venous bleeding. This can be done simultaneously with a laparotomy but a formal laparotomy is not necessary and the packs can be placed preperitoneally. In order to create an effective packing, a form of fracture fixation has to be carried out[67] either with an external fixator or symphyseal plating. The gauzes have to be removed in 24-48 hours. Although packing itself seems an effective way to tamponade venous bleeding, several authors showed that mortality remains high in these patients in extremis[68-70].

Packing is not suitable for patients with arterial bleeding. In cases of arterial bleeding, the options are direct ligation or angiography and selective embolization of the bleeding vessel. The past decades, a great progress has been made in interventional radiology. Patients, who show an arterial blush on the contrast-enhanced CT-scan, are catheterized through the femoral artery. Through this catheters, which can be placed super-selectively, the bleeding vessel can be sealed with foam or coils. In a recent review[71], arterial embolization is strongly recommended in unstable patients with pelvic injuries and blood loss when other sources of bleeding have been excluded, patients demonstrating extravasation of contrast or in elderly patients with high energy injuries regardless their haemodynamic status. Repeated evaluation with angiography was sometimes necessary[72]. In another review done by Papakostidis et al.[73], the efficacy rate of embolization rangd from 81-100% and an overall low complication rate was found. However, the procedure is time consuming and prevents simultaneous treatment on other injuries[74]. Also, the availability of an interventional radiologist and angio suite is mandatory. Therefore, the exact treatment algorithm is an ongoing debate.

DEFINITIVE FIXATION AND APPROACHES

Fixation of pelvic fractures usually occurs with plate and screws. Depending on the fracture pattern, several approaches are described for the fixation of pelvic fractures. The Stoppa (modified preperitoneal) approach is often used for access to the anterior ring but through this exposure the SI joints can be reached[75]. The ilio-inguinal approach is extensive and is widely used for the fixation of pelvic ring and acetabular fractures. Through the creation of 3 windows (1 lateral from the iliopsoas muscle and femoral nerve, 1 between the iliopsoas and the external iliac vein and artery and 1 medial of the vessels), the whole pelvic rim can be reached[76]. In both approaches the SI joint can be fixated with plates and screws.

The Si joint can also be fixated from a posterior approach. The patient has to be in prone position and the anterior ring can't be reached. Since the late 90's, more focus came on minimal invasive techniques such as percutaneous SI screws[77] and percutaneous pubic rami screws[78].Initially, these techniques were done with fluoroscopy on the OR. Nowadays, computer navigated surgery is gaining a lot of territory in the minimal invasive treatment[79].

OUTCOME

The primary outcome measure of a pelvic fracture is mortality. As mentioned earlier, overall mortality of pelvic ring injuries is approximately 15%[80]. Secondary outcome measurements are mal- or nonunion and persistent pain[81]. To determine functional outcomes, different questionnaires are used, the most frequently used are the Majeed score[82], which is validated for pelvic injuries and health related quality of life questionnaires like the EQ5D[83].

Oliver et al. studied long term quality of life in patients with unstable pelvic fractures in general, regardless of type of management, and found a 14% physical impairment and 5,5% mental impairment when compared to the American population[84]. Suzuki et al. focused on the influencing factors of long term outcomes and concluded that neurological impairment of the lower extremities is the main predictor for poor quality of life and functional outcome[85].

Because of the relatively low incidence of pelvic fractures and the wide variety in clinical presentation and treatment options, outcome is likely to be influenced by a high level of exposure to these demanding injuries. In the guidelines of the Dutch society of surgery (NVvH), pelvic and acetabular fractures are classified as high-complex low volume surgery that should only be treated in dedicated centers who treat more than 20 patients per year[86]. It is to be expected that the number of patients treated per year will be raised in the future.

The Radboudumc is a dedicated center for pelvic and acetabular surgery with state-of-the-art diagnostic and therapeutic modalities. However, in the last decade only limited data regarding our patients group, therapy and outcome were analyzed.

The aim of this thesis is to gain insight in our different patients groups, therapy and outcome in order to compare our care with reports from other centers abroad. Also, we want to demonstrate that the Radboudumc is indeed an expert centre for pelvic and acetabular fractures now and in the future.

This thesis focuses on different clinical aspects of pelvic ring injuries in the period 2004-2015 in the Radboudumc Nijmegen.

In chapter 2 we describe our population with a pelvic fracture. Because the Radboudumc is a level 1 trauma center and a tertiary referral center for pelvic and acetabular fractures in the Netherlands, we tried to identify what patient and injury characteristics were, what sort of fracture types were seen and to review our therapy and outcome. Outcome was measured in mortality and the destination after discharge.

In chapter 3 we reviewed our treatment protocol in relation with mortality. As mentioned earlier, the exact treatment protocol for pelvic ring injuries remains unclear and is often dictated by hospital facilities. We reviewed the patient charts and tried to establish if they were treated according to our local treatment protocol. Then a comparison was made between the surviving and diseased patients whether or not the treatment protocol was followed, in order to determine the effect of our protocol.

Chapter 4 analyses the open pelvic fractures in our population. Open pelvic fractures have been known to have a high mortality and morbidity rate because the loss of tamponade effect and the high risk of secondary sepsis due to contamination. In our opinion, however, these fractures are not as lethal as mentioned in the literature, if operated upon aggressively. Our treatment protocol, treatment given and outcome was determined in these patients and were compared to the literature.

In chapter 5 we analyzed a subgroup of patients with an isolated iliac wing fracture. Isolated iliac wing fractures are intrinsic stable because the pelvic ring remains intact (Tile type A2). Therefore, they are considered as relatively benign fractures. However, high energy is required to fracture the strong iliac wing. These patients have significant concomitant injuries. Our hypothesis is that an isolated iliac wing fracture is a predictor for a severe injured patient which can be compared with patients sustaining an unstable pelvic ring injury. A comparison was made between this fracture type, other stable fractures (Tile type A1, A3 and B2) and Tile B1, B3 and Tile C fractures.

Chapter 6 focusses on pediatric patients. Pediatric trauma patients are in need of a different type of treatment than adult patients. The immature pelvis has greater elasticity at the sacroiliac joints and symphysis, which makes fractures dependent on high energy forces. Usually a lot of concomitant injuries are seen. Also, the growth plates close at the age of 12-16 years, which can cause growth disturbances when the fracture is near a growth plate. However, due to greater remodeling capacities, operative fracture treatment can be different in pediatric patients. We tried to compare our cohort of pediatric pelvic fractures

over a period of 20 years (1993-2013) with an adult cohort and tried to identify differences in fracture type, treatment and outcome.

In chapter 7 our results of a multicenter study regarding long-term quality of life after sustaining a pelvic ring injury are shown. Many studies focused on radiological and functional outcome after pelvic injury. However, only few studies focused on the Health-related-quality-of-life (HRQoL) and sexual-function after pelvic ring injury. These studies had small populations, conflicting results or only included Tile type B and C fractures instead of A, B and C type fractures. Therefore, the purpose of this study is to conduct a cross-sectional analysis of patients with all types of pelvic ring fractures using HRQoL-instruments. Therefore, we used the Majeed pelvic score and the Short Musculoskeletal Function assessment (SMFA) as functional outcome tools. Also we used the EQ5D as a tool to determine HRQoL.

Chapter 8 describes our results of a multicenter study we did to evaluate the use of computer-navigated positioning of SI-screws. Conventionally, these screws are placed with a fluoroscope on the OR. Inlet, outlet and lateral views have to be obtained in order to position the screws correctly. However, due to the changes in position of the fluoroscope, this is not an easy procedure. Incorrect positioning of the SI screws can lead to serious complications as nerve root damage. Computer navigation is a technique in which the same images are obtained as in fluoroscopy except they are stored in the computer. A LED-device which is placed in a fixed position on the pelvis is a reference for the computer to determine the exact spot for screw placement. Therefore, it is hypothesized that the use of computer navigation should lead to more adequately positioned SI-screws with less complications.

In the future, we suspect that the population we see in our hospital with pelvic fractures are becoming older. Insufficiency fractures will be more encountered. Operative techniques should be minimal invasive and should regard the often osteoporotic quality of bones that may require special techniques. In future perspectives, we describe the elderly patient with pelvic insufficiency fractures and we will focus on new minimal invasive techniques and studies with 3D-printing.

Finally, a summary of this thesis is given in English and Dutch.

REFERENCES

1. Hauschild O, Strohm PC, Culemann U et al. Mortality in patients with pelvic fractures: results from the german pelvic injury register J Trauma 2008;64:449-55
2. Schlickewei W, Keck T Pelvic and acetabular fractures in childhood Injury 2005;36 Suppl 1:A57-63
3. Schlickewei W, Götze B, Salm R Beckenverletzungen beim Kind—Besondere Aspekte beim Polytrauma In: Rueger JM, Schlickewei W, Engert J, and Sommerfeld DW (eds) *Das kindliche Polytrauma*. 1st ed: Darmstadt: Steinkopff Verlag 2004;83-97
4. Olson Sa, Pollak AN Assessment of pelvic ring instability after injury. Indications for surgical stabilization Clin Orthop 1996;329:15-27
5. Shah AP, Mevcha A, Wilby D et al. Continence and micturation, an anatomical basis Clin Anat 2014;27:1275-83
6. Bharucha AE, Wald A, Enck P et al. Functional anorectal disorders Gastroent 2006;130:1510-8
7. Moore KL, Dalley AF Clinical oriented anatomy 5th edition Lippincott Williams and Wilkins 2005
8. Okcu G, Erkan S, Yercan HS, et al. The incidence and location of corona mortis: a study on 75 cadavers. Acta Orthop Scand 2004;75:53-5.
9. Tornetta P, Hochwald N, Levine R Corona Mortis: incidence and location Clin Orthop 1996:329:97-101
10. Kataoka Y, Maekawa K, Nishimaki H et al. Iliac vein injuries in hemodynamically unstable patients with pelvic fracture caused by blunt trauma J Trauma 2005;58:704-8
11. Tile M, Helfet DM, Kellam JF Fractures of the pelvis and acetabulum 3rd edition Baltimore Williams and Wilkins 2003
12. De Ridder VA, de Lange S, Popta JV Anatomical variations of the lateral femoral cutaneous nerve and the consequence for surgery J Orthop Trauma 1999;13:207-11
13. Hollinshead WH Anatomy for surgeons: the back and limbs 3rd edition Philidephia, Harper and Row 1982
14. Stahel PF, Hammerberg EM History of pelvic fracture management: a review WJ Em Surg 2016;11:18
15. Fakler JKM, Stahel PF, Lundy DW Classification of pelvic ring injuries, in: Smith WR, Ziran BH, Morgan SJ (ed) fractures of the pelvis and acetabulum CRC press 2007
16. Pennal GF, Tile M, Waddell JP et al. Pelvic disruption: assessment and classification Clin Orthop rel res 1980;151:12-21

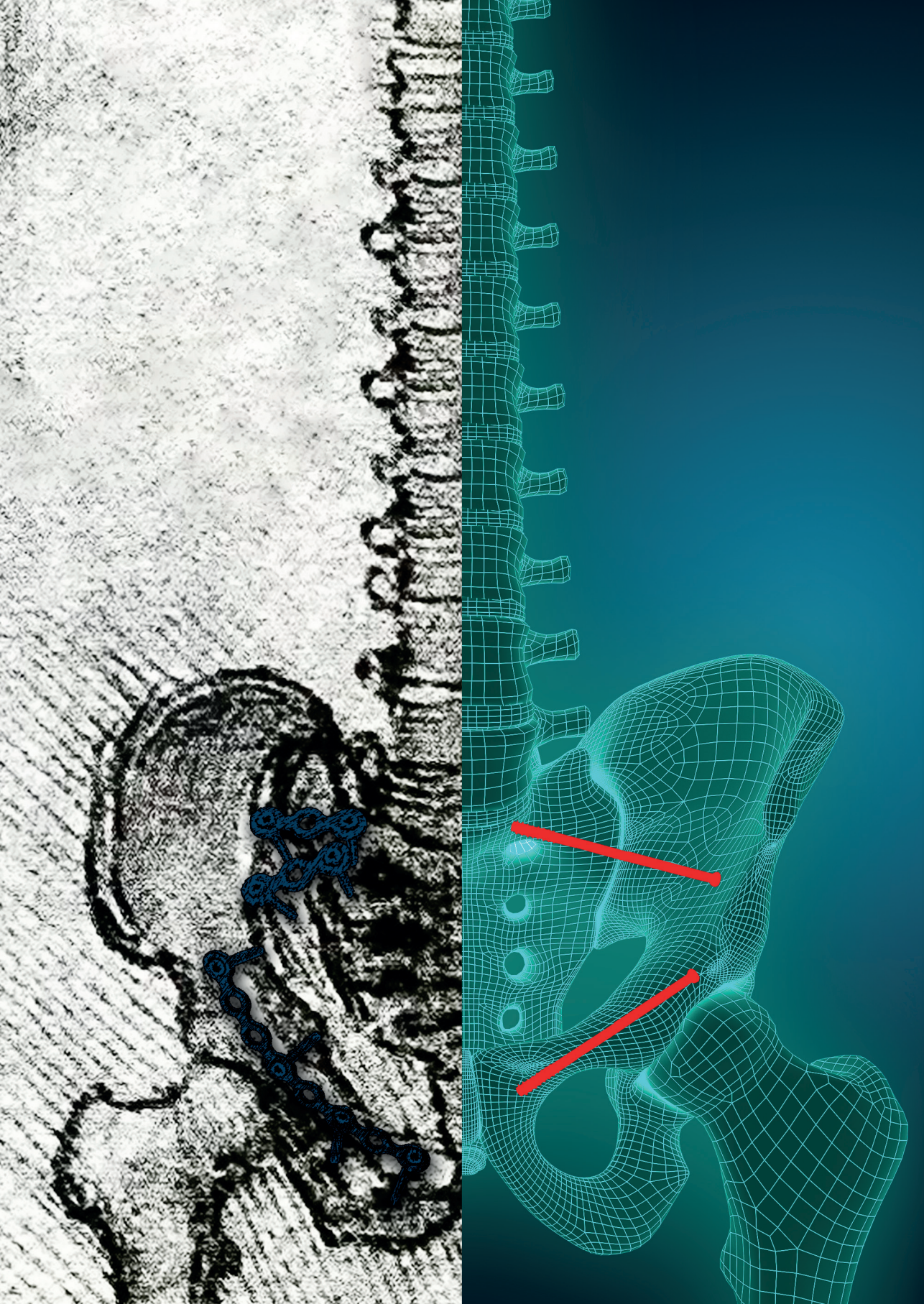
17. Weinberg AM, Reilmann H The Pelvic Professional Section of the German Society of Accident Surgery and the German Section of AO-International Orthopade 1992;21:449-52
18. McKinney BI, Nelson C, Carrion W Apophyseal avulsion fractures of the hip and pelvis Orthopedics 2009;32:42
19. Young JW, Burgess AR, Brumback RJ et al. Pelvic fractures: value of plain radiography in early assessment and management Radiology 1986;160:445-51
20. Dalal SA, Burgess AR, Siegel JH et al. Pelvic fracture in multiple trauma: classification by mechanism is key to pattern of organ injury, resuscitative requirements, and outcome J Trauma 1989;29:981-1000
21. Burgess AR, Eastridge BJ , Young JR et al. Pelvic ring disruptions: effective classification system and treatment protocols J Trauma 1990;30:848-56
22. Denis F, Davis S, Comfort T Sacral fractures: an important problem. Retrospective analysis of 236 cases Clin Orthop Relat Res 1988;227:67-81
23. Bydon M, Fredrickson V, De la Garza-Ramos R, et al. Sacral fractures Neurosurg Focus 2014;37:E12
24. Aresti N, Murugachandran G, Shetty R Cauda equina syndrome following sacral fractures: a report of three cases J Orthop Surg 2012;20:250-3
25. Khan JM, Marquez-Lara A, Miller AN Relationship of Sacral Fractures to Nerve Injury: Is the Denis Classification Still Accurate? J Orthop Trauma 2017;31:181-4
26. Data landelijke trauma registratie 2015
27. Gansslen A, Pohlemann T, Paul C et al. Epidemiology of pelvic ring fractures Injury 1996;27 suppl 1:S-A13-20
28. Grotz MR, Allami MK, Harwood P, et al. Open pelvic fractures: epidemiology, current concepts of management and outcome Injury 2005;36:1-13
29. Leenen LP Pelvic fractures: soft tissue trauma Eur J Trauma Emerg Surg 2010;36:117-23
30. Dong JL, Zhou DS Management and outcome of open pelvic fractures: a retrospective study of 41 cases Injury 2011;42:1003-7
31. Huittinen V, Slatis P Postmortem angiography and dissection of the hypogastric artery in pelvic fractures. Surgery 1973;73:454–62
32. Croce MA, Magnotti LJ, Savage SA et al. Emergent pelvic fixation in patients with exsanguinating pelvic fractures J Am Coll Surg 2007;204:935-9
33. Ruhli FJ, Ikram S Purported medical diagnoses of Pharaoh Tutankhamun, c. 1325 BC- Homo 2014;65:53-61

34. Malgaigne JF Double vertical fractures of the pelvis (1859) Clin Orthop Rel Res 2007;458:17-9
35. Holdsworth FW Dislocation and fracture-dislocation of the pelvis J Bone Joint Surg (Br) 1948;30:461-66
36. Pennal GF The use of external fixation.Presented at the annual meeting of the Canadian Orthopaedic Association 1958
37. Tile M Pelvic ring fractures: should they be fixed? J Bone Joint Surg (Br) 1988;70:1-12
38. Routt ML, Simonian PT, Defalco AJ et al. Internal fixation in pelvic fractures and primary repairs if associated urogenitoury disruption: a team approach J Trauma 1996;40:784-90
39. Halawi MJ Pelvic ring injuries: surgical management and long term outcomes J Clin Orthop Trauma 2016;7:1-6
40. Routt ML, Falicov A, Woodhouse E et al. Circumferential pelvic antishock sheeting: a temporary resuscitation aid J Orthop Trauma2002;16:45-8
41. Tan EC, van Stigt SF, van Vugt AB Effect of a new pelvic stabilizer (T-POD®) on reduction of pelvic volume and haemodynamic stability in unstable pelvic fractures Injury 2010;41:1239-43
42. Bottlang M, Simpson T, Sigg J et al. Noninvasive reduction of open-book pelvic fractures with circumferential compression J Orthop Trauma 2002;16:367-73
43. Simpson T, Krieg JC, Heuer F et al. Stabilization of pelvic ring disruptions with a circumferential sheet J Trauma 2002;52:158-61
44. Frank LR Is the MAST past? The pros and cons of MAST usage in the field JEMS 2000;25;38-41
45. Dickinson K, Roberts I Medical anti-shock trousers (pneumatic anti-shock garments)for circulatory support in trauma Cochrane database sys rev 2000 ;(2):CD001856
46. Khorsandi M, Skouras C, Shah R. Is there any role for resuscitative emergency department thoracotomy in blunt trauma? Interact Cardiovasc Thorac Surg. 2013;16:509-16.
47. Hughes CW Use of an intra-aortic balloon catheter tamponade for controlling intra-abdominal hemorrhage in man Surgery 1954;36:65-8
48. Bühren V, Trentz O Intraluminal balloon occlusion of the aorta in traumatic massive hemorrhage Unfallchirurg 1989;92:309-13
49. Napolitano LM Resuscitative Endovascular Balloon Occlusion of the Aorta: Indications, Outcomes, and Training Crit Care Clin 2017;33:55-70
50. Saito N, Matsumoto H, Yagi T et al. Evaluation of the safety and feasibility of resuscitative endovascular balloon occlusion of the aorta J Trauma Acute Care Surg. 2015;78:897-903; discussion 904

51. Moore LJ, Martin CD, Harvin JA et al. Resuscitative endovascular balloon occlusion of the aorta for control of noncompressible truncal hemorrhage in the abdomen and pelvis Am J Surg 2016;212:1222-30
52. Fitzgerald CA, Morse BC, Dente CJ Pelvic ring fractures: has mortality improves following the implementation of damage control resuscitation Am J Surg 2014;208:1083-90
53. Holcomb JB, Jenkins D, Rhee P et al. Damage control resuscitation: directly addressing the early coagulopathy of trauma J Trauma 2007;62:307-10
54. Roberts I, Shakur H, Coats T et al. The CRASH-2 trial: a randomised controlled trial and economic evaluation of the effects of tranexamic acid on death, vascular occlusive events and transfusion requirement in bleeding trauma patients Health Technol Assess 2013;17:1-79
55. Landelijk Protocol Ambulancezorg (LPA) 2016
56. Roberts I, Evans P, Bunn F et al. Is the normalization of blood pressure in bleeding trauma patients harmful Lancet 2001;357:385-7
57. Stensballe J, Ostrowski SR, Johansson PI Haemostatic resuscitation in trauma: the next generation Curr Opin Crit Care 2016;22:591-597
58. Joseph B, Azim A, Zangbar B et al. Improving mortality in trauma laparotomy through the evolution of damage control resuscitation: Analysis of 1,030 consecutive trauma laparotomies J Trauma Acute Care Surg 2017;82:328-33
59. Giannoudis PV, Pape HC Damage control orthopaedics in unstable pelvic ring injuries Injury 2004;35-671-7
60. Ponsen KJ, Hoek van dijke GA, Joosse P et al. External fixators for pelvic fractures: comparison of the stiffness of current systems Acta Orthop Scand 2003;74:165-71
61. Ponsen KJ, Hoek van dijke GA, Joosse P et al. External fixation of the pelvic ring. An experimental study on the role of pin diameter, pin position ans parasymphyseal fixator pins Acta Orthop 2007;78:648-53
62. Ganz R, Krushell RJ, Jakob RP et al. The antishock pelvic clam. Clin Orthop Relat Res 1991;267:71-8
63. Ertel W, Keel M, Eid K, et al.: Control of severe hemorrhage using C-clamp and pelvic packing in multiply injured patients with pelvic ring disruption J Orthop Trauma 2001;15:468–74
64. Schutz M, Stockle U, Hoffmann R, et al. Clinical experience with two types of pelvic C-clamps for unstable pelvic ring injuries Injury 1996;Suppl 1: 46–50
65. Pohlemann T, Culemann U, Gansslen A, et al. Die schwere Beckenverletzung mit pelviner Massenblutung: Ermittlung der Blutungsschwere und klinische Erfahrung mit der Notfallstabilisierung Unfallchirurg 1996;99:734–43

66. Wollgarten M, Keel MJB, Pape HC Editorial: Emergency fixation of the pelvic ring using the pelvic C clamp –has anything changed? Injury 2015;46 Suppl 3:S1-2Cothren CC, Osborn PM,
67. Moore EE et al. Preperitonal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift J Trauma. 2007;62:834-9
68. Ertel W, Keel M, Eid K, et al. Control of severe hemorrhage using C-clamp and pelvic packing in multiply injured patients with pelvic ring disruption J Orthop Trauma 2001;15:468–74.
69. Ertel W, Eid K, Keel M, et al. Therapeutical strategies and outcome of polytraumatized patients with pelvic injuries: a six-year experience Eur J Trauma 2000;6
70. Suzuki T, Smith WR, Moore EE. Pelvic packing or angiography: competitive or complementary? Injury 2009;40:343-53
71. Cullinane DC, Schiller HJ, Zielinski MD et al. Eastern Association for the Surgery of Trauma Practice Management Guidelines for Hemorrhage in Pelvic Fracture—Update and Systematic Review J Trauma 2011;71:1850-68
72. Tosounidis TI, Giannoudis PV Pelvic fractures presenting with haemodynamic instability: Treatment options and outcomes Surgeon 2013;11:344-51
73. Papakostidis C, Kanakaris N, Dimitriou R et al. The role of arterial embolization in controlling pelvic fracture haemorrhage:A systematic review of the literature Eur J Radiol 2012;81:897-904
74. Gansslen A, Giannoudis PV, Pape HC Hemorrhage in pelvic fracture: who needs angiography? Curr Op Crit Care 2003;9:515-23
75. Ponsen KJ, Joosse P, Schigt A et al. Internal fixation using the Stoppa approach in pelvic ring and acetabular fractures: technical aspects and operative results J Trauma 2006;61:662-7
76. Matta JM Operative treatment of acetabular fractures through the ilioinguinal approach: a 10 year perspective J Orthop Trauma 2006;20:S20-9
77. Barei DP, Bellabarba C, Mills WJ et al. Percutaneous management of unstable pelvic ring disruptions Injury 2001;32 Suppl 1:SA33-44
78. Chen L, Zhang G, Song D et al. A comparison of percutaneous reduction and screw fixation versus open reduction and plate fixation of traumatic symphysis pubis diastasis Arch Orth Tr Surg 2012;132:265-70
79. Richter PH, Gebhard F, Dehner C et al. Accuracy of computer-assisted iliosacral screw placement using a hybrid operating room Injury 2016;47:402-7
80. Pohlemann T, Stengel D, Tosounidis G et al. Survival trends and predictors of mortality in severe pelvic trauma: estimates from the German Pelvic Trauma Registry Initiative Injury 2011;42:997-1002

81. Pavelka T, Salášek M, Weisová D Complications associated with surgical treatment of pelvic ring fractures Acta Chir Orthop Traumatol Cech 2013;80:208-15
82. Majeed SA Grading the outcome of pelvic fractures J Bone Joint Surg Br. 1989;71:304-6
83. Stolk E, Krabbe P, Busschbach J Using the Internet to collect EQ-5D norm scores: a valid alternative? Proceedings of the 24th Scientific Plenary Meeting of the EuroQoL Group; 2009 p.153-6
84. Oliver CW Twaddle B, Agel J et al. Outcome after pelvic ring fractures: evaluation using the medical outcomes short form SF-36 Injury 1996;27:635-41
85. Suzuki T, Shindo M, Soma K et al. Long-term functional outcome after unstable pelvic ring fracture J Trauma 2007;63:884-8
86. Nederlandse Vereniging voor Heelkunde, beleidsdocument normering chirurgische behandelingen 7.0 juni 2017



CHAPTER 2

Epidemiology of pelvic ring fractures in a level 1 trauma center in the Netherlands

E. Hermans, MJR Edwards, J. Biert

Hip&Pelvis 2017;29:253-261

ABSTRACT

Purpose: This study was conducted to study the epidemiology, classification, treatment and outcome of a large patient group with pelvic ring injury in a level 1 trauma center in the Netherlands.

Materials and Methods: In the period of 2004-2014 we encountered 537 patients with a pelvic fracture. Many of them are due to a High Energy Trauma (HET) and therefore many concomitant injuries are observed. Tile A fractures were seen in 137 patients (25.5%), Tile B fractures in 211 (39.3%) and Tile C fractures in 189 patients (35.2%).

Results: Patients with unstable fracture types (Tile B1 and B3, Tile C) had significantly higher Injury Severity score (ISS), transfusion rates, need for laparotomy and definitive operative stabilization and complication rate. However, mortality did not differ significantly among Tile A, B or C fractures.

Conclusion: Overall outcome was good with a mortality rate of 13.6%, which is comparable with other reports. Almost half of the patients treated could directly be dismissed to their own homes.

INTRODUCTION

Of all skeletal injuries, approximately 3% consist of pelvic fractures[1]. Especially in high energy trauma (HET), disruption of the pelvic ring occurs in approximately 13-17% of all pelvic fractures[2]. High forces are required to disrupt the pelvic ring and the association with other significant injuries is therefore high[3]. Mortality is reported to be as high as 10-16% in this patient group[4]. When there is an open fracture, mortality as frequent as 50% has been reported[5]. Significant hemorrhage is an often encountered complication seen in unstable pelvic ring injuries[6-8]. Because early exsanguination is the major cause of death in these patients, early identification of the bleeding source and rapid stabilization of the fracture are therefore critical in their survival[9].

The exact treatment pathway of hemodynamically unstable patients with an unstable pelvic ring fracture remains controversial and is often dictated by available hospital facilities. Mortality and functional outcome of pelvic ring injuries are determined by several factors, especially concomitant injuries. The major factors influencing chronic disablities are urogenital and neurological injuries[10,11]

This study was conducted to evaluate the patient profile, fracture characteristics, treatment and outcome of a large patient group with various pelvic ring injuries in our clinic.

PATIENTS AND METHODS

A total of 537 patients with a pelvic fracture were admitted to our hospital (Radboudumc Nijmegen, The Netherlands) in the period January 1, 2004 to January 1, 2015. Our hospital is a level 1 trauma center and a supra-regional referral center for pelvic and acetabular fractures in the Netherlands. Also, it is the main referral center for the Dutch Helicopter Emergency Medical Service (HEMS) for the middle, east and south part of the Netherlands.

After the approval from the Institutional Review Board of the Radboudumc, all data were analyzed from the electronic patient charts and the trauma database. Data analyzed included patient demographics, date, cause and type of the accident, HEMS involvement, transfusion requirement, associated injuries, Abbreviated Injury Scale (AIS) for each body region, Injury Severity Score (ISS), treatment in the Emergency Room (ER), length of intensive care unit (ICU) and hospital stay, complications and mortality. The pelvic fractures were

described according to Tile's classification[12]. In our center, each patient with a pelvic fracture is routinely evaluated with a CT-scan. The specific fracture sites were also described. If operative therapy was performed, type of fixation, secondary operations and operation time were recorded.

Data of patients with an isolated acetabular fracture were excluded as well as data of patients who were referred for non-, or malunions of pelvic fractures.

During this 10-year period no significant changes in management or diagnostic work-up of pelvic fractures were made.

STATISTICAL ANALYSIS

Statistical analyses were performed using SPSS 13.0 (SPSS, Chicago, Ill, USA). Mann-Whitney *U* test was performed to establish significance between the number of days of admittance in both groups. Chi-square test was performed to determine significance in nonparametric variables.

RESULTS

537 patients had suffered pelvic fractures. There were 328 (61.1%) men and 209 (38.9%) woman. Mean age was 44 years (SD 18) [range 2-100]. Age didn't differ significantly between men and women. There were 45 pediatric patients in the range from 2 to 17 years. The HEMS was involved on the place of accident in 200 patients (37.2%).

CAUSE OF ACCIDENT

In the majority of cases (465/537; 86.6%), the pelvic injury was due to a high energy trauma. From the high energy trauma patients 302 (65%) were due to a road traffic accident, 121 (26.0%) to a fall from height and 42 (9.0%) to a crush accident. 72 cases were due to a low energetic trauma, like a domestic fall.

REFERRAL OF PATIENTS TO TRAUMA CENTER

Four hundred and twenty-four patients (79.0%) were initially transported to a level 1 trauma center, most of them to our hospital. 9 patients (2%) were initially presented to a hospital abroad, this because of the function of our hospital as a level 1 trauma center for the part of

Germany in the proximity of the border. These hospitals are all level 2 or 3 trauma center. All other patients (n=104, 19.4%) were stabilized in another hospital and transferred to our hospital later.

CLASSIFICATION

We encountered 137 Tile type A fracture (25.5%), 211 type B fractures (39.3%) and 189 type C fractures (35.2%) (Figure 1). Of all type A fractures, the type of A1 was zero (0%), the type of A2 was 125 (83.9%) and the type of A3 was 22 (16.1%). Of the type B fractures , the type of B1 was 49(23.2%), the type of B2 was 129 (61.1%) and the type of B3 was 33 (15.6%). Of the type C fractures, the type of C1 was 118 (62.4%), the type of C2 was 31 (16.4%) and the type of C3 was 40 (21.2%).

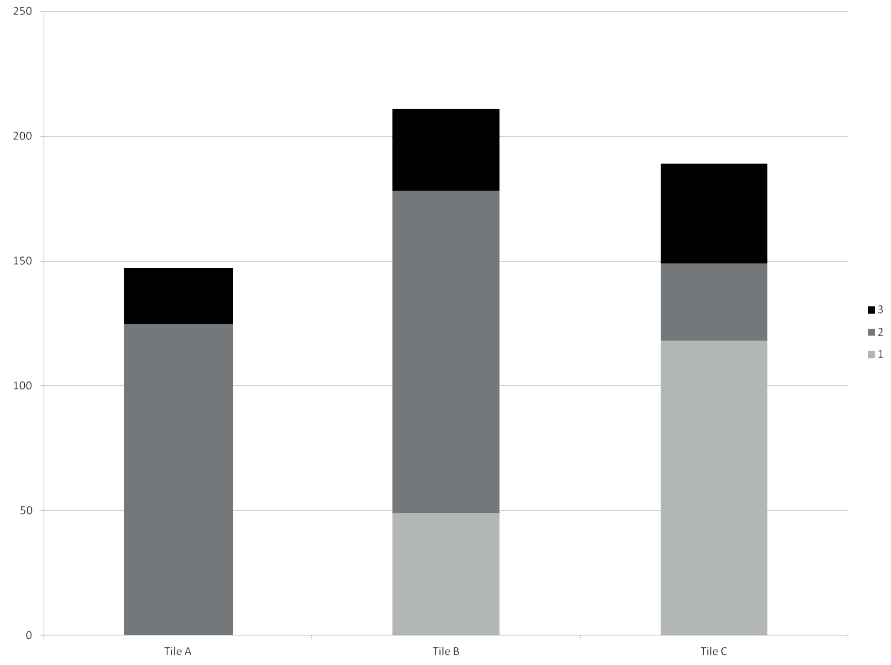


FIGURE 1 Fracture type and subclassification within Tile A, B or C (number of patients)

PRESENTATION

Mean Revised Trauma Score (RTS) was 11 [range3-13]. Eight-six patients had as RTS <10, which was mainly due to a low Glasgow coma scale (GCS)-score. The RTS didn't differ significantly among Tile A,B or C fractures.

Mean ISS was 26. Only 132/537 patients (24.6%) had an ISS <16. Mean ISS was significantly higher in more complex fracture types (33 in Tile C vs. 26 in Tile B vs. 19 in Tile A).

SHOCK CLASS

Mean shock class according to Advanced Trauma Life Support (ATLS®; Trauma programs, Chicago, IL, USA)[13] was 2. Of all patients, 256 (47.7%) were hemodynamically unstable (shock class 2 or higher according to ATLS® when they arrived at the ER. Patients with a Tile C fracture were significantly more often hemodynamically unstable than patients with a Tile A or B fracture (68.2% vs 38.4% vs 34.1% p<0,01). In total, 205 patients (38.2%) received transfusion with packed red blood cells (PRBC's). Mean PRBC transfusion was 3,5 units (range 1-30) within the first 24 hours after the accident. Mean PRBC transfusion was significantly higher in Tile C fractures compared to Tile A and B fractures (1700 vs 1000 vs 1100mL p<0,04).

CONCOMITANT INJURIES

Concomitant injuries are shown in figure 2. Concomitant injuries were seen in 80.3% of the patients with a Tile A fracture, in 83.2% of the patients with a Tile B fracture and in 90.4% in patients with a Tile C fracture. Only 84 patients had an isolated pelvic ring fracture.

OPEN PELVIC FRACTURES

Twenty-four (5%) patients had an open pelvic fracture. Mean age was 33 years (range 5-58). Mean RTS was 11, mean ISS was 31, mean shock class was 2. Patients with open fractures received a mean of 5 PRBC's (range 0-28) within 24 hours after the accident. Except for the RTS, these findings were all significantly higher than patients with closed fractures.

7 patients had a grade 1 open injury (according to Gustilo and Anderson[14], 12 patients had a grade 2 open fracture, 5 patients a grade 3 open injury. In this group, no traumatic hemipelvectomies were encountered.

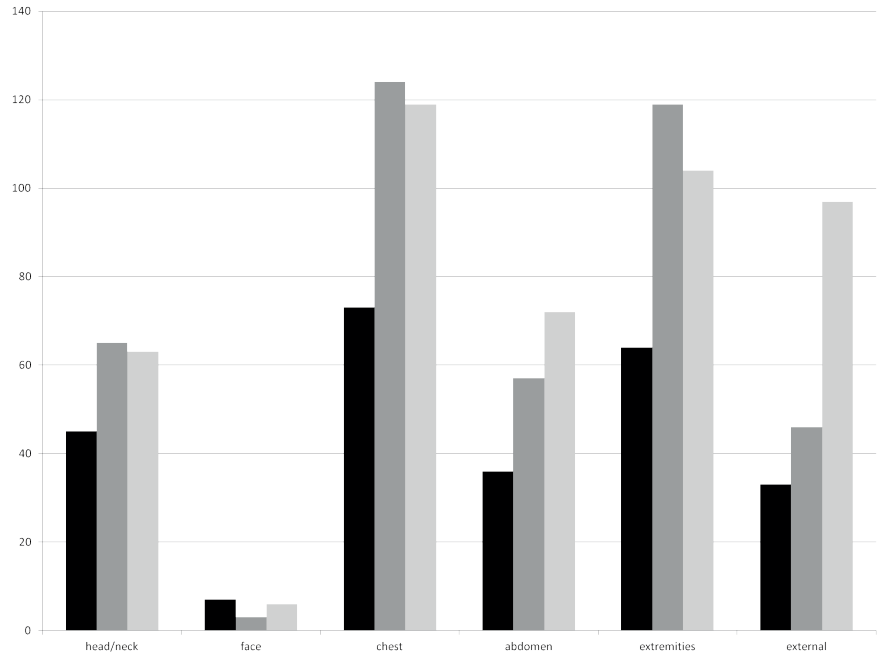


FIGURE 2 Number of concomitant injuries. Tile A: black, Tile B: dark grey, Tile C: light grey

PRE-HOSPITAL STABILIZATION AND STABILIZATION IN THE ER

Pre-hospital stabilization was done with a T-POD® (Pyng medical, Richmond, BC, Canada) or a pelvic sling in 2 patients with a Tile A fracture, 31 patients with a Tile B fracture and 54 patients with a Tile C fracture. Additional emergency stabilization was carried out on the ER in 5 patients with a Tile A fracture, 60 patients with a Tile B fracture and 103 patients with a Tile C fracture. Also in 2 patients with a Tile C fracture a pelvic C-clamp was applied in the ER.

ACUTE STABILIZATION

Acute stabilization of the different fracture types are listed in table 1. Only 1 patient with a Tile A fracture was operatively stabilized because of severe dislocation. In Tile B fractures,

73.5% were not operatively stabilized in the acute phase. This is mainly due to the large number of type B2 fractures. In patients with a Tile C fracture, ORIF was conducted in 50.8% of the patients. This includes open plating as well as percutaneous screw placement (anterior and posterior). In 65.0% of these patients, only the anterior ring was stabilized as a damage control procedure. In the remaining group the anterior and posterior ring was stabilized (early total care). In 23 patients angiography with selective embolization was carried out as to stabilize the patient. A complex fracture type was seen in 15 of 23 patients (65.2%).

A laparotomy was done in 70 patients, of which in 50 patients (71.4%) this was a damage control laparotomy (DCL). DCL were distributed equally among the different fracture types. In 22 additional patients with a Tile C injury, the lesser pelvis was packed with gauzes without a formal laparotomy. In all other patients, bowel or diaphragm injuries were the reason for laparotomy.

DEFINITIVE STABILIZATION

In Tile A fractures no further operative stabilizations were carried out. Definitive operative stabilization for Tile B and C fractures are listed in table 2. Only 36% of the Tile B fractures was stabilized operatively. This is mainly due to the high percentage of Tile B2 fractures in our population (61%). In the Tile C group, definitive stabilization was done in 83% of the patients.

Of the patients who weren't operated, many of them died before definitive care could be performed, or they were not fit for surgery due to infectious complications or severe head trauma. Figures 3A-C demonstrate a typical case of a type C injury, plate fixation of the anterior ring initially and secondary SI screw placement.

