Martijn Hommes

THE INJURED LIVER

Management of hepatic injuries in the traumapatient

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Management of Hepatic Injuries in the Trauma Patient

Martijn Hommes

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“*It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change.*”

Charles Darwin

“voor mijn ouders”

LIST OF ABBREVIATIONS

AAST	American Association for Trauma Surgery
ACS	Abdominal Compartment Syndrome
AE	Angioembolization
AIS	Abreviated Injury Score
ATLS	Advanced Trauma Life Support©
ATOM	Advanced Trauma Operative Management©
BD	Base Deficit
BLI	Blunt Liver Injury
CI	Cardiac Injury
CT	Computed Tomography
CTA	Computed Tomography Angiography
CVP	Central Venous Pressure
DCL	Damage Control Laparotomy
DCS	Damage Control Surgery
DPL	Diagnostic Peritoneal Lavage
DR	Defintive Repair
DSTC	Definitve Surgical Trauma Care©
ECG	Electrocardiography
ERC	Endoscopic Retrograde Cholangiography
ERCP	Endoscopic Retrograde Cholangio-Pancreaticography
FAST	Focussed Assessment with Sonography for Trauma
FNOM	Failure of Nonoperative Management
GCS	Glascow Coma Scale
GSW	Gunshot wound
Hb	Hemoglobin level
HLOS	Hospital Lenght of Stay
ICU	Intensive Care Unit
ICULOS	ICU Lenght of Stay
INR	International Normalized Ratio
IOS	Injury Organ Score
IQR	Interquartile Range
ISS	Injury Severity Score
IVC	Inferior Vena Cava
LI	Liver Injury
LPV	Left Portal Vein
MVA	Motor Vehicle Accident
NOM	Nonoperative Management

NTL	Non Therapeutic Laparotomy
OM	Operative Management
P	P-value
PATI	Penetrating Abdominal Trauma Index
PD	Percutaneous Drainage
PVA	Pedestrian Vehicle Accident
RCT	Randomized Controlled Trial
RTS	Revised Trauma Score
RUQ	Right Upper Quadrant
SBP	Systolic Blood Pressure
SD	Standard Deviation
SICU	Surgical Intensive Care Unit
SLI	Stabwound Liver Injury
SNOM	Selective Nonoeprative Management
SPW	Subxiphoid Pericardial Window
SW	Stabwound

CONTENTS

Chapter 1

INTRODUCTION AND OUTLINE OF THIS THESIS

INTRODUCTION

Trauma is a global problem, and carries a high price that is paid by individuals, communities, and nations. Road traffic accidents, industrial injuries, farming accidents and interpersonal violence account for traumatic injuries with varying prevalences throughout the world.[1,2,3,4]

Globally the liver is the most frequent injured intra-abdominal organ following trauma.[5,6,7,8,9] The spectrum of liver injuries ranges from minor lacerations with minimal bleeding that stop spontaneously and require no intervention, to major lobar crush injuries and lacerations of the retrohepatic vena cava and hepatic veins that are often lethal and tax the skill, and resources of experienced surgical teams.[10,11] The magnitude of the liver injury and the complexity of the operative intervention required depend on the trauma mechanism, the anatomical location of the injury, the extent of parenchymal and vascular damage, and the type and severity of the additional injury present.[12] Overall the mortality of liver injuries ranges from 10% to 42% and is largely dependent on the type of injury and the associated injuries.[13] Exsanguination causes more than half of the deaths, and if three major organs are injured, mortality approaches 70 %. [14,15]

Selection of patients with liver injuries for nonoperative management, definitive surgical repair or a damage control laparotomy is the topic of ongoing debates. [16,17,18,19]

The surgeon, who encounters a severely injured patient with a liver injury, will rapidly need to make several critical decisions. This thesis on management of liver injuries focusses on preoperative assessment and selection of patients who require an urgent laparotomy, the surgical techniques to achieve hemostasis, the treatment of liver related complications, and the surgical strategy in order to manage associated perihepatic injuries.