TABLE 1 Acute stabilization of Tile A,B or C injuries

variable	Tile A (n=137)	Tile B (n=211)	Tile C (n=189)
Stabilization			
None	136 (99.3%)	155 (73.5%)	71 (37.6%)
External Fixator	0	15 (7.1%)	15 (7.9%)
C-clamp	0	0	7 (4%)
ORIF	1 (0.7%)	41 (19.4%)	96 (50.8%)
Acute operation			
Thoracotomy	0	1 (0.5%)	0
Laparotomy	11 (7.5%)	19 (9.0%)	40 (21.2%)
Embolization	0	8 (3.8%)	11 (5.8%)

TABLE 2 Definitive stabilization of patients with Tile B and C injuries

definitive fixation	Tile B (n=211)	Tile C (n=189)
none	136 (64.5%)	33 (17.5%)
ant. plating	17 (8.1%)	11 (5.8%)
ant screw fixation	0	2 (1.1%)
post. plating	0	2 (1.1%)
post. screw fixation	1(0.5%)	6 (3.2%)
ant. plating/post. Screw fixation	37 (17.5%)	85 (45.0%)
ant. and post. plating	2 (0.9%)	15 (7.9%)
ant. and post. screw fixation	10 (4.7%)	23 (12.2%)
ant. screw fixation and post. plating	2 (0.9%)	2 (1.1%)
external fixator	6 (2.8%)	7 (3.7%)
ex fix and ORIF	0	3 (1.6%)

Ant.: anterior, post.:posterior, ORIF: open reduction&internal fixation

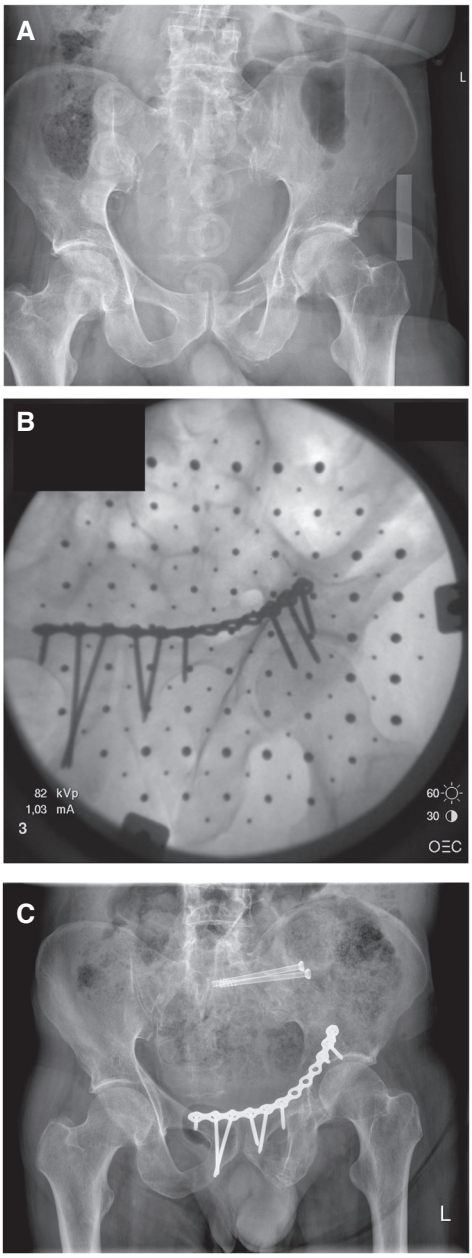


FIGURE 3 Fig 3A: type C injury with T-POD in place. Fig 3B: fluoroscopy during plate fixation anterior ring. Fig 3C: post-operative x-ray after definitive care (placement SI screws left)

COMPLICATIONS

Complications during admittance are listed in table 3.

Urogenital injuries were seen in 8 patients; 3 patients with a Tile B and 5 patients with a Tile C fracture. 6 patients had a urethral rupture. One patient had a severe open fracture with a penile laceration and 1 patient complained of erectile dysfunction during follow-up.

Neurologic injuries were seen in 20 patients. Seven patients were hemiplegic directly due to a vertebral fracture with spinal cord injury. Nerve palsies were seen in 13 patients. In 4 patients this was a distal nerve palsy related to a fracture of the lower leg. Nerve palsy of the sciatic nerve or lumbosacral root was seen in 9 patients; 4 patients had a Tile B fracture, 5 patients a Tile C fracture.

MORTALITY

Overall mortality in our group was 13.6% (73/537). Mean ISS of diseased patients was 47 (range 4-75). Forty-five of 73 patients (62%) received PRBC's. Twenty-eight patients that did not get transfusion were considered responders to volume replacement. The number of deaths remained the same over the years with a peak incidence in 2012 (figure 4).

Of the 73 patients that died, 20 patients had a Tile A, 21 a Tile B and 32 a Tile C fracture. Mortality was significant higher ($p<0,05$) for Tile C injuries compared with Tile B, but not for Tile A injuries.

Nineteen of 73 patients (26.0%) died within the first 24 hours after the accident. Nine of these patients (47.4%) died solely to severe head trauma. In 10 patients (52.6%), hemorrhagic shock contributed to, or was the cause of death. In all patients, the pelvic fracture contributed significantly to the hemorrhagic shock.

The other 54 patients died in a range of 2-59 days. Most of them died due to late sequelae of hemorrhagic shock or neurotrauma.

LENGTH OF STAY

Mean length of stay was 20 days. In total, 291 patients were admitted to the ICU (54.2%). Mean length of stay on the ICU was 5,5 days. Length of stay was significantly longer for patients with a Tile C injury than for patients with a Tile A or B injury. Length of stay on the ICU didn't differ significantly.

TABLE 3 Complications in patients with a pelvic fracture

complication	Tile A (n=137)	Tile B (n=211)	Tile C (n=189)
Major complication			
Sepsis	8 (5.8%)	8 (3.8%)	15 (7.9%)
SIRS	1 (0.7%)	11 (5.2%)	11 (5.8%)
pneumonia	8 (5.8%)	23 (10.9%)	29 (15.3%)
recurrent bleeding	0	3 (1.4%)	4 (2.1%)
failure osteosynthesis	0	1 (0.5%)	6 (3.2%)
Minor complication			
UTI	7 (5.1%)	6 (2.8%)	15 (7.9%)
superficial wound infection	10 (7.3%)	17 (8.1%)	14 (7.4%)
delerium	9 (6.5%)	27 (12.8%)	9 (4.8%)
other	12 (8.7%)	32 (15.2%)	27 (14.3%)

SIRS: Severe Inflammatory Response Syndrome; UTI: Urinary Tract Infection

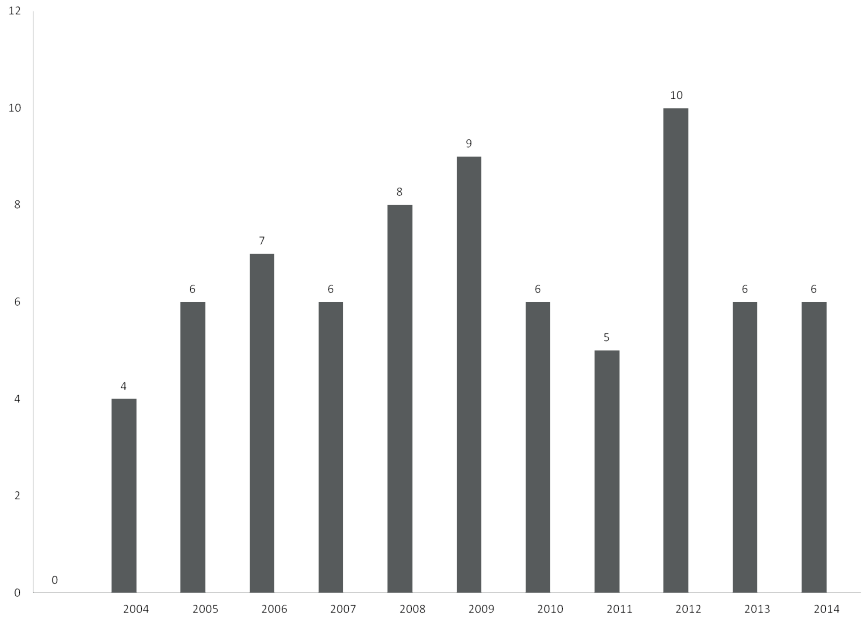


FIGURE 4 Mortality of patients per year

DESTINATION AFTER DISCHARGE

Destination after discharge is listed in table 4. Almost half of the patients could be discharged to their homes. Patients with stable fracture types could be discharged to home significantly more often than patients with unstable fracture types (p<0,03). An additional group of 19.9% were discharged to home after treatment in a rehabilitation clinic. 15.5% of the patients were transferred to other hospitals, mainly to a hospital closer to home.

TABLE 4 destination after discharge

destination after discharge	Tile A (n=137)	Tile B (n=211)	Tile C (n=189)	Total (n=537)
Home	67 (48.9%)	118 (55.9%)	64 (33.9%)	249 (46.4%)
rehabilitation clinic	22 (16.3%)	32 (15.2%)	53 (28.0%)	107 (19.9%)
other hospital	25 (18.2%)	23 (10.9%)	34 (18.0%)	82 (15.3%)
nursing home	2 (2.2%)	8 (3.8%)	6 (3.2%)	17 (3.2%)
deceased	20 (14.6%)	23 (10.9%)	30 (15.9%)	73 (13.6%)
unknown	0	7 (3.3%)	2 (1.1%)	9 (1.7%)

The sum of the percentages does not equal 100% because of rounding

COMPARISON TILE A VS B VS C

An overview of the different fracture types is given in table 5. Patients with an unstable pelvic injury (Tile B1, B3 and C) presented with a significant higher ISS and shock class (p<0.02). Also, the rate of acute stabilization, the need for laparotomy and definitive operative stabilization was significantly higher in patients with an unstable fracture (p<0.04). Major complications were seen more often in patients with a Tile C fracture in comparison with a Tile A or B fracture (p<0.02). However, mortality between all groups didn't differ significantly.

Patients with a stable B2 fracture had a significantly lower ISS, shock class and stabilization rate than patients with an unstable fracture.

Of all patients who were in need of operative stabilization of the fracture (n=222), 138 were managed in the acute phase (62.2%).

TABLE 5 Comparison between Tile A, B and C fractures

variable	Tile A (n=137)	Tile B (n=211)	Tile B1+3 (n=82)	Tile C (n=189)	p-value
Mean ISS	19	26	28	33	p<0.02
Shock class 3-4	28 (20.4%)	29 (13.7%)	25 (30.5%)	76 (40.2%)	p<0.01
acute stabilization	1 (0.7%)	29 (13.7%)	56 (68.3%)	118 (62.4%)	P<0.01
laparotomy	11 (8.0%)	56 (26.5%)	16 (19.5%)	40 (21.2%)	p<0.04
definitive stabilization	1 (0.7%)	19 (9.0%)	70 (85.4%)	156 (82.5%)	p<0.01
LOS ICU (days)	5	5	5	7	NS
LOS total (days)	13	19	21	25	P<0.03
Major complciations	17 (12.4%)	73 (34.6%)	32 (39.0%)	65 (34.3%)	p<0.02
Mortality	20 (14.6%)	20 (9.5%)	11 (13.4%)	30 (15.9%)	NS

ISS: injury Severity Score, LOS: Lenght of stay, ICU: Intensive Care Unit, NS: not significant

DISCUSSION

The patient data describe a consecutive patient series over a period of 10 years in a level 1 trauma center in the Netherlands and describes our experiences with pelvic fractures.

As shown by other authors[1,14], pelvic fractures are predominantly seen in men less than 50 years of age and are involved in a high energy trauma of which most of them in a motor vehicle accident (MVA). These findings are similar to our patient group.

An explanation for the majority of HEMS involvement after 2006 can be explained by the fact that operating hours were extended to 24 hours a day and the criteria for HEMS involvement were broadened.

Tile A fractures are thought to be relatively benign because the stability of the pelvic ring remains intact and the risk of severe hemorrhage from the venous plexus is considered low[15]. However, in our group of patients with a Tile A fracture, almost 80% had concomitant injuries and had a relatively high ISS with a mean of 22. Also, almost 40% was hemodynamically unstable. Possible explanations can be that most patients with a simple fracture of the pubic ramus are not admitted and can be treated in the out-patient clinic with analgesics and physical therapy and therefore are not included in our analysis. This can bias our results. Also, in patients with an isolated iliac wing fractures, high energy impact is necessary to cause this type of fracture and a lot of concomitant injuries are seen

in these patients. Therefore, this group of patients have similar patient profiles and outcomes as patients with unstable fractures have.

In the patient group with a Tile B-type fracture, also a high ISS was seen also. Prehospitally, in only 31 patients (14.7%) a pelvic stabilization device was used. This might be related to the limited use of pelvic compression devices by the EMT, unclear findings in physical examination or insufficient documentation of the paramedics or the ER department. Experience nowadays in our clinic is that in patients with the slightest suspicion of a pelvic fracture, a pelvic stabilization device is used. This subject is currently studied in a new prospective case series.

Early total care was done in 50.8% of the patients with an intrinsic unstable fracture with a shock class of 2 or lower. Most of these patients were treated with symphyseal plating alone. In hemodynamically unstable patients, damage control principles were followed; either an external fixator was placed or a symphyseal plate was used. When the patient was stabilized, a secondary procedure was performed with placing of SI screws. Plating of the symphysis is a fast and easy procedure and if the patient and the fracture allow it, we prefer this over the external fixator. The advantage of this approach is direct and often better reduction of the anterior ring without the complications of external fixation devices, such as pintract infections or non-adequate placement of pins. The posterior pelvis was often stabilized in a second procedure.

The patients with the Tile B2 type fracture were treated conservatively, because we believe that this type of fracture is intrinsic stable. However, one patient with a B2 fracture who could not mobilize due to extensive pain in the SI joint were stabilized later with percutaneous SI screws, with good result.

The majority of our patients had a Tile C fracture. 90% had concomitant injuries. Therefore, the mean ISS was high. As expected the rate of major complications and mortality was the highest in the type C group. However, the number of urogenital and neurologic complications was considerably low, especially considering the amount of complex pelvic fracture patients included in this study.

Most complications seen were due to late effects of hemorrhage (SIRS) and due to thoracic trauma (Adult Respiratory Distress Syndrome (ARDS), pneumonia). Patients who had an open fracture suffered mostly from infectious complications.

The number of complications reported here is suspected to be higher than documented. This is especially true for the minor complications like electrolyte disturbances and urinary

tract infections. Major complications requiring operative therapy or ICU admittance are well documented and are therefore believed to be accurate.

Mortality in our total group was 13.6%, which is acceptable in comparison with other studies[1,4,11,16]. For example, Rommens and Hessmann report a mortality rate of 5% in the group with Tile B fractures and 14,8% in Tile C fractures[16]. In this group also a lot of concomitant injuries were seen. Death due to hemorrhage shock was seen in 9 patients (40%) compared with 10 patients (52.6%) in our group. Mortality over the past 10 years didn't change. However, this study can be the basis for evaluating our protocol in order to reduce mortality even further.

Approximately 47% of all patients could be discharged to their homes with physical therapy and no further need for clinical rehabilitation. Outcome was therefore considered generally good. However, no functional outcome scores was measured during follow-up. Information regarding walking, pain and return to former jobs could only be found in a select number of patient-charts, so no conclusions can be made of this retrospective data. Evaluation of functional outcome with the SF-36 and the Majeed[17] questionnaire is currently being studied in a prospective trial.

CONCLUSION

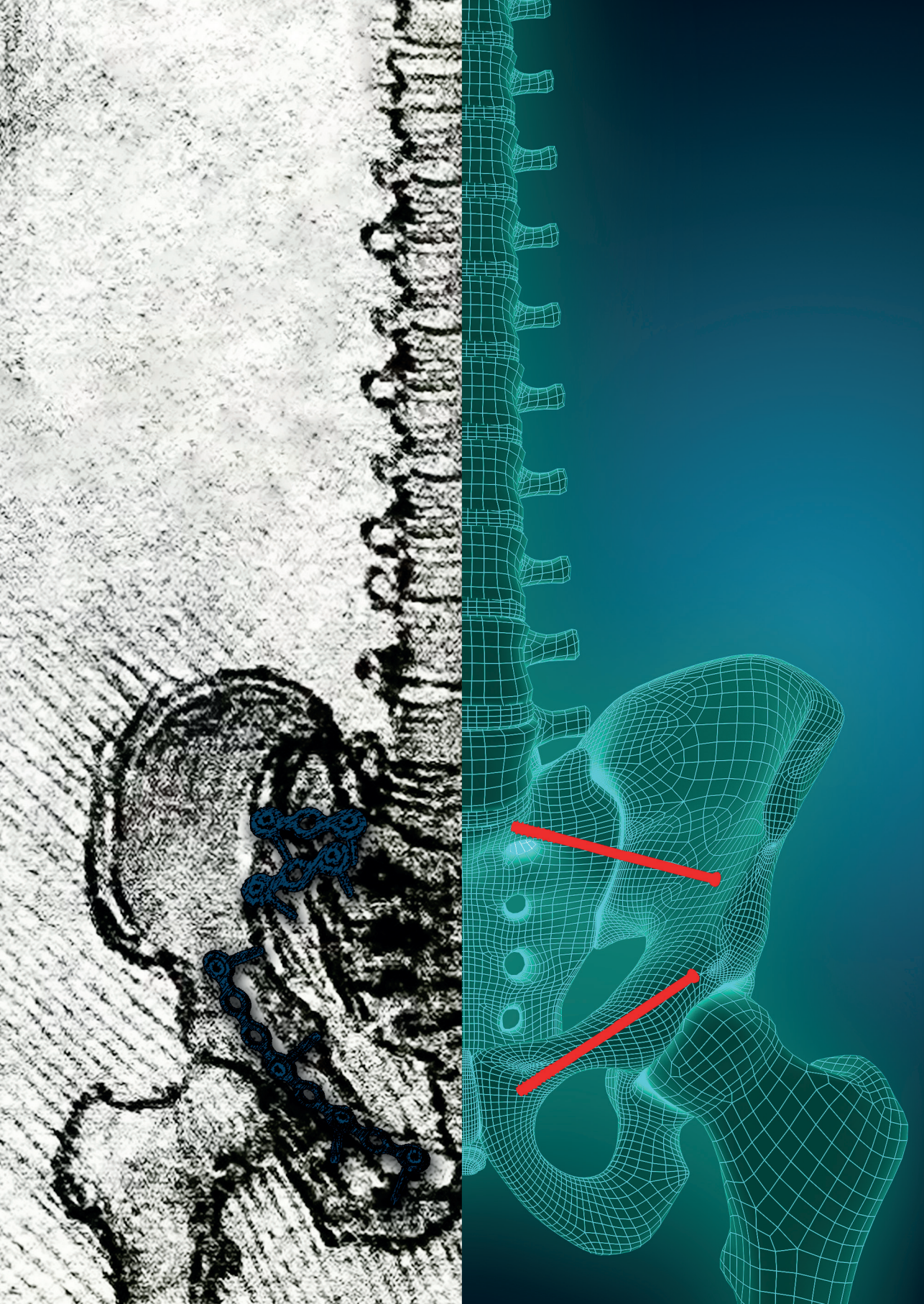
This study, conducted in a trauma center in The Netherlands which is dedicated to the treatment of pelvic ring injuries, shows a high incidence of pelvic fractures. To our knowledge, this is the largest reported single centre experience in The Netherlands. Patients with a Tile C fracture are more severely injured and require more resources. Mortality doesn't differ between the 3 fracture types according to Tile. This is suggestive that mortality is caused by a variety of other injuries such as neurotrauma. The overall outcome is considered good with almost half of the patients can be discharged to their homes.

This data is an important tool to evaluate our treatment protocol and thereby improving outcome.

REFERENCES

1. Gänsslen A, Pohlemann T, Paul C et al Epidemiology of pelvic ring injuries Injury 1996;27 Suppl 1:S-A13-20
2. Burckhardt M., Kristen A., Culemann U. et al. Pelvic fracture in multiple trauma: are we still up-to-date with massive fluid resuscitation? Injury 2014;45 Suppl 3:S70-5
3. Dalal S, Burgess AR, Siegel JH et al Pelvic fracture in multiple trauma:classification by mechanism is the key to pattern of organ injury, resuscitative requirements and outcome J Trauma 1989;29:981-1002
4. Grotz MR, Allami MK, Harwood P, et al. Open pelvic fractures: epidemiology, current concepts of management and outcome Injury. Int J Care Injured 2005;36:1-13
5. Leenen LP Pelvic fractures: soft tissue trauma Eur J Trauma Emerg Surg 2010;36:117-23
6. Gänsslen A, Giannoudis P, Pape HC Hemorrhage in pelvic fractures; who needs angiography? Curr Opinion Crit Care 2003;9:515-23
7. Van Vugt AB, van Kampen A An unstable pelvic ring. The killing fracture. J Bone Joint Surg Br. 2006;88:427-33
8. Marzi I, Lustenberger T., Management of bleeding pelvic fractures Scand J Surg 2014;103:104-111
9. Giannoudis P, Pape HC Damage control orthopedics in unstable pelvic ring fractures Injury 2004;35:671-7
10. Suzuki T, Shindo M, Soma K, Minehara H, Nakamura K, Uchino M, Itoman M.
11. Long-term functional outcome after unstable pelvic ring fracture. J Trauma 2007;63:884-8
12. Hessmann MH, Rickert M, Hofmann A, Rommens PM, Buhl M. Outcome in pelvic ring fractures Eur J Trauma Emerg Surg 2010;36:124-30
13. Tile M Acute Pelvic Fractures: I. Causation and Classification J Am Acad Orthop Surg 1996;4:143-51
14. American College of surgeons Committee on Trauma Advanced Trauma Life Support for doctors Student Course Manual 8th edition 2008
15. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. J Bone Joint Surg Am 1976;58:453-8
16. Abrassart S, Stern R, Peter R Morbidity associated with isolated iliac wing fractures J Trauma 2009;66:200-3

17. Rommens PM, Hessmann MH Staged reconstruction of pelvic ring disruption: differences in morbidity, mortality, radiologic results, and functional outcomes between B1, B2/B3, and C-type lesions J Orthop Trauma 2002;16:92-8
18. Majeed SA Grading the outcome of pelvic fractures J Bone Joint Surg Br. 1989;71:304-6



CHAPTER 3

Research on relation of mortality and hemodynamics in patients with an acute pelvic ring fracture

E. Hermans, J. Biert, AB van Vugt, MJR Edwards

Journal of Acute Disease 2016;2:117-122

3

ABSTRACT

Objective: To study the treatment pathway of hemodynamic unstable patients with a pelvic ring fracture and analyze the causes of death in this group.

Methods: Retrospectively, all data of hemodynamic unstable patients with a pelvic ring fracture in the period 1 January 2003 till 1 June 2010 were analyzed. For all patients the treatment protocol was assessed and compared with our protocol.

Results: The data of 268 patients were analyzed. Among them, 89 cases presented as hemodynamic unstable. A total of 22/89 patients died (25%). Seven patients died because of an isolated circulatory problem, 1 of an isolated neurotrauma. Fourteen patients died because of a combination of vital injuries, in which 11 sustained extensive hemorrhage. Hemorrhage contributed to mortality in 18/22 patients (82%). In 12 of the 22 patients who died, the treatment protocol was not followed. This was significantly higher than in the group survivors ($P < 0.01$).

Conclusions: Mortality in patients with a pelvic fracture is most often caused by hemorrhage or sequelae from hemorrhage. A standardized treatment protocol reduces mortality.

INTRODUCTION

Injury to the bony pelvis with disruption of the pelvic ring represents a serious clinical problem. In the majority of cases the cause is a high-energy motor vehicle accident (MVA); other typical traumas are a fall from height or local compression by high forces [10]. Because of the massive energy transfer involved in such trauma, many patients sustain multiple injuries. Mechanical instability of the pelvic ring occurs in 13-17% of all fractures [1]. A complication frequently seen in this type of injury is life-threatening hemorrhage with an overall reported mortality rate of 5-50% [25,33].

Exsanguination is a leading cause of early and late mortality in this patient group. Anatomically external blood loss, chest, abdominal, pelvic and extremity injury or a combination of those contribute to the hypovolaemic shock. Mortality exclusively due to pelvic hemorrhage is rarely seen and occurs usually do so within the first 24 hours of injury. Late deaths are caused by multisystem organ failure and sepsis [13]. Rapid diagnostic work-up and efficient treatment of pelvic hemorrhage is critical for patient survival [22].

Pelvic bleeding can originate from the fracture surfaces, or from involved arteries or veins. Notorious is the presacral venous plexus, which can cause massive blood loss if ruptured. Venous and fracture bleeding sites constitute 85% of all cases [11]. Early stabilization of the fracture is most important to stop venous bleeding or bleeding from fracture surfaces [16]. This can be combined with peripelvic packing during open stabilization of the pelvis. Arterial bleeding, accounting for 15% of all cases, can be treated using ligation, packing, or angiography and selective embolization [13].

Fortunately, mortality associated with a pelvic fracture has steadily decreased in most series over the last 20 years with the introduction of a multidisciplinary team approach and improved protocols such as damage control orthopedics.

In this study we reviewed the medical care given to patients with an unstable pelvic ring fracture, presenting with hemorrhagic shock, and analyzed the causes of death and effects of our clinical pathway.

PATIENTS AND METHODS

The data of adult patients (aged 15 years or older) who arrived alive at the emergency department of the Radboudumc (RUMC) in the period 1-Jan-2003 to 1-June-2010 were analyzed. Only patients with a partially or complete unstable pelvic ring fracture (Tile type B or C) and signs of hemodynamic instability (shock class 2, 3 or 4 according to ATLS® [2]) were included. Excluded were patients who were initially treated in another hospital and referred to the RUMC for definitive pelvic fracture treatment. Furthermore, patients who died later than one month after initial trauma were excluded because the cause of death was considered not to be related to the primary injury of the pelvis itself.

The following data were collected of each patient: gender, age, mechanism of injury, pulse rate, blood pressure, Revised Trauma Score (RTS) [21], Abbreviated Injury Scale (AIS) [8] for each body area, Injury Severity Score (ISS) [3], Tile classification [31], concomitant injuries, acute treatment given, cause and time of death. If available, autopsy data were included as well. Autopsy in trauma related mortality is not mandatory by law in the Netherlands. The data were collected from medical registration systems of our hospital.

Death was classified as related directly to the pelvic fracture if the patient required massive transfusions, died within the first 24 hours of admission and had no other body area injury with AIS ≥4 responsible for persistent hemorrhagic shock.

For all patients the clinical pathway was assessed. Specific attention was paid to differences related to the decision between acute surgery (Damage Control) versus diagnostic work-up with CT-scan as well as procedures related to acute stabilization of the pelvic ring and packing.

A patient was considered to have followed the standardized treatment protocol [figure 1] in the following cases:

- **ER:** Hypovolemic shock and receiving IV fluid therapy and/or transfusion in the primary survey
- **ER:** primary adjuncts X thorax, X-pelvis, FAST completed
- **ER**: stabilization by pelvic sling or C-clamp device in class 3 of 4 shock
- **OR:** damage control surgery (DCS) in class 3 or 4 shock; non- or poor responders
- **CT-scan**: including spine, thorax, abdomen and pelvis. Selective embolization on indication in shock class 2 or class 3/4 responders.

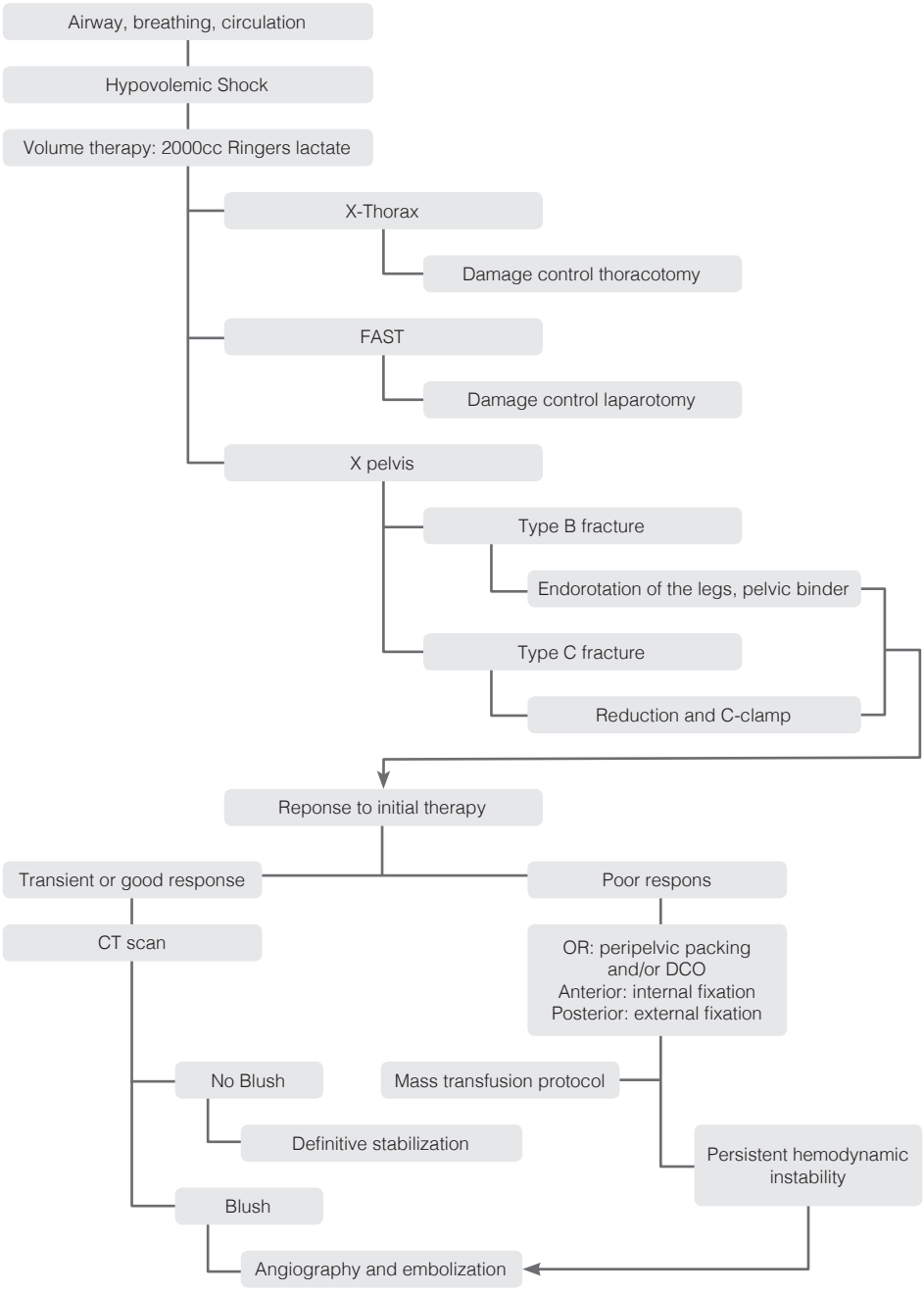


FIGURE 1 Adapted from van Vugt et al [2]

RESULTS

In total, the data of 268 patients with pelvic ring fractures were reviewed. We encountered 63 Tile type A fracture (23%), 79 type B fractures (30%) and 126 type C fractures (47.0%).

In our emergency department, 31/79 patients with a type B fracture and 58/126 with a type C injury presenting with signs of hypovolaemic shock, were included in our analysis. Of these 89 patients 55 were male. The mean age was 42 years (range 17-85) with a mean ISS of 31 (range 4-66). A total of 22/89 patients died (25%) within 30 days post injury. Patient and fracture specifics are listed in table 1. Non-survivors were significantly older ($p<0,05$), had a higher ISS ($p<0,01$) and showed a higher shock classification ($p<0,01$) and lower RTS on admission ($p<0,01$).

TABLE I Patient and Fracture specifics

		survivors (n=121)	non-survivors (n=18)	p-value
Cause of injury				
	MVA	71 (59%)	13 (72%)	NS
	FFH	37 (30%)	4 (23%)	NS
	Crush	13 (11%)	1 (5%)	NS
Age (mean)		36	50	p<0,05
Male		83 (69%)	8 (44%)	NS
RTS				p<0,01
	12	66 (74%)	4 (23%)	
	9--11	16 (18%)	5 (27%)	
	≥8	7 (8%)	9 (50%)	
ISS (mean)		22	44	p<0,01
Shock class				p<0,01
	II	100 (83%)	8 (44%)	
	III/IV	21 (17%)	10 (56%)	
Type of fracture				NS
	AP compression	24 (20%)	5 (29%)	
	Lat compression	5 (4%)	1 (5%)	
	Vertical shear	73 (60%)	10 (56%)	
	Complex type	19 (16%)	2 (10%)	
Open Fracture		2 (1%)	2 (11%)	NS

ACUTE THERAPY PRE-HOSPITALLY AND IN THE SHOCKROOM

Table 2 lists the shock classification. All patients received IV fluids in the primary survey. Eighteen non-survivors (82%) and 32 survivors (48%) needed transfusion with packed red blood cells (PRBC's) ($p<0,01$)

Patient with a class IV shock all received PRBC's as well as the transient or non-responders in shock class III.

TABLE 2 Shock class in relation with fracture type

Shock class	Survivors type B fracture	Non survivors type B fracture	Survivors type C fracture	Non-survivors type C fracture	Total
II	17	3	28	5	53
III	5	1	14	6	26
IV	2	3	1	4	10
total	24	7	43	15	89
Mortality		23%		26%	25%

All patients had a chest x-ray, pelvic x-ray and an abdominal ultrasound within 15 minutes after arrival.

Acute stabilization of the pelvic ring in the ER was carried out 48 times. A pelvic binding device was used in 37 cases, a C-clamp device in 11 patients. The use of acute stabilization related to the initial shock classification and fracture classification is demonstrated in Table 3.

Twenty-two patients were not treated according to our protocol because they received no form of pelvic binder or C-clamp and had a class 3-4 shock. 10/22 of this group of patients died. Of 23 patients who received a binder according to protocol, 7 died. ($p=0,30$)

TABLE 3 pre-hospital treatment and shock class

		Open Book		Vertical Shear	
		B1		C	
Pelvic Binder	**Shock**	**Survivors**	**†**	**Survivors**	**†**
	II	5	2	13	2
	III	3	0	6	2
	IV	0	0	1	2
		8	2	20	6
C-Clamp					
	II	0	0	1	1
	III	0	0	6	1
	IV	0	0	0	2
		0	0	7	4
Total (PB and C-clamp)		8	2	27	10
				12/48 = 25%	
No ER Fix					
	II	12	1	15	3
	III	2	1	8	4
	IV	2	3	0	2
		16	5	23	9
				14/53= 26%	

ROUTING AND TREATMENT

NON-SURVIVORS (N=22)

Table 4 list the routing of all patients. 5 patients died in the ER. A shock class III/IV non responders was seen without exception. All patients received transfusion with PRBC's. 3 patients had an unstable pelvic fracture; only in 1 patient with a type C fracture a pelvic binder was applied. In 2 patients an emergency thoracotomy was performed on the ER with fatal outcome.

Ten patients underwent a CT-scan after primary survey; 2 patients sustained a shock class of III/IV and were therefore not treated according to our protocol which dictated acute surgery. Of these 10 patients, 8 were brought up directly to the OR for operative treatment. Two patients were transferred to the ICU for further treatment.

TABLE 4 Routing patients and shock class

	Shock class	Survivors (n=67) number	Non-Survivors (n=22) number	percentage
Died in ER		**0**	**5**	100%
	II		0	
	III/IV		5	
OR		**11**	**7**	39%
	II	4	0	
	III/IV	7	7	
CT-OR		**43**	**8**	16%
	II	29	6	
	III/IV	14	2	
CT-ICU		**13**	**2**	13%
	II	12	2	
	III/IV	1	0	

Seven patients were transferred directly to the operating room (OR) for DCS for a diversity of injuries. Their shock class was III/IV nonresponding, unanimously. Two patients remained hemodynamic unstable after DCS. They were transferred to the angio suite, according to protocol.

Of the 17 patients that were treated operatively, a damage control laparotomy was performed in 10 patients. Those patients had significant intraabdominal bleeding demonstrated on FAST and/or CT. In 2 patients no fixation of the pelvis could be applied, because of fatal outcome due to uncontrollable intraabdominal bleeding. In 4 patients the C-clamp which was already placed on the ER was left in place and only a laparotomy was performed. In 4 patients the laparotomy was combined with operative stabilization of the pelvic fracture and peripelvic packing. All had plate fixation of the ruptured symphysis.

In 5 patients acute stabilization of the pelvic ring was carried out as only procedure. An anterior external fixator was applied twice. 1 patient had plate fixation of the ruptured symphysis. In 2 patients definitive stabilization was carried out by the means of symphyseal

plating and percutaneous sacro-iliac screws (early total care). Both procedures were carried out within 95 minutes. These patients sustained a shock class II. Both patients died on the ICU within 2 weeks of SIRS.

The 2 remaining patients that underwent acute surgery had external fixation of femoral fractures and an endovascular device was placed for a traumatic rupture of the aorta. Fixation of the also diagnosed type B2 fracture of the pelvis was not required.

Reviewing the treatment protocol, only 2 patients were not treated according to our protocol.

SURVIVORS (N=67)

In 56 patients a CT scan was performed. 13/56 patients were brought to the ICU after CT. 6 of them were treated with ORIF of the pelvic fracture within one week. 7 patients were treated non-operatively for the pelvic fracture, mainly due to neurological problems.

43/56 patients were treated operatively after CT. 22 patients underwent laparotomy, of which in 9 patients this was the only performed procedure in the acute phase. In 3 patients, a peripelvic packing was done.

In 34 patients the pelvic fracture was stabilized. In 2 patients with a shock class III/IV an external fixator was placed. The remaining patients all had Open reduction and internal fixation (ORIF). 16/32 patients were treated with plate fixation of the anterior ring combined with SI-screws.

11 patients were directly transferred to the OR for damage control surgery; shock classification was II in 4/11 patients. Therefore these patients were not treated according to protocol. In 3 of these patients, urgent surgery was performed because of the need of fracture stabilization of compound fractures to the lower extremity. In 1 patient a laparotomy was performed due to evisceration of the small bowel.

CAUSES OF DEATH (N=22)

Eleven patients died within 24 hours, the other 11 patients died 2-30 days after the initial trauma.

According to ATLS®-principles classification of (potential) lethal injuries was made in (A)irway, (B)reathing, (C)irculation and (D)isability (table 5). Autopsy was not performed in any or our patients.

We lost no patients solely due to an Airway or Breathing problem. C(irculation) was the death cause in 7 patients (32%) who died due to exsanguination. D(isability) resulted in one fatal case (5%) which was related to an isolated major head trauma.

In the remaining 14 patients (63%) there was a combination of fatal factors. 4 patients died due to a combination of B and C problems, a combination of C and D problems was seen 6 times. 1 patient died due to a combination of B, C and D injuries. The remaining 3 patients died because of a combined B and D problem without signs of shock.

In conclusion, hemorrhagic shock (C) contributed to mortality in 18 out of 22 patients (82%). In 8 of these 22 cases the unstable pelvic ring fracture contributed to the fatal outcome due to hypovolaemic shock.

TABLE 5 causes of death

Injury	A	B	C	D	combination	
No	0	0	7	1	B+C	4
					C+D	6
					B+D	3
					B+C+D	1

In the 7 patients who died due to exsanguination as a single cause, all had massive hemorrhage in the pelvis combined with other major bleeding sources (AIS ≥4) in chest (4 cases), abdomen (5 cases) or extremities (6 cases). Only one patient, who sustained a pelvic crush injury type Tile B, the pelvic fracture, was the only bleeding source. The symphyseolysis was fixated with a symfyseal plate. Also the lesser pelvis was packed with gauzes. After initial stabilization, the patient rapidly detoriated and died while going to the operating theatre for a second look. Fatal outcome occurred within the first 24 hours after admission. Therefore, this patient's death was classified directly related to the pelvic fracture.

MORTALITY IN RELATION WITH THE TREATMENT PROTOCOL

In 12/22 (55%) patients that died, the treatment pathway was not followed according to our protocol. This was mainly due to the lack of use of a pelvic binding device on the ER.

In 11/67 (16%) survivors the treatment given was not according to our protocol. This was a significant difference between the 2 groups ($p<0,01$).

DISCUSSION

Hemorrhage causing hypovolemic shock remains the key complication in pelvic ring injuries. In our study, hemorrhagic shock is the leading cause of deaths (82%). Therefore, rapid detection and treatment is essential. Treatment of hemorrhagic shock and prevention of further deterioration should start in the field by applying a pelvic binding device next to IV fluid substitution. [7,9,12,24]. Some authors promote prophylactic use of a pelvic binder even if a pelvic fracture is not clinically evident [6,30]. Similar for posterior injuries of the pelvic ring, a C-clamp, which can be applied in the ER, has proven to be effective in reducing excessive blood loss [15,18,28].

In this study, a pelvic binder was used in 54% of patients. Despite the absence of level I and II evidence for the clinical effectiveness of pelvic binding devices, papers so far report that pelvic binding devices are effective in reducing fractures and associated hemorrhage [27].

The exact treatment pathway of hemodynamic unstable patients with an unstable pelvic ring fracture remains controversially and is often dictated by hospital facilities. Some authors promote embolization before surgical therapy. [29,34]. Arguments supporting this strategy are the frequent concomitant injuries to liver and spleen (which can be treated with selective embolization as well), the easy access to the femoral artery, even if a pelvic binder is in place, and the presence of a false aneurysm or a total transsection of a vessel on CT-angiography (which is a risk factor for late onset or new hemorrhage) [32]. Arguments against this strategy are the length of the procedure, inhibition of simultaneous treatment of other injuries and the availability of an experienced intervention radiologist [17,20]. Also, bleeding injuries coming from other than liver, spleen or kidney are not addressed.

In our hospital, fixation before embolization is preferred as seen in our treatment algorithm. Mortality of hemodynamic unstable patients with an unstable pelvic ring fracture is reported as high as 40% [36]. In our study, we observed a mortality rate of 25%.

Early total care in a hemodynamic unstable patient is often not the method of choice [13,16,23]. Complete open stabilization of the pelvic ring is time consuming and enhances

the chance of post-operative complications such as SIRS [4]. However, stabilization of the anterior ring with symphyseal plating is a relatively easy, fast procedure [5]. In specific patients, with good response to volume therapy, early definitive stabilization of the pelvic ring with i.e. SI screws, can be performed in a relatively short time if the surgeon is familiar with this technique [19,26]. To ensure good outcome continuous evaluation of the patient's condition by the surgeon and anesthesiologist is necessary. In our study, in 23 patients the entire pelvic ring was stabilized. 2 patients died on the ICU after several days. It is questionable if these deaths could have been prevented when only DCO had been performed.

CAUSES OF DEATH

In 4 out of 22 (18%) patients who died, the routing was not according to the treatment protocol. Both patients with a class III shock died directly after the CT-scan. Both patients seemed to be good responders on IV fluid therapy, but collapsed during the CT scan. Resuscitation in the ER wasn't successful; 1 patient had an emergency laparotomy in the ER. It is uncertain if these patients would have survived if immediately damage control surgery had been performed. The 2 other patients were treated with definitive stabilization and were discussed earlier.

Exsanguination entirely due to an unstable pelvic ring fracture is uncommon. In the literature the incidence of this condition varies between 0.8% and 1.4% [14]. In our study only one patient died of exsanguination from an isolated pelvic ring fracture.

This retrospective study shows that although the mortality of pelvic ring fractures as an isolated injury is low, the combination with other major injuries, leads to a high mortality. Death is most often caused by hemorrhage or sequalae from hemorrhage. Since pelvic fractures are a major bleeding source, these injuries contribute considerably in hemorrhage as a cause of death. Definitive fracture stabilization, when performed by an experienced surgeon, is possible in selected patients.

Also we believe that a treatment algorithm for this complex type of injury reduces mortality.

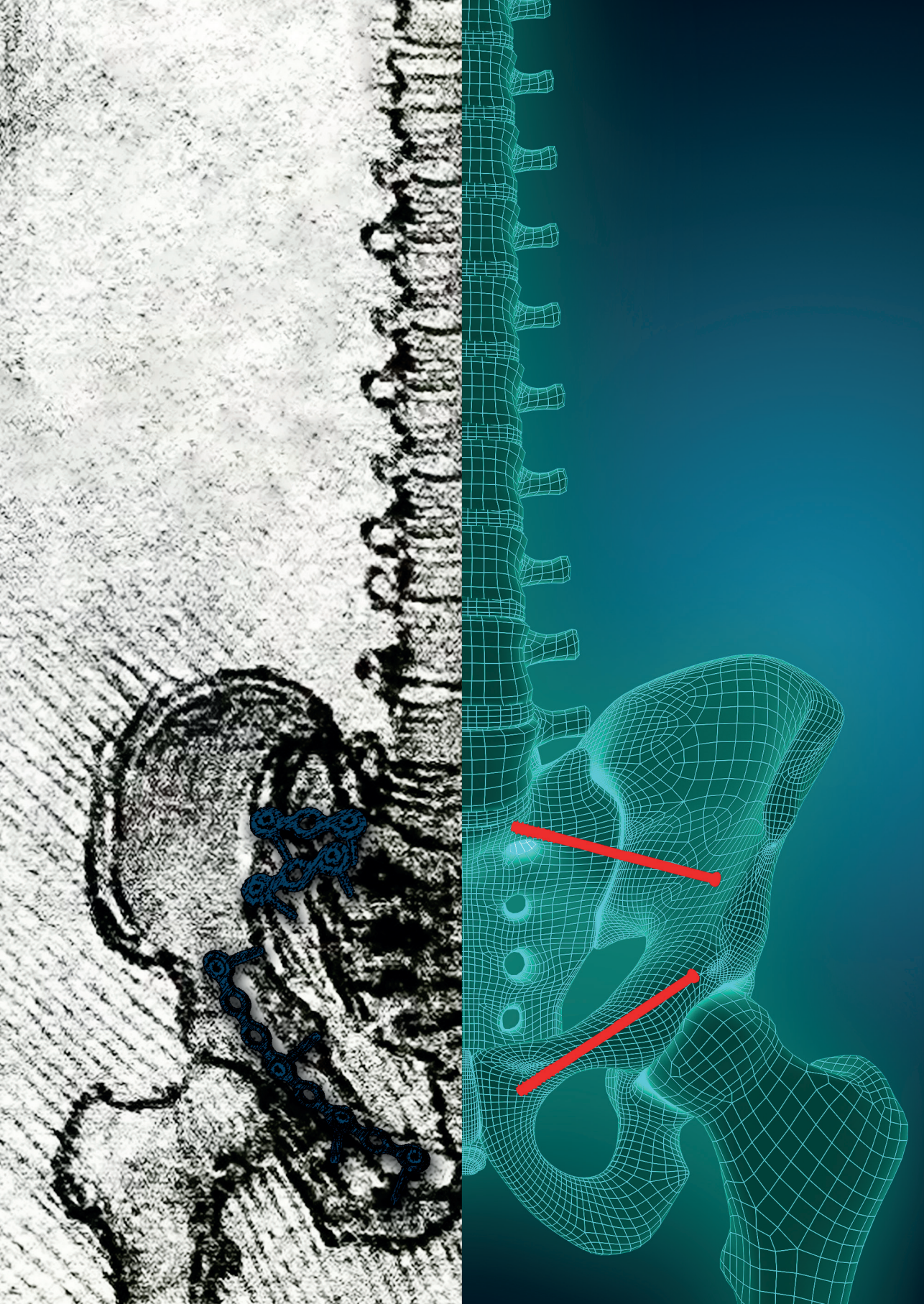
The weakness of our study is its retrospective set up and the great heterogeneity of our patient group resulting in the wide variety of injuries all patients suffered. However, most studies regarding pelvic fractures have great heterogeneity in the patient population because most patients with pelvic fractures are polytraumatized. Further studies which address optimal treatment strategies in a prospective way are in progress.

REFERENCES

1. Abrassart S, Stern R, Peter R. Unstable pelvic ring injury with hemodynamic instability: What seems the best procedure choice and sequence in the initial management? Orthopaedics & Traumatology: Surgery & Research, 2013;99:175–82
2. American College of Surgeons Advanced Trauma Life Support for doctors, student course manual,9th edition 2012
3. Baker SP, O'Neill B, Haddon W Jr et al. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187-96
4. Balogh ZJ, Reumann MK, Gruen RL et al. Advances and future directions for management of trauma patients with musculoskeletal injuries. Lancet 2012;380:1109-19.
5. Becker SC, Holstein JH, Pizanis A. et al. Anterior approaches to the pelvic ring Unfallchirurg. 2013;116:198-204
6. Chesser TJ, Cross AM, Ward AJ. The use of pelvic binders in the emergent management of potential pelvic trauma. Injury 2012;43:667 -9
7. Clarke G, Mardel S. Use of MAST to control massive bleeding from pelvic injuries. Injury 1993; 24: 628-29
8. Copes WS, Sacco WJ, Champion HR et al. Progress in characterizing anatomic injury In proceedings of the 33rd annual meeting of the association for the advancement in automotive medicine ,Baltimore, MA, USA 1989 205-218
9. Cullinana DC, Schiller HJ, Zielinski MD et al. Eastern Association for the surgery of trauma practice management guidelines for hemorrhage in pelvic fracture- update and systematic review J Trauma 2011;71: 1850-68
10. Dalal S, Burgess AR, Siegel JH et al. Pelvic fracture in multiple trauma: classification by mechanism is the key to pattern of organ injury, resuscitative requirements and outcome J Trauma 1989; 29:981-1002
11. Dormagen JB, Tötterman A, Røise O et al. Efficacy of plain radiography and computer tomography in localizing the site of pelvic arterial bleeding in trauma patients Acta Radiol. 2010;51:107-16
12. Frank LR. Is the MAST past? The pros and cons of MAST usage in the field JEMS 2000;25:38-41,44-45
13. Gänsslen A, Giannoudis P, Pape HC. Hemorrhage in pelvic fractures; who needs angiography? Curr Opinion Crit Care 2003; 9:515-23

14. Gänsslen A, Pohlemann T, Paul C et al. Epidemiology of pelvic ring injuries Injury 1996;27 Suppl 1:S-A13-20
15. Gänsslen A, Hildebrand F, Pohlemann T. Management of hemodynamic unstable patients "in extremis" with pelvic ring fractures. Acta Chir Orthop Traumatol Cech 2012;79:193-202
16. Giannoudis P, Pape HC. Damage control orthopedics in unstable pelvic ring fractures Injury 2004;35:671-7
17. Hamill J, Holden A, Paice R et al. Pelvic fracture pattern predicts pelvic arterial hemorrhage Aust NZ J Surg 2000;70:338-43
18. Koller H, Keil P, Seibert F. Individual and team training with First time users of the Pelvic C-clamp: do they remember or will we need refresher trainings? Arch Orth Tr Surg 2013,133:343-9
19. Langford JR, Burgess AR, Liporace FA et al. Pelvic fractures: part 2. Contemporary indications and techniques for definitive surgical management. J Am Acad Orthop Surg 2013;21:458-68
20. Marzi I, Lustenberger T. Management of Bleeding Pelvic Fractures. Scand J Surg 2014;103:104-11.
21. Oestern HJ, Kabus K. Comparison of various trauma score systems. An overview Unfallchirurg 1994;97:177-84
22. Pavić R, Margetić P. Emergency treatment for clinically unstable patients with pelvic fracture and haemorrhage. Coll Antropol 2012;36:1445-52
23. Pohlemann T, Braune C, Gänsslen A, et al. Pelvic emergency clamps: anatomic landmarks for a safe primary application J Orthop Trauma 2004;18:102-5
24. Routt M, Falicov A, Woodhouse E. et al. Circumferential pelvic antishock sheeting: a temporary resuscitation act J Ortop Trauma 2002;16:45-8
25. Ruatti S, Guillot S, Brun J et al. Which pelvic ring fractures are potentially lethal? Injury. 2015;46:1059-63
26. Schep NW, Haverlag R, van Vugt AB. Computer-assisted versus conventional surgery for insertion of 96 cannulated iliosacral screws J Trauma. 2004;57:1299-302
27. Spanjersberg WR, Knops SP, Schep NW et al. Effectiveness and complications of pelvic circumferential compression devices in patients with unstable pelvic fractures: a systematic review of literature Injury 2009;40:1031-5
28. Stahel PF, Mauffrey C, Smith WR et al. External fixation for acute pelvic ring injuries: decision making and technical options J Trauma Acute Care Surg 2013 ;75:882-7
29. Suzuki T, Smith WR, Moore EE. Pelvic packing or angiography: competitive or complementary? Injury 2009;40:343-53

30. Tan EC, van Stigt SF, van Vugt AB. Effect of a new pelvic stabilizer (T-POD®) on reduction of pelvic volume and haemodynamic stability in unstable pelvic fractures. Injury 2010;41:1239-43
31. Tile M. Acute Pelvic Fractures: I. Causation and Classification J Am Acad Orthop Surg 1996;4:143-51
32. van der Vlies CH, Saltzherr TP, Reekers JA et al. Failure rate and complications of angiography and embolization for abdominal and pelvic trauma. The Journal of Trauma and Acute Care Surgery 2012;73:1208-12
33. Van Vugt AB, van Kampen A. An unstable pelvic ring. The killing fracture. J Bone Joint Surg Br. 2006;88:427-33
34. Vardon F, Harrois A, Duranteau J et al. The initial management in intensive care of pelvic ring injury patients Ann Fr Anesth Reanim 2014;33:344-52
35. Waibel BH, Rotondo MF. Damage control in trauma and abdominal sepsis Crit Care Med. 2010;38(9 Suppl):S421-30
36. White CE, Hsu JR, Holcomb JB. Haemodynamically unstable pelvic fractures Injury 2009;40:1023-30



CHAPTER 4

Open pelvic fracture: the killing fracture?

E. Hermans, MJR Edwards, JC Goslings, J. Biert

Journal of Orthopaedic Surgery and Research 2018

4

ABSTRACT

Background: Open pelvic fractures are rare but represent a serious clinical problem with high mortality rates. The purpose of this study was to evaluate the outcomes of open pelvic fractures in our clinic and to compare the results from our patient group with those of closed fractures and with the literature from the past decade

Methods: Data of patients older than 16 years of age who were admitted to our hospital with a pelvic fracture between 01-01-2004 and 31-12-2014 were analyzed. The collected data were patient demographics, mechanism of injury, RTS ,ISS, transfusion requirement during the first 24 hours, Gustilo & Anderson and Faringer classification, , number and type of interventions complications, mortality and length of stay.

Results: Twenty-four of 492 patients (5% of all pelvic fracture patients) had an open fracture. Their mean age was 36 years, the mean ISS was 31, and the mean number of transfused packed red blood cells was 5.5. These numbers were all significantly higher than in the patients with a closed fracture, although they were comparable to other studies with open fractures. The mortality was 4% in the open group versus 14% in the closed group (p=0.23). The reported mortality in the literature ranges between 4 and 45% .

Conclusion: Open pelvic fractures are relatively rare but are a cause of significant morbidity. In this series, we treated patients with open pelvic fractures successfully, with a survival rate of 96%. There was no significant difference in survival rate between open and closed pelvic fractures. Compared with other studies, the mortality in our study was relatively low.

INTRODUCTION

Pelvic fractures are often caused by high-energy trauma, and these patients often have multiple injuries. Open pelvic fractures are rare, with an estimated incidence of 2-4% of all pelvic fractures[1]. Open pelvic fractures are characterized by direct communication between the fracture hematoma and the external environment (through the rectum, vagina or skin). Patients are at risk for early exsanguination because massive hemorrhage can occur due to disruption of the natural anatomic compartment and loss of the tamponade effect (figure 1). Late mortality is caused by pelvic sepsis and multiple organ failure[2]. Historically, mortality rates up to 50% were reported in the 1970s[3], which was considerably higher than the mortality rates reported for closed fractures in the same period[4]. In the 1990s, there was an improvement in treating these injuries. Leenen et al.[5] reported a mean ISS of 48 and mortality rate of 14,3% in their open pelvic fracture group. Other studies from the 90s also reported mortality rates of 15-30% [1]. However, some authors have even reported mortality rates as low as 5%[6,7]. This decline was set in motion by new aggressive trauma protocols including damage control surgery, fecal diversion, a multidisciplinary team approach and advances in critical care.

The purpose of this study was to evaluate the outcomes of open pelvic fractures in our clinic and to compare the results from our patient group with those of closed fractures and with the literature from the past decade.

FIGURE 1 Open pelvic fracture with massive hemorrhage. Initial packing in the emergency department. A pelvic binder is already applied.

PATIENTS AND METHODS

The RadboudumcNijmegen (RUMCN) is a level 1 trauma center and an expert center for pelvic and acetabular fractures in the Netherlands.

All data were analyzed from our electronic database. All patients who arrived alive at the RUMCN with a pelvic fracture between 01-01-2004 and 31-12-2014 were included if they were 16 years or older and were admitted to our clinic. The following data were collected: patient demographics, mechanism of injury, vital signs in the emergency room (ER), Glasgow Coma scale (GCS) score in the ER, Revised Trauma Score (RTS), Abbreviated Injury Scale (AIS), Injury Severity Score (ISS), fracture classification according to Tile[8], severity of soft tissue damage according to Gustilo and Anderson[9], injury zone classification according to Faringer[10], concomitant injuries, amount of blood products administered during the first 24 hours and/or intravenous fluids (colloid, crystalloid), treatment in the ER, operative treatment,

number of surgical interventions, infectious complications within 30 days after admission as recorded in the patient chart , length of stay (LOS), mortality, cause of death, time of death after the accident and destination after discharge. Urogenital complaints during follow-up as well as consolidation of the fracture on X-ray or CT were noted.

An open pelvic fracture was defined as a fracture with a direct connection between fracture surfaces and the external environment (through the skin, rectum or vagina). Patients were divided in 2 groups: one group with open pelvic fractures (OG), and one group with closed pelvic fractures (CG). Figure 2 illustrates the Faringer classification. We considered bowel injuries and vaginal wounds to be zone 1 lesions.

A pelvic sepsis was defined as a sepsis caused by intrapelvic abcessess which required percutaneous drainage.

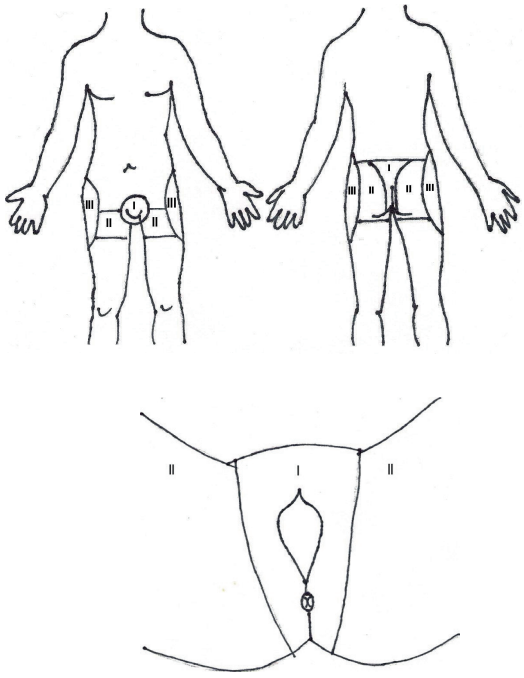


FIGURE 2 The Faringer classification

LITERATURE SEARCH

To compare our results with recent literature, a literature search of all studies regarding the outcome of open pelvic fractures from 2005-2017 was done in pubmed. The following MeSH terms were used: (open[All Fields] AND ("pelvis"[MeSH Terms] OR "pelvis"[All Fields] OR "pelvic"[All Fields]) AND ("fractures, bone"[MeSH Terms] OR ("fractures"[All Fields] AND "bone"[All Fields]) OR "bone fractures"[All Fields] OR "fracture"[All Fields]) AND outcome[All Fields]). In total, 233 articles were found. After reading the abstracts, only 7 articles were eligible for our study.

TREATMENT PROTOCOL

Patients were treated in the trauma room according to ATLS® guidelines[11]. When patients were in severe hemorrhagic shock, principles of damage control resuscitation were applied, and our massive transfusion protocol was initiated. Since 2014, the early administration of tranexamic acid, as advocated in the CRASH-2 trial by Roberts et al.[12], has been added to our resuscitation protocol. A pelvic binder was applied immediately when a pelvic fracture was suspected. A CT scan was performed in all patients, except for patients who were non-responders to initial therapy. These patients were directly moved to the operating theatre. A full physical examination was performed on each patient, including a perineal and vaginal exam if a pelvic fracture was suspected. All patients with open fractures received tetanus prophylaxis and antibiotics. Patients with a grade 1 open fractures, according to Gustilo and Anderson , received cephazolin IV once. All grade 2 or higher open fractures, , were treated with IV cephazolin for at least 5 days and aggressive surgical debridement and temporary closure with vacuum assisted closure (VAC) therapy or, if feasible, primary closure of the traumatic pelvic wound. When patients had a rectal injury or a massive perineal injury, an emergency laparotomy was performed and a colostomy was placed for fecal diversion. When patients had a urethral or bladder injury, the urologist was consulted, and a suprapubic catheter was inserted. Operative stabilization of the fracture was performed in unstable pelvic fractures (Tile B1 and 3, Tile C1-3) according to damage control principles. Throughout our study period, this protocol remained the same.

STATISTICAL ANALYSIS

All statistical analyses were performed with SPSS© statistical software version 22.0 (SPSS, Chicago, IL). We calculated the p-values using the independent samples t-test or Mann-

Whitney test to compare means and the chi-square test for categorical variables. A p-value of <0,05 was considered significant.

RESULTS

Between January 2004 and December 2014, 537 patients with a pelvic ring fracture were admitted to the RUMCN. We excluded 48 children. The data of 492 patients were analyzed. Twenty-four of 492 patients had an open pelvic fracture (5%).

DEMOGRAPHICS AND TRAUMA SEVERITY

Patient characteristics and trauma severity scores are listed in Table 1.

TABLE 1 Patient characteristics

	Open Average ± SEM	n = 24 Range	Closed Average ± SEM	n = 468 Range	*p*
Age	36 ± 2,7	17-58	43 ± 1,2	16-90	0,008
Male (%)	17 (71)		311 (66)		0,88
RTS	11 ± 0,3	7-12	10 ±0,15	4-12	0,38
ISS	31 ± 4,4	9-66	26 ± 1	9-75	0,008
Shock class>3	11		119		0,03
PRBCs (<24 h)	5,5 ± 4,2	0-30	3,5 ± 0,4	0-34	0,004

PRBCs (packed red blood cells)

The male: female ratio in both groups was approximately 3:1. All patients in the OG suffered high energy trauma (HET) compared with 87% in the CG (p<0,01). The mechanisms of injury are listed in Table 2.

TABLE 2 Mechanism of injury

	Open (n=24) No. of patients (%)	Closed (n=468) No. of patients (%)	*P*
High energy trauma	24 (100)	407 (87)	0,01
Low energy trauma	0 (0)	61 (13)	
Trauma mechanism			
Traffic accident	19 (80)	265 (65)	
Fall from height	2 (8)	106 (26)	
Crush Injury	3 (12)	37 (9)	

TABLE 3 Tile classification

	Open (n=24) No. of patients (%)	Closed (n=468) No. of patients (%)
A	7 (29)	108 (23)
A1	0	0
A2	6	92
A3	1	16
B	5 (21)	140 (30)
B1	2	32
B2	1	87
B3	2	21
C	12 (50)	220 (47)
C1	6	139
C2	3	35
C3	3	46

TABLE 4 Associated injuries

	Open (n=24)	Closed (n=468)
Head & Neck	6	85
Chest	16	157
Abdomen	9	85
Spine	6	62
Extremities	17	141

Patients with an open fracture were significantly younger (mean, 36 yrs vs 43 yrs p=0,008), had a higher ISS (mean 31 vs 26 p=0,008), were more likely to present a shock class of 3 or higher (p=0,03) and received significantly more packed red blood cell-units (PRBCs) during the first 24 hours (mean 13,2 vs 4,1 p=0,004). The Tile classifications for both groups are listed in Table 3. Tile C fractures were more frequently observed in the OG (p<0,01).

Associated injuries were frequently observed in both groups, as reflected by a high ISS in both groups. Only 3 patients (12,5%) in the OG had no other injuries than the open pelvic fracture. In the CG, 45 patients (9,5%) had no other injuries. In both groups, additional injuries to the chest and extremities were most often encountered. Additional injuries are listed in Table 4.

TREATMENT OF OPEN PELVIC FRACTURES

Nine patients were treated with a pelvic binder on scene by the paramedics. An additional 4 patients had a pelvic binder applied in the trauma room on clinical suspicion. In 11 patients with a shock class of 3 or higher and in 4 patients with a shock class of 2, the massive transfusion protocol was initiated.

In 14 patients with an open pelvic fracture, immediate operative stabilization of the pelvic fracture was performed. In 10 patients, open reduction and internal fixation (ORIF) was performed, and in 2 additional patients, this was combined with a pelvic C-clamp. One patient was treated with a pelvic C-clamp only, and in another patient, both a pelvic C-clamp and an external fixator were placed. Ten patients were not treated operatively for their pelvic fractures in the acute phase.

Two additional patients were treated operatively after a period of stabilization in the ICU. In addition, in all patients with an external fixator or C-clamp, internal fixation was performed, either with ORIF or with percutaneous screws.

In 8 patients, the pelvic fractures were treated non-operatively. These were all patients with intrinsic stable pelvic fractures (Tile A and B2). Additional angiography and selective embolization because of persistent hemodynamic instability after operative treatment was successfully performed in 3 patients (12%). In the closed group, selective embolization was done in 20 patients (4%). This was not significantly different between both groups, although a trend towards significance was found in favor of the OG (p=0.09).

TABLE 5 Patients with open fractures

No.	Sex	Age	MOI	ISS	Tile	Location	Far	GA	LOS	Col	Survivor
1	M	42	Crush	4	A	Iliac wing	3	I	5	N	Y
2	M	24	MVA	41	C	buttocks	2	II	47	N	Y
3	M	45	MVA	29	B	rectum	1	II	30	Y	Y
4	F	27	MVA	45	C	vulva	1	II	26	N	Y
5	M	47	MVA	38	A	Small bowel	3	IIIa	96	N	Y
6	M	44	MVA	38	C	Perineum	1	II	55	Y	Y
7	M	39	MVA	34	B	Rectum	1	IIIa	12	Y	Y
8	M	38	MVA	66	C	Iliac wing	3	IIIa	59	N	Y
9	F	19	MVA	16	C	Anal cleft	1	II	16	Y	Y
10	M	58	MVA	38	B	perineum	1	II	25	Y	Y
11	M	27	MVA	59	B	perineum	1	IIIa	71	Y	Y
12	M	27	MVA	22	A	Iliac wing	3	I	47	N	Y
13	F	20	Crush	48	C	perineum	1	I	29	N	Y
14	M	42	MVA	9	A	Iliac wing	3	I	0	N	Y
15	M	44	MVA	38	C	Groin	2	II	12	N	Y
16	M	55	FFH	33	C	Iliac wing	3	I	44	N	Y
17	M	39	MVA	13	A	Buttock	2	II	9	N	Y
18	F	36	Crush	4	C	groin	2	I	7	N	Y
19	F	17	MVA	57	C	vagina	1	I	59	N	Y
20	F	42	FFH	32	C	rectum	1	II	42	Y	N
21	M	47	MVA	29	A	Abdominal wall	3	IIIA	67	N	Y
22	M	19	MVA	14	A	Abdominal wall	3	II	4	N	Y
23	F	54	MVA	22	B	Iliac wing	3	II	23	N	Y
24	M	19	MVA	16	C	scrotum	1	II	11	N	Y

MOI Mechanism of injury, GA Gustilo Anderson classification, LOS length of stay (days), Col colostomy. MVA motor vehicle accident, Far Faringer zone, FFH Fall from height

FECAL DIVERSION AND PELVIC INFECTIONS

Table 5 shows our patients with open fractures.

Eleven of our patients had a Faringer zone 1 injury, 4 patients had a zone 2 injury, and 9 patients had a zone 3 injury. The Gustilo Anderson classification in relation to the Faringer zone is listed in table 6.

Of the 11 patients with an injury in Faringer zone 1, 3 patients had lacerations of the scrotum or vagina. They all were treated with debridement and primary closure. No fecal diversion was necessary in these patients.

Eight patients had a rectal or perineal injury; 7 of them underwent fecal diversion. The patient without fecal diversion had a GA I open fracture of the perineum and was treated with wound debridement and antibiotics.

TABLE 6 Relationship Faringer and Gustilo&Anderson classification

	Faringer 1	Faringer 2	Faringer 3
GA I	2	1	4
GA II	7	3	2
GA III	2	0	3

One patient with a Faringer zone 1 injury developed pelvic sepsis. This patient had a type C fracture with perforation of the rectum. The ISS of this patient was 32, and there were additional injuries to the chest and small bowel. A colostomy was placed, and secondary plate fixation of the sacrum was performed on day 6. During admittance, the patient developed a pulmonary embolism and had multiple intra-abdominal and intrapelvic abscesses that required drainage. Despite multiple operative procedures, the patient developed uncontrollable sepsis and died on day 42. None of the other patients with a zone 1 injury developed pelvic sepsis or infectious complications related to the perineal injury.

In patients with zone 2 or 3 injuries, no fecal diversion was performed, in accordance with our protocol. Infectious complications were observed in 4 patients. One patient had multiple small bowel perforations due to osseous fragments perforating the small bowel and developed multiple intra-abdominal abscesses, which required multiple laparotomies for drainage.

Two patients with an open iliac wing fracture developed an infected hematoma and were treated with debridement and VAC-therapy; 1 patient with a groin laceration developed a superficial wound infection, which was treated by opening the closed wound and secondary healing.

MORTALITY

Outcomes are listed in table 7. The total length of stay as well as the length of stay in the ICU was significantly higher in the OG.

One patient in the OG died due to uncontrollable sepsis (4%). In the CG, 68 patients died (14%).

TABLE 7 Outcomes

	Open (n=24) No. days ± SEM	Range	Closed No. days ± SEM	Range	*p*
LOS	44,1 ± 9,3	4-166	20,3 ± 1,4	0-142	0,021
ICU LOS	15,4 ± 6,1	0-107	6 ± 0,7	0-64	0,032
Mortality no. (%)	1 (4%)		68 (14%)		NS

LOS=Length of stay, ICU=Intensive care unit

TABLE 8 destination after discharge

Destination	OG (n=24) No. (%)	CG (n=468) No. (%)
Home	11 (46)	197 (42)
Other hospital	0	94 (20)
Rehabilitation facility	11 (46)	89 (19)
Nursing Home	1 (4)	19 (4)
Unknown	0	1 (1)
Deceased	1 (4)	68 (14)

DISCHARGED PATIENTS

For the destination after discharge, see Table 8. In the OG, the patients who were discharged home had a significantly lower mean ISS and shock class (p=0,02) and received substantially fewer packed red blood cells during the first 24 hours (p=0,1). There were no significant

differences in the Tile classification. In the CG, the mean ISS, shock class and number of RBCs admitted during the first 24 hours were significantly lower (p=<0,005). The group that was released to home had fewer Tile C fractures (36 vs 58) (p=0,07).

FOLLOW-UP

The mean follow-up of the OG was 6 months (range, 6 weeks-4 yrs). Restoration of continuity of the bowel was performed in 5 patients (71%). Median time to surgery was 4 months (range 6 weeks-1.2 years). The 2 other patients were not deemed fit for surgery. No problems of fecal or urinary incontinence were detected in the OG. In 2 patients, sexual problems were noted; 1 patient had dyspareunia, and 1 patient complained of impotence. Non-unions were not observed during the follow-up.

COMPARISON WITH THE LITERATURE

Table 9 shows the outcome of studies conducted from 2005 to the present. In total, 7 other studies were identified[13-19]. All studies but 1 had an inclusion period of 10 years. Most studies encountered 1 to 5 patients per year with an open pelvic fracture. The mean age was 36 years (range, 28-41), the mean ISS was 27 (range 21-31,5), and the mean number of transfused PRBC's was 10.5 (range 5.5-17.2). The mortality differed greatly between groups, with a range of 4%-45%. The mean mortality rate was 27%.

TABLE 9 reported outcomes in the literature

authors	Year of publication	No of patients	Study period	Mean age	Mean ISS	Mean no of PRBCs	Mortality (%)
This study	2017	24	2004-2014	36	31	5.5	4%
Giordano et al.	2016	30	2000-2010	28.4	21	NS	40%
Fitzgerald et al.	2014	181	2002-2012	33.6	22.7	7.2	17%
Hasankhani et al.	2013	15	2006-2010	38.6	29	8	13.3%
Wei et al.	2012	16	2000-2010	41	29	NS	31%
Dong et al.	2011	41	2001-2010	32.8	31.4	17.2	24%
Black et al.	2011	52	1999-2009	39	23	14	19%
Dente et al.	2005	44	1995-2004	39.2	29.6	11.5	45%

PRBCs: packed red blood cells NS= not specified

DISCUSSION

Patients with open pelvic fractures are rare. Most authors that reported on this fracture type encounter this type of injury 2-5 times a year. In a 10 year period, we treated 24 patients with this injury at our level 1 trauma center, which is the largest series reported in The Netherlands.

All patients with open fractures had suffered high energy trauma, which illustrates the high kinetic forces that are required to develop an open fracture. Because of the high kinetic forces involved, concomitant injuries are high, as was reflected in this study by the high ISS scores (mean, 31 in the OG vs 26 in the CG). Compared with other reports, this was relatively high, with only one study reporting a higher mean ISS (31.4)[17].

After the source of hemorrhage is controlled and the patient is adequately stabilized, aggressive wound debridement and irrigation is indicated. According to Woods et al.[20], fecal diversion is only useful in patients with extensive soft tissue injury or posterior wounds.

Faringer et al.[10] advocated that all Faringer zone I open pelvic fractures should undergo fecal diversion. In our study, 11 patients had an injury to Faringer zone 1. Seven patients underwent a diverting colostomy. Infectious complications were only observed in 1 patient, as noted earlier. The patients in whom no colostomy was performed had vaginal or scrotal lesions. These patients were classified as having a Faringer zone 1 injury, but these wounds were no reason for a colostomy. We believe a low threshold should be employed for the use of a diverting colostomy and rectal wash-out in patients with large perineal wounds and rectal injuries. This recommendation is supported by other authors[21,22].

Although patients in the OG were more severely injured, the mortality from open pelvic fractures did not differ significantly from that in patients with closed pelvic fractures. The trend of higher survival rates in the open group is possibly caused by the relatively small number of open pelvic fractures compared with a large group of closed fractures. Fracture types were comparable to other studies[5,14,19]. When comparing our study to 7 other studies published in the 90s[1], the ISS in our patient group was the 2nd highest compared with 8 studies, and the mean age was the 3rd highest; however, only one study had a comparable mortality rate[7]. We compared our results to those of more recent studies. The mortality varied greatly. Dente et al.[19] reported a mortality rate of 45%. They reported a higher mean age (39,2), a lower mean ISS (29.6), a lower mean RTS (9.5) and a lower transfusion requirement during the first 24 hours (11,5); their male:female ratio was comparable. Forty-three percent had a

grade III Gustilo-Anderson injury vs 64% in our study. In the study conducted by Giordano et al.[13], the mean age and ISS were lower, although the mortality was as high as 40%. Their explanation for this high number was the high ISS and a high relationship to Jones type 3 injuries, which are unstable pelvic ring injuries with a concomitant rectal injury[2]. However, the patients in our study had a higher ISS and a comparable number of rectal injuries. Other studies show a comparable mean age, ISS and transfusion rate. However, some authors only included patients with extensive perineal injuries[15,16] which may be the cause of the different mortality rates.

It remains unclear why the mortality rates in different studies show so much variation. We feel that the contribution to mortality of the open pelvic fracture by itself can be divided in two distinct effects: massive blood loss because of loss of containment, and infectious complications. In both subgroups, an aggressive treatment protocol was shown to be effective in our group of patients, resulting in a low mortality rate. The third contribution to mortality should be found in the high energy transfer to the rest of the body. Of course, head trauma, chest injuries and blunt abdominal trauma form a variety of causes for patient demise. In this patient group, time is of the essence. Obtainability of dedicated urgent care in regional trauma centers in the Dutch situation with short prehospital transfer times can be beneficial. This possibly explains why the mortality rates in other studies may be higher.

It can be questioned whether mortality or patient-related outcome measurements (PROMS) should be the endpoint of interest in this type of injury. PROMS are currently being evaluated in a prospective study in our center.

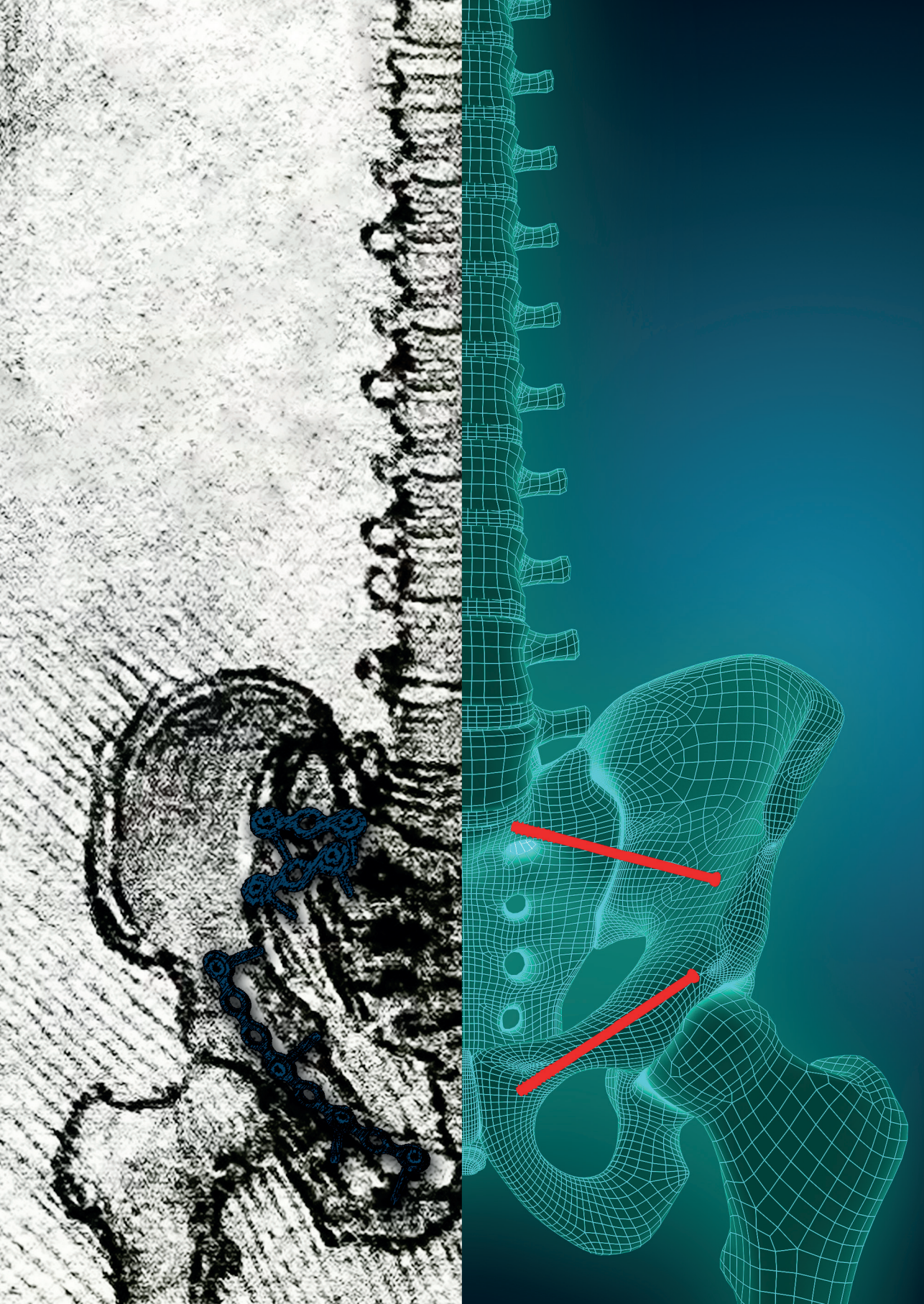
CONCLUSION

Although open pelvic fractures are relatively rare, the morbidity and use of resources are higher than in patients with closed pelvic fractures. In our series, however, the mortality was not significantly higher in comparison with closed pelvic fractures. We recommend aggressive surgical debridement and stabilization in patients with open pelvic fractures to prevent ongoing hemorrhage and pelvic sepsis to change this injury from a “killing fracture” to a survivable injury.