OUTLINE OF THIS THESIS

In hemodynamic stable patients with a liver injury presenting without an acute abdomen, nonoperative management (NOM) of blunt liver injuries (BLI) has become the standard of care. Optimal treatment of patients with penetrating wounds of the liver is a topic of debate, and nonoperative management of penetrating liver injuries is infrequently practiced. Selective nonoperative management (SNOM) of abdominal stab wounds is widely accepted. Conversely, the SNOM of gunshot wounds of the abdomen is slowly gaining momentum in patients without peritonitis or sustained hypotension. Concern has been expressed about the potential overuse of NOM and the fact that failed NOM is associated with higher mortality rate. In the first part of **Chapter 2** the management of BLI in 134 severely injured patients was analysed, and the second part validated the feasibility and safety of the SNOM of penetrating liver injuries in order to find answers to the following questions:

- Which factors might indicate the need for a surgical intervention in patients who sustained blunt liver trauma?
- How efficient is NOM in patients who sustained blunt liver trauma?
- How often do patients who sustained penetrating wounds of the liver require a delayed laparotomy?
- What is the incidence of liver related complications in patients undergoing SNOM?

The majority of liver injuries stop bleeding spontaneously. Lethal exsanguination and delayed bleeding are feared complications in patients who have sustained severe liver trauma. Operative techniques that are available for the surgeon dealing with liver injuries include simple drainage of a non-bleeding liver, temporary packing, Pringle maneuver, suture ligation, finger fracture, balloon tamponade, therapeutic perihepatic packing, non-anatomical resection, anatomical liver resection, total hepatic isolation and the atriocaval shunt. In **chapter 3** the methods of control of liver bleeding were examined, answering the following questions:

- Is direct suture repair, perihepatic packing and selective use of angiography a safe strategy and efficient in order to control liver bleeding?
- What is the optimal time of pack removal, in order to minimise the risk of rebleeding and lower the risk of septic complications?

Biliary leak secondary to blunt or penetrating hepatic trauma and damage to the intrahepatic biliary tree presents a challenging problem. The management of traumatic bile leaks was studied in **chapter 4**. In the first part the incidence and management of bile leaks following operative management was examined. In the second part of this chapter a cohort of 412 patients who sustained liver trauma was studied and bile leaks were classified as minor or major. Minor leaks were managed conservatively, and major leaks underwent endoscopic retrograde cholangiogram and endoscopic biliary stenting. This study was initiated in an attempt to formulate answers to the following questions:

- What is the incidence of bile leaks following liver trauma?
- Is conservative management of traumatic intrahepatic bile leaks successful?
- Do all patients with a traumatic bile leak require endoscopic internal drainage?

Mortality in severe hepatic injury is 10 % when only the liver is injured, but if three major organs are injured, mortality approaches 70 %. Simultaneous treatment of the most severe injuries in a multidisciplinary trauma team is mandatory to optimise survival chances. The surgical members of the trauma team therefore require skills and knowledge also of the organs surrounding the liver. An occult cardiac injury may be present in patients with an acute abdomen after thoracoabdominal trauma. In **chapter 5** patients with complex patterns of injuries are studied. In the first part we evaluate the selection criteria for damage control laparotomy in severely injured patients. In the second part the role of a subxiphoid window to exclude occult cardiac injury in patients sustaining penetrating thoracoabcominal trauma has been studied. These studies were initiated aiming to answer the following questions:

- Which criteria dictate the need for a damage control laparotomy in patients with a complex pattern of thoracoabdominal injuries?
- Is the subxiphoid window an efficient and safe manoeuvre to perform in patients with thoracoabdominal injuries?

Chapter 6 presents two clinical illustrations of the treatment challenges that have been studied in this thesis. The two cases reflect the challenges that one may experience in presentation of severely injured patients and the resourcefulness and flexibility that a well-trained multidisciplinary team needs to bring patients with the worst prognosis to a successful outcome.