REFERENCES

1. Grotz MR, Allami MK, Harwood P, et al. Open pelvic fractures: epidemiology, current concepts of management and outcome Injury Int J Care Injured 2005;36:1-13
2. Cannada LK, Taylor RM, Reddix R et al. The Jones-Powell classification of open pelvic fractures: a multicenter study evaluating mortality rates J Trauma Acute Care Surg 2013:74;901-6
3. Rothenberger DA, Velasco R, Strate RG et al. Open pelvic fracture: a lethal injury J. Trauma 1978:18;184-7
4. Rothenberger DA, Fisher RP, Strate RG et al. The mortality associated with pelvic fractures Surg 1978:84;356-64
5. Leenen LPH, van der Werken C, Schoots F et al. Internal fixation of open unstable pelvic fractures J Trauma 1993;35:220-5
6. Ferrera PC, Hill DA. Good outcomes of open pelvic fractures Injury Int. J. Care Injured 1999;30:18790
7. Davidson BS, Simmons GT, Williamson PR et al. Pelvic fractures associated with open perineal wounds: a survivable injury J Trauma 1993;35:36-9
8. Tile M. Pelvic Ring Fractures: Should they be fixed? J Bone Joint Surg Br 1988;70:1-12
9. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses J Bone Joint Surg Am 1976;58:453-8
10. Faringer PD, Mullins RJ, Feliciano PD, et al. Selective fecal diversion in complex open pelvic fractures from blunt trauma Arch Surg 1994;129:958-64
11. American College of Surgeons Advanced Trauma Life Support for doctors, student course manual,9th edition 2013
12. Roberts 1, Shakur H, Afolabi A et al. The importance of early treatment with tranexamic acid in bleeding trauma patients: an exploratory analysis of the CRASH-2 randomised controlled trial Lancet 2011:377;1096-101
13. Giordano V, Koch HA, Gasparini S et al Open Pelvic fractures: review of 30 cases Open Orth J 2016:10;772-8
14. Fitzgerald CA, Morse BC, Dente CJ Pelvic ring fractures: has mortality improved following the implementation of damage control resuscitation? Am J Surg 2014;1083-90
15. Hasankhani EG, Omidi-Kashani F Treatment outcomes of open pelvic fractures associated with extensive perineal injuries Clin Orth Surg 2013;5:263-8

16. Wei R, Cao X, Tu D Clinical treatment of open pelvic fractures with associated perineal injury Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2012;26:550-3
17. Dong JL, Zhou DS Management and outcome of open pelvic fractures: a retrospective study of 41 cases Injury Int J Care Injured 2011:42;1003-7
18. Black EA, Lawson CM, Smith S et al. Open pelvic fractures: The University of Tennessee Medical Center at Knoxvilleexperience over 10 years Iowa Orthop J 2011:31;192-8
19. Dente CJ, Feliciano DV, Rozycki GS et al. The outcome of open pelvic fractures in the modern era Am J Surg 2005;190:831–7
20. Woods RK, O'Keefe G, Rhee P et al. Open Pelvic Fracture and Fecal Diversion Arch Surg 1998;133:281-6
21. Govaert G, Siriwardhane M, Hatziforis M et al. Prevention of pelvic sepsis in major open pelviperineal injury Injury Int J Care Injured 2012:43;533-6
22. Van Wessem KJP, Mackay PJ, King KL et al. Selective faecal diversion in open pelvic fractures: reassessment based on recent experience Injury Int J Care Injured 2012;43:522-5



CHAPTER 5

Isolated comminuted iliac wing fractures: are they really that benign?

E. Hermans, J.Biert, MJR Edwards

Accepted for Acta Orthopaedica Belgica

5

ABSTRACT

Aim: The aim of this study was to review the incidence, management and outcome of isolated iliac wing fractures and to compare them with other type A, B and C fractures.

Patients & Methods: From 2004 to 2015, the data of 537 patient with a pelvic fracture regarding age, gender, RTS, ISS, treatment, complications and mortality were analyzed and a comparison was made between iliac wing fractures and the other pelvic fractures.

Results: We encountered 30 isolated iliac wing fractures. The ISS, shock class, transfusion rate, complications and mortality were comparable to those of patients with an unstable pelvic fracture. Concomitant injuries were observed in 93% of the patients. None of the fractures were operatively stabilized.

Conclusion: Isolated iliac wing fractures are rare, and operative stabilization of the fracture itself is often not necessary. However, these fractures are serious injuries with characteristics and outcome resembling those of patients with an unstable pelvic ring injury.

INTRODUCTION

Isolated fractures of the iliac wing after a direct impact are uncommon, and little information can be found in the literature regarding this injury. The incidence of this type of fracture is reported to be around 2% of all pelvic fractures[1,14]. The fracture is classified as a Tile A injury[15] or as 61-A2 according to the AO/OTA[11], which means that the integrity of the pelvic ring remains intact. The risk for major bleeding from the venous plexus, which is often seen in unstable pelvic fractures, is considered low. However, arterial injury is sometimes seen[14].

Because of the rare incidence of this type of fracture, little evidence is available in the current literature regarding the management of these fractures. Some authors promote open reduction and internal fixation[14]. However, the general opinion is that these fractures do not require operative stabilization, and patients can be managed non-operatively[1]. Due to the force of the impact that is required to fracture the iliac wing[6], a high risk of concomitant injuries exists. Reported associated injuries have included large skin injuries, organ ruptures[1], neurological lesions[2], and significant damage to the abdominal wall.

The aim of this study was to review the incidence of these fractures in our hospital, evaluate the treatment, complications and outcome in this patient group and compare these fractures with other pelvic ring injuries.

PATIENTS AND METHODS

The charts of 537 consecutive patients with pelvic fractures and were admitted to the Radboud University Nijmegen Medical Center (RUNMC) during the period of 2004 to 2015 were reviewed. The RUNMC is a trauma center and a supra-regional referral center for pelvic and acetabular fractures. Also, it is the primary hospital for the Dutch Helicopter Emergency Medical Service (HEMS) for the central, south and east part of the Netherlands. Patients with an isolated iliac fracture without involvement of the pelvic ring or acetabulum were selected. Patients younger than 16 years were excluded. The diagnosis of an isolated iliac wing fracture was confirmed on a plain pelvic X-ray as well as on a CT scan. No patients who were referred to our clinic with late/secondary problems (such as a pseudoarthrosis) were included in this analysis.

The following data were reviewed: gender, age, mechanism of injury, Revised Trauma Score (RTS)[10], Injury Severity Score (ISS)[3], shock class, concomitant injuries, open fracture classification according to Gustilo and Anderson[7], treatment, complications and mortality.

A comparison was made among the isolated iliac wing fractures, other Tile A fractures and unstable fractures (Tile B/C).

RESULTS

Among 537 patients, we evaluated 137 Tile type A fractures (26%), 211 type B fractures (39%) and 189 type C fractures (35%).

Of the Tile A fractures, 0 were of the type A1 (0%); 112 were type A2 (63%); and 25 were type A3 (17%). Of the Tile B fractures, 49 patients had a B1 fracture (23%); 129 had a B2 fracture (61%); and 33 had a B3 fracture (16%). Of the Tile C fractures, 118 patients had a C1 fracture (62%); 31 had a C2 fracture (16%); and 40 had a C3 fracture (22%).

Of the 112 patients with a Tile A2 fracture, 30 had an isolated iliac wing fracture (27%) (Figure 1).

Of these 30 patients with an isolated iliac wing fracture, 25 (83%) were male. All but 2 patients had high-energy trauma and were treated according to ATLS® guidelines. The other 2 patients were involved in a fall from stairs. Seventeen patients were involved in a motor vehicle accident, 9 patients fell from a height (range 5-12 meters) and 2 patients sustained a crush injury. The mean age was 45 years (range 16-80 years), the mean RTS was 10.5 (range 6-12), and the mean ISS was 25 (range 4-75). At presentation to the ER, 4/30 patients had an unstable pelvis during the physical examination and were given a T-POD.

Minor displacement of the iliac wing fracture was observed in 9 patients. In 21 patients, major displacement (>2 cm) or severe comminution were present.

Table 1 shows a comparison of patient characteristics between the different fracture types. Patients with an isolated iliac wing fracture had a high ISS (mean 25), percentage of hemodynamic instability (53%) and percentage of open pelvic fractures (20%). These findings were comparable to the profile of patients with unstable pelvic ring fractures.

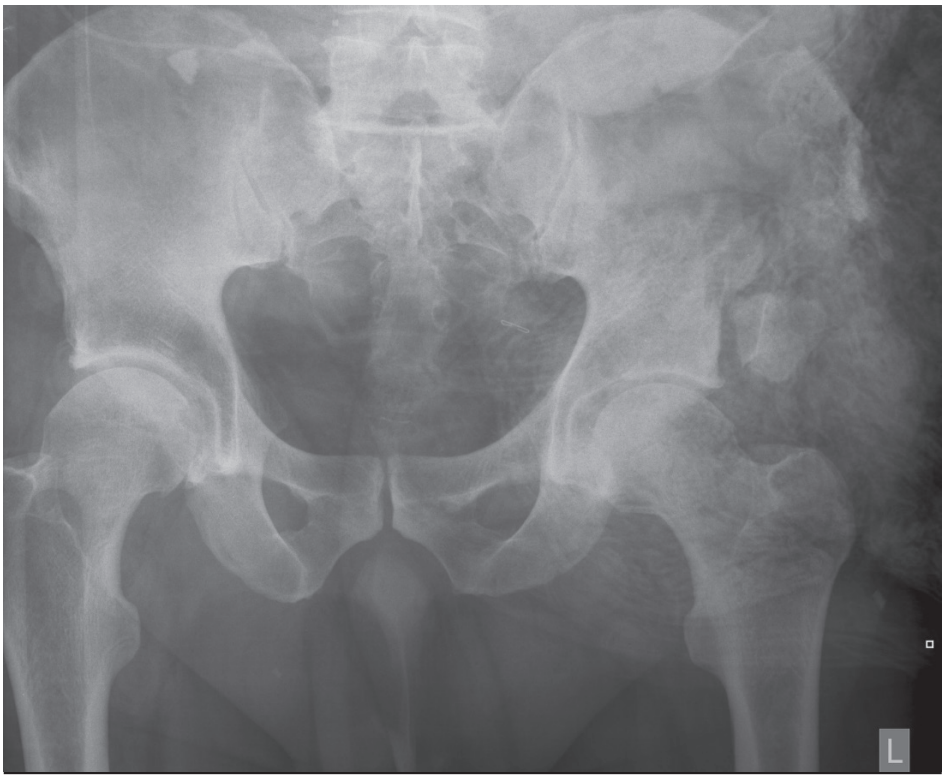


FIGURE 1 Comminuted fracture of the left iliac wing

TABLE 1 Patient characteristics

	Isolated iliac wing (n=30)	Tile A other (n=107)	Tile B (n=211)	Tile C (n=189)
Age (years)	45 (16-80)	56 (19-100)	42 (18-88)	40 (17-87)
Males	28 (93%)	49 (42%)	140 (66%)	120 (63%)
HET	28 (93%)	47 (40%)	195 (92%)	184 (97%)
RTS	10.5 (6-12)	11 (7-12)	11 (5-12)	10 (4-12)
ISS	25 (4-75)	18 (4-66)	26 (9-75)	33 (16-75)
Shock class≥2	16 (53%)	40 (34%)	72 (34%)	128 (68%)
Transfusion with PRBCs	10 (33%)	27 (23%)	56 (27%)	112 (59%)
Open fracture	6 (20%)	0	4 (2%)	13 (7%)

All values are presented as the mean (range), except for Males, HET and Open fractures. HET=high-energy trauma.

Of the patients with an open fracture in this group, 5 had grade 2 injuries according to Gustilo and Anderson, and 1 patient had a grade 3 open injury. Of these 6 patients, 2 had an evisceration of the small bowel through the fracture site. All patients were treated with antibiotics, debridement in the OR and, if necessary, closure of the abdominal wall (either primarily or with a vacuum-assisted closure device). In one additional patient, a Morel Lavallee injury was observed on the contralateral side. Operative drainage of the seroma was performed on day 5, with good recovery of the patient. No operative fixation of the fracture was performed in these patients.

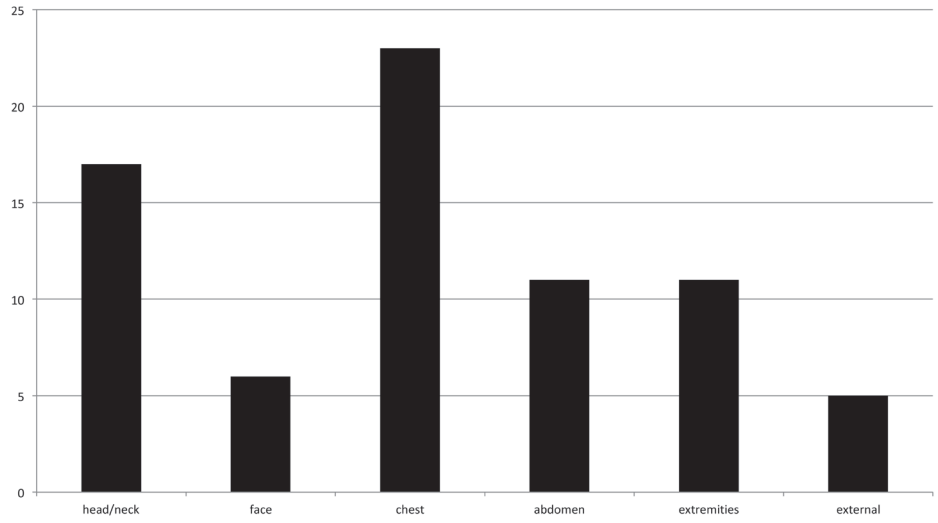


FIGURE 2 Concomitant injuries

Concomitant injuries were observed in 28 patients (93%), and concomitant injuries of patients with an isolated iliac wing fracture are listed in Fig. 2. The percentages of concomitant injuries were 83% and 90% in the groups with Tile B and C fractures, respectively. The percentage was 76% among patients with other type A fractures.

Before admission, 3 patients were treated with a pelvic binder due to the suspicion of an unstable pelvic fracture. The binders were removed after the diagnosis was made. No patients underwent surgical treatment of an iliac wing fracture. In the 6 patients with open fractures, the wounds were debrided, and sequesters were removed if necessary. A

laparotomy was performed in 8/30 patients. No patients In the group with Tile A2 and A3 fractures were surgically treated for the fracture. The stabilization percentages in the groups with Tile B and C fractures were 36% and 83%, respectively.

The complications for all groups are listed in Table 2. Thirteen patients with an iliac wing fracture did not develop complications during admission. Complications related to bowel injury were observed in 4 patients with an iliac wing fracture. Two patients developed ileus, of which, one case was due to herniation through the fracture fragments. These patients had to be operated upon to release the obstructed bowel from the hernia. The hernias were repaired with a mesh, and some fracture fragments were excised. The patients recovered uneventfully. Two patients were admitted with small bowel injuries and had multiple intra-abdominal abscesses and several re-operations. In one of the patients with small bowel injury, enterocutaneous fistulae developed, and the patient was treated with prolonged IV nutrition and resection of the fistulae after 3 months. In both patients, fracture fragments were the cause of the bowel perforation. Fig. 3 shows a CT image of a patient with severe displacement of the iliac wing fracture and disruption of the abdominal wall.

TABLE 2 Complications

Major Complications	Isolated iliac wing (n=30)	Tile A other (n=107)	Tile B (n=211)	Tile C (n=189)
Sepsis	4 (13%)	4 (4%)	8 (4%)	15 (8%)
SIRS	0	1 (1%)	11 (5%)	11 (6%)
Pneumonia	4 (13%)	4 (4%)	23 (11%)	29 (15%)
Recurrent bleeding	0	0	3 (1%)	4 (2%)
Failure of osteosynthesis	0	0	1 (1%)	6 (3%)
Minor complications				
Urinary tract infections	0	7 (7%)	6 (3%)	15 (8%)
Superficial wound infection	3 (10%)	7 (7%)	17 (8%)	14 (7%)
Delirium	4 (13%)	5 (5%)	27 (13%)	9 (5%)
Other	7 (23%)	5 (5%)	32 (15%)	27 (14%)

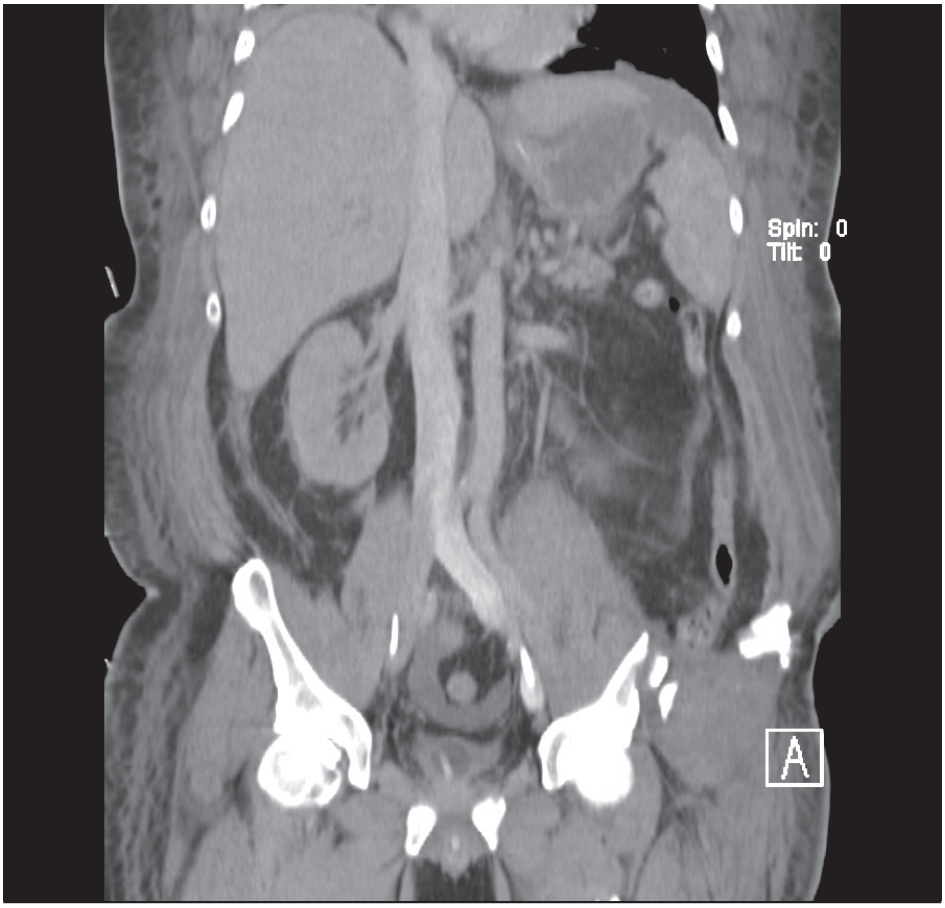


FIGURE 3 Iliac wing fracture with severe displacement and disruption of the abdominal wall

In the group with Tile B and C fractures, 11 patients sustained injuries to the bowel and were managed operatively. However, the fracture fragments did not penetrate the bowel in any of these patients.

The mean length of stay (LOS) was 16 days. Twenty of 30 patients were admitted to the ICU. The mean LOS in the ICU was 7 days. Four patients died (13%). Three patients died due to (sequelae of) hemorrhagic shock after 3-50 days. A combination of intra-abdominal bleeding caused by splenic, liver and kidney ruptures and the bleeding related to pelvic fracture contributed to this shock. One patient died because of respiratory failure. This patient had a history of COPD Gold 4.

Comparisons of the LOS, ICU LOS and mortality between the different fracture types are listed in Table 3. In the group with isolated iliac wing fractures, patients with open fractures were admitted to the hospital for significantly longer than patients with closed fractures were (44 vs. 7 days, P<0.01), mainly due to intra-abdominal abscesses and enterocutaneous fistulae. In the patients with Tile B or C fractures, the LOS did not differ significantly between the open and closed fractures.

Complications during the follow-up of isolated iliac wing fractures were observed in 3 patients (10%). One patient developed pseudoarthrosis of a closed comminuted fracture, with significant displacement of the fragments. However, he had only mild complaints and did not wish to undergo surgery. In 2 patients, a hernia developed above the iliac crest. In both patients, the hernia was repaired at a later stage. The mean follow-up was 29 months (range, 1.5-84 months).

TABLE 3 Length of stay in days (range) and mortality

	Isolated iliac wing	Tile A other	Tile B	Tile C
LOS	16 (1-120)	13 (1-142)	19 (1-72)	25 (1-160)
ICU LOS	7 (0-37)	4 (0-39)	5 (0-64)	7 (0-59)
Mortality	4 (13%)	16 (15%)	20 (9%)	30 (16%)

DISCUSSION

Comminuted fractures of the iliac wing without instability of the pelvic ring are often regarded as less severe injuries than rotatory or vertically unstable pelvic fractures. Nevertheless, the iliac bone is as resistant to heavy forces as are the other pelvic bones[6]; consequently, a high-energy impact is necessary to cause the fracture. In our study, most patients had multiple injuries. Our cohort had a mean ISS of 25, and most patients had severe concomitant injuries. A comparison of these patients with patients with an unstable pelvic ring injury showed that all patients had a similar profile with respect to ISS, shock class and transfusion rates.

The iliac wing fractures were not operatively stabilized in any of our patients.

Switzer et al.[14] reported 13 patients with an iliac wing fracture, of which, 8 had concomitant fractures that compromised the stability of the pelvic ring. Five patients with an isolated fracture of the iliac wing were also treated operatively with open reduction and internal fixation (ORIF). Fracture healing was successful in all patients. In our patient group, only 1 patient had pseudoarthrosis of the fracture, with only mild complaints. A study by Abrassart et al.[1] also showed successful healing of non-fixated comminuted iliac wing fractures in 8 patients, and 2 patients were operated upon due to severe displacement of the fragments and obstruction of the bowel. They concluded that standard operative fixation for these fractures should not be advocated. However, follow-up of these patients remains necessary because the incidence of symptomatic pseudoarthrosis or abdominal hernia might be underestimated in this series. Patients referred to our clinic with painful pseudoarthrosis of an iliac wing fracture are encountered incidentally, and operative treatment is usually necessary in this group.

In our group of patients with iliac wing fractures, a high incidence of open pelvic fracture was observed (20%). In most studies regarding open pelvic fractures[4,5,8], there seems to be a predominance of type B and C injuries and a high mortality rates. In our study, none of the patients with an open fracture died. This can be explained by the fact that no significant bleeding occurs due to the fracture. However, the morbidity is high, especially in patients with bowel perforations. In our group, 2 patients had a bowel perforation resulting from dislocated fracture fragments that had penetrated the small bowel. These patients required multiple surgeries to manage intra-abdominal abscesses, wound dehiscence and enterocutaneous fistulae. Open fractures, especially grade 2 and 3 fractures, should be treated aggressively with extensive irrigation of the wound and debridement, as well as the use of antibiotics[5]. For grade 1 open fractures, a less aggressive approach is warranted, involving wound excision and primary closure with antibiotic treatment.

Anatomically, the transverse abdominal, external and internal oblique muscles are attached to the iliac crest. Therefore, should severe fracture displacement occur, herniation of the abdominal contents through the disrupted abdominal wall can result. This is a known entity after bone grafting from the iliac crest[12,13]. In our study, 2 patients underwent surgery due to a bowel obstruction at the fracture site. During the follow-up, 1 patient developed a symptomatic hernia above the iliac crest, and this patient was treated with a component separation technique to restore the abdominal wall.

The mortality was quite high in this patient group (13%) and was comparable to the mortality among patients with type C fractures. The lower mortality in the type B group was explained by the presence of a high percentage of intrinsic, stable type B2 fractures with a relatively low ISS in our cohort. This finding can also explain the low percentage of fixation in type B fractures.

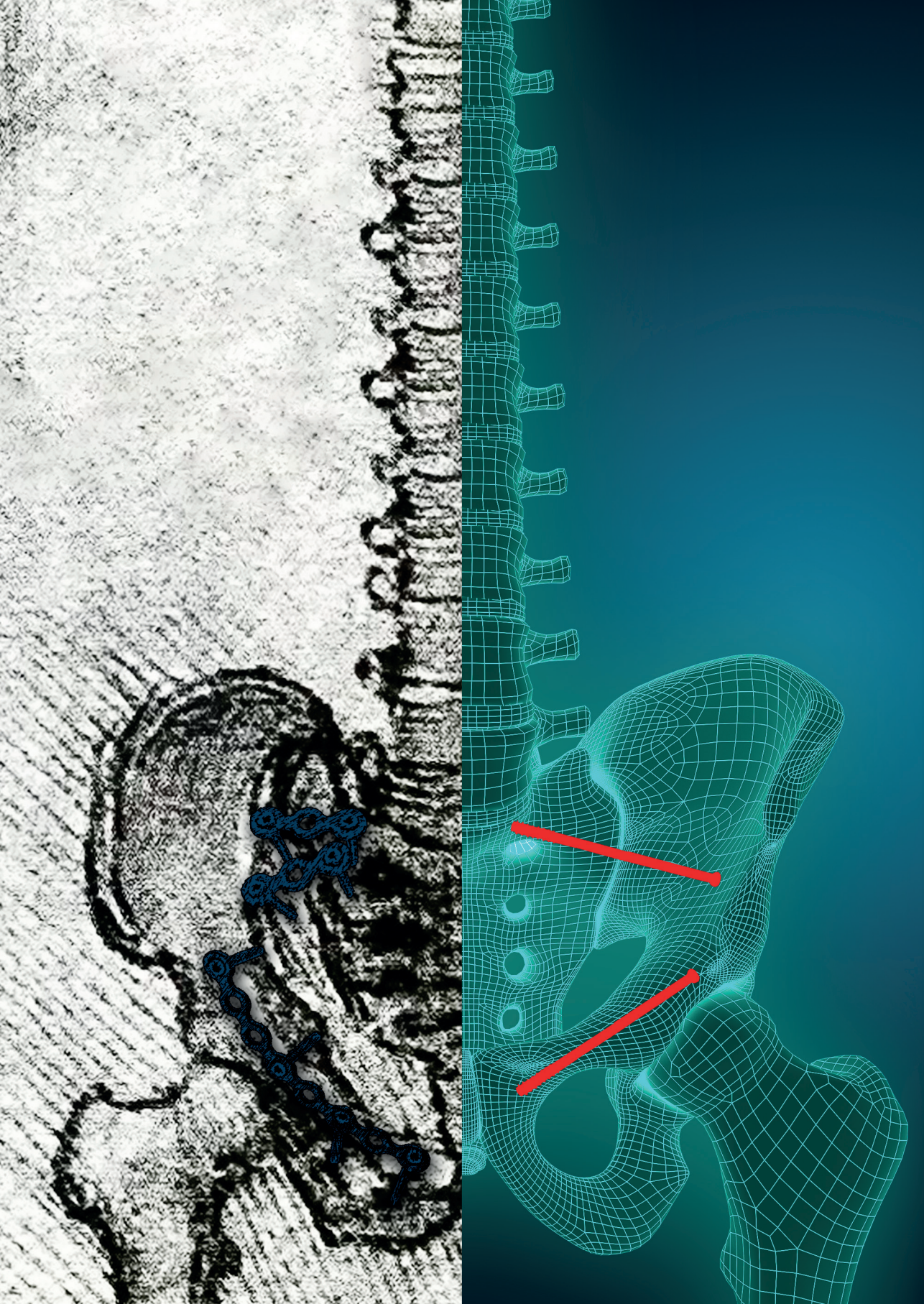
The mean follow-up was 29 months. However, a limitation of this study is the lack of standardized long-term follow-up and no measurement of functional outcome scores. An evaluation of functional outcome with the SF-36 and the Majeed questionnaire[9] is currently being conducted in a prospective trial.

CONCLUSION

Isolated iliac wing fractures without instability of the pelvic ring are rare. Although the stability of the pelvic ring is intact, and fracture stabilization is not mandatory, most patients have severe concomitant injuries. The ISS, shock class, complications and mortality are high and are not significantly lower than in patients with an unstable pelvic ring injury. Furthermore, complications during follow-up are not uncommon. Therefore, patients with an isolated iliac wing fracture after a high energy trauma warrant a high level of caution and should be regarded as having a potentially serious injury.

REFERENCES

1. Abrassart S, Stern R, Peter R. Morbidity associated with isolated iliac wing fractures. J Trauma. 2009;66:200-3.
2. Amr SM, Abdel-Meguid KM, Kholeif AM. Neurologic injury caused by fracture of the iliac wing (Duverney's fracture): case report. J Trauma. 2002;52:370–6
3. Baker SP, O'Neill B, Haddon W Jr et al. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974; 14: 187-96
4. Davidson BS, Simmons GT, Williamson PR et al. Pelvic fractures associated with open perineal wounds: a survivable injury J Trauma 1993;35:36-9
5. Grotz MR, Allami MK, Harwood P, et al. Open pelvic fractures: epidemiology, current concepts of management and outcome Injury. Int J Care Injured 2005;36:1-13
6. Guillemot H, Besnault B, Robin S, et al. Pelvic injuries in side impact collisions: a field accident analysis and dynamic tests on isolated pelvic bones. In Proceedings of the 41st Stapp Car Crash Conference, Orlando, FL 1997: 91–100
7. Gustilo RB, Anderson JT Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses J Bone Joint Surg Am 1976;58:453-8
8. Leenen LPH, van der Werken C, Schoots F et al. Internal fixation of open unstable pelvic fractures J Trauma 1993;35:220-5
9. Majeed SA Grading the outcome of pelvic fractures J Bone Joint surg Br 1989;71:304-6
10. Oestern HJ, Kabus K. Comparison of various trauma score systems. An overview Unfallchirurg. 1994;97:177-84
11. Orthopaedic Trauma Association committee for coding and classification Fracture and dislocation compendium J Orthop Trauma 1996;10(supp 1):66 –70
12. Ou CJ, Sternfeld WC, Stausmire JM. Iliac Crest Herniation Secondary to Autogenous Bone Grafting Found on Osteopathic Examination J AM Osteopath Assoc 2015;115:518-21
13. Prabhu R, Kumar N, Shenoy R. Iliac crest bone graft donor site hernia: not so uncommon BMJ Case Rep 2013;12:2013
14. Switzer JA, Nork SE, Routt ML Jr. Comminuted fractures of the iliac wing. J Orthop Trauma. 2000;14:270–6
15. Tile M Acute Pelvic Fractures: I. Causation and Classification J Am Acad Orthop Surg 1996;4:143-51



CHAPTER 6

Paediatric pelvic fractures; How do they differ from adults?

E. Hermans, ST Cornelisse, J. Biert, ECTH Tan,

MJR Edwards

Journal of Children's Orthopaedics 2017;11:49-56

6

ABSTRACT

Background: The aim of this article was to review the incidence, presentation, treatment and complications of paediatric pelvic fractures of children who were admitted to our level 1 trauma center and compare them with the our data of adult pelvic fracture patients.

Methods: We conducted a retrospective chart review of all children with pelvic fractures who were managed at our institution between January 1993 and December 2013 and compared it with our database on pelvic fractures in adults of the period 2007-2012.

Results: We identified 51 children and 268 adults with pelvic fractures. The median age of the paediatric patients was 11 years. Children were significantly more involved in traffic accidents than adults ($p< 0.001$). Adults had a significant higher Injury Severity Score (ISS) (31 vs 24.5, $p< 0.03$) and were significantly more often hemodynamic unstable ($p<0.01$). Adults had more often a type C fracture, children a type B fracture ($p<0.001$). Associated injuries were seen in both groups; however, thoracic injuries were significantly higher in adults ($p<0.01$) and injuries to the extremities were higher in children ($p<0.01$). Adults were significantly more often treated with open reduction and internal fixation ($p<0.001$). Mortality in both groups however, did not differ (6 vs 8%).

Conclusion: Paediatric pelvic fractures are rare. They differ from adult pelvic fractures in presentation, associated injuries and management. Mortality however, is substantial and does not differ from the adult population. Mortality is often due to concomitant injuries and not to exsanguination from the pelvic fracture.

INTRODUCTION

Pelvic fractures in children are rare, with an incidence estimated to be in the range of 0.5% to 7.0% (1-4) of all blunt paediatric traumas. However, mortality is significant with a reported range of 1.4% to 25%, and an average of 6.4%[1, 2, 5, 6, 7].

The immature pelvis has greater elasticity at the sacroiliac joints and symphysis, which makes fractures dependent on high energy forces[8]. Most patients with a pelvic fracture are therefore multitraumatized patients with injuries to the head, chest, abdomen and extremities[6, 9]. The extent of the associated injuries and the complications result in greater morbidity and mortality than the fracture itself[5, 6, 10].

Acetabular fractures co-occur with pelvic fractures, but they do not constitute life-threatening injuries by themselves. However, due to articular involvement, the clinical outcome can be very disappointing. The development of the acteabulum starts with the three great ossification centres of the ischium, ilium and pubis, and join in the triradiate cartilage. Fusion of these growth plates is seen between the age of 13 and 16 years[11].

Several classification systems aim to describe the stability of pelvic fractures and to predict morbidity and mortality in the setting of severe trauma. These models include those developed by Torode and Zeig[12] and Tile[13]. Both are widely used. Torode and Zeig divide fractures into stable and unstable but did not differentiate between fracture type and degree of instability[12]. The Tile system[13] combines the mechanism of injury and pelvic ring stability and makes a distinction between stable (Type A), rotationally unstable (Type B) and vertically unstable (Type C) pelvic fractures.

In this article, we review the incidence, presentation, treatment and complications of paediatric pelvic fractures in patients admitted to our trauma center, and compare this to a group of adult patients with a pelvic ring fracture from our institution, and to literature. All pediatric and adult patients were treated by the same group of 6 traumasurgeons.

METHODS

A retrospective chart review was performed of children younger than 16 years with a pelvic fracture who were managed between January 1st 1993 and December 31st 2013 at a referral centre for pelvic and acetabular surgery, the Radboud University Medical Center (RUMC).

Data including patient details, mechanism of injury, pre-hospital treatment, vital signs on admission, Glasgow Coma Scale (GCS), Injury Severity Score (ISS)[14] and associated injuries, treatment, length of stay (LOS), ICU admittance, outcome and clinical outcome in follow-up were extracted from our prospectively collected database. All available radiology examinations were reevaluated and classified by two senior authors, both trauma surgeons with an extensive experience in the field of pelvic trauma. Pelvic fractures were classified according to Tile (13). Additional acetabular fractures were noted. All pelvic fractures were discussed in the trauma group, supervised by one of the authors (JB). Our current consensus is that if the displacement of the acetabular fractures was more than 2mm, operative treatment was indicated.

Operative treatment for pelvic fractures was indicated when the pelvic fracture was rotationally or vertically unstable or there was severe displacement of the fracture.

Associated injuries were classified into five groups: intraabdominal, intrathoracic, intracranial/head, extremities and vertebral column. Our database in children was compared with a database composed of pelvic factures in adults (age>16 years) from our clinic and with the literature. Data retrieval on adults was done in a similar way as in children. All adult patient data was collected between 2007 and 2012.

RESULTS

CHILDREN

Between 1 January 1993 and 31 December 2013, we identified 51 children with a pelvic fracture; 44 children sustained a pelvic fracture only and in 7 the acetabulum was also involved. The median age was 11 years (range 3-16 years) and 57% were boys (n=29) [Table 1]. Figure 1 shows the age distribution of the children.

The most common causes of injury were traffic accidents, fall from height and injuries during sport [Table 1]. The incidence of pelvic fractures varied over the years between one and seven children, with a mean incidence of 2 to 3 children a year.

TABLE 1 Characteristics of paediatric pelvic fracture compared with adults

	Children (n=51)	Adults (n=268)	p-value
Age (Mean)	11 years (3-16)	42 (18-90)	-
Male	57% (n=29)	66% (n=178)	0.19
Clinical presentation			
mean ISS	24.5	31	**0.03**
Hemodynamic unstable	2 (4%)	89 (33%)	**<0.01**
Blood transfusion	10 (20%)	50 (19%)	0.15
Length of stay	17 days (1-80)	17 days (1-142)	0.99
ICU admission	68 % (n=34)	56% (n=150)	0.16
Length of ICU stay	8 days (1-23)	5 days (1-39)	0.11
Outcome			
Death	3 (6%)	22 (8%)	0.57
Mechanism of Injury			
Motor Vehicle Accidents	40 (78%)	150 (56%)	**0.003**
Fall from height >2m	6 (12%)	57 (21%)	0.12
Crush	1 (2%)	25 (10%)	0.08
Other	4 (8%)	36 (13%)	0.27

TABLE 2 fracture type

	Children (n=51)	Adults (n=268)	p-value
Tile A	14	63	0.67
Tile B	29	79	**<0.001**
Tile C	8	126	**<0.001**

Of the 51 children, 14 (27%) sustained a Tile A fracture, 29 (57%) a type B fracture and 8 (16%) a type C fracture [table 2].

At their presentation in the emergency room, 21 children (43%) exhibited a depressed level of consciousness (Glasgow Coma Scale <15, (mean 4, range 3-13), 4 children were hemodynamically unstable [Table 1]. A blood transfusion was required in 8 children (16%) within the first 48 hours. Three of the four hemodynamically unstable children underwent surgery acutely, one patient responded to blood transfusion and stabilized hemodynamically.

The median ISS (as calculated by the national trauma registry) was 24.5 (range 7-50). Only four children scored ≤16. There was no significant link between type of fracture and ISS score.

A total of 34 patients (68%) were initially admitted to the intensive care unit (ICU). Thirty-one recovered and spent a mean of 8 days in the ICU (range 1-23 days). Their median hospital stay was significantly longer than that of patients who were not admitted to the ICU ($p<0.05$). Type of pelvic fracture was not significantly related to admittance to the ICU ($p=0.33$), or to length of stay on the ICU ($p=0.075$). The median length of stay of patients with a pelvic fracture was 17 days (range 0-80). Length of stay was significantly related ($p=0.042$) to type of pelvic fracture, longer admissions were associated with more severe pelvic fractures (B and C types).

Five patients (10%) did not require hospital admission; all of these patients had a type A pelvic fracture and were instructed to begin movement within the limits of pain. These patients were seen in our outpatient clinic as frequently as required.

The median length of stay of the seven patients with a pelvic ring fracture and an acetabular fracture was 22 days (range 5-68 days).

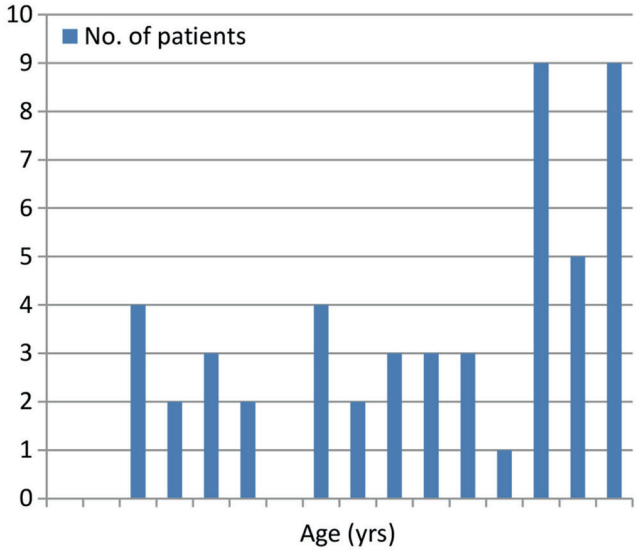


FIGURE 1 Age distribution (yrs)

ADULTS

In the period between 1 January 2007 and 31 December 2012 , the data of 268 adult patients were reviewed. We encountered 63 Tile type A fracture (23%), 79 type B fractures (30%) and 126 type C fractures (47.0%). Most common cause of accident was a MVA (56% of the patients). A crush injury was the cause in 10% of the patients, a fall from height in 21%.

Of the 268 patients, 178 were male (66%). The mean age was 42 years (17 to 90) with a mean ISS of 31 (4 to 66).

In total, 89 patients (33%) were hemodynamically unstable and 50 of these patients required a blood transfusion. The other 39 patients responded to volume therapy and placement of a pelvic binder alone.

Median length of stay was 17 days (1 to 142). All patients were admitted at least one day to our hospital. Patients with a non-displaced type A fracture (e.g. a pubic ramus fracture) who could be mobilized at the ER were dismissed and were seen in our outpatient follow-up but were not included in this analysis. Of the patients, 56% were admitted to the ICU with a median length of stay of 5 days. Also in our adult group, longer admissions were associated with more severe pelvic fractures (B and C types).

ASSOCIATED INJURIES

CHILDREN

In addition to their pelvic fracture ,70% of the patients had associated injuries. A total of 50% sustained associated injuries in 2 or more separate regions. The most frequent associated injuries were femoral fractures (24%), intracranial bleeding (24%), pneumothorax (16%) and urinary tract injuries (12%) [Table 3]. There was no significant link between fracture type and associated injuries in any of the subgroups.

ADULTS

In adults, almost 85% of the patients had 1 or more concomitant injuries. Thoracic injuries were most frequently seen in adults. However, the number of urogenital and neurologic injuries was considerably low (6%), especially considering the amount of complex pelvic fractures in our patient group.

TABLE 3 Concomittant Injuries

AIS region	Children (n=51)	Adults (n=268)	p-value
Head/neck	22 (43%)	85 (32%)	0.11
Face	4 (8%)	8 (3%)	0.09
Chest	12 (24%)	158 (60%)	**<0.01**
Abdomen	19 (37%)	85 (32%)	0.43
Extremities	39 (76%)	142 (53%)	**<0.01**

MANAGEMENT

CHILDREN

A total of 11 patients (21%) were managed surgically, based on the stability of the fracture and the clinical condition of the patient. Three patients had a type B fracture and eight a type C fracture. Seven patients (14%) underwent external fixation to stabilize their pelvis, in 3 cases followed by internal fixation with a SI-screw and plate. Four children had immediate open reduction and internal fixation with plates and screws [table 4]. Non-operative treatment consisted of bed rest followed by progressive mobilization within the limits of pain.

TABLE 4 Definitive operative treatment

	Children (n=51)	Adults (n=268)	p-value
External fixation	4 (8%)	12 (4%)	NS
Internal fixation	7 (14%)	151(56%)	**<0,001**
Laparotomy	7 (14%)	51 (19%)	NS

Three patients had an open pelvic fracture, as a result of skin lacerations, degloving or wounds from burns. Antibiotics were prescribed for all of these patients. One patient had a ruptured rectum and another had a ruptured bladder and a retroperitoneal hematoma. In all cases of urological damage, the Urology Department was consulted for advice on treatment. Five other patients with urethral injury were primarily managed with a transurethral catheter; of these, 2 were managed with secondary reconstruction in the OR at a later time by the

pediatric urologist. Seven patients with a pelvic fracture sustained an additional acetabular fracture which, due to minimal displacement, were all managed non-operatively.

Figures 2 to 4 demonstrate a pelvic fracture in a 12 year old patient, operative treatment and one year later with fracture healing.

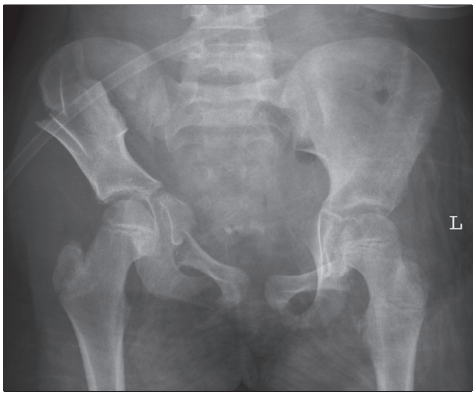


FIGURE 2 Type C pelvic ring injury in a 12 year old girl

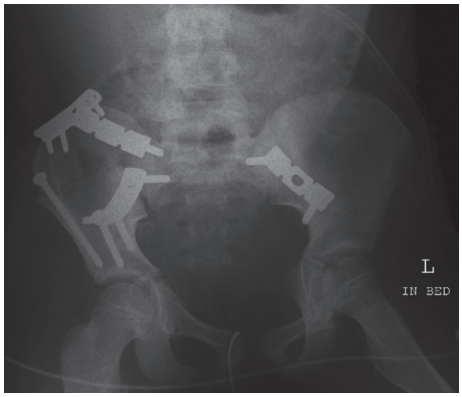


FIGURE 3 Post-operative radiograph with bilateral plate osteosynthesis

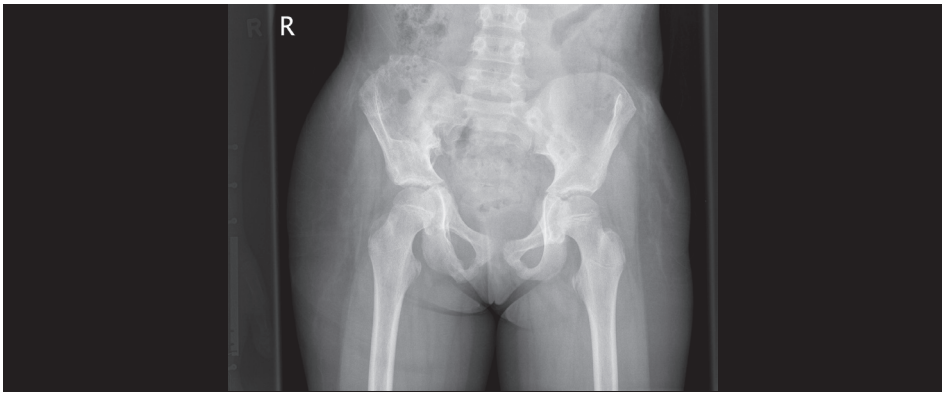


FIGURE 4 Pelvic radiograph one year after injury: uncomplicated fracture healing, removal of hardware, non-operatively treated anterior pelvic ring shows realignment. At follow-up after two years, the patient had a normal gait and was able to enjoy soccer and jazz ballet without much complaints.

ADULTS

Of the adult patients, 56% were managed surgically; of these, 42% had a form of operative treatment in the acute setting. In most cases, a form of open reduction and internal fixation was performed. An external fixator or C-clamp was also placed in several patients. We consider plating of the symphysis pubis in a type B or C fracture a fast and relative easy procedure and prefer this procedure over the external fixator. The posterior ring was often treated in a second session. Treatment in adults varied. Type B injuries were treated with symphyseal plating or percutaneous pubic screws. When patients had rotational instability in the sagittal plane (bucket handle lesions), the preferred treatment was the placement of percutaneous SI screws.

Type C fractures were treated the same, but for complex sacral fractures plates were used.

Open fractures were seen 13 patients (5%). Three patients had a grade 1 open injury, six patients had a grade 2 open fracture and four patients had a grade 3 open injury. In this group, no traumatic hemipelvectomies were encountered. Grade 1 open fractures were treated with antibiotics alone. Grade 2 and 3 injuries were treated with aggressive surgical debridement and antibiotics. Five patients had a colostomy due to perineal injury.

MORTALITY

CHILDREN

Three children (6%) died due to their associated injuries; two due to their severe head trauma (two and five days after trauma) and the third child hours after abdominal surgery. Autopsy later revealed a massive pulmonary embolism.

On arrival, all of these children exhibited a depressed level of consciousness (mean GCS 6) and non-reactive pupils. The two patients who died of head trauma had a type B pelvic fracture. The third patient had a type C fracture.

ADULTS

Overall mortality in our group was 8% (22/268). Mean ISS of diseased patients was 47 (4 to 75). Packed red blood cells were given to 14 of the 22 patients (62%). The remaining eight patients responded to volume replacement alone in conjunction with placement of a pelvic binder.

Within the first 24 hours of the accident nine patients (41%) died. Two of 22 (9%) patients died solely due to severe head trauma; two died primarily of a respiratory problem. One patient died due a tracheal rupture and one patient of a bilateral tension pneumothorax. This last patient had end stage chronic obstructive pulmonary disease (COPD) and died of progressive respiratory failure. In 18 patients (82%), haemorrhagic shock contributed to or was the cause of death.

OUTCOME

CHILDREN

The mean follow-up time was seven months (six weeks to six years). The large variation in follow-up time was due to the associated injuries. Patients with an acetabular fracture were observed for a longer period to identify growth disturbances, until the growth plates were closed. Four children were transferred to a hospital in their home country, including one in the United Kingdom and three in Germany, and were lost to follow-up. None of these patients had an acetabular fracture.

Three children suffered a persistent disability due to the pelvic fracture that consisted of pain and reduced stamina at the end of outpatient follow-up (mean follow-up of 10 months). All three had a type B fracture and were treated conservatively. One patient had a leg-length discrepancy of 1 cm due to a type C fracture that was without clinical significance. This patient also had an acetabular fracture. In none of the patients with an associated acetabular fracture, preliminary closure of the growth plates was observed. No growth disturbances were observed during follow-up. Good clinical results after operation were achieved in 11 of 51 (22%) children. The 48 patients (94%) achieved full range of motion without pain in the hip or lower back in active daily life. Nine of 11 patients that were operated upon were in this group. In 6/7 patients who had internal fixation, the plates and screws were removed after fracture healing.

ADULTS

Mean follow-up time in adults was five months (six weeks to eight years). Approximately 47% of all patients could be discharged to their homes with physical therapy and no further need for clinical rehabilitation. Outcome was therefore considered generally good. However, no functional outcome scores were measured during follow-up. Information regarding walking,

pain and return to former jobs could only be found in a select number of patient-charts so no conclusions can be made of this retrospective data. In only a select group of patients, the plates and screws were removed after fracture healing.

COMPARISON WITH PELVIC FRACTURES IN ADULTS

Compared with pelvic fractures in children, adults had higher ISS scores and had a greater frequency of hemodynamic instability at presentation at the emergency room (Table 1).

However, the requirement of transfusion with packed red blood cells was not higher in adults. Fracture type differed significantly between both groups. Adult patients presented more often with a type C fracture, children with a type B fracture (Table 2).

Although average overall length of admission was equal between the two groups, children were admitted longer to the ICU. Most patients had concomitant injuries. In comparison with adults, children suffered more from head and extremity injuries. Adults had significantly more chest injuries compared with children (Table 3).

In the adult group 22 patients died, in 18 of these haemorrhage contributed significantly to the cause of death. Only one adult patient died solely due to the sequelae of haemorrhage from the pelvic fractures, in all other adult patients there was a combination of injuries. Mortality did not differ significantly between groups.

DISCUSSION

In the period between January 1993 and December 2013, we treated 51 children with a pelvic fracture in our trauma centre. The baseline characteristics of our study group matched with the recent literature (Table 5). The mean age of our group (11.1 years) was high compared with other studies, which have reported a mean age ranging from 8.4 to 9.4 years.[[1,5,6,16]] The 28 children (55%) were aged 12 years or older. In the Netherlands, there are many cyclists. In 15 children (30%) they had an accident and fractured their pelvis whilst riding a bike; of these children, 13 were aged 12 years or older.

TABLE 5 Comparison of baseline characteristics in other studies

Author	Year of publication	Number of patients	Age (Mean)	Mortality	Operative treatment (n and %)
This study	2017	51	3-16 years (11.1)	6%	11 (21%)
Marmor [4]	2015	5325	<13 years	10.2%	265 (5.0 %)
Leonard [10]	2011	39	1-14 years (8,6)	3%	2 (5%)
Banjaree [2]	2009	44	1-16 years (11,4)	16%	1 (2%)
Vitale [21]	2005	1190	0-20 years (11)	7.2%	n.a.
Karunakar [20]	2004	148	<16 years	n.a.	14 (9%)
Chia [6]	2004	120	1- 16 years (9)	4%	7 (6%)
Grisoni [9]	2002	57	1,2-15 years (9)	4%	5 (9%)
Rieger [5]	1997	54	5-16 years (10,9)	6%	38 (70%)

n.a. = not applicable

The aetiology of pelvic fractures in children differs from that in adults. Compared with adults, children suffer more from MVAs (Table 1) and are less involved in falls from heights or crush injuries. Adults are often the drivers of a car, while children are usually struck by a car from the side whereby they sustain lateral compression type injuries.[[10]] Also in bike trauma, severe crush injuries due to being run over by a car are often seen. This leads to open fractures with severe soft-tissue injury.

Considering the concomitant injuries, there are well-known differences in pathophysiological mechanisms in children as compared with adults. Rib cage fractures are rare in children but common in adults because of the elasticity of the ribs. In the Netherlands, until recently protective helmets for bicyclists were hardly ever in use for children. Combined with the fact that children have a relatively larger and heavier head, this might explain the high incidence of serious head injury. The origin of the different number of extremity trauma remains unclear. In this study, the majority of the MVAs (81%) is the result of being struck as a pedestrian/cyclist by a car or truck. The high incidence of type B2 fractures (lateral compression and internal rotation) supports this assertion. Only five children were car passengers.

According to the ATLS protocol, the gold standard for radiological examination of pelvic injuries in the emergency setting is the anteroposterior (AP) pelvic radiograph.

In recent years, the CT scan had been increasingly used for the evaluation of paediatric trauma patients.[2,15] Consequently, we diagnosed additional pelvic fractures in children that were initially missed on pelvic radiograph. CT scan occasionally resulted in changes in the classification of the pelvic fracture; however, there were no changes in treatment even though the classifications changed.

The use of CT scans in children is associated with increased cancer risk due to the higher doses of ionising radiation delivered by CT, especially CT scans of the abdomen and pelvis.[18,21] Therefore, we advise for general practice that a standard pelvic radiograph is performed and that additional CT is performed only for patients with highly complex fractures and for patients in which it is doubtful that their injuries can be managed non-operatively.

In the past, paediatric pelvic fractures were usually managed non-operatively because children possess greater ability of healing and remodelling after a fracture.[1,10,15]

In our hospital, all type A pelvic fractures and 79% of the type B fractures were treated conservatively, with adequate pain management and progressive mobilisation.[15] The conservative treatment of unstable and displaced pelvic fractures may result in pelvic asymmetry that can lead to serious disabilities and pain, similar to adult patients.[1,5,17,20] Several authors have observed that paediatric pelvic asymmetries do not remodel and deformities result in high morbidity.[5,17,21]

In the last few decades, surgical treatment of type B and C pelvic fractures in children has been promoted by several authors.[1,3,15,19] Unstable and displaced pelvic fractures (types B and C) should be reduced and stabilised.[20] External fixation is the preferred technique in the emergency setting because it can be applied rapidly, particularly in multi-traumatised patients.[1,5] In type C pelvic fractures, anterior external fixation may not be sufficient and placement of a C-Clamp is needed. In five patients, internal stabilisation of the SI joint was achieved with SI screws or plates over the SI joint, all of which were applied within 48 hours of the trauma. In the emergency setting, all of these patients were treated initially with an external fixator.

In this series, the percentage of severe pelvic fractures (types B and C) and mean ISS were high compared with those reported in the literature.[1] We treated 22% of the children operatively. In the literature, operative treatments are in the range of 0.6% to 30%.[1,5,6]

The high percentage of operative treatment in our clinic was the result of patient selection. Because our clinic is a level 1 trauma centre (and a national referral centre for pelvic and

acetabular fractures), many severely injured patients are presented in our emergency room, which increased the number of unstable pelvic fractures and the ISS score.

The mean ISS of children differs from that of adults. It is questionable whether the method by which the ISS is calculated in adults can be applied to children.

A total of 50% of the paediatric patients had injuries in more than two regions close to the pelvic fracture. The incidence of associated injuries was similar to those of other series.[1] Intracranial injuries in particular have a substantial influence on prognosis and outcome.

In paediatric pelvic fractures, haematuria is a very common clinical finding and is usually present without significant injury of the urinary tract.[5,6] In this series, six patients (12%) were diagnosed with urogenital injuries. Others have reported associated genitourinary injury rates in the range of 6% of 24%.[1,5,6,15].

In contrast to adults, children have lower rates of exsanguinating haemorrhage. Blood transfusion requirements are approximately equal, but only two children had a large retroperitoneal hematoma. Perhaps this result is due to a more effective vasoconstriction response of less friable and non-atherosclerotic blood vessels.[6] All polytrauma patients, children and adults were resuscitated under supervision of one of the six trauma surgeons, in adherence to the hospital massive blood transfusion protocol. In case of haemodynamic instability, all patients (children and adults) are treated according to this protocol.

Mortality in our paediatric group was 6% which was comparable with other authors. However, the study by Marmor et al[[4]] reviewed the United States national databank and mortality was 10.2%. This might advocate treatment in specialised trauma centres with specific knowledge of treatment of the rare injuries.

This study was a retrospective analysis of collected data and thus may be subject to bias. Our conclusions regarding outcomes and effect on active daily life are based on data that were found on the medical chart. The follow-ups varied widely; therefore, no firm conclusions about the long-term results can be made.

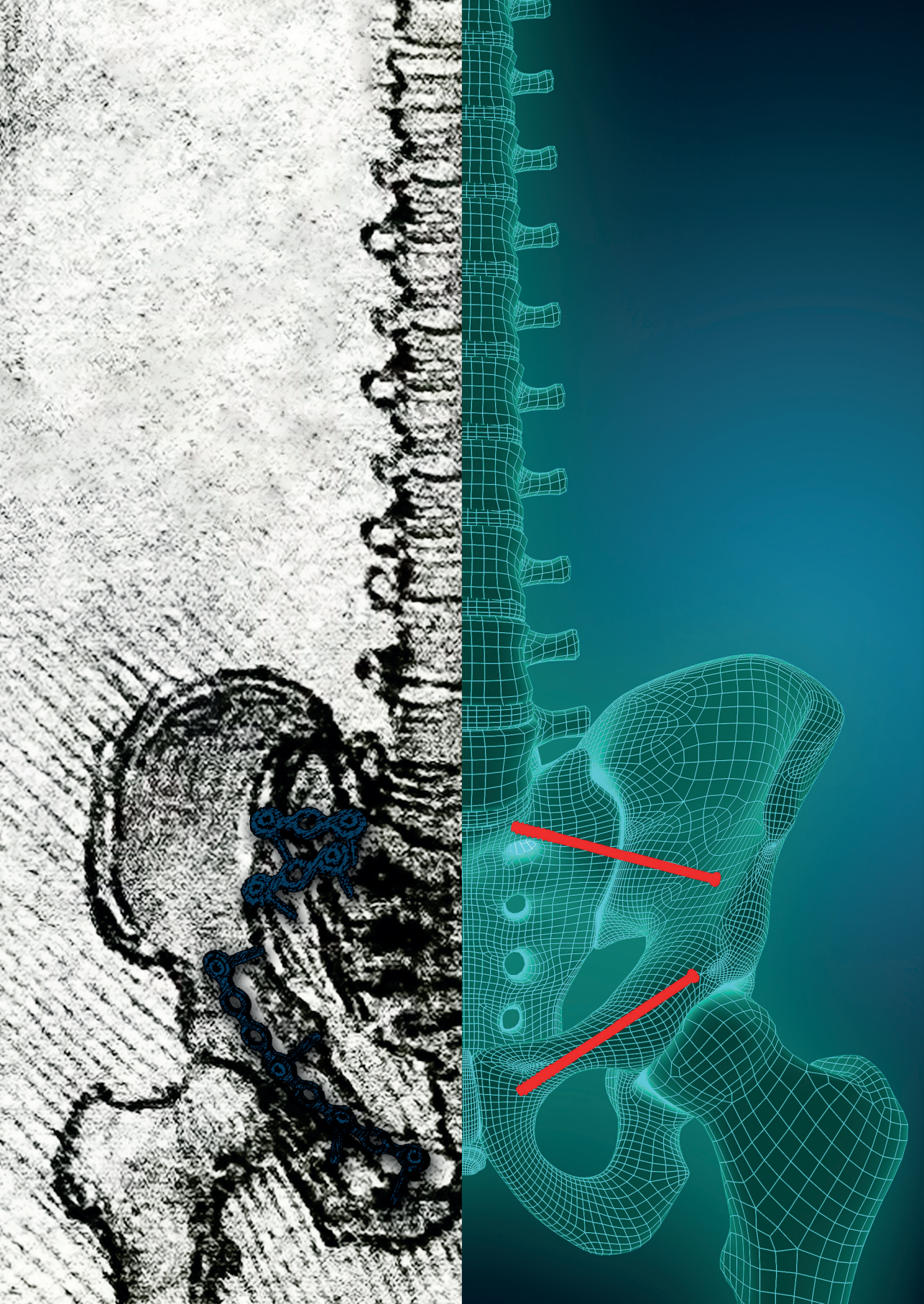
Paediatric pelvic fractures are rare and differ from adults in aetiology, fracture type and associated injuries. They are observed in multi-trauma patients, with severe associated injuries. Treatment of these patients in specialised hospitals is likely to provide the best outcome because of the rarity of these fractures. Only a small percentage of the fractures need operative treatment. In a significant proportion of the operated patients, morbidity and mortality were not linked to the pelvic fractures, but to the associated injuries. Compared

with adults, children die less often due to sequelae of haemorrhage. Mortality does not differ between groups. Evaluation of functional outcome with the SF-36 and the Majeed questionnaire[23] is currently being studied in a prospective trial.

REFERENCES

1. Gänsslen A, Heidari N, Weinberg AM. Fractures of the pelvis in children: a review of the literature. Eur J Orthop Surg Traumatol 2013;23:847-861.
2. Banerjee S, Barry MJ, Paterson JM. Paediatric pelvic fractures: 10 years experience in a trauma centre. Injury 2009;40:410-413.
3. Blasier RD, McAtee J, White R, Mitchell DT. Disruption of the pelvic ring in pediatric patients. Clin Orthop Relat Res 2000;376:87-95.
4. Marmor M, Elson J, Mikhail C, Morshed S, Matityahu A. Short-term pelvic fracture outcomes in adolescents differ from children and adults in the National Trauma Data Bank. J Child Orthop 2015;9:65-75.
5. Rieger H, Brug E. Fractures of the pelvis in children. Clin Orthop Relat Res 1997;336:226-239.
6. Chia JP, Holland AJ, Little D, Cass DT. Pelvic fractures and associated injuries in children. J Trauma 2004;56:83-88.
7. Smith WR, Oakley M, Morgan SJ. Pediatric pelvic fractures. J Pediatr Orthop 2004;24:130-135.
8. Shore BJ, Palmer CS, Bevin C, Johnson MB, Torode IP. Pediatric pelvic fracture: a modification of a preexisting classification. J Pediatr Orthop 2012;32:162-168.
9. Grisoni N, Connor S, Marsh E, et al. Pelvic fractures in a pediatric level I trauma center. J Orthop Trauma 2002;16:458-463.
10. Leonard M, Ibrahim M, Mckenna P, Boran S, McCormack D. Paediatric pelvic ring fractures and associated injuries. Injury 2011;42:1027-1030.
11. Ponseti IV. Growth and development of the acetabulum in the normal child. Anatomical, histological, and roentgenographic studies. J Bone Joint Surg [Am] 1978;60-A:575-585.
12. Torode I, Zieg D. Pelvic fractures in children. J Pediatr Orthop 1985;5:76-84.
13. Tile M. Pelvic ring fractures: should they be fixed? J Bone Joint Surg [Br] 1988;70-B:1-12.
14. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187-196.
15. Schlickewei W, Keck T. Pelvic and acetabular fractures in childhood. Injury 2005;36:A57-A63.
16. Junkins EP, Furnival RA, Bolte RG. The clinical presentation of pediatric pelvic fractures. Pediatr Emerg Care 2001;17:15-18.
17. Oransky M, Arduini M, Tortora M, Zoppi AR. Surgical treatment of unstable pelvic fracture in children: long term results. Injury 2010;41:1140-1144.

18. Kevill K, Wong AM, Goldman HS, Gershel JC. Is a complete trauma series indicated for all pediatric trauma victims? Pediatr Emerg Care 2002;18:75-77.
19. Miglioretti DL, Johnson E, Williams A, et al. The use of computed tomography in pediatrics and the associated radiation exposure and estimated cancer risk. JAMA Pediatr 2013;167:700-707.
20. Pascarella R, Bettuzzi C, Digennaro V. Surgical treatment for pelvic ring fractures in pediatric and adolescence age. Musculoskelet Surg 2013;97:217-222.
21. Karunakar MA, Goulet JA, Mueller KL, Bedi A, Le TT. Operative treatment of unstable pediatric pelvis and acetabular fractures. J Pediatr Orthop 2005;25:34-38.
22. Vitale MG, Kessler MW, Choe JC, et al. Pelvic fractures in children: an exploration of practice patterns and patient outcomes. J Pediatr Orthop 2005;25:581-587.
23. Majeed SA. Grading the outcome of pelvic fractures. J Bone Joint Surg [Br] 1989;71-B:304-306.



CHAPTER 7

Quality of life after pelvic ring fractures: long-term outcomes. A multicentre study

E. Hermans, L. Brouwers, T. van Gent, J. Biert,

MAC de Jongh, KWW Lansink, MJR Edwards

Submitted Injury

ABSTRACT

Aims: This study was conducted to determine long-term (5-10 years) health-related quality of life (HRQOL) and ceiling effects in patients with a pelvic ring fracture.

Patients and methods: We identified all patients with pelvic ring fractures after high-energy trauma admitted at two level 1 trauma centres in the Netherlands from 2006 to 2011. Patients were asked to complete the Majeed Pelvic Score (MPS), EuroQol-5D (EQ-5D) and Short Musculoskeletal Function Assessment (SMFA) questionnaires. HRQOL analysis used a multiple linear regression model.

Results: In total, 136 patients returned the questionnaires. The median follow-up period was 8.7 years. The mean MPS and EQ-5D-VAS scores were 85.1 and 74, respectively. The mean EQ-5D index scores were 0.87, 0.81 and 0.82 in Tile B, A and C patients, respectively. The mean SMFA index was 24. A ceiling effect was observed for 1/3 of the patients. After multiple linear regression analysis, no differences were identified among the various fracture types for each questionnaire, with the exception of 2 subscales of the MPS.

Conclusion: Patients who suffer pelvic ring fractures generally have good HRQOL outcomes after 5-10 years. No significant differences were found among different fracture types. Long-term follow-up of patients with Tile C fractures is warranted.

INTRODUCTION

Pelvic fractures with disruption of the pelvic ring usually occur due to high-energy trauma (HET).[1] Patients with pelvic ring fractures often sustain multiple additional injuries.[2] Mortality and morbidity are significant, and the mortality rate can reach approximately 10-16%.[3,4]

Numerous studies have been performed regarding the early management of pelvic fractures to improve functional outcomes.[2,5] The results of the conservative management of unstable fractures are poor, with complications such as mal- or non-union and chronic pain.[6] Surgical therapy for unstable fractures is therefore currently an accepted treatment.[7]

Few studies have focused on long-term health-related quality of life (HRQOL) evaluation and functional outcomes at 5-10 years after trauma. Oliver et al.[8] examined long-term HRQOL in patients with unstable pelvic fractures and found a 14% physical impairment and a 5.5% mental impairment compared to the American population, regardless of the type of management. Suzuki et al.[9] concluded that neurological impairment of the lower extremities was the main predictor of worsened quality of life and poor functional outcomes. Factors that contribute to poor outcomes identified in other studies include age, presence of a complex fracture type, surgery and chronic pain.[10,11] Additionally, several authors have identified sexual and urological dysfunction as risk factors for decreased quality of life.[12] However, these studies included relatively small patient groups, with a follow-up period of only 2 years.[13,14]

As a result, patient outcomes 5-10 years after trauma are not well understood. Furthermore, it is not clear how long the HRQOL of patients continues to improve. Several authors[15] have reported an improvement in HRQOL up to the fifth year after injury; however, other authors[16] have reported a significant decrease in HRQOL over time. The degree of increase or decrease in HRQOL can be measured using the maximum HRQOL score. Several studies have shown a large ceiling effect (>15% of patients with the highest score[17]) in follow-up analyses of patients with pelvic ring fractures. Brouwers et al.[18] and Lefaivre et al.[19] demonstrated ceiling effects at 29 and 56 months after injury, respectively. The present study was conducted to determine long-term (5-10 years) HRQOL and ceiling effects in pelvic ring fracture patients.

PATIENTS AND METHODS

The study was reviewed by the medical ethics committee of the Radboudumc and was determined to fall outside the scope of the Medical Research Involving Human Subjects Act.

We identified all patients with a pelvic ring fracture who were admitted to two level 1 trauma centres in the Netherlands from 2006 to 2011 from our trauma registry. These trauma centres are both larger hospitals in the Netherlands, which treat >350 patients with an ISS>16 per year. Patients were included if they were 18-80 years old, and their accident involved a HET, which was defined as an accident involving a moped travelling >30 km/h, a car accident at a high velocity, being thrown out of a vehicle/motorcycle, a collision with a pedestrian at >30 km/h, a fall from a high altitude (>5 metres) or severe entrapment with long extrication.

Patients with osteoporotic fractures or a low-energy trauma (LET) were excluded. We also excluded patients who died and patients who did not demonstrate good command of the Dutch language.

Data concerning patient and trauma characteristics, fracture type (according to Tile category), Injury Severity Score (ISS),[20] concomitant injuries, acute and definitive treatment, complications and mortality were acquired from the relevant hospital databases.

All patients were asked to complete the Majeed Pelvis Score (MPS),[21] EuroQol-5D (EQ-5D)[22] and Short Musculoskeletal Function Assessment (SMFA)[23] questionnaires.

The MPS is widely used in research concerning quality of life of patients with pelvic injuries and is divided into 5 "subscales": pain (30 points), work (20 points), sitting (10 points), standing (36 points total: walking aids, 12 points; gait unaided, 12 points; walking distance, 12 points), and sexual intercourse (4 points). If sexual intercourse was not attempted, for any reason, a score of four points was given.[15]

The EQ-5D is a questionnaire with five dimensions: mobility, self-care, usual activities, pain or discomfort, and anxiety or depression. Each dimension has three levels: no problem, moderate problem, or severe problem. The EQ Visual Analogue Scale (EQ-5D-VAS) records the patient's self-rated state of health on an analogue scale between 0 (worst imaginable health state) and 100 (best imaginable health state). In addition, a scoring algorithm is available by which each health status (HS) description can be expressed as a summary score. This summary score, the EQ-5D index, ranges from 1 for full health to 0 for death and

can be interpreted as a judgement on the relative desirability of an HS compared to perfect health. A normal score on the EQ-5D index for the Dutch population is 0.87 (SD: 0.18).[24]

The SMFA is designed to assess the HS and HRQOL of patients with a broad range of musculoskeletal injuries and disorders. The Function index contains 39 items, and the Bother index contains 14 items. Both indices use a five-point Likert scale with scores ranging from 1 (not at all/never/none) to 5 (unable to do/always/extremely). The indices range from 0 to 100. Higher scores indicate a lower HS and lower HRQOL. The adapted Dutch version of the SMFA has been validated in patients with fractures of the upper or lower extremities[23]. In this study, only questions regarding the lower extremities were used.

DATA ANALYSIS

Patient characteristics were analysed with descriptive statistics. A multiple linear regression model was used for the HRQOL analysis. The following demographic and clinical characteristics and relevant adjustment factors for the present analysis were considered: the EQ-5D dimensions were dichotomized into "no problems" and "problems", and multiple logistic regression was performed. The results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). Continuous variables including the EQ-5D-VAS, EQ-5D index score and MPS were analysed using a multiple linear regression model with correction for the following confounders that were thought to have a significant impact on outcome: age, sex, ISS, fracture type (stable versus unstable), neurologic injury, urogenital injury, open fracture, injuries to the lower extremities and surgical treatment. The results are presented as β-coefficients (B) with 95% CIs. All statistical analyses were performed using SPSS, version 22 (SPSS Inc, Chicago, IL, USA), with consultation from biostatisticians. A p-value of ≤ 0.05 was considered statistically significant.

RESULTS

In total, 336 patients with a pelvic ring injury were identified. Of these 336 patients, 42 had died, 46 patients did not speak Dutch, and the contact addresses of 17 patients were not found. Therefore, 231 patients were ultimately eligible for this study. These patients were contacted and asked to complete the MPS, SMFA and EQ-5D questionnaires. One

hundred thirty-six patients completed the questionnaires (59%). No significant differences were observed in age, gender, Tile classification and ISS between the included patients and patients who were not contacted.

The mean age of the included patients was 39 (SD 17) years, and the mean ISS was 22.8 (SD 14). Thirty-one patients (22.7%) were haemodynamically unstable upon presentation in the ER (shock class 3 or higher). Eighty-one patients were male (58.8%). Of the 136 patients returning the questionnaire, 23 had a Tile A fracture (16.9%), 65 had a Tile B fracture (47.7%), and 48 had a Tile C fracture (35.3%). Patient characteristics for the various Tile groups are listed in Table 1. Patients with a complex fracture type had a significantly higher ISS and shock class and were more often treated surgically.

TABLE 1 Patient Characteristics

	Total (N=136)	Tile A (N=23)	Tile B (N=65)	Tile C (N=48)	p-value
Age (yrs)	39	38	36	43	NS
Male (%)	81	12 (52)	42 (65)	27 (56)	NS
ISS	29.9	16	28	33	p<0.01
Shock ≥grade3 (%)	31 (23)	5 (22)	7 (11)	19 (40)	p=0.02
Open fracture (%)	10 (7)	2 (8)	4 (6)	4 (8)	NS
Surgical treatment (%)	75 (55)	0	34 (52)	41 (85)	p<0.01
Concomitant injuries (%)	119 (88)	19 (83)	57 (88)	43 (90)	NS
Lower extremity (%)	44 (32)	10 (43)	18 (28)	16 (33)	NS
Neurological injury (%)	47 (35)	7 (30)	23 (35)	17 (35)	NS
Urogenital injury (%)	5 (4)	1 (4)	1 (2)	3 (6)	NS

NS=not significant

Open fractures were observed in 10 patients (7.3%), of which seven were grade two or higher based on the scale reported by Gustilo & Anderson.[25] Seventy-five patients were treated operatively for the pelvic fracture (55.1%). Concomitant injuries were identified in

87% of patients. The majority of patients had concomitant injuries to the chest or extremities. Concomitant injuries to the lower extremities were observed in 44 patients (32.4%).

Neurological injury was observed in 47 patients (34.5%); of whom, 28 suffered severe head trauma (20.6%). Focal neurological deficits were observed in 9 patients (6.6%). Two patients exhibited complete paralysis due to spinal cord injury (1.5%).

Urogenital injuries were observed in five patients (4%); three patients had an urethral rupture, and two had a bladder rupture. The median follow-up period was 8.7 years (range: 5-10 years).

OUTCOME SCORES

MPS

All 136 patients completed the MPS. The mean MPS score was 85.1 (SD 16.6). MPS scores are listed in Table 2. Almost 25% of patients reported significant sexual problems (fewer than 3 points on the MPS). No significant differences were found among the different fracture types. Return to work was reported in 57% of patients with a Tile A fractures, 63% with a Tile B fractures and 52% with a Tile C fractures. Regarding our follow-up period, 34% of patients had a maximal score of 100 points on the MPS, including 32% of Tile A, 36% of Tile B and 33% Tile C fracture patients.

EQ-5D

The results of the EQ-5D are shown in Table 3. This questionnaire was completed by all included patients. The EQ-5D-VAS score was 74-76 of 100 and did not differ significantly among the Tile groups. The EQ-5D index score also did not differ significantly among the fracture types. A mean index score of 0.87 was observed in Tile B patients, while for Tile A and C patients, the mean index scores were 0.81 and 0.82, respectively. The average EQ-5D index score of the general Dutch population is 0.87[24].

TABLE 2 MPS

MPS dimension	Description	MPS points	Tile A, % N=23	Tile B, % N=65	Tile C, % N=48
Pain	Intense, continuous at rest	5	0	0	2
	Intense with activity	10	4	2	2
	Tolerable, but limits activity	15	13	9	19
	Moderate activity, abolished by rest	20	9	8	10
	Mild, intermittent, normal activity	25	17	15	6
	Slight, occasional or no pain	30	57	66	60
Work	No regular work	4	39	29	38
	Light work	8	4	3	0
	Change of job	12	0	5	8
	Same job, reduced performance	16	4	12	8
	Same job, same performance	20	53	51	44
Sitting	Painful	4	0	0	0
	Painful if prolonged or awkward	6	26	23	25
	Uncomfortable	8	13	3	6
	Free	10	61	74	69
Sexual intercourse	Painful	1	4	2	0
	Painful if prolonged or awkward	2	9	8	10
	Uncomfortable	3	0	3	8
	Free	4	87	87	82
Standing A *(walking aids)*	Bedridden or almost bedridden	2	0	0	0
	Wheelchair	4	0	0	2
	Two crutches	6	13	3	10
	Two sticks	8	0	0	0
	One stick	10	4	0	6
	No sticks	12	83	97	82
Standing B *(gait unaided)*	Cannot walk or can barely walk	2	4	2	4
	Shuffling small steps	4	0	0	4
	Gross limp	6	0	2	0
	Moderate limp	8	0	6	10
	Slight limp	10	17	8	25
	Normal	12	78	82	57
Standing C *(walking distance)*	Bedridden or few metres	2	0	0	0
	Very limited time and distance	4	9	0	21
	Limited with sticks, difficult without prolonged standing possible	6	0	6	6
	One hour with a stick, limited without	8	4	2	0
	One hour without sticks, slight pain or limp	10	13	12	8
	Normal for age and general condition	12	74	80	65

** Linear-by-linear association chi-squared test*

TABLE 3 EQ-5D

	Tile A	Tile B	Tile C
N (%)	23 (16.9)	65 (47.8)	48 (35.3)
Mean age, yrs (SD)	38 (19)	36 (16)	43 (17)
EQ-5D			
Mobility, %	61	77	48
Self-care, %	91	92	90
Usual activities, %	57	72	56
Pain, %	44	55	56
Anxiety/depression, %	78	88	81
EQ-5D-VAS score (SD)	74 (18)	76 (15)	76 (15)
Average EQ-5D index (SD)	0.81 (0.19)	0.87 (0.19)	0.82 (0.22)

SMFA (LOWER EXTREMITIES)

The results of the SMFA are listed in Table 4. The Function questionnaire was completed by 126 patients (92.6%), and the Bother questionnaire was completed by 123 patients (90.4%). The mean score of the SMFA Function index was 24 (SD 19), and the mean score of the Bother index was 24 (SD 23).

TABLE 4 SMFA

	Tile A	Tile B	Tile C	p-value
SMFA Bother, mean (SD)	21 (17)	24 (18)	25 (21)	0.695
SMFA Function, mean (SD)	20 (22)	22 (21)	27 (25)	0.384

MULTIPLE LINEAR ANALYSIS

Table 5 shows adjusted linear regression coefficients, after adjusting for age, sex, ISS, fracture type (stable versus unstable), neurologic injury, urogenital injury, open fracture, injuries to the lower extremities and surgical treatment.

Regarding the MPS, a significant difference was found in the dimension of standing (walking aids), with an OR of 0.26 (95% CI: 0.11-0.66), p=0.02. Patients with a Tile B fracture scored significantly higher than patients with a Tile C injury. The mean MPS scores did not differ significantly among the fracture types.

For the EQ-5D, a significant difference was found in the domain of mobility. Similar to the MPS, patients with type B fractures scored significantly higher than patients with type C fractures (ß-coefficient: 0.73 (95% CI: 0.04-1.42) p=0.048).

No differences were found among the fracture types for the EQ-5D-VAS and index scores.

For both the SMFA Bother and Function indices, no differences were found among the fracture types.

TABLE 5 Multiple logistic regression model

EQ-5D	Odds ratio	95% CI	Significance
Mobility			p=0.02
Tile B-Tile A	0.50	0.17-1.46	
Tile C-Tile A	1.90	0.61-5.92	
Tile B-Tile C	0.26	0.11-0.66	
Self-care			p=0.88
Tile B-Tile A	0.63	0.10-4.12	
Tile C-Tile A	0.79	0.12-5.42	
Tile B-Tile C	0.79	0.17-3.58	
Usual activities			p=0.14
Tile B-Tile A	0.46	0.16-1.28	
Tile C-Tile A	0.98	0.33-2.90	
Tile B-Tile C	0.47	0.99-1.04	
Pain			p=0.43
Tile B-Tile A	0.54	0.20-1.49	
Tile C-Tile A	0.52	0.17-1.53	
Tile B-Tile C	1.05	0.47-2.43	
Anxiety/Depression			p=0.33
Tile B-Tile A	0.39	0.11-1.43	
Tile C-Tile A	0.69	0.18-2.58	
Tile B-Tile C	0.56	0.18-1.77	
	ß-coefficient	**95% CI**	
EQ-5D-VAS			p=0.73
Tile B-Tile A	3.00	(-5.33-11.34)	
Tile C-Tile A	3.39	(-5.47-12.26)	
Tile C-Tile B	-0.39	(-6.93-6.15)	
EQ-5D index			p=0.24
Tile B-Tile A	0.07	(-0.03-0.17)	
Tile C-Tile A	0.02	(-0.09-0.13)	
Tile B-Tile C	0.05	(-0.03-0.14)	
Majeed	**ß-coefficient**	**95% CI**	
Pain			p=0.22
Tile B-Tile A	2.15	(-0.95-5.24)	
Tile C-Tile A	0.24	(-3.07-3.54)	
Tile B-Tile C	1.91	(-0.62-4.44)	

>>

Work			p=0.73
Tile B-Tile A	1.17	(-2.40-4.73)	
Tile C-Tile A	0.17	(-3.66-4.01)	
Tile C-Tile B	0.99	(-1.98-3.98)	
Sitting			p=0.63
Tile B-Tile A	0.39	(-0.45-1.24)	
Tile C-Tile A	0.21	(-0.71-1.11)	
Tile C-Tile B	0.19	(-0.51-0.89)	
Sexual Intercourse			p=0.83
Tile B-Tile A	0.09	(-0.25-0.43)	
Tile C-Tile A	0.03	(-0.34-0.39)	
Tile C-Tile B	0.07	(-0.22-0.35)	
Standing A (walking aids)			p=0.048
Tile B-Tile A	0.84	(-0.03-1.72)	
Tile C-Tile A	0.11	(-0.82-1.05)	
Tile C-Tile B	0.73	(0.04-1.42)	
Standing B (gait unaided)			p=0.11
Tile B-Tile A	0.34	(-0.79-1.46)	
Tile C-Tile A	-0.62	(-1.83-0.58)	
Tile C-Tile B	0.96	(0.07-1.85)	
Standing C (walking distance)			p=0.06
Tile B-Tile A	0.42	(-0.94-1.78)	
Tile C-Tile A	-0.87	(-2.33-0.59)	
Tile C-Tile B	1.29	(0.22-2.37)	
Total MPS			p=0.15
Tile B-Tile A	2.41	(-6.13-10.94)	
Tile C-Tile A	-4.23	(-13.40-4.95)	
Tile C-Tile B	6.63	(-0.08-13.34)	
SMFA Function			p=0.47
Tile B-Tile A	1.56	(-9.90-13.02)	
Tile C-Tile A	6.62	(-5.81-19.05)	
Tile C-Tile B	-5.06	(-14.40-4.28)	
SMFA Bother			p=0.73
Tile B-Tile A	1.51	(-8.72-11.72)	
Tile C-Tile A	4.04	(-6.94-15.02)	
Tile C-Tile B	-2.54	(-10.70-5.63)	

DISCUSSION

In this study, we evaluated the long-term HRQOL of pelvic ring fracture patients with a minimum follow-up period of 5 years. To our knowledge, our study is the first to describe a follow-up period of more than 5 years in a large patient group with pelvic ring fractures.

Recently, Brouwers et al.[18] reported the short and mid-term HRQOL of patients with pelvic ring fractures. They found that pain was increased in patients with a Tile C injury and observed significantly lower EQ-5D and MPS scores in patients with a Tile C injury than in patients with Tile A and B fractures.

In our study, no significant differences in pain and no large significant differences in functional outcomes and HRQOL were observed among the different Tile types. Significant differences were found in only 2 dimensions: mobility on the EQ-5D and standing on the MPS. In both dimensions, patients with Tile B fractures scored significantly better than those with Tile C fractures, while no significant difference between patients with Tile A and C fractures was found. The reason for this finding could be the relatively high percentage of Tile B2 fractures. Tile B2 fractures are lateral compression injuries with intact ligaments. Patients are normally allowed to mobilize within their pain limits and often do not require operative treatment. Patients with a Tile A fracture often suffer an isolated iliac wing fracture. The characteristics, ISS and concomitant injuries of patients with iliac wing fractures resemble those of patients with type C fractures[26]. This finding could explain why the scores for Tile B fracture patients are higher for certain dimensions than for those with other fractures.

Most studies report lower HRQOL values in patients with a pelvic ring fracture than in the normal population.[9,10,27,28] Ayvaz et al.[29] reported SF-36 scores of patients treated with closed reduction and internal fixation that were comparable with the normal population. The results of the EQ-5D index score in our group were also comparable with those of the validated Dutch population. However, an analysis comparing the composition of our study population and that of Stolk et al.[24] was not performed. Therefore, we do not know whether both groups have comparable patient characteristics.

The mean MPS in our study was high compared to the studies of Suzuki[9] and van den Bosch[30] (85.1 versus 79.7 and 78.6, respectively). The EQ-5D index score in our group was 0.84, which was also higher than the results of Harvey-Kelly[12] (0.59) and Holstein[10] (0.78). The EQ-5D-VAS was 75.6 in our study, compared to 64.1 reported by Harvey Kelly[12] and 70.5 reported by Kerschbaum.[28]

The ISS score in our group is higher than that found in previous studies.[9,12] Only in the study by van den Bosch[30] was the mean ISS higher (30.4). The follow-up periods in the above studies were all shorter than that in our study. Therefore, a possible explanation for these differences could be a change in the ability of patients to manage their present situation. Another hypothesis could be that more patients had fully recovered during the longer follow-up period of our study. We observed a maximal MPS score in 34% of patients, with a median follow-up of 8.7 years. Brouwers et al.[18] reported a maximal MPS score in 31% of Tile A, 28% of Tile B and 0% of Tile C fracture patients, with a median follow-up period of 2.5 years. Lefaivre et al.[19] reported a maximum MPS score in 18.4% of patients, with a median follow-up period of 4.5 years. However, that study only included Tile B and C fractures.

Furthermore, no large differences were observed in our study among the Tile groups. Approximately one-third of the pelvic patients with Tile A (32%), Tile B (36%) and Tile C (33%) fractures were reportedly at the highest end of the MPS scale. Comparing these results with those of Brouwers et al.[18], it could be concluded that between 2.5 and 8.7 years of follow-up, no substantial increase in HRQOL was observed in patients with Tile A or B Fractures. However, the HRQOL of patients with Tile C fractures increased from 0 to 33%. This finding could illustrate that the recovery of patients with Tile C fractures may be longer than previously assumed[2] and that long-term follow-up is warranted in these patients.

Previous studies have shown that age, injury severity, fracture type, neurological injury, urological injuries, sexual dysfunction and method of treatment could influence the functional and HRQOL outcomes.[9,10,12,14,31] These factors, including open fractures, were identified as confounders in our linear regression model.

Chronic pain due to persistent neurological injury is a well-recognized factor that influences outcomes and is very difficult to treat.[6] The prevalence of focal neurologic deficits was low in our group (6.6%). Additionally, the prevalence of urogenital disorders was low (4%). However, almost 25% of all patients reported sexual problems on the MPS. One possible explanation could be that sexual complaints are underreported by patients during follow-up because of the sensitive nature of these complaints. This hypothesis is supported by the findings of Harvey-Kelly et al[12], who reported a high rate (28%) of patients who declined to complete the sexual questionnaires. Another explanation could be that, although there are no obvious injury to the urogenital systems, the lumbosacral plexus

is damaged and causes severe problems. Pro-active evaluation by the treating physician should be mandatory in the follow-up of patients with a pelvic ring injury.

There are certain limitations to this study. The first is the cross-sectional nature of this study, which did not allow us to obtain baseline values of these patients for a comparison of our results. Hernefalk[32] reported that the pre-traumatic QOL in patients with surgically treated pelvic fractures is generally high and that pre-existing discomfort from the pelvic region is uncommon. Currently, we are performing a longitudinal designed study, which includes pre-injury assessment, short term outcomes.[33]

Second, the possibility of selection bias exists. Of the 336 total patients with pelvic fractures identified in the study period, only 136 patients (40%) were ultimately included. This may have influenced the overall outcomes. However, of the 231 eligible patients who were contacted, no differences were found between the responders and non-responders in terms of age, gender, Tile classification and ISS.

CONCLUSION

Patients who have suffered a pelvic ring fracture generally have good HRQOL outcomes after 5-10 years. With the exception of 2 subscales of the evaluated questionnaires, no significant differences were found among the different fracture types in these patients. Long-term follow-up of patients with Tile C fractures is warranted.

TAKE HOME MESSAGES:

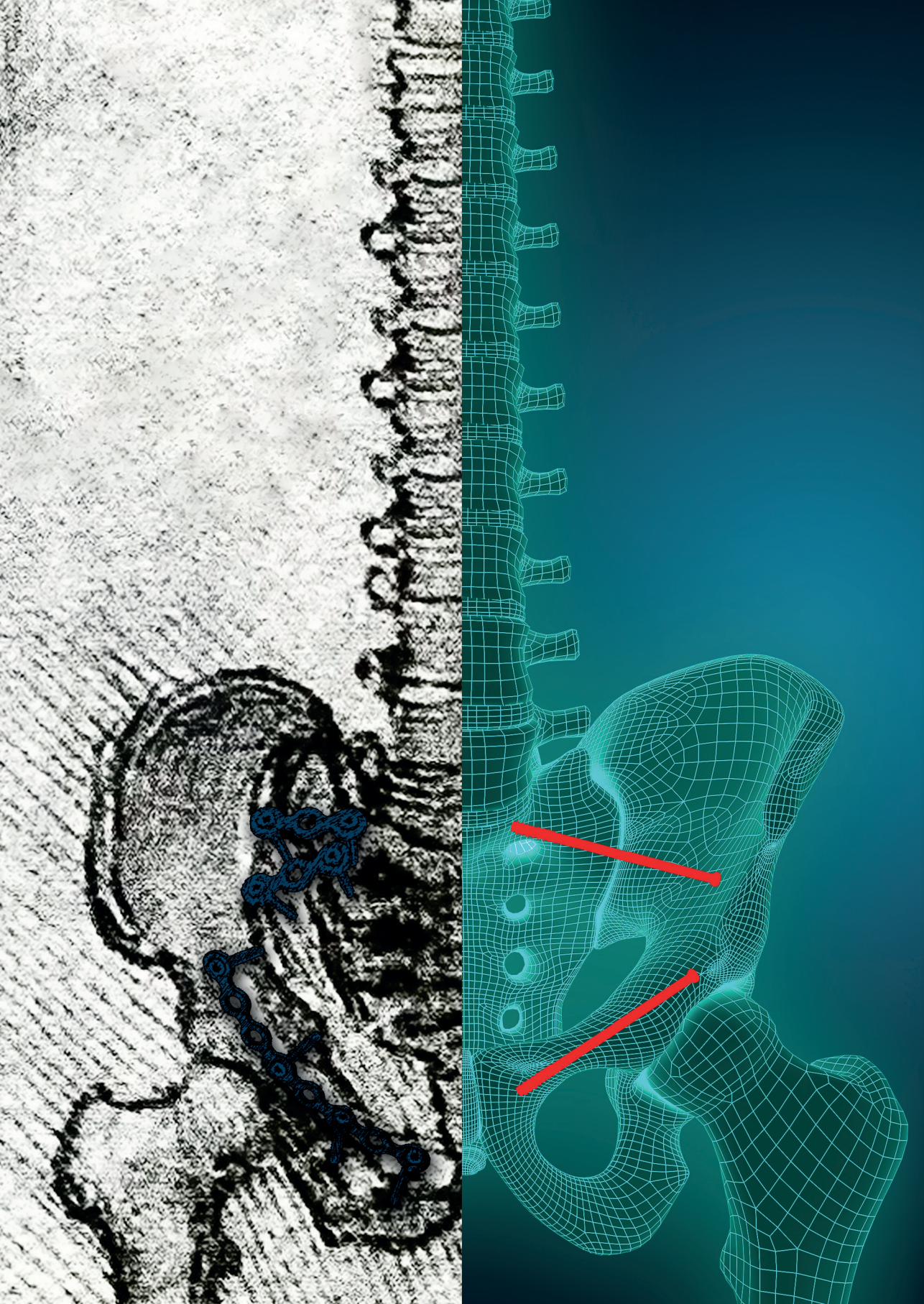
- The long-term HRQOL of pelvic ring fracture patients is generally good, with no significant differences among different Tile fracture types.
- A ceiling effect is observed in approximately 1/3 of patients.
- Patients with a Tile C fracture require longer to exhibit the ceiling effect.

REFERENCES

1. Dalal SA, Burgess AR, Siegel JH, Young JW, Brumback RJ, Poka A, Dunham CM, Gens D, Bathon H. Pelvic fracture in multiple trauma: classification by mechanism is key to pattern of organ injury, resuscitative requirements, and outcome. J Trauma 1989;29:981–1000; discussion 1000.
2. Rommens PM, Hessmann MH. Staged reconstruction of pelvic ring disruption: differences in morbidity, mortality, radiologic results, and functional outcomes between B1, B2/B3, and C-type lesions. J Orthop Trauma 2002;16:92-8.
3. Hermans E, Biert J, Edwards MJR. Epidemiology of Pelvic Ring Fractures in a Level 1 Trauma Center in the Netherlands. Hip Pelvis 2017;29:253-61.
4. Gansslen A, Pohlemann T, Paul C, et al. Epidemiology of pelvic ring fractures Injury 1996;27 (Suppl 1):S-A13-20.
5. Giannoudis PV, Pape HC. Damage control orthopaedics in unstable pelvic ring injuries Injury, 2004:35-671-7.
6. Hessmann MH, Rickert M, Hofmann A, Rommens PM, Buhl M. Outcome in pelvic ring fractures. Eur J Trauma Emerg Surg 2010;36:124-30.
7. Gautier E, Rommens PM, Matta JM. Late reconstruction after pelvic ring injuries Injury 1996;27:39-46.
8. Oliver CW, Twaddle B, Agel J, Routt ML. Outcome after pelvic ring fractures: evaluation using the medical outcomes short form SF-36;27. Injury 1996;27:635-41.
9. Suzuki T, Shindo M, Soma K, Minehara H, Nakamura K, Uchino M, Itoman M. Long-term functional outcome after unstable pelvic ring fracture. J Trauma 2007;63:884-8.
10. Holstein JH, Pizanis A, Köhler D, Pohlemann T, Working Group Quality of Life After Pelvic Fractures. What are predictors for patients' quality of life after pelvic ring fractures? Clin Orthop Relat Res 2013;471:2841-45.
11. Gerbershagen HJ, Dagtekin O, Isenberg J, Martens N, Ozgür E, Krep H, Sabatowski R, Petzke F. Chronic pain and disability after pelvic and acetabular fractures--assessment with the Mainz Pain Staging System. J Trauma 2010;69:128-36.
12. Harvey-Kelly KF, Kanakaris NK, Obakponovwe O, West RM, Giannoudis PV. Quality of life and sexual function after traumatic pelvic fracture. J Orthop Trauma 2014;28:28-35.
13. Kabak S, Halici M, Tuncel M, Avsarogullari L, Baktir A, Basturk M. Functional outcome of open reduction and internal fixation for completely unstable pelvic ring fractures (type C): a report of 40 cases. J Orthop Trauma 2003;17:555-62.

14. Morris RO, Sonibare A, Green DJ, Masud T. Closed pelvic fractures: characteristics and outcomes in older patients admitted to medical and geriatric wards. Med J 2000;76:646-50.
15. Soberg HL, Bautz-Holter E, Finset A, Roise O, Andelic N. Physical and mental health 10 years after multiple trauma. Journal of Trauma and Acute Care Surgery 2015;78:628-33.
16. Fleischhacker E, Trentzsch H, Kuppinger D, et al. Long-term changes of patient-reported quality of life after major trauma: the importance of time elapsed after injury injury 2017 Epub ahead of print doi: 10.1016/j.injury.2017.10.020.
17. McHorney CA, Tarlov AR. Individual-patient monitoring in clinical practice: are available health status surveys adequate? Qual Life Res 1995;4:293-307.
18. Brouwers L, Lansink KWW, de Jongh MAC. Quality of life after pelvic ring fractures: a cross-sectional study;49. Injury 2018;49:812-8.
19. Lefaivre KA, Slobogean GP, Ngai JT, Broekhuyse HM, O'Brien PJ. What outcomes are important for patients after pelvic trauma? Subjective responses and psychometric analysis of three published pelvic-specific outcome instruments. J Orthop Trauma 2014;28:23-7.
20. Baker SP, O'Neill B, Haddon W, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187-96.
21. Majeed SA grading the outcome of pelvic fractures J Bone Joint Surg (Br) 1989;71-B:304-6.
22. Rabin R, de Charro F. EQ-5D: a measure of health status from the EuroQol Group Ann Med;33. Ann Med 2001;33:337-43.
23. van Delft-Schreurs CCHM, van Son MAC, de Jongh MAC, Gosens T, Verhofstad MH, de Vries J. Psychometric properties of the Dutch Short musculoskeletal Function Assessment (SMFA) questionnaire in severely injured patients;46. Injury 2016;47:2034-40.
24. Stolk E, Krabbe P, Busschbach J. Using the Internet to collect EQ-5D norm scores: a valid alternative? Proceedings of the 24th Scientific Plenary Meeting of the EuroQol Group. In:. Kijkduin – The Hague. EuroQol Grouped, , 2009:153-6.
25. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. J Bone Joint Surg Am 1976;58:453-8.
26. Hermans E, Edwards MJR, Biert J. Isolated iliac wing fractures after a high energy trauma; are they really that benign? Accepted Acta Orth Belg
27. Borg T, Berg P, Fugl-Meyer K, et al. Health-related quality of life and life satisfaction in patients following surgically terated pelvic ring fractures. A prospective observational study with two years follow-up Injury 2010;41:400-4.

28. Kerschbaum M, Hausmann N, Worlicek M, Pfeifer C, Nerlich M, Schmitz P. Patient-related outcome of unstable pelvic ring fractures stabilized with a minimal invasive screw-rod system. Health Qual Life Outcomes 2017;15:248.
29. Ayvaz M, Cağlar O, Yılmaz G, Güvendik GI, Acaroğlu RE. Long-term outcome and quality of life of patients with unstable pelvic fractures treated by closed reduction and percutaneous fixation. Ulus Travma Acil Cerrahi Derg 2011;17:261-6.
30. Van den Bosch EW, van der Kleyn R, Hogervorst M, Van Vugt AB. Functional outcome of internal fixation for pelvic ring fractures. J Trauma 1999;47:365-71.
31. Pohlemann T, Gänsslen A, Schellwald O, Culemann U, Tscherne H. [Outcome evaluation after unstable injuries of the pelvic ring]. Unfallchirurg 1996;99:249-59.
32. Hernefalk B, Eriksson N, Borg T, Larsson S. Estimating pre-traumatic quality of life in patients with surgically treated acetabular fractures and pelvic ring injuries: does timing matter? Injury 2016;47:389-94.
33. de Jongh MA, Kruithof N, Gosens T, van de Ree CL, de Munter L, Brouwers L, Polinder S, Lansink KW Prevalence, recovery patterns and predictors of quality of life and costs after non-fatal injury: the Brabant Injury Outcome Surveillance (BIOS) study Inj Prev. 2017;23:59



CHAPTER 8

Correct positioning of percutaneous iliosacral screws with computer-navigated versus fluoroscopically guided surgery in traumatic pelvic ring fractures

J. Verbeek, E. Hermans, AB van Vugt, JPF Frolke

J Orthop Trauma. 2016;30:331-5

8

ABSTRACT

Objectives: To assess the correct positioning of iliosacral screw in patients with unstable traumatic pelvic ring injury by comparing fluoroscopically guided computer-navigated surgery (CNS) with conventional fluoroscopy (CF) through reviewing post-operative CT scans and clinical indicators.

Design: A comparative multicenter cohort study.

Setting: Two level I Trauma Centers in The Netherlands.

Patients: The computer-navigated group (n=56) and the conventional fluoroscopy group (n=24) were comparable regarding age (mean, 43 yr), gender (58%, male), BMI (25 kg/m2), ISS (27), injury-to-surgery interval (7 days) and OTA classification (40% 61-B, 60% 61-C).

Main Outcome Measurements: The position of the iliosacral screws was evaluated on postoperative CT scans. Additionally, clinical morbidity and re-operation were assessed.

Results: In the CNS group, a total of 111 screws were placed (2.0 per patient), of which 83% were placed correctly. In the CF group, 39 screws (1.6 per patient) were placed, 82% of them correctly. Inadequate fixation included neural foramina hit (12 screws (11%) in the CNS group vs. 3 screws (8%) in the CF group, p=0.58) and extra osseous dislocation (7 screws (6%) vs. 4 screws (10%), respectively, p=0.42). Five patients required re-operation, all in the computer-navigated surgery group, p=0.18. We observed more adequate positioning with increased surgical experience, p=0.12.

Conclusions: In contrast to what has been suggested by previous studies, we found no benefit from computer-navigated iliosacral screw fixation compared to fluoroscopically guided surgery regarding the correct positioning of iliosacral screw on postoperative CT scans and related morbidity.

Level of Evidence: Level II, therapeutic study

INTRODUCTION

Percutaneous iliosacral (IS) screw positioning is commonly used to stabilize the posterior pelvic ring in patients with unstable pelvic fractures.[1,2] This method provides adequate mechanical stability with minimum blood loss and soft tissue damage.[3] IS screw placement, however, is challenging due to variable posterior pelvic ring anatomy and sacral dysmorphism.[4] Incorrect IS screw placement may lead to unfavorable complications, such as iatrogenic nerve root injury, which ranges from 0% to 23.5%.[2,5,6] A nerve canal full hit as visible in the CT scan, however, is not always associated with neurological function and clinical performance, it also depends on whether the nerve root it's self is affected.[7-10] Risk factors for incorrect placement are sacral dysmorphism, screw placement in S2 and bilateral multiple IS screw fixation.[11] A comparison of studies is hindered by the lack of a clear definition of correct IS screw placement. Some authors describe margins for a safe zone in normal sacral anatomy and in sacral dysmorphism.[12-14] Others define correct positioning in terms of revision rates or occurrence of (neurological) complaints and complications. To accomplish adequate IS screw placement several techniques are available, the two most commonly used techniques are conventional fluoroscopy (CF) and fluoroscopically guided computer-navigated systems (CNS).[3]

In current practice, most hospitals use CF, mainly because of the lower financial costs. Major disadvantages of the CF technique are limited visibility of the pelvic bone and that every movement of the guide wire must be confirmed in three views. Therefore, a high degree of three-dimensional thinking and detailed knowledge of the pelvic anatomy are required for correct screw placement by CF. Furthermore, fluoroscopic imaging is of lower quality and may be complicated by obesity and bowel gas. An additional disadvantage is radiation exposure to the surgical team and patient. Many surgeons consider purchasing an expensive CNS to improve the quality of IS screw positioning. CNS techniques are thought to allow for more accurate screw placement because of simultaneous visibility of three relevant images and less radiation exposure time.[2,15-17] CNS does require thorough calibration prior to clinical application. Thus, CNS may provide several advantages over CF. In spite of this, it is still unclear which technique is the most accurate in the clinical setting. The currently available evidence is based on cadaver studies and retrospective cohort studies with small numbers of patients.[18,19] There is an ongoing discussion on the necessity of CNS in IS-screw positioning in pelvic trauma. So far, the current literature is lacking a clear-cut answer pro

or contra CNS with variable study protocols and inherent study design inconsistencies. The few existing retrospective cohort studies were performed over different periods of time, whereas trials with CF took place before the introduction of CNS.[2,18] This time difference may introduce confounding bias by differential learning curves and surgeons' experience. The primary aim of our study was to assess the correct positioning of IS screws in CNS versus CF-guided surgery by reviewing post-operative CT scans. We hypothesized that CNS would achieve higher prevalence of adequate screw position in this era of guided imaging technology. Secondly, we explored contributory factors of screw malpositioning.

PATIENTS AND METHODS

PATIENT POPULATION

Patients were eligible for participation in this study based on the following criteria: they were older than 18 years of age and received percutaneous IS screw fixation for the treatment of an unstable traumatic pelvic ring injury. The study took place three years after purchasing the CNS. Recruitment of patients was conducted at Radboud University Medical Center in Nijmegen and Medical Spectrum Twente in Enschede, both in The Netherlands. In all patients with the OTA classification 61-B or 61-C use of CNS was indicated to aid the insertion procedure.[20] However, before starting the operation we had already faced technical problems when starting the CNS technique in 24 patients. These issues were purely technical and were not patient- or surgeon-related. Those patients received CF and served as the control group in our study. Patients with non-percutaneous screw insertion and patients with previous surgery on the pelvic bone or acetabulum were excluded. Age, gender, body mass index, Injury Severity Score (ISS) and number of days between injury and surgery were registered preoperatively. The design of the research was a cohort study, for which the data were collected and reviewed retrospectively.

SURGICAL PROCEDURE

All operations were performed under general anesthesia with patients in the supine position. A complete radiolucent table was used and fluoroscopy was carried out with a 12-inch image intensifier (9800 ES General Electric, Eindhoven, the Netherlands). Inlet, outlet and lateral views were obtained in both CF and CNS prior to the operative procedure. To allow

CNS, light emitting diodes (LEDs) were attached to the C-arm, pelvis and a 3 mm drill sleeve. After merging the positional information of the pelvis by the LEDs, drill sleeve and C-arm, the virtual position of the drill sleeve was visualized in the fluoroscopic images displayed on the workstation (Medtronic Heerlen, The Netherlands).[2] Inlet view, outlet view and lateral pelvic images were loaded into the workstation. Next, the virtual drill sleeve was enlarged to 200 mm with a diameter of 3 mm to visualize the position and direction of the guide wire in all three fluoroscopic images. After placement of screws of sufficient length, new images were loaded for adequate matching and real time screw positioning to allow for the ensuing CNS surgery on the contralateral SI joint.

For CF, a guide wire was inserted in the bone with continuous fluoroscopic control until adequate position was obtained in the "safe" zone as mentioned above. Then, positioning of the wires to an appropriate depth was completed, followed by insertion of self-drilling and self-tapping cannulated screws (Biomet BV Dordrecht, The Netherlands). All screws were placed in the first sacral vertebral body.

ASSESSMENTS

The main outcome of interest in our study was the correct positioning of the IS screws. This was measured on a CT scan performed within one week postoperatively. Correct positioning was defined as screws being within the cortical margins of the sacrum with no indication of perforation into the sacral canal or into the sacral foramina (Figure 1).[2,13]

Assessment of all CT scans was blinded regarding the image-guided screw placement method utilized. Clinical morbidity due to malplacement and re-operations were registered as secondary outcome measurements. Finally, we addressed the impact of surgical experience on the outcomes. To describe surgeon's experience an objective and subjective classification was taken into account. Experts performed ≥25 screw placements, experienced surgeons ≥10 placements and the less experienced <10 screws at most. After we categorized the surgeons in the objective way we asked them if they could agree with the classification of themselves and the other surgeons, which turned out to be the case. Additionally, we categorized all surgeons who gained experience before the study took place in the expert group.

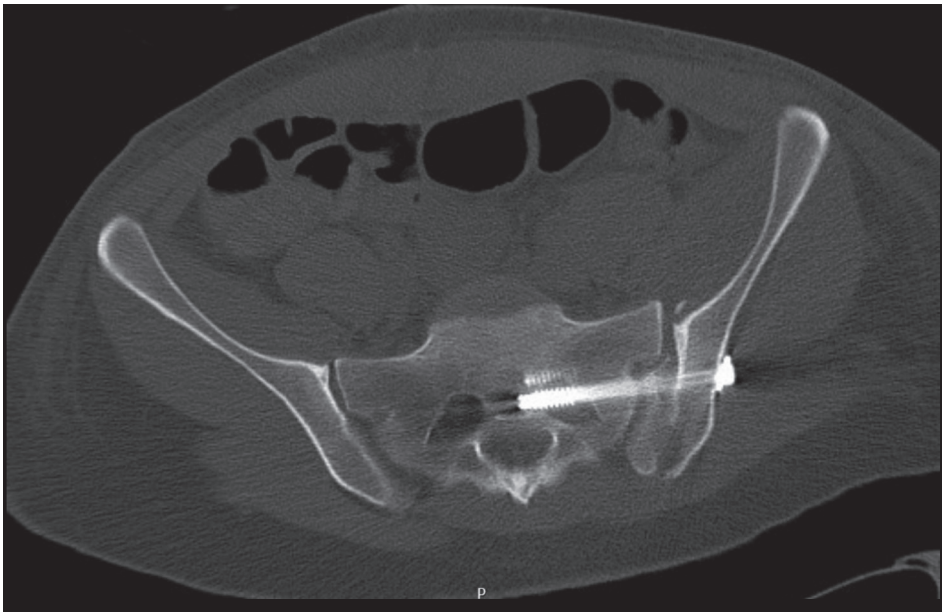


FIGURE 1 Placement of two SI screws displayed in a postoperative CT scan. The posterior SI screw is placed through the neuroforamina

STATISTICAL ANALYSES

Differences in the rates of correct placement of IS screws between the CNS and CF patient groups were analyzed using contingency tables and chi-square statistics. Whenever the expected numbers in cell entries were smaller than 5, Fisher's exact test was applied to calculate p-values. To address the comparability of both groups, descriptive statistics were presented as proportions for categorical variables and means plus standard deviations for continuous variables. All statistical analyses were performed with SPSS© statistical software version 22.0 (SPSS, Chicago, IL). P-values <0.05 (2-sided) were considered statistically significant.

RESULTS

In both Level 1 trauma centers in the period 2008-2013, 151 patients underwent surgery for unstable pelvic injuries. Of these patients, 107 received IS screws. We excluded 27

patients from analysis for the following reasons: 12 had non-percutaneous surgery, 11 had undergone a previous operation, 2 had no postoperative CT scan, and 2 were excluded for other reasons. This resulted in 56 patients with computer navigation system and 24 patients with conventional fluoroscopy (Table 1). Between both groups, no differences were observed in age (mean, 43 yr), gender (58% male), BMI (25 kg/m^2), ISS (27) and injury-surgery time interval (7 days). The 24 patients in the fluoroscopy group were scored with fluoroscopy imaging and classified to the OTA register of 61-B1, 61-B2, 61-B3, 61-C1, 61-C2 and 61-C3 as 4, 4, 2, 7, 4 and 3 respectively; for the 56 CNS patients the numbers were 5, 5, 12, 22, 7 and 5, corresponding with p=0.47. There were 9 (38%) transiliac dislocation fractures in the fluoroscopy patients and 18 (32%) in the CNS group; p=0.69.

TABLE 1 Characteristics of the patients with CNS or CF surgery

characteristic	CNS (n=56)	CF (n=24)	p-value
Age (yrs) m±SD	43 ±18	43±18	0,9
Gender, male %	60%	54%	0,64
BMI kg/m^2, m±SD	25±2	25±6	0,6
ISS severity 0-100, m±SD	26±10	28±12	0,71
OTA cat 61-C, n (%)	26 (58%)	15 (61%)	0,61
Interval injury-surgery, days, M±SD	7±11	7±7	0,86

Additional anterior surgical procedures were required 18 times in the fluoroscopy group (75%) and 55 times (98%) in the CNS group; p<0.001. In both groups, anterior surgery mainly consisted of 57 symphyseal plating (78%) and 16 anterograde or retrograde superior pubic ramus screws (22%); p=0.54. The cause of fracture (CNS versus CF group) included car accidents (10 vs. 7), falls from 4 meters or higher (15 vs. 8), crushed by heavy object (10 vs. none), pedestrian (4 vs. 1), bicycle (6 vs. 2), horse (6 vs. 3), motorcycle (2 vs. 3), and other injuries (3 vs. none).

In the 56 CNS patients, a total of 111 screws were inserted (2.0 per patient); 92 (83%) were judged to be adequately positioned on the postoperative CT scan (Table 2). In the 24 CF patients, 39 screws (1.6 per patient) were inserted; 32 (82%) of these were adequately positioned. Inadequate fixation included neural foramen hits and extra-osseous dislocation.

The former occurred with 12 screws in the CNS category (11%) vs. 3 screws in CF (8%), p=0.76; in the latter, we observed 7 screws in CNS (6%) vs. 4 screws in CF (10%), p=0.47.

As secondary outcome measures, neurological deficit, pain and revision were considered. Neurological deficit or neuralgic pain occurred in seven patients: two because of a neural foramen hit, one instance of extra-osseous location, and four patients with correct SI screw placement who were treated conservatively, while the others were re-operated.

TABLE 2. Main effect of CNS or CF aided surgery on outcomes of IS screw placement

IS screw placement			
screws	**adequate**	**inadequate**	
		neural foramina margin	**cortex**
CNS: n=111	92 (83%)	12 (11%)	7 (6%)
CF: n=39	32 (82%)	3 (8%)	4 (10%)
total screws: n=150	124 (83%)	15 (10%	11 (7%)

In total, five patients required re-operation, two because of a neuroforamen hit and three due to extra-osseous location. Of the latter three, one had a neurological deficit, another had pain because of screw protrusion, and one experienced malposition through the ilium resulting in no stability. All re-operations took place in the CNS group, but this was not statistically significant, p=0.32. Finally, 15 screws had been placed in the neural foramen; in two instances this necessitated re-operation (serious neuralgic pain); the remaining 13 reported a good neurological record.

Eleven surgeons performed the operations. Two of them were judged as experts in the field and placed 73 screws in 33 patients. Two others were classified as experienced and inserted 49 screws in 31 patients; the remaining 7 surgeons placed 28 screws in 16 patients. The rate of malposition stratified according to surgical experience and CNS or CF modality is shown in Figure 2. At the patient level, after analyzing the total patient population (see upper panel), an upward trend in malposition rate in surgeons with less experience was observed (p=0.12); this led to p=0.04 when comparing experts with less experienced surgeons. Similar

results were obtained in the CNS and CF groups. At the screw level, i.e., based on the total numbers of screws (shown in the lower panel), the overall rate is lower (18%) with small differences between expert and experienced surgeons. Combined, experts fared better than the less experienced surgeons, but the difference is not significant (p=0.10).

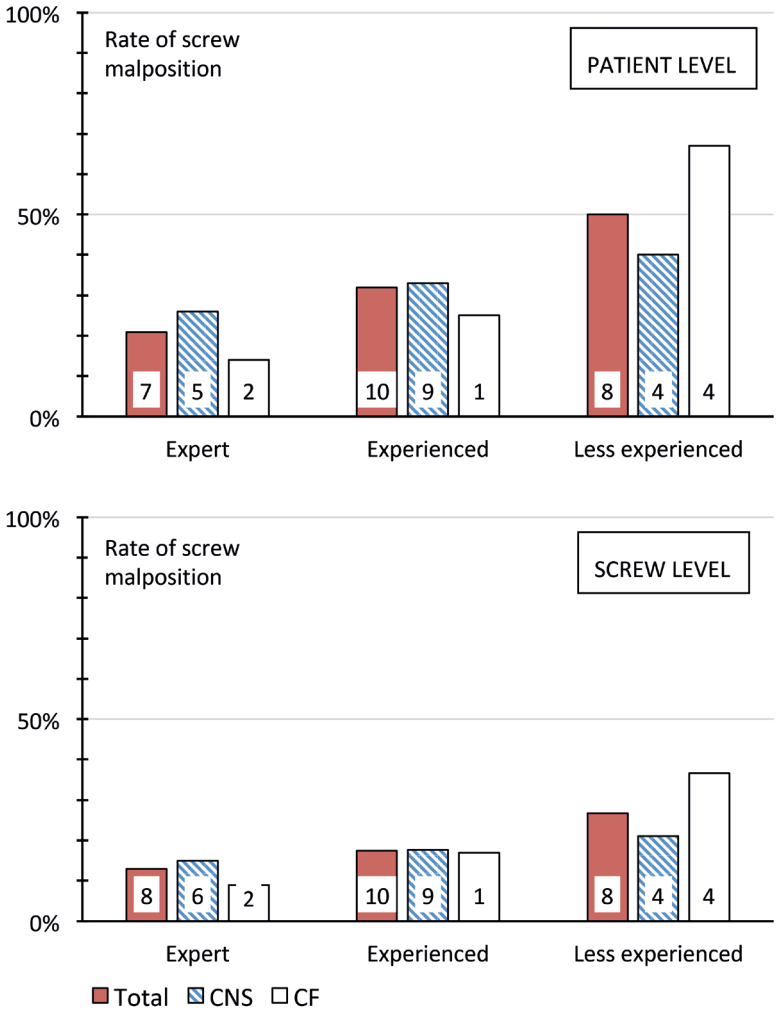


FIGURE 2 Rate of screw malposition in 56 CNS and 24 CF patients categorized by surgeon's experience at patient level (upper panel) and screw level. Figures in uncolored box are absolute numbers of malposition.

The number of screws inserted is another important determinant of adequate positioning.[22, 25] Twenty-five patients had 1 screw inserted, 21 (84%) of which were inserted adequately. Fifty-five patients received two or more screws and in this group the rate of adequate positioning was lower (58%, p=0.03), with no differences for unilateral or bilateral screw placement. In the CNS group, 41 of the 56 patients (73%) received two or more IS-screws, in the 24 CF patients 14 (58%). Correction for the number of inserted screws does not change the finding that CNS and CF achieved similar results.

DISCUSSION

In this study we compared fluoroscopically guided computer-navigated surgery with conventional fluoroscopy on the placement of iliosacral screws by reviewing post-operative CT scans. The findings indicate that, in our practice, CNS and CF achieve similar results. Nevertheless, a relatively high rate of malposition was observed, which may indicate that the surgeons were still in their learning curve trajectory. Previous studies found that the malposition rate was influenced by the surgeon's individual experience.[21,22] In our study, both techniques were performed during the same period of time, whereas many other authors applied the techniques sequentially. It is possible that in previous studies surgeons may have already been beyond their learning curve, which could have been advantageous to the computer-navigated technique. Our study was performed in an academic setting, wherein rotations among the surgeons was common during the study period. Therefore, we were able to analyze the influence of surgical experience. We observed a tendency toward a lower malposition rate with higher surgical experience. In our study, two of the surgeons performed iliosacral screws in 33 patients in the 5-6 years of the study period; approximately 3 patients per year for the expert group of surgeons. Unfortunately, there are no references available about surgical experience in this field of pelvic ring trauma operations, and there is no information on a comparable definition of experience. It is likely that pelvic ring traumata are infrequent occurrences. Focusing on the CF technique, the influence of surgical experience was more distinct. This was not the case for the CNS technique. This may have been caused by a systemic error. The computer navigation system is a virtual reality representation of the conventional fluoroscopic imaging and can, therefore, never be more accurate. There is always a margin of error with the computer-navigated system,

which at the best will be equal. With the upcoming 3D CT navigation techniques different outcomes of malposition rate could be possible.[11]

In 2013, a systematic review on IS screw fixation compared malposition and revision rates for various imaging modalities.[18] However, proper interpretation of the review results was hampered by the use of a great variety of study outcomes, and the absence of a clear definition of correct IS screw positioning. In some studies, malposition was reported only if a revision of the screw took place or if a neural foramen was hit, which may have underestimated the actual instances of malposition. Furthermore, most studies did not assign juxta-foraminal screw location. A study that compared three dimensional CNS and CF reported other ranges of correct positioning: 81% adequately positioned screws for the CNS vs. 42% for the CF technique.[16] Finally, the systematic review mentioned that CT navigation made the IS screw positioning superior to the CF techniques, but not to the CNS.[18,23,24]

In this study, patient groups were comparable in ISS score and OTA classification. Clinical data from the same time period and a clear definition of screw positioning allowed for a reliable comparison between CNS and CF. Initially, we faced a high number of technical problems with the CNS system. These were purely technical and not caused by visibility issues, sacral dysmorphism, and other patient- or surgeon-related findings, for example obesity. Therefore, we do not expect any bias in patient selection of the two groups. Furthermore, newer techniques will probably yield better results in terms of screw placement and are less likely to be affected by technical problems.

Unfortunately, no data were available on the dysmorphism of the pelvis, which may have misrepresented our findings.[12,13] Ideally, random allocation of the patients to CNS or CF would guarantee a similar spectrum of pelvic dysmorphism. This study did not address radiation exposure. An advantage of the CNS technique is the potentially lower radiation exposure to the patient and surgical team.

When looking at the revisions, five patients required re-operation and two of these experienced a neuroforamen hit. Not every neuroforamen hit in our study required re-operation, and therefore re-operation may not be a reliable measure of screw misplacement. We propose using neurological symptoms such as pain as an outcome measure that correlates with screw misplacement.

Finally, the number of iliosacral screws required for stable fixation of the posterior pelvic ring is still a matter of debate. Although we only inserted screws into S1, we noticed

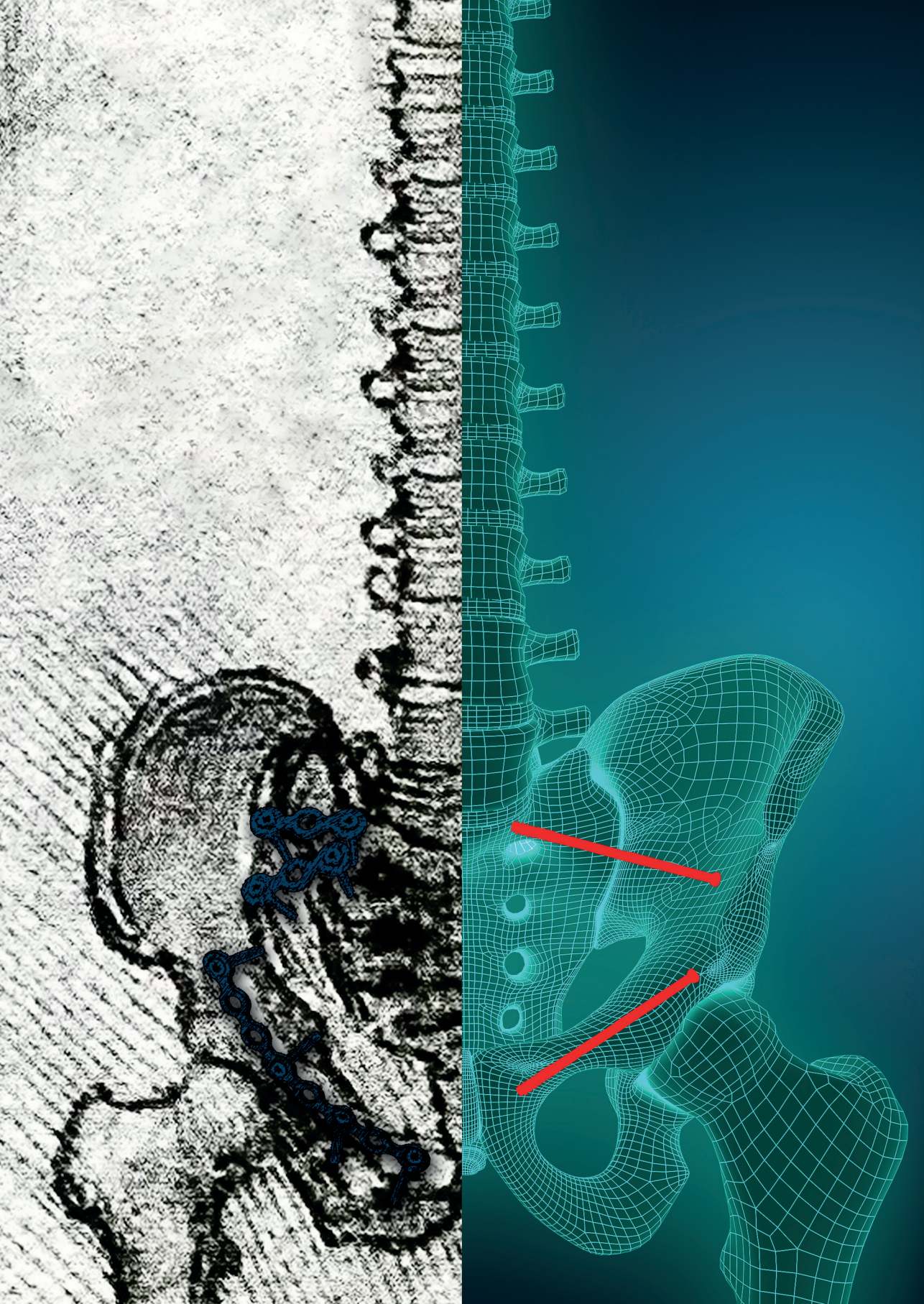
that a higher number of inserted screws was associated with a higher frequency of screw misplacement. This did not depend on whether it was unilateral or bilateral, in contrast with a previous study.[25,26] The CNS and CF groups showed different numbers of screws, i.e., 2 vs. 1.6 per patient. Possible explanations refer to a newer technique obtaining higher numbers of screws; more often anterior surgical procedures had been applied in the CNS group; and less experienced surgeons operated using CNS. Furthermore, it is still debatable how many screws have to be placed to give a stable fracture.

In conclusion, this study demonstrates that computer-navigated systems and conventional fluoroscopy deliver similar results in adequate IS screw positioning as measured by postoperative CT scan. Whereas the literature indicates a beneficial effect of the navigation procedures, the experience of the surgeon and the number of screws to be inserted are instrumental in adequate screw positioning. Future trials need to address these issues as well as patient characteristics for the appropriateness of adjuvant imaging techniques. In current practice, we advise the use of fluoroscopic guidance because computer navigation techniques still have a margin of error and fluoroscopy in an expert's hands is of great value at lower cost.

REFERENCES

1. Matta JM, Saucedo T. Internal fixation of pelvic ring fractures. Clin Orthop Relat Res. 1989 May;(242):83-97.
2. Schep NW, Haverlag R, van Vugt AB. Computer-assisted versus conventional surgery for insertion of 96 cannulated iliosacral screws in patients with postpartum pelvic pain. J Trauma. 2004 Dec;57(6):1299-302.
3. Shuler TE, Boone DC, Gruen GS, et al. Percutaneous iliosacral screw fixation: early treatment for unstable posterior pelvic ring disruptions. J Trauma. 1995 Mar;38(3):453-8.
4. Miller AN, Routh CML Jr. Variations in sacral morphology and implications for iliosacral screw fixation. J Am Acad Orthop Surg. 2012;20:8–16
5. Tonetti J, Carrat L, Lavalleé S, et al, Chirossel JP. Percutaneous iliosacral screw placement using image guided techniques. Clin Orthop Relat Res. 1998 Sep;(354):103-10.
6. Tonetti J, Carrat L, Blendea S, et al. Clinical results of percutaneous pelvic surgery. Computer assisted surgery using ultrasound compared to standard fluoroscopy. Comput Aided Surg. 2001;6(4):204-11
7. Keating JF, Werier J, Blachut P, et al. Early fixation of the vertically unstable pelvis: the role of iliosacral screw fixation of the posterior lesion. J Orthop Trauma. 1999;13:107–113
8. Gänsslen A, Hüfner T, Krettek C. Percutaneous iliosacral screw fixation of unstable pelvic injuries by conventional fluoroscopy. Oper Orthop Traumatol. 2006;18:225–244.
9. Routt MLC, Simonian PT, Inaba J. Iliosacral screw complications. Oper Tech Orthop. 1997;7:206–220.
10. Routt ML Jr, Nork SE, Mills WJ. Percutaneous fixation of pelvic ring disruptions. Clin Orthop Relat Res. 2000;375:15–29.
11. Takao M, Nishii T, Sakai T, et al. Iliosacral screw insertion using CT-3D-fluoroscopy matching navigation. Injury. 2014; 45: 988-94.
12. Gardner MJ, Morshed S, Nork SE, et al. Quantification of the upper and second sacral segment safe zones in normal and dysmorphic sacra. J Orthop Trauma. 2010;24:622–629.
13. Conflitti JM, Graves ML, Routt MLC. Radiographic quantification and analysis of dysmorphic upper sacral osseous anatomy and associated iliosacral screw insertions. J Orthop Trauma. 2010;24:630–636.
14. Templeman D, Schmidt A, Freese J, et al. Proximity of iliosacral screws to neurovascular structures after internal fixation. Clin Orthop Relat Res. 1996 Aug;(329):194-8.

15. Day AC, Stott PM, Boden RA. The accuracy of computer-assisted percutaneous iliosacral screw placement. Clin Orthop Relat Res. 2007; 463:179–186.
16. Zwingmann J, Konrad G, Mehlhorn AT, et al. Percutaneous iliosacral screw insertion: malpositioning and revision rate of screws with regards to application technique (navigated vs. Conventional). J Trauma. 2010 Dec;69(6):1501-6.
17. Van den Bosch EW, van Zwienen CM, van Vugt AB. Fluoroscopic positioning of sacroiliac screws in 88 patients. J Trauma. 2002;53: 44–48.
18. Zwingmann J, Südkamp NP, König B, et al. Intra- and postoperative complications of navigated and conventional techniques in percutaneous iliosacral screw fixation after pelvic fractures: Results from the German Pelvic Trauma Registry. Injury. 2013 Dec;44(12):1765-72.
19. Collinge C, Coons D, Tornetta P, et al. Standard multiplanar fluoroscopy versus a fluoroscopically based navigation system for the percutaneous insertion of iliosacral screws: a cadaver model. J Orthop Trauma. 2005 Apr;19(4):254-8.
20. Marsh JL, Slongo TF, Agel J, et al. Fracture and Dislocation Classification Compendium - 2007: Orthopaedic Trauma Association Classification, Database and Outcomes Committee. J Orthop Trauma. 2007;21 Supplement 10 pp: S1-S133
21. Briem D, Rueger JM, Begemann PG, et al. Computer-assisted screw placement into the posterior pelvic ring: assessment of different navigated procedures in a cadaver trial. Unfallchirurg. 2006 Aug;109(8):640-6.
22. Grossterlinden L, Rueger J, Catala-Lehnen P, et al. Factors influencing the accuracy of iliosacral screw placement in trauma patients. Int Orthop. 2011 Sep;35(9):1391-6.
23. Blake-Toker AM, Hawkins L, Nadalo L, et al. CT guided percutaneous fixation of sacroiliac fractures in trauma patients. JTrauma. 2001 Dec;51(6):1117-21.
24. Goldberg BA, Lindsey RW, Foglar C, et al. Imaging assessment of sacroiliac screw placement relative to the neuroforamen. Spine (Phila Pa 1976). 1998 Mar 1;23(5):585-9.
25. Gras F, Marintschev I, Wilharm A, et al. 2D-fluoroscopic navigated percutaneous screw fixation of pelvic ring injuries--a case series. BMC Musculoskelet Disord. 2010 Jul 7;11:153.
26. Smith HE, Yuan PS, Sasso R, et al. An evaluation of image-guided technologies in the placement of percutaneous iliosacral screws. Spine (Phila Pa 1976). 2006 Jan 15;31(2):234-8.



SUMMARY AND FUTURE PERSPECTIVES

9

SUMMARY

Although pelvic ring fractures are relatively rare, they pose a great challenge for the trauma surgeon. Life threatening hemorrhage is often encountered and must be addressed promptly. Treatment of hemorrhagic shock is often multidisciplinary care of the anesthesiologist, radiologist and trauma surgeon combined and is dictated by hospital facilities, such as the availability of the angio suite.

However, when the patient is stabilized and the patient is ready for definitive care, the pelvic surgery itself can be demanding with extensive approaches and high risk of complications like iatrogenic damage to nerves or blood vessels or massive thrombosis.

Because of the low incidence on the one side and the demanding treatment on the other side, we suggest that treatment of patients with these injuries should be concentrated and performed in specialized hospitals. The Radboudumc is a level 1 trauma center and is a tertiary referral center for pelvic and acetabular fractures. The aim of this thesis was to gain insight in different patients groups, therapy and outcome in order to compare our care with reports from other national and international centers. The insights gained are part of improvement of quality of care in the Radboudumc.

In the period 1-1-2004 to 1-1-2015, 537 patients with pelvic fractures were treated. **Chapter 2** describes this patient group, treatment and outcome. To our knowledge, this is the largest reported single centre experience with pelvic fractures in the Netherlands. Tile A fractures were seen in 137 patients (25.5%), Tile B fractures in 211 (39.3%) and Tile C fractures in 189 patients (35.2%). Patients with unstable fracture types (Tile B1 and B3, Tile C) had significantly higher Injury Severity score (ISS), transfusion rates, need for laparotomy and definitive operative stabilization and complication rate. The mortality rate in our group was 13.6% and did not differ significantly among Tile A, B or C fractures. This is suggestive that mortality is caused by a variety of other injuries such as neurotrauma. The mortality rate in the Radboudumc was comparable with other reports found in the literature. Almost half of the patients treated could be discharged to their own homes. This data is an important tool to evaluate our treatment protocol and thereby improving outcome for future patients.

In **Chapter 3** we reviewed our treatment protocol in relation to mortality. As mentioned earlier, the exact treatment protocol for pelvic ring injuries remains unclear in the literature and is often dictated by hospital facilities. The patient charts of a cohort of 289 patients in the period of 1-1-2003 to 1-6-2010 were evaluated. The was established if they were

treated according to our local treatment protocol. Specific attention was paid to differences related to the decision between acute surgery (Damage Control) versus diagnostic work-up with CT-scan as well as procedures related to acute stabilization of the pelvic ring and packing. Critical points were emergency stabilization with a pelvic binder or C-clamp in the ER in patients with shock class of 3 and 4 and damage control surgery in non-responders versus full diagnostic work-up in responders with angiography and selective embolization on indication.

Also, when a patient died, the cause of death was analyzed. In this group 22 patients died (7%). Hemorrhage contributed to mortality in 18/22 patients (82%). In 12 of the 22 patients who died, the treatment protocol was not followed on critical points. This was mainly due to the lack of use of a pelvic binding device on the ER. This was significantly higher than in the group survivors ($P < 0.01$). Therefore, a standardized treatment protocol may attribute to a reduction in mortality.

Open pelvic fractures are even more rare, with an estimated incidence of 2-4% of all pelvic fractures. Open pelvic fractures are characterized by direct communication between the fracture hematoma and the external environment (through the rectum, vagina or skin). Patients are at risk for early exsanguination because massive hemorrhage can occur due to disruption of the natural anatomic compartment in the pelvis and loss of the tamponade effect. Late mortality is caused by pelvic sepsis and multiple organ failure. Historically, mortality rates are up to 50%. In **Chapter 4**, we focused on these patients with open pelvic fractures. Twentyfour patients with an open pelvic fracture were encountered in the study period of 11 years. These patients had a significantly higher ISS and transfusion rate compared with patients with closed fractures. In this series, a survival rate of 96% was found in patients with open fractures. There was no significant difference in survival rate between open and closed pelvic fractures. Compared with other studies, the mortality in this study was low. The contribution to mortality of the open pelvic fracture by itself can be divided in two distinct effects: massive blood loss because of loss of containment, and infectious complications. Therefore, a standardized protocol, including aggressive surgical debridement, antibiotics, stabilization of the fracture and fecal diversion with a colostomy in case of severe rectal or perineal injury contributes to good outcome. Also, obtainability of dedicated urgent care in regional trauma centers in the Dutch situation with short prehospital transfer times can be beneficial.

When the integrity of the pelvic ring remains intact (AO/Tile type A), the risk of exsanguinations is considered low and therefore, these fractures are often considered as a benign. **Chapter 5** deals with isolated iliac wing fractures. The iliac wing is a strong bone and is resilient to high forces. Considerable forces are needed to cause a fracture. In this study was hypothesized that due to the high forces, patient characteristics and outcome are similar to patients with unstable pelvic fractures. Thirty patients with an isolated iliac wing fracture were identified. The ISS, shock class, transfusion rate, complications and mortality were indeed comparable to those of patients with an unstable pelvic fracture. In this group of patients with iliac wing fractures, a high incidence of open pelvic fracture was observed (20%). Concomitant injuries were observed in 93% of the patients. Operative stabilization of the fracture was not performed in any of these patients. However, surgery for complications of these injuries such as abdominal wall hernia's or infectious complications of open fractures were not uncommon. Isolated iliac wing fractures should therefore warrant a high level of caution and should be regarded as having a potentially serious injury.

Chapter 6 describes pelvic fractures in children. They occur even less frequent than in adults. In 20 years, 51 children with a pelvic fracture were treated at the Radboudumc. The patient and fracture characteristics, treatment and outcome of pelvic fractures in children were compared with an adult cohort. Pelvic fractures in children were more often caused by traffic accidents than in adults. Children with a pelvic fracture present more often with a lower ISS than adults and are less often hemodynamic unstable. Type B fractures are more often seen in children when compared to adults who present more often with type C injuries. Associated injuries were seen in both groups; however, thoracic injuries were significantly higher in adults and injuries to the extremities were higher in children. Adults were significantly more often treated with open reduction and internal fixation. Mortality in both groups however, did not differ (6 vs. 8%). Compared with adults, children die less often due to sequelae of haemorrhage, but of concomitant injuries like severe head trauma. In comparison with other studies, the mortality rate was in the same range.

Clinical outcome was generally good, with no observed growth disturbances during follow-up. Forty-eight patients (94%) achieved full range of motion and no pain in the hip or lower back in active daily life. However, these conclusions regarding outcomes and effect on active daily life are based on data that were found in the medical chart. The follow-ups varied widely; therefore, no firm conclusions about the long-term results can be made. A study regarding the long-term health-related quality of life is currently being performed in our clinic.

Treatment of these patients in specialised hospitals is likely to provide the best outcome because of the rarity of these fractures.

In **chapter 7** long-term Health related Quality of Life (HrQoL) was studied in patients who were treated for a pelvic fracture over a period of 5-10 years. HrQoL was measured with the Majeed Pelvic Score (MPS), the EuroQol-5D (EQ-5D) and the Short Musculoskeletal Function Assessment (SMFA) questionnaires. This study was conducted in two level 1 trauma centers (RUMC and ETZ). In total, 136 patients returned the questionnaires. There were no differences found between the fracture types and the outcomes of the MPS, EQ-5D and the SMFA. Then a linear regression analysis was performed, which was adjusted for age, sex, ISS, fracture type (stable versus unstable), neurologic injury, urogenital injury, open fracture, injuries to the lower extremity and surgical treatment. Significant differences were found in the MPS in the domain of standing (walking aids) and in the domain of mobility in the EQ-5D. Type B fractures performed worse than type A and C fractures. This could be explained because of the great number of type B2 fractures in the overall type B group. However, regarding all outcome scores, outcomes were generally good, with a mean MPS score of 85, a mean EQ-5D VAS score of 75, which is comparable to the standard Dutch population.

Finally, **chapter 8** describes the early use of 2D navigation for the placement of iliosacral screws. Conventional fluoroscopic guided placement was compared with the 2D navigation. The position of the iliosacral screws was evaluated on postoperative CT scans. Additionally, clinical morbidity and re-operation were assessed. 83% of the screws placed with navigation versus 82% of the screws placed with conventional fluoroscopy were placed adequately. Five patients required re-operation, all in the computer-navigated surgery group. So in contrast to what has been suggested by previous studies, we found no benefit from 2D computer-navigated iliosacral screw fixation compared to fluoroscopically guided surgery regarding the correct positioning of iliosacral screw on postoperative CT scans and related morbidity. More adequate positioning was observed with increased surgical experience.

The main reason no benefit was found, is that the surgeon has to rely on the same images made with the fluoroscope which are loaded in the computer. So the quality of the images of the fluoroscope determine the success rate of your screw placement. Therefore, improvement of the navigation system, improvement of the quality of the radiologic imaging and the use of CT instead of conventional fluoroscopy can enhance the quality of navigation based surgery. Currently the use of 2D and 3D navigation in the hybrid OR with state of the art equipment is studied in our centre.

When comparing our data to the recent literature, the baseline characteristics of our patients with pelvic fractures are comparable. Overall mortality in our group was 8%. This is also comparable to most series, which report a mortality rate of 4-20%. In the group of patients with open pelvic fractures, the achieved mortality rate is one of the lowest in the world. When comparing our results of pelvic fractures in children, this cohort is relatively large and results are comparable to other authors. To ensure that the level of healthcare delivered to these patients remains at a constant high level, further research is warranted.

Future research should focus on improving prehospital care, adequate diagnostic workup, novel treatment modalities and on collecting patient related outcome measurements (PROM's).

Prehospitally, the HEMS supports ambulance services in providing care to the patients with compromised vital parameters. Since 2017, the HEMS is equipped with uncrossmatched type O Rhesus negative packed red blood cells. If transfusion on scene is beneficial for patients with severely unstable pelvic fractures is yet to be determined. Also, the quality and the reliability of the physical examination of the pelvis on scene is under investigation. Preliminary results show a positive predictive value of 50% and it is debatable if the pelvis should be tested at all or a prophylactic pelvic binder should be placed regardless of clinical findings .

Patients with a high energy trauma, including those with pelvic fractures, should be triaged to a level 1 trauma center. Ideally, all patients with a life-threatening or limb-threatening should be treated at these centers. After initial work-up, patients with low demanding or non-vital injuries can be transferred to a level 2 center for definitive treatment. Cost-effectiveness and effects on outcome of this triage should be further studied.

Improving care in the ER is another point of interest. Currently, the use of the CT scan is far more liberal than it was 10 years ago. The CT scan is at close proximity of the shock room and the radiation dose has been decreased dramatically the last decade with the use of the split bolus contrast protocol. Angiography was mainly done on angio suites. Performing simultaneous surgery was often difficult because the angio suites weren't equipped for surgical intervention. Nowadays, hybrid OR's can facilitate CT scans in the OR. The use of this modality with combination of angiography and embolization while being in the OR can have impact on the treatment protocol. For example, an external fixator can be applied while the groin is being prepared for angiography. Further studies regarding the need for laparotomy or angiography should be addressed in the future.

Patient related outcome measurements are also a hot topic of interest. Mortality rates still can be further reduced. But when you truly evaluate your therapy, it is critical to know how the survivors are doing in the short-, middle-, and long-term. Currently, new studies regarding long term outcome in children and outcome in geriatric patients with high energy pelvic fractures are ongoing. Measurement of HR-QoL will be standardized in our outpatient clinic.

Finally, the feasibility of new techniques should be further investigated. These new techniques are discussed in the future perspectives.

FUTURE PERSPECTIVES

The treatment of pelvic ring injuries will enter an interesting era with some challenges in treatment of osteoporotic fractures but also with the further development of minimal invasive operative techniques, the use of 3D printing and augmented reality.

FRAGILITY FRACTURES

Because of the increasing life-expectancy in the industrialized world, the number of elderly people is increasing fast[1]. Osteoporosis is often seen in elderly people and the number of osteoporotic fractures is increasing fast as well[2]. Also, elderly people become more active (for example the use of e-bikes). The incidence of osteoporotic pelvic fractures is estimated to be twice as high in 2030 compared with 2013[3]. For elderly people, pelvic fractures may have a major impact on quality of life as they lead to immobility, pain and loss of indepence[4].

Fragility fractures form the pelvis are caused by a low energy trauma, eg a domestic fall. They differ from pelvic fractures caused by high energy trauma. Because of the fragile bone, the strength of the bony structures is lower than that of the surrounding ligaments. This means that only the bone is fractured, while the ligaments remain intact. This leads to unique fracture patterns[5].

Rommens et al[5] proposed a classification system for insufficiency (fragility) fractures of the pelvis in 2013. This classification system is based on morphological characteristics and has a direct relation with the degree of instability. The classification is fluent, which means that if the fracture is not treated correctly, the fracture may progress from a relatively stable

into an unstable fracture. The classification resembles morphologically to the Tile of Young& Burgess classification, however, the concomitant soft tissue damage is far less severe.

The classification is demonstrated in figure 1. In type I fractures, there's a disruption of the anterior ring without involvement of the posterior ring. Operative fixation is often not needed for this fracture type.

Type II fractures are non-displaced posterior fractures, which can occur bilaterally. Also, in type IIB and C fractures, the anterior ring is fractured. In contrast with sacral fractures in high energy trauma, which are often transforaminal, the fragility fractures are usually transalar. Surgical fixation should be considered in type II fractures when conservative treatment fails and patients complain of persistent pain during mobilization and the inability to achieve full weight bearing within 6 weeks.

Type III injuries are highly unstable. Besides the anterior involvement, there's a dislocation in the posterior part of the pelvis. Operative therapy is usually necessary and requires open en extensive approaches to achieve adequate fixation.

Type IV fractures have the highest instability and are characterized by a complete dissociation of the iliolumbar spine to the pelvis. They require operative stabilization with pedicle screws and bars to re-attach the spine to the pelvis.

Adequate fixation of the fractures are often difficult in patients with osteoporosis. Various authors[6,7] report augmentation of the ostheosynthesis with cement. However the risk of cement extrusion in the neuroforamina can cause iatrogenic nerve damage[8].

Comorbidity is also of influence on the choice of therapy and on outcome. High risk surgeries with extensile approaches and a great amount of blood loss are not favorable. Currently, the effects of comorbidity are studied in geriatric patients with a high energy trauma.

Recently, the photodynamic stabilization system (IlluminOss™, IlluminOss medical USA) is described as a form of augmentation in patients with a fragility fracture of the pelvis[9].The IlluminOss™ system consists of a light activated monomer which is inserted in an angioplasty balloon. This balloon can be introduced percutaneously in the intramedullary canal of the superior pubic ramus. After being filled with the monomer, a light source cures the monomer and gives it longitudinally strength and rotational stability. Additionally, plate and screw fixation can be performed through the inflated and cured balloon. The balloon itself can also be sufficient enough to provide stability without the use of other hardware.

The place for IlluminOss™ as a form of augmentation in pelvic fractures is currently being studied in several centers in The Netherlands.

Also, new promising techniques which are now studied ex-vivo are the development of “bone-glue”. This is a biological glue that is injected at the fracture site which creates a stable fixation. Ideally, the glue is resorbed or is converted in normal bone.

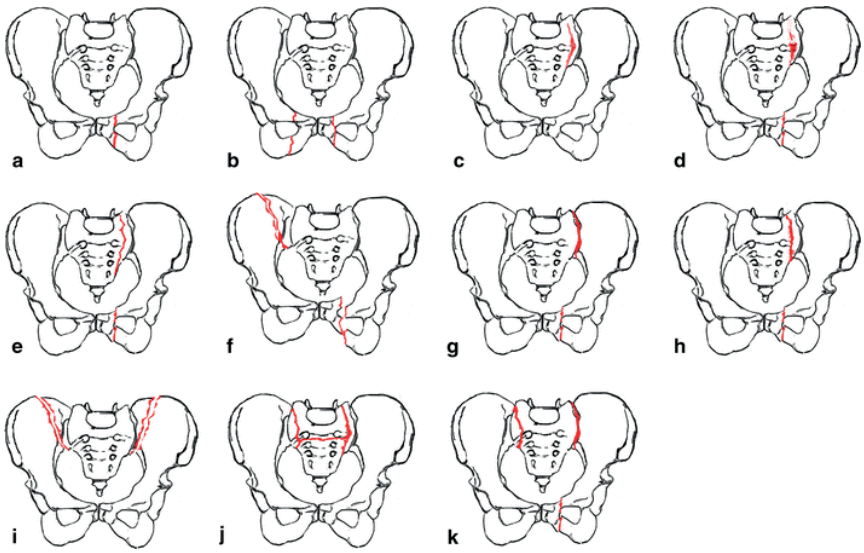


FIGURE 1 Fragility fractures of the Pelvis classification according to Rommens

A	**FFP type IA**	unilateral disruption anterior ring
B	**FFP type IB**	bilateral disruptiont anterior ring
C	**FFP type IIA**	isolated sacral fracture
D	**FFP type IIB**	sacral crush with anterior disruption
E	**FFP type IIC**	disruption ventral and dorsal cortex of the sacral ala with anterior disruption
F	**FFP type IIIA**	displaced unilateral iliac fracture with anterior disruption
G	**FFP type IIIB**	displaced sacroiliac fracture with anterior disruption
H	**FFP type IIIC**	displaced sacral fracture with anterior disruption
I	**FFP type IVA**	bilateral dorsal iliac fracture
J	**FFP type IVB**	spinopelvic dissociation
K	**FFP type IVC**	combination of dorsal and anterior fracture patterns

3D PRINTING AND COMPUTER NAVIGATED SURGERY

Often, patients with high energy pelvic fractures are polytraumatized patients. The surgical burden of an operation should be therefore as limited as possible. However, several exposures (e.g. the ilioinguinal, the extended iliofemoral or the Kocher-Langenbeck with/without the trochanteric osteotomy) are extended approaches which are used in pelvic or acetabular surgery.

With the new 3D printing techniques, full size and scale models can be constructed with data of the CT scan. This provides better understanding of the fracture type (10) and the surgery can be planned meticulously. The full size 3D print of the mirrored healthy side can be used to pre-bend the plates that are going to be used. This has several advantages. First, the plates have to be inserted in the wound only once, which can reduce the risk of infection and iatrogenic damage[11]. Second, the view and the shape of the pelvic bone are not impaired by soft tissue which makes it easier to acquire the desired shape. It can reduce operating time and blood loss[12].

Another tool in facilitating minimal invasive screw placement is the navigation based surgery, which is discussed earlier. Computer navigation is already widely used in neurosurgery and stereotaxy[13,14], in the oromaxillofacial surgery[15] in spinal surgery[16] and in joint replacement surgery[17] and is currently subject to ongoing developments and improvements.

A surgical navigation system resembles the navigation of a car system in some ways[18]. Both attempt to localize a position in space in the context of its surroundings. However, the actual localization in the surgical navigation doesn't depend on a GPS with geostationary satellites but use infrared stereoscopic cameras which can determine the 3D position of marker spheres. These marker spheres are attached with a frame to a fixed point on the patient and on the surgical instruments. Intra-operative imaging are then acquired and uploaded in the computer. When the correct images are acquired, the screw position and length can be planned virtually. Computer navigated surgery can be done 2D and 3D. In 2D surgery, 3 standard images are required; the inlet, outlet and lateral view are mandatory, an AP view is optional. In 3D navigation, a CT scan can be uploaded in the computer and can be compared with the fluoroscopical images (same as for 2D surgery) which are made during surgery. Alternatively, a CT scan is made during surgery (with the O-arm or Zeego). With these images virtual screws can be planned. When the virtual screw is planned, the position of the surgical instruments is compared with the route of the planned screw. When

the surgical instruments are in the position which is in the same trajectory of the virtually planned screw, the "green light" is given and the screw can be placed.

Advantages of this system are enabling minimal invasive techniques, reduction of radiation dose intra-operatively and potentially more accurate screw placement, especially when 3D navigation is used. In neurosurgical patients, an improved outcome is seen in several studies[19,20], as well as an improved surgical confidence[21].

Further developments are the use of clinical online networks, so that pre-operative planning can be done from the office (or even home) and can be discussed with colleagues online, and the integration of several pre-operative scans with preoperative planning information and acquired data intra-operatively. In an ideal situation, the fractured pelvis is loaded as a model, the fracture pieces are marked and are virtually reduced and the plates and screws are virtually placed. This reconstructed model is the placed over the original fracture model so that optimal reduction and hardware placement is monitored intra-operatively.

Pre-, or intra-opertaive planning can be combined with the use of a robotic arm, which can be used for minimal invasive screw placement. The coordinates of the planned screws are given to the robotic arm, which can adjust itself in the appropriate direction and can place the screws with minimal collateral damage to the surrounding structures.

TEN YEARS FROM NOW…

We expect a shift in the population with acetabular and pelvic fractures. As mentioned earlier, people are getting older and are more active than twenty years ago. E-bikes and other technical aids are getting more popular. The number of incidents with these vehicles is expected to increase. On the other hand prevention strategies from the government for motor vehicle accidents (MVA) as well as improved technology in cars (e.g. park and break assist) will likely reduce the number of MVA's. Therefore, the number of high energy pelvic fractures (usually in young adults) will shift to osteoporotic low energy fractures in more elderly patients.

Due to the further centralization of complex, low-volume surgeries, pelvic and acetabular surgery will be performed in 3 supraregional trauma centers in The Netherlands. Treatment is done by multi-disciplinary teams which consist of a trauma surgeon, orthopedic surgeon, trauma anesthesiologist, interventional radiologists, rehabilitation physician, technical physician and a team of physical therapists according to a clinical pathway. Other medical specialists like geriatricians and neurologists can be consulted.

Pre-operatively, the patient and the fracture will be assessed by our pelvic expert team. Based on this evaluation and on available long term PROMS data, a plan is made for the appropriate treatment.

Pre-operative screening of risk factors for surgery and optimalization of the patient will start the day of admission. For example, pulmonary training will be initiated by the physical therapist. Pre-operative planning will be performed by the technical physician who makes a 3D-print of the fracture.

Operative fixation will be done in a semi-acute setting with a fully dedicated team. Minimal invasive techniques will used in order to fixate the fractures. Percutaneous screw placement is done with 3d navigation.

When a more extensive approach for plate fixation is needed, the plates are pre-bended on the printed model and the type of screws and screw length are planned as well. For difficult fractures, the plates can also be printed on a personal basis. Also for these fractures, 3D based techniques are used. From the CT scan which is made on the operating table, each of the fracture fragments can be isolated in and the reduction of each fragment can be performed virtually. When you link these images to a holo lens and you project these fragments real-time on the patient, the surgeon can achieve an accurate reduction of the fracture and optimalization of screw placement. Also, the final reduction and osteosynthesis can be reviewed directly with the peroperative use of the ZEEGO in the operating theatre.

An integrated post-operative pathway focused on these type of patients will allow patients to start with early mobilization with active weightbearing within pain limits. As early as the day of admission, the situation at home will be assessed so that the need for help post-operatively at home can be anticipated.

All patients are seen in the outpatient clinic or in combination with e-health at a standard follow-up time. Before the visit, each patient is asked to fill out several Health-related Quality of Life questionnaires, which will be send to them automatically before the visit to the hospital. All this data is collected in a prospective database which allows evaluation of short-term and long-term outcomes.

A lot of these items above can be implemented far sooner than 10 years. Currently, a clinical pathway for patients with acetabular fractures is being constructed in the Radboudumc. Outpatient follow-up, including the HR-QOL questionnaires , will be standardized for pelvic and acetabular fractures in the second half of 2018. Prebending of

plates on 3D printed models is already current practice and the group of Groningen (22) reported the use of a pre-printed plate in an acetabular fracture.

Most of the operative techniques described above rely on the further development of the augmented reality and the object-oriented reality, which are used in the navigation based surgeries. Also, the availability of the ZEEGO and the peroperative CT scan is nowadays still very limited. However, recently the first 3D navigated SI screws were placed with the aid of the ZEEGO in our hospital (figure 2 and 3).

With the ongoing technical development, the expanding research in our center and the high dedication for good clinical care for patients with pelvic fractures, the Radboudumc will remain a leading center in the Netherlands and in Europe.

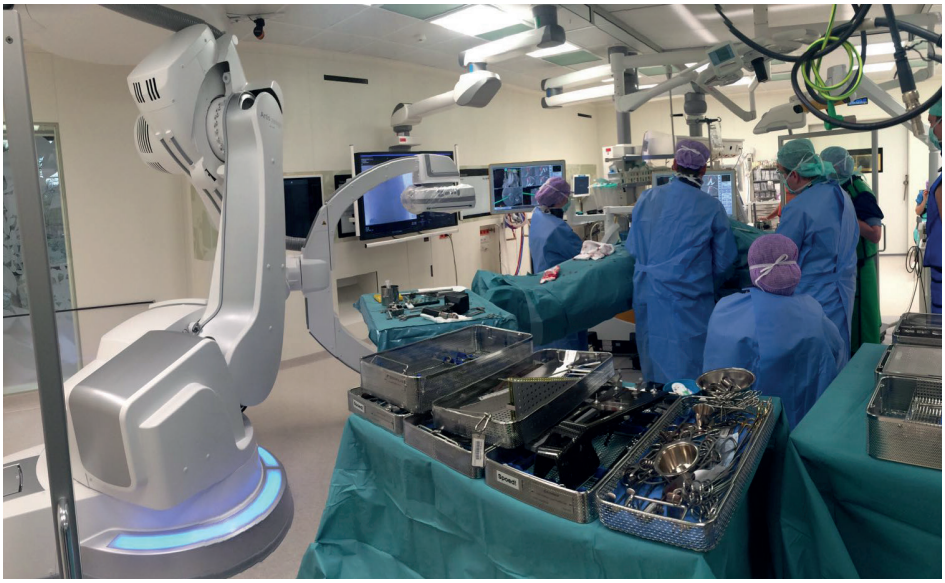


FIGURE 2 3D navigated placement of SI screws with the use of the Zeego

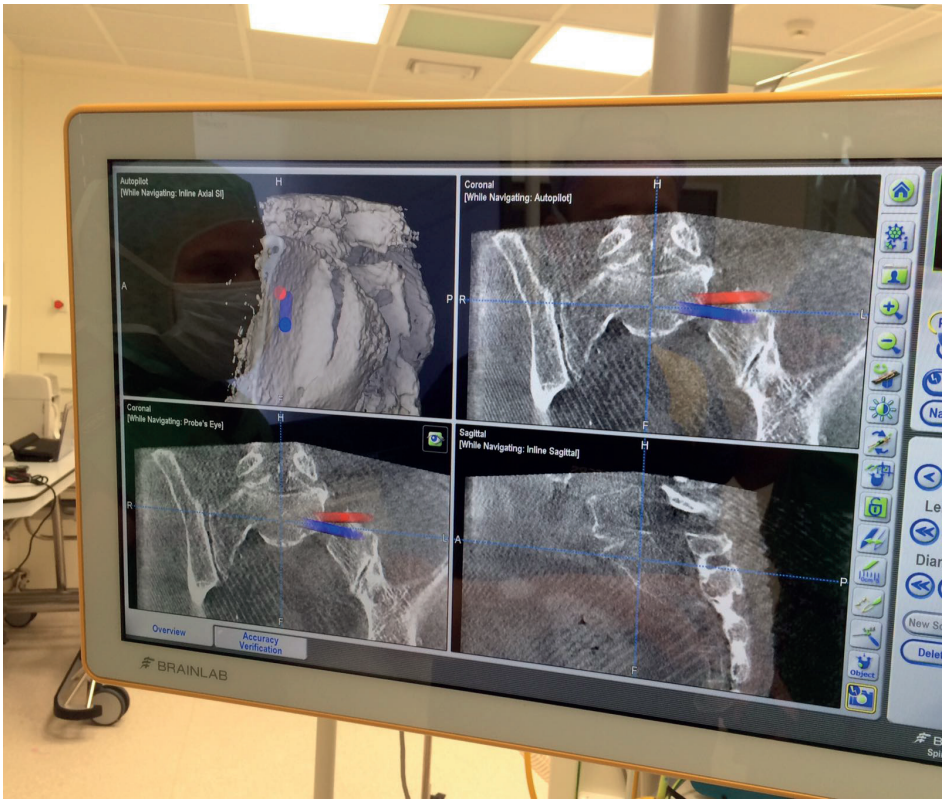
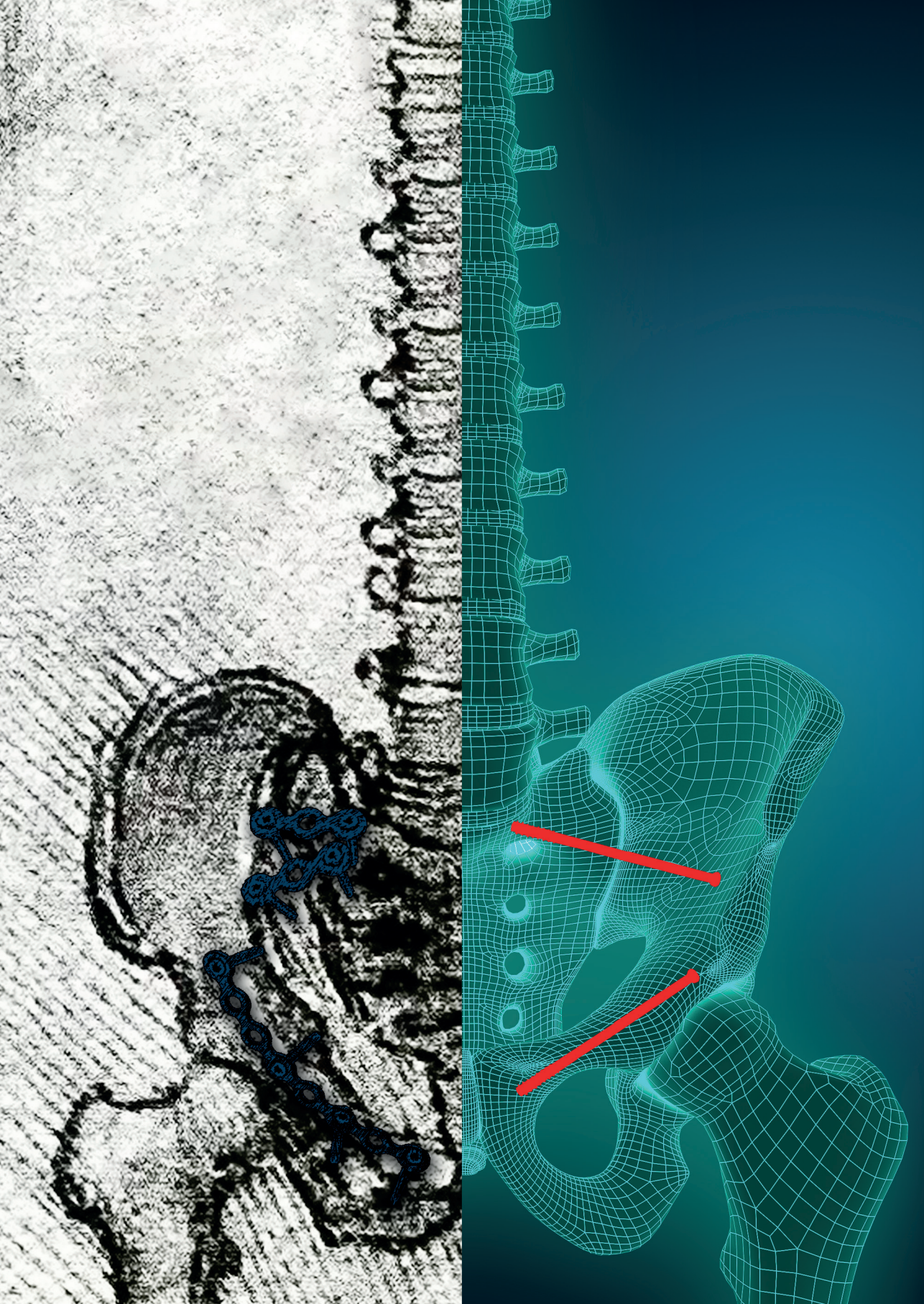


FIGURE 3 3D planning of SI screws with the Brainlab navigation system

REFERENCES

1. Sullivan MP, Baldwin KD, Donegan DJ et al. Geriatric fractures about the hip: divergent patterns in the proximal femur, acetabulum, and pelvis Orthopedics 2014;37:151-7
2. Friedman SM, Mendelson DA Epidemiology of fragility fractures Clin Geriatr Med 2014;30:175-81
3. Kannus P, Parkkari J, Niemi S et al. Low-trauma pelvic fractures in elderly Finns in 1970-2013 Calc Tissue Int 2015;97:577-80
4. Rommens PM, Wagner D, Hofmann A Fragility fractures of the pelvis JBJS reviews 2017;5:e3
5. Rommens PM, Hofmann A Comprehensive classification of fragility fractures of the pelvic ring: recommendations for surgical treatment Injury 2013;44:1733-44
6. Thardes T, Paffrath T, Beathis H et al. Computer assisted percutaneous placement of augmented sacroiliac screws. A reasonable alternative to sacroplasty Spine2008;33:1497-1500
7. Muller F, Fuchtmeier B Perkutane zementaugmentierte Verschraubung einer bilateralen osteoporotischen Sakrumfraktur Unfallchirurg 2013;116:950-4
8. Hulme PA, Krebs J, Ferguson Sj et al. Vertebroplasty and kyphoplasty: a systematuic review of 69 clinical studies Spine 2006;31:1983-2001
9. Stumpf M, Kraus T, Plotz W et al. Stabilisierung einer Beckeninsuffizienzfraktur mit einem photosensiblen Kunststoff (IlluminOss) Unfallchirurg 2015;118:279-82
10. Brouwers L, Pull ter Gunne AF, de Jongh MAC et al. The value of 3D printed models and Virtual Reality in understanding acetabular fractures Poster presentation OTA 2017
11. Nijsink J Object-oriented navigation using augmented reality: a new way of image guided surgery Thesis technical medicine University Twente 2017
12. Zeng C, Xiao J, Wu Z Evaluation of three-dimensional printing for internal fixation of unstable pelvic fracture from minimal invasive para-rectus abdominis approach: a preliminary report Int J Clin Exp Med 2015;8:13039-44
13. Buchalla R, Hopf-Jensen S, Rubarth O et al. Frameless navigated biopsy with the BrainLAB® VarioGuide system: a technical note J Neurol Surg A Cent Eur Neurosurg 2013;74:321-4
14. Ashour AM, Elbabaa SK, Caputy AJ et al. Navigation-Guided Endoscopic Intraventricular Injectable Tumor Model: Cadaveric Tumor Resection Model for Neurosurgical Training World Neurosurg 2016;96:261-6
15. Wood JS, Purzycki A, Thompson J et al. The Use of Brainlab Navigation in Le Fort III Osteotomy J Craniofac Surg 2015;26:616-9.

16. Pirris SM, Nottmeier EW A case series on the technical use of three-dimensional image guidance in subaxial anterior cervical surgery Int J Med Robot 2015;11:44-51
17. Mason JB, Fehring TK, Estok R, et al. Meta-analysis of alignment outcomes in computer-assisted total knee arthroplasty surgery J Arthroplasty 2007;8:1097-1106
18. Mezger U, Jendrewski C, Bartels M Navigation in surgery Langenbecks Arch Surg 2013;398:501-14
19. Kurimoto M, Hayashi N, Kamiyama H et al. Impact of neuro-navigation and image-guided extensive resection for adult patients with supratentorial malignant astrocytomas: a single-institution retrospective study Minim Invasive Neurosurg 2004;47:278-83
20. Wirtz CCR, Albert FK, Schwadere M et al. The benefit of neuro-navigation for neurosurgery analyzed by its impact on glioblastoma surgery Neurol Res 2000;22:354-360
21. Ferroli P, Tringali G, Acerbi F et al. Advanced 3D planning in neurosurgery Neurosurg suppl 2013;1:A54-62
22. Merema BJ, Kraeima J, Ten Duis K et al. The design, production and clinical application of 3D patient-specific implants with drilling guides for acetabular surgery Injury 2017;48:2540-7



SAMENVATTING IN HET NEDERLANDS

10

SAMENVATTING IN HET NEDERLANDS

Bekkenfracturen zijn relatief zeldzaam, en vormen daardoor een uitdagend letsel voor de traumachirurg. Levensbedreigende bloedingen bij patiënten met een bekkenletsel zijn niet ongewoon en moeten acuut behandeld worden. Hierbij moeten anesthesiologen, radiologen en traumachirurgen nauw samenwerken om de bloeding te stelpen.

Wanneer een patiënt hemodynamisch gestabiliseerd is en het bekkenletsel definitief verzorgd kan worden, biedt dit ook de nodige uitdagingen. De benaderingen zijn vaak groot en er is een aanzienlijk risico op complicaties zoals iatrogene schade aan de zenuwen of bloedvaten of massale longembolie dan wel trombose.

Doordat bekkenfracturen relatief zeldzaam zijn en de behandeling ervan complex is, wordt de behandeling van deze letsels geconcentreerd in gespecialiseerde ziekenhuizen. Het Radboudumc is een level 1 traumacentrum en een tertiair verwijscentrum voor bekken-, en acetabulumfracturen. Het doel van dit proefschrift was inzicht te verkrijgen in onze verschillende patiëntgroepen, de behandeling en uitkomsten hiervan en de resultaten hiervan te vergelijken met andere (inter)nationale bekkencentra. Door de verkregen inzichten willen we de kwaliteit van onze zorg voor deze patiëntengroep verbeteren.

In de periode 1 januari 2004 tot 1 jan 2015 werden 537 patiënten met een bekkenletsel behandeld. In **Hoofdstuk 2** worden deze patiënten populatie, de uitgevoerde behandelingen en resultaten hiervan uitgebreid beschreven. Dit is de grootste beschreven patiëntenserie van 1 centrum in Nederland. In totaal zagen we 137 patiënten (25.5%) met een Tile A fractuur, 211 patiënten (39.3%) met een Tile B fractuur en 189 patiënten met een Tile C fractuur (35.2%). Patiënten met een instabiele fractuur (Tile B1, B3 en C) hadden een significant slechtere Injury Severity Score (ISS), een hogere transfusie behoefte, een hogere noodzaak voor laparotomie en voor definitieve osteosynthese en hoger percentage complicaties. In totaal overleed 13,6% van de patiënten (n=73). Het overlijden van de patiënten verschilde niet significant tussen de typen fractuur. Dit suggereert dat het overlijden veroorzaakt wordt door bijkomende letsels, zoals neurotrauma. Het percentage overleden patiënten met een bekkenletsel in het Radboudumc is vergelijkbaar met andere studies. Bijna de helft van de patiënten die we behandelden konden direct naar huis worden ontslagen. Deze data vormen een belangrijk instrument om ons behandelprotocol te evalueren en te verbeteren voor toekomstige patiënten.

Het juiste behandelprotocol blijft onderwerp van discussie in de internationale literatuur en is vaak afhankelijk van de faciliteiten binnen een ziekenhuis. In **hoofdstuk 3** beschrijven we een patiëntencohort van in totaal 289 patiënten in de periode 1-1-2003 tot 1-6-2010. Van elke patiënt werd nagegaan of ze behandeld waren volgens ons lokale protocol. Hierbij werd specifiek gelet op de beslissingen rondom acute chirurgie (Damage Control) versus uitgebreide diagnostiek middels CT en de procedures omtrent acute fixatie van het bekken en packen. Kritieke punten in ons protocol waren spoedstabilisatie van het bekken met een bekkenband of C-clamp in de traumakamer bij patiënten met een shock klasse van 3 of 4, damage control chirurgie bij patiënten niet reagerend op vulling versus uitgebreide diagnostiek middels CT bij hemodynamisch stabiele patiënten of patiënten reagerend op volume resuscitatie met angiografie en embolizatie op indicatie.

Wanneer een patiënt overleed, werd de doodsoorzaak geanalyseerd. In deze groep overleden 22 patiënten (7%). Bij 18 van de 22 (82%) patiënten droeg verbloeding bij aan het overlijden. Bij 12 van de 22 patiënten werd van het behandelprotocol afgeweken op eerder genoemde kritische punten. Dit betrof meestal het niet aanleggen van een bekkenband op de SEH. In de groep overleden patiënten werd significant hoger afgeweken van protocol dan in groep overlevenden ($p<0.01$). Het behandelen van patiënten met een bekkenringletsel volgens een standaard behandelprotocol draagt daarom bij aan een betere uitkomst.

Open bekkenfracturen zijn erg zeldzaam, met een geschatte incidentie van 2-4% van alle bekkenletsels. Bij open bekkenfracturen bestaat er een directe verbinding tussen het fractuurhematoom en de buitenwereld (door rectum, vagina of huid). Deze patiënten hebben een hoog risico op verbloeding doordat het natuurlijke compartiment, wat het bekken vormt, verbroken is en er geen tamponade effect meer mogelijk is. Daarnaast is er een hoger risico op overlijden door sepsis en multi-orgaan falen. Historisch zijn er mortaliteitspercentages tot 50% beschreven. **Hoofdstuk 4** focust op de patiënten met een open bekkenringletsel. In de studieperiode van 11 jaar zagen we 24 patiënten met een open letsel. Deze patiënten hadden een significant hogere ISS en transfusiebehoefte in vergelijking met patiënten met een gesloten letsel. In onze serie overleefden 96% van de patiënten met een open bekkenringletsel, hetgeen niet significant verschilde van patiënten met een gesloten letsel. In vergelijking met andere studies was het de mortaliteit in onze serie laag.

Er zijn 2 factoren die bijdragen aan de mortaliteit bij open bekkenletsels. De eerste is het massale bloedverlies bij het verlies van het natuurlijke compartiment, de tweede factor

is het optreden van infectieuze complicaties. Een gestandaardiseerd behandelprotocol zoals dat van het Radboudumc, met daarin aandacht voor agressief chirurgisch debrideren van de wonden, het geven van antibiotica, het stabiliseren van de fractuur en het aanleggen van een colostoma in geval van ernstige rectum of perineum letsel, draagt bij aan een betere uitkomst in deze patiëntencategorie. Daarnaast speelt de verspreiding en de relatieve nabijheid van level 1 traumacentra in Nederland een rol in de uitkomst in vergelijking met centra in het buitenland.

Wanneer er sprake is van een bekkenfractuur waarbij de bekkenring niet is onderbroken (AO/Tile type A) wordt het risico op verbloeding ingeschat als klein. Men beschouwt deze fracturen dan ook over het algemeen als relatief goedaardig. In **hoofdstuk 5** beschrijven we een groep patiënten met een geïsoleerde iliumvleugelfractuur. De iliumvleugel is een sterk bot wat bestand is tegen grote krachten. Er is dus aanzienlijke kracht nodig om de iliumvleugel te breken. We onderzochten de hypothese dat patiënten met een geïsoleerde iliumvleugelfractuur eenzelfde profiel en zelfde uitkomsten hebben als patiënten met een instabiel bekkenring letsel. In onze groep hadden 30 patiënten een geïsoleerde iliumvleugelfractuur. De ISS, shock klasse, transfusiebehoefte, het aantal complicaties en mortaliteit bleke inderdaad vergelijkbaar te zijn met patiënten met een instabiele fractuur. Wat tevens opviel was een hoog percentage van open fracturen (20%). Bijkomend letsel werd gezien bij 93% van de patiënten. Operatieve fractuurbehandeling was bij geen van de patiënten noodzakelijk. Wel werden er ingrepen verricht met betrekking tot verzorging van de open fractuur en procedures om complicaties zoals buikwand herniaties te herstellen. Geïsoleerde iliumvleugelfracturen moeten derhalve beschouwd worden door de traumachirurg als een potentieel ernstig letsel in plaats van een goedaardige fractuur.

Hoofdstuk 6 beschrijft onze ervaring met bekkenfracturen bij kinderen. Bekkenfracturen bij kinderen komen nog minder frequent voor dan bij volwassenen. In 20 jaar tijd zijn in het Radboudumc 51 kinderen met een bekkenfractuur behandeld. The demografische gegevens, de fractuurkenmerken, de behandelingen en de uitkomsten zijn vergeleken met een cohort volwassen patiënten. We constateerden dat bekkenletsels bij kinderen vaker dan bij volwassenen veroorzaakt worden door een verkeersongeval. De ISS was daarentegen lager en kinderen waren minder vaak hemodynamisch instabiel. Type B letsels werden vaker gezien bij kinderen, bij volwassenen zagen we vaker type C letsels. In beide groepen hadden de patiënten veel bijkomende letsels. Thoraxletsels werden vaker bij volwassen patiënten gezien, extremiteitsletsels vaker bij kinderen. Een operatieve behandeling was

vooral bij volwassenen noodzakelijk. De mortaliteit verschilde niet tussen beide groepen (6 versus 8%). In vergelijking met volwassenen, overleden kinderen minder vaak aan de gevolgen van verbloeding maar eerder aan bijkomende letsels zoals ernstig neuroletsel. In vergelijking met andere studies over kinderen met bekkenfracturen was de mortaliteit vergelijkbaar. De uitkomsten bij kinderen waren goed; er werden geen groeistoornissen geobjectiveerd tijdens follow-up. Bij 48 kinderen (94%) was er sprake van een full range of motion zonder pijn in de heup of onderrug in het normale dagelijkse leven. Als kanttekening mag opgemerkt worden dat deze resultaten gedurende follow-up verkregen zijn uit notities in de status. Tevens varieerde de follow-up aanzienlijk per patiënt. Derhalve kunnen geen stevige conclusies getrokken worden uit deze gegevens. Momenteel wordt een studie verricht die gericht is op lange termijn uitkomsten bij kinderen met bekkenletsels in onze kliniek. De behandeling van kinderen met deze zeldzame letsels hoort in gespecialiseerde centra teneinde een zo goed mogelijke uitkomst te bewerkstelligen.

De lange termijnresultaten bij volwassenen worden beschreven in **Hoofdstuk 7**. De gezondheidsgerelateerde kwaliteit van leven (Health related Quality of Life (HrQoL)) werd onderzocht bij patienten 5-10 jaar na een bekkenletsel. De HrQoL werd bepaald door middel van de Majeed pelvic score (MPS), de EuroQol-5D (EQ-5D) en de Short Musculoskeletal Function Assessment (SMFA) vragenlijsten. De studie werd uitgevoerd in 2 level 1 traumacentra (Nijmegen en Tilburg). In totaal vulden 136 patienten de vragenlijsten in. Er werden geen verschillen gevonden tussen de fractuurtypen en de uitkomsten van de verschillende vragenlijsten. Er werd een lineaire regressie analyse verricht waarbij gecorrigeerd werd voor leeftijd, geslacht, ISS, fractuurtype (stabiel of instabiel), neurologisch letsel, urogenitaal letsel, open fracturen, letsels aan de onderste extremiteit en operatieve behandeling. Er werden significante verschillen gevonden in de MPS in het domein van staan (lopen met hulpmiddelen) en in het domein mobiliteit van de EQ-5D. Hierbij deden patiënten met een type B letsel het slechter dan de patiënten met een A of C letsel. Kijkend naar alle scores, hebben patiënten 5-10 jaar na een bekkenletsel over het algemeen hoge scores. De MPS was gemiddeld 85, de EQ-5D 75, hetgeen te vergelijken is met de standaard Nederlandse populatie.

Tot slot worden in **hoofdstuk 8** de resultaten beschreven van onze eerste ervaringen met het gebruik van 2D navigatie voor het plaatsen van SI-schroeven. Hierbij wordt de 2D navigatie vergeleken met de conventionele fluoroscopie. De positie van de SI schroeven

werd gecontroleerd met behulp van een post-operatieve CT-scan. Tevens werden de peri-operatieve complicaties (zoals zenuw-uitval) en het aantal re-operaties gescoord. In totaal werden 83% van de schroeven geplaatst met navigatie adequaat geplaatst. Bij de conventionele fluoroscopie was dit 82%. Vijf patienten moesten een re-operatie ondergaan. Deze patienten waren allemaal met 2D navigatie geopereerd. In tegenstelling wat er in andere studies is beschreven, vonden wij geen direct voordeel van de navigatie. Een adequatere positie van de schroeven hing wel samen met de ervarenheid van de chirurg. De voornaamste reden waarom er geen voordeel behaald is, is dat de chirurg afhankelijk is van dezelfde fluoroscopische beelden. De beelden worden op dezelfde manier verkregen met de beeldversterker. Bij de 2D navigatie worden deze beelden in de computer geladen en kan een virtuele schroef gepland worden. De kwaliteit van de beelden bepaalt uiteindelijk de succeskans voor het plaatsen van de schroef. Waarschijnlijk wordt de kans op een succesvolle schroef groter als de beelden beter zijn. Het gebruik van CT beelden in plaats van de standaard fluoroscopische beelden van de beeldversterker (3D navigatie) wordt momenteel onderzocht op onze hybride operatiekamer.

Als we onze data vergelijken met recente publicaties, zijn de karakteristieken van de patiënten met bekkenringfracturen vergelijkbaar. De mortaliteit in onze groep bedroeg 8%. Dit is vergelijkbaar met andere grote studies die een mortaliteit rapporteren van 4-20%. In de groep van patiënten met open fracturen is de mortaliteit in onze serie zelfs een van de laagste gerapporteerd. Qua kinderfracturen is onze serie vergelijkbaar qua grootte en resultaten met andere gespecialiseerde centra. Om ervoor te zorgen dat de kwaliteit van de door ons geleverde zorg optimaal en state of the art blijft, blijft verder onderzoek noodzakelijk.

Toekomstig onderzoek moet zich richten op het verbeteren van de prehospitale zorg, adequate diagnostische workup, nieuwe behandelmogelijkheden en op het verzamelen van patient gerapporteerde uitkomstmaten (PROM's).

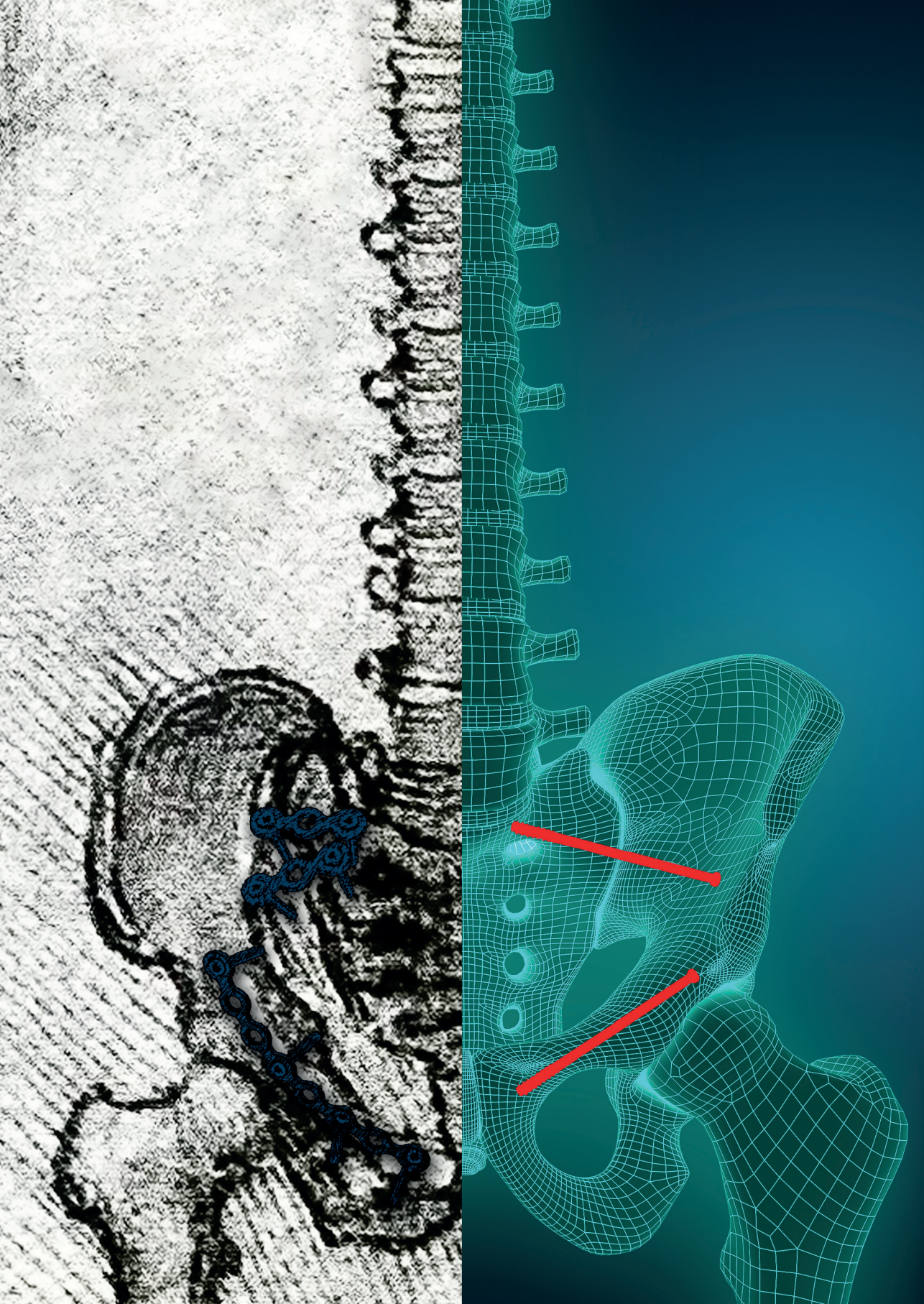
Het Mobiel Medisch Team (MMT) wordt ingeschakeld om prehospitale zorg te verlenen bij patiënten met bedreigde vitale parameters. Sinds 2017 is het MMT uitgerust met O negatieve bloed. Of transfusie met ongekruisd bloed voordeel biedt aan patiënten in shock met een instabiele bekkenbreuk is nog niet vastgesteld. Daarnaast wordt de waarde van het lichamelijk onderzoek, in het veld en op de spoedeisende hulp, momenteel onderzocht. Voorlopige resultaten laten een betrouwbaarheid zien van 50%. Het is daarom discutabel of het lichamelijk onderzoek überhaupt verricht moet worden bij de verdenking op

een instabiele bekkenbreuk of dat er op grond van het bepaald ongevalsmechanisme profylactisch een bekkenband aangelegd moet worden, onafhankelijk van de bevindingen bij lichamelijk onderzoek.

Alle patiënten met een hoog-energetisch letsel, waaronder de patiënten met een bekkenringfractuur, zouden idealiter gepresenteerd moeten worden in een Level 1 traumacentrum. Alle patiënten met een levensbedreigend danwel ledemaat bedreigend letsel moeten hier behandeld worden. Na de initiele workup van deze patiëntengroep, waarbij is vastgesteld dat de letsels niet levens of ledemaat bedreigend zijn, kunnen deze patiënten overgeplaatst worden naar een lager level (level 2 of 3) ziekenhuis. Het bestuderen van de uitkomsten en kosteneffectiviteit hiervan zou verder in kaart moeten worden gebracht.

Ook het verbeteren van de zorg op de SEH en de OK verdient aandacht. Tegenwoordig wordt de CT scan tijdens de trauma opvang liberaal gebruikt, veel meer dan 10 jaar geleden. De CT scan staat in het Radboudumc direct naast de traumakamer en de stralingsbelasting is het afgelopen decennium drastisch verlaagd, mede door een zogenaamd split bolus contrast protocol. Arteriele blushes kunnen snel worden geindentificeerd. Het vraagstuk fixatie versus angiografie en embolisatie is dankzij de komst van de hybride OK een stuk eenvoudiger geworden. Nu kan simultaan het bekken gefixeerd worden met een fixateur terwijl de liezen worden voorbereid op een angiografie. De angiokamer waar men weinig chirurgische opties heeft wordt hiermee overgeslagen. Helaas is de hybridekamer nog niet continu beschikbaar. Nieuwe studies moeten de waarde van de hybride OK bij dit soort patienten bewijzen.

Patient gerapporteerde uitkomsten zijn tegenwoordig een hot topic. Hoewel de mortaliteit nog steeds naar beneden kan worden gebracht, is het veel interessanter om te weten wat de korte, middel en lange termijn uitkomsten zijn bij de patiënten die het letsel overleven. Momenteel lopen er studies naar de kwaliteit van leven bij kinderen en bij geriatrische patiënten. Het meten van PROM's zal standaard worden in de follow-up van patiënten met een bekkenletsel op de polikliniek. Tot slot, de (on)mogelijkheden van nieuwe technieken, zoals de minimaal invasieve osteosynthesen en de 3D genavigeerde chirurgie, zal verder onderzocht moeten worden. Deze technieken worden besproken in het hoofdstuk Future Perspectives.



LIST OF PUBLICATIONS

2019 Stability Examination and Treatment Of the Pelvis (STOP) in the pre-hospital phase.
E.A.P. van Leent, B. van Wageningen, Ö.Sir, **E. Hermans** , J. Biert
(submitted EJEM)

2018 Quality of life and functional outcome in patients with unstable pelvic fractures .
E. Hermans, L. Brouwers, K. Lansink, J. Biert, MJR Edwards (submitted Injury)

2018 Isolated comminuted iliac wing fractures: are they really that benign?
E. Hermans, J.Biert, MJR Edwards (accepted for publication Acta Orth Belg)

2018 Open pelvic fractures: the killing fracture?
E. Hermans, J. Biert, MJR Edwards J Orthop Surg Res. 2018 Apr 13;13(1):83

2017 Epidemiology of pelvic ring fractures.
E. Hermans, JPF Frolke, J. Biert, MJR Edwards Hip&Pelvis 2017;29:253-261

2017 Paediatric pelvic fractures; How do they differ from adults?
E. Hermans, ST Cornelisse, J. Biert, ECTH Tan, MJR Edwards
J child orthop 2017;11:49-56

2016 Correct positioning of percutaneous iliosacral screws with computer-navigated versus fluoroscopically guided surgery in traumatic pelvic ring fractures.
J. Verbeek, **E. Hermans**, AB van Vugt, JPF Frolke J Orthop Tr 2016;30:331-335

2016 Research on relation of mortality and hemodynamics in patients with a pelvic ring fracture.
E. Hermans, J. Biert, AB van Vugt, MJR Edwards J Acute Dis 2016:5:117-122

2009 Poor outcome of colonic surgery in elderly patients.
E. Hermans, P.M. van Schaik, H. Prins, M.F. Ernst, K. Bosscha
J Oncol. 2010:865908 Epub 2010 Jun 13

2009 Are micrometastasis a predictor of the development of distant metastasis in colonic cancer?
PM van Schaik, **E Hermans**, JC van der Linden, MF Ernst, K Bosscha
EJSO 2009;35:492-6

2007 ATLS en damage control surgery
AWA Bruggeman, **E. Hermans** en AB van Vugt NTvG-s 2007;10:12-3

2005 Congenitale heupdysplasie
E. Hermans in: Practische radiologie, Hoofdstuk 34, blz. 145-7, onder redactie van Lemmens en Aries, Bohn Stafleu en van Loghum 2005

2003 Doorgelicht: een toevallige bevinding
E. Hermans, L. van Die en J.A.M. Lemmens NTvG-s 2003;6:22

DANKWOORD

Eindelijk af, dat is wel van toepassing op dit werk! Als student heb ik de eerste schreden op het bekkenpad gezet. Uiteindelijk hebben die paar eerste stappen op het wetenschappelijke pad geleid tot een echte passie voor bekkenletsels en natuurlijk ook dit boekje. Graag wil ik de mensen bedanken die me geholpen hebben met de totstandkoming van het proefschrift.

Prof. Dr. M.J.R. Edwards, beste Michael, du moment dat ik bij je aangaf dat ik wilde promoveren op bekkenfracturen zei je: Bezint eer ge begint. Ik heb eerst tot 22 geteld, het een plekje gegeven maar ben er uiteindelijk toch vol voor gegaan. Van jouw adviezen, zowel rondom dit proefschrift, als de momenten op en buiten de OK, heb ik veel geleerd (bv iets met strengetjes). Je bent een oprecht mens en staat achter je team. We mogen blij zijn met zo'n roerganger bij de trauma. Ik dank je voor alle mogelijkheden die je me hebt gegeven, zowel met dit proefschrift als op de werkvloer.

Dr. J. Biert, Beste Jan, jij bent een van de grootste drijvende krachten achter dit boekje. Sinds mijn ANIOS tijd hier ben je mijn begeleider geweest en je hebt altijd de moed erin gehouden, ook in de periode dat ik in het hoge noorden zat en het niet heel hard ging met het onderzoek. Ik dank je voor al je hulp en adviezen, mijn opleiding tot een completere traumachirurg en het overdragen van je kennis met betrekking tot de bekkens in het bijzonder. Je hebt jouw passie voor bekkenfracturen over weten te dragen op een volgende generatie. Het bekkenexpertisecentrum staat als een huis! Hopelijk is dit boekje het eerste van vele vanuit ons centrum!

Prof. Dr. A.B. van Vugt, beste Arie, als student verscheen ik bij je op de kamer omdat ik onderzoek wilde doen. Soms kon ik ook weer gaan omdat "the genius out was". Jij hebt me op het pad van de bekkens gezet. Nu besef ik me pas wat voor life-changer dat moment is geweest. Je hebt daarna in Enschede een grote rol gespeeld in mijn opleiding tot chirurg en hebt me altijd gesteund. Dank hiervoor!

Prof. Dr. J.C. Goslings en Dr. K.W.W. Lansink, beste Carel en Koen, dank voor jullie waardevolle adviezen en bijdragen aan dit boekje van buiten dit huis.

Prof. Dr. C.J.H.M. van Laarhoven, beste Kees, dank voor het vertrouwen dat je afgelopen jaren in me gesteld hebt. Ooit heb je me proberen te strikken voor een onderzoek naar pouches. Ik denk dat het goed is geweest voor ons beiden dat ik daar niet aan begonnen ben. Er ligt nu in ieder geval wel een boekje dat jou als oud-traumachirurg toch ook moet kunnen bekoren.

Dank aan de overige leden van de manuscriptcommissie (Prof dr. H.W.B. Schreuder, Prof. Dr. M. de Kleuver, Prof dr. V. de Ridder en Prof. dr. M. Poeze) voor het beoordelen van dit proefschrift en het zitting nemen in de oppositie.

Alle co-auteurs (Thijs, Simon en Lars), dank voor jullie waardevolle hulp en input voor de verschillende hoofdstukken. Lars, ik heb bewondering voor hoe je de kar blijft trekken tijdens je AIOSschap. Ik kijk uit naar de verdediging van jouw boekje.

De collega's van de binnenste ring. Jan Paul, Edward, Vincent, Micha, Edwin, Erik, Bas, Joost en Alyssa. Jullie zijn de reden dat ik elke dag met plezier naar mijn werk ga en dat waarschijnlijk de koffiecorner beneden bestaansrecht heeft. Het is typerend dat de barrista's beneden precies weten hoe wij onze koffie drinken. Dank voor het vervolmaken van mijn traumachirurgische opleiding en de onwijs prettige samenwerking.

Tjarda. Ons onderzuuks-durske! We is ut toch vergimmes mooi hoe gij ut allemaol regelt mee diejen protocollen. Da ge bedankt zijt da witte! Snel weer op sjouw in ons watervrij moeras met oewe Maot en Fred.

Staf Heelkunde Radboudumc: een mooi team met kundige en bevlogen mensen. Ondanks de steeds verdergaande differentatie binnen de pijlers worden de contact momenten schaars. Desalniettemin is het een voorrecht om binnen zo'n team te mogen werken.

Collega's van de orthopedie. Door het ringensysteem en de gezamelijke overdracht 's ochtends weten we elkaar steeds beter te vinden. Jullie input bij de ochtendoverdracht bij de traumapatient is waardevol en ik denk dat wij nog veel kunnen leren van jullie manier van strakke proceslijnen en visie. Hopelijk kunnen we deze manier van werken in de toekomst op een prettige manier verder uitbouwen!

Collega's van de anesthesie, MMT en SEH. Het behandelen van de traumapatient is teamwork bij uitstek en dat gaat niet zonder jullie. De samenwerking wordt in ieder geval mijn kant als erg goed ervaren. Laten we zo doorgaan om optimale zorg voor de traumapatient te (blijven) geven.

Collega's van de OK. Het is altijd weer een feest om te mogen opereren (vooral tussen 9 en 10 met het foute uur). Hoewel sommige mensen op de bezemsteel naar het werk komen (ik noem verder geen namen behalve Mandy en Marjolein), is het desondanks erg gezellig met jullie.

Collega's van de verpleegafdeling C2 Trauma. Jullie zijn een fijn team met veel compassie voor de patient. Mede dankzij jullie inzet gaat ons acetabulumpad een succes worden! Goed om te weten dat er goed op onze patiënten gelet wordt.

Collega's van de poli. Door jullie hulp, enthousiasme en optimale verzorging van zowel de patient als de dokter, is het doen van spreekuur bijna leuk geworden (in ieder geval voor een middagje per week).

Collega's van het secretariaat en het planbureau. Dank voor alle ondersteuning! Hans, jij houdt als een soort pater familias de afdeling bij elkaar en weet deuren te openen waarvan zelfs de ontwerper van het gebouw niet wist dat ze bestonden. Esther Rutjes, het is fijn zaken met jou doen als ik weer eens iets om moet gooien in het rooster vanwege de planning van de OK. Dank voor al je hulp en flexibiliteit. Esther, Diana en Frits, onbegrijpelijk dat jullie me nog niet letterlijk achter het behang geplakt hebben als ik weer eens iets wissel op de Flex-OK en er weer een driftige mail van mij komt over hoe het nou weer kan dat er een mammapatiënt geopereerd moet worden op de flex. Dank voor jullie geduld en meedenken.

Mijn oud opleiders: Dr. W.B. Mastboom (MST), Dr. R.J. van Ginkel (UMCG), Dr. S.H. van Helden (Isala) en Dr. B.H.P. Elsman (Deventer Ziekenhuis). Dank voor het vormen van mij tot chirurg en voor alle mogelijkheden die jullie me gegeven hebben.

Stafleden en assistenten regio VI: gedurende mijn opleiding ben ik in meerdere ziekenhuizen werkzaam geweest en heb met veel van jullie samen mogen werken en samen mogen feesten, borrelen, skiën, en congressen mogen bezoeken. Ondanks de forse afstanden tussen de ziekenhuizen zijn jullie een mooie, en ook hechte groep mensen. Het is goed te weten dat we elkaar tegen blijven komen op bijvoorbeeld de chirurgendagen. Ik dank jullie voor een mooie tijd!

Trauma-buddies Vincent, Eelco en Ivo. Het is mooi dat wij elkaar gevonden hebben in het Noorden. Van kroegentochten in Nijmegen tot het beklimmen van wat "heuveltjes" in Canada met 3L bier op je nek, van het ingevoerde "protocol" bij de traumadagen tot het uithuwelijken van elkaars kinderen; We hebben mooie dingen beleefd en gaan nog veel van dit soort mooie momenten tegemoet! Ik zeg Roadtrip USA bij de volgende OTA.

Almar. Studiemaatje van het eerste uur. Met jou ben ik veel het ziekenhuis in geweest om dingen live te bekijken en te ervaren. Het begon met een scopiedagje op de MDL, later een stage op de radiologie en een stage op de trauma en de kinderIC (ik zal het niet hebben over de collaps in de lift). Ook buiten het ziekenhuis hebben we mooie dingen beleefd! Even een heuveltje opfietsen in Toscane was nog nooit zo onderschat als toen. Ik dank je

voor je kameraadschap, je humor en de nooit aflatende belangstelling, zelfs vanuit het hoge noorden!

Stijn. Jouw kijk op de wereld (en ook op het gebied van mijn onderzoek) is verhelderend en leidt vaak tot goede gesprekken. Bij voorkeur op een late zomeravond met een glas whisky en een goede sigaar. Het is allemaal wat lastiger te plannen dan vroeger maar gelukkig hebben we altijd Oeteldonk nog als excuus om lekker op sjouw te gaan. Veel succes met je eigen ondernemingen!

De Muskebiers (Johan, Erik, Erik, Thijs en Roel): Lieve biervrienden, wat hebben we goed ons best gedaan de afgelopen tijd. De cijfers op untappd liegen er niet om. Een paar nieuwe levers heb ik al laten bestellen. Waarschijnlijk komt Thijs met zijn moordende tempo als eerste aan de beurt. Maar de humor, de gezelligheid en de gedeelde passie voor speciaalbier is uniek. Laten we hier vooral nog lang mee doorgaan (in ieder geval tot aan de levertransplantatie).

Mijn paranimfen. Hans, jou ken ik het langst van iedereen, namelijk van de zwangerschapsgym. Het is bijzonder dat we een deel van de studie samen hebben mogen doen en even samen gebivakkeerd hebben in dat hok bij de hospita en later op Welgelegen. Ondanks dat je al vroeg de voorkeur gaf aan een vak zonder diensten (psychiatrie) heb je toch je wetenschappelijke stage destijds gedaan met het onderwerp open bekkenfracturen. Jouw werk (en artwork) heeft uiteindelijk geleid tot een deel van dit boekje. Het is een ware eer dat jij vandaag hier naast me staat. Roel, mijn maatje van de middelbare school en mede biervriend. Waar een (matig) succesvol experimenteel onderzoek en een zelfgemaakt ballenbak van Lingo toe kan leiden. We hebben volgens mij een enorme invloed gehad op elkaars leven en je hebt menig vervelende ex bij me uit de buurt weten te houden dankzij je enorm grote tweede teen. Ik ben je dankbaar voor je vriendschap en ook trots dat jij hier naast me wil staan.

Lieve familie en schoonfamilie. Dank voor jullie niet aflatende belangstelling voor de vordering omtrent mijn proefschrift en gezelligheid.

Lieve schoonouders, Ans en Martien. Jullie helpen ons vaak uit de brand als we weer eens oppas nodig hebben. Dank voor jullie flexibiliteit, aandacht en oprechte interesse.

Lieve pap en mam. Jullie hebben er voor gezorgd dat ik nu hier kan staan. Jullie hebben Alex en mij altijd gesteund en op 1 gezet. Dank voor alles wat jullie voor mij en ons gedaan hebben. Ik hoop dat jullie nog lang in goede gezondheid van de (klein)kinderen en van het leven (met de nodige vakantie op z'n tijd) mogen genieten.

Lieve Wouter en Jasmijn. Al heb ik nog zo'n rotdag gehad op het werk, 1 lachje van jullie en alles is vergeten. Jullie zijn mijn grote trots! De Gruffalo en Bert & Ernie zijn momenteel veel leukere boekjes voor jullie maar wellicht bladeren we hier in de toekomst nog eens doorheen.

Tot slot,

Lieve Ellen, mijn grote steun en toeverlaat. Zonder jou was dit niet gelukt. Als het thuis niet lekker loopt, loopt het op het werk ook niet. Jij geeft me alle mogelijkheden om me te ontwikkelen op het werk, regelt het hele huishouden met 2 kleine kids, regelt de hele agenda en ons sociale leven en zo kan ik nog wel even doorgaan. Ik heb ontzettend veel bewondering hoe jij het allemaal doet. Je bent een soort supervrouw en –moeder. Ik hou ontzettend veel van je. Nu we dit eindelijk achter de rug hebben moeten we maar eens een ander feestje gaan plannen ;)!

Mezelf kennende ben ik ongetwijfeld mensen vergeten te noemen; weet dat ik jullie extra dankbaar ben voor alles!

CURRICULUM VITAE

Erik Hermans was born on June 20th 1983 in Waalwijk. He grew up in Drunen, in the beautiful province of Brabant. In 2000, he graduated from gymnasium Beekvliet in Sint-Michielsgestel.

He started the same year with his medical study in Nijmegen. During his study, several clinical traineeships were followed. In 2003 he trained at the radiology department for a month and in 2004 he followed an internship at the trauma department (prof dr. A. van Vugt). Since then, he knew he wanted to become a trauma-surgeon. Despite lots of social activities, he received his medical degree without significant delays in 2006.

In 2007, he started working at the Jeroen Bosch Hospital in Den Bosch as a senior house officer and became involved in research regarding micrometastasis in colonic cancer (Dr. K. Bosscha). After 2 years, he was offered a PhD project but because his heart was with traumasurgery, he returned to the Radboudumc to start working on the fundaments of this thesis.

In 2011, he started his residency in Enschede, in the Medisch Spectrum Twente (Dr. W. Mastboom). After 3 years, he spent 1 year in the UMCG (Dr. RJ van Ginkel). His differentiation in traumasurgery was followed in the Isala Zwolle (Dr. SH van Helden) and in the Deventer Hospital (Dr. B. Elsman/Dr. WH Roerdink). The last part of his residency, he returned to Nijmegen to finish this thesis.

In july 2017, he started his fellowship at the department of trauma surgery in the Radboudumc (Prof M. Edwards/Dr. J. Biert) with focus on the polytraumatized patient and especially pelvic and acetabular fractures. In 2019, he did an OTA fellowship in Houston with Dr. ML Routt to gain more expertise in treating complex pelvic and acetabular fractures.

He is a certified traumasurgeon and is a member of the Dutch Trauma Society (Nederlandse vereniging voor Traumachirurgie). He is an instructor for several courses as the Advanced Trauma Life Support (ATLS®) and the Advanced Hazmat Life Support (AHLS®).

During his residency, he developed a particular interest in craft beer. Together with an expanding group of friends, he still discovers new flavors in the wonderful world of the craft beer.

He currently lives in Lent with his fiancé Ellen and his 2 beautiful children, Wouter (2016) and Jasmijn (2018).

Financial support for printing and distribution of this thesis was kindly provided by:

nederlandse vereniging
voor traumachirurgie

Radboudumc

EXERGEN Global
Industrial Sales

Pro-Motion
MEDICAL
SPECIALIST IN BEWEGING