Chapter 7 presents a general discussion and future perspectives. The final discussion focusses on preoperative assessment and selection of patients, the surgical techniques and strategies to achieve hemostasis, and the treatment of liver related complications.

Chapter 8 summarises the findings and the answers presented in this thesis.

Chapter 9 presents a Dutch and German summary of the contents.

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Chapter 2

MANAGEMENT OF BLUNT AND PENETRATING LIVER TRAUMA

Management of Blunt Liver Trauma in 134 severely Injured Patients

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Injury 2015

ABSTRACT

Background: In haemodynamic stable patients without an acute abdomen, nonoperative management (NOM) of blunt liver injuries (BLI) has become the standard of care with a reported success rate of between 80-100%. Concern has been expressed about the potential overuse of NOM and the fact that failed NOM is associated with higher mortality rate. The aim of this study was to evaluate factors that might indicate the need for surgical intervention, and to assess the efficacy of NOM.

Methods: A single center prospective study between 2008 and 2013 in a level-1 Trauma Centre. One hundred thirty four patients with BLI were diagnosed on CTscan or at laparotomy. The median ISS was 25 (range 16-34).

Results: Thirty five (26%) patients underwent an early exploratory laparotomy. The indication for surgery was hemodynamic instability in 11 (31%) patients, an acute abdomen in 16 (46%), and 8 (23%) patients had CT findings of intraabdominal injuries, other than the hepatic injury, that required surgical repair. NOM was initiated in 99 (74%) patients, 36 patients had associated intraabdominal solid organ injuries. Seven patients developed liver related complications. Five (5%) patients required a delayed laparotomy (liver related (3), splenic injury (2)). NOM failure was not related to the presence of shock on admission (p=0,641), to the grade of liver injury (p=0,473) or associated intraabdominal injuries (p=0,533).

Conclusion: Physiologic behavior or CT findings dictated the need for operative intervention. NOM of BLI has a high success rate (95%). Nonoperative management of BLI should be considered in patients who respond to resuscitation, irrespective of the grade of liver trauma. Associated intraabdominal solid organ injuries do not exclude NOM.

INTRODUCTION

In haemodynamic stable patients without an acute abdomen, nonoperative management (NOM) is the standard of care for patients with blunt liver injuries (BLI). Successful NOM results in lower transfusion requirements, abdominal infection rate, hospital length of stay, and has a positive impact on survival in high grade liver injuries in haemodynamically stable patients.[1-7] Patients that are haemodynamically stable or who respond to resuscitation, can be managed nonoperatively with high success rates.[8,9] On the other hand, shock on admission has been reported to be associated with failure of NOM.[10] NOM is based on early computed tomography (CT) evaluation of the presence and severity of abdominal organ injuries. Signs of active bleeding and associated splenic injuries are reported to be predictive for early laparotomy and failure of NOM.[11] However hepatic extravasation seen on CT scan can be managed successfully without surgical or an angiographic intervention.[12,13]

Despite the initial enthusiasm and success of managing blunt liver injuriesnonoperative, failed NOM has been associated with a higher mortality rate and a concern over the potential overuse of NOM has been expressed by other authors.[14] Patient selection for NOM is critical and may improve outcomes in patients with severe BLI. This study evaluated factors that indicate the need for surgical intervention, and assessed the efficacy and safety of NOM. Ethical approval was granted from the Human Research Ethics Committee of the Faculty of Health Sciences of the University of Cape Town.

METHODS

One hundred thirty four patients with BLI were diagnosed on CT-scan or at laparotomy and included in a prospective study between 2008 and 2013 in a level-1 Trauma Centre. The study was conducted in a level-1 Trauma Center and tertiary hepatobiliary referral hospital, serving a population of 2.5 million people. Patient demographics, mechanism of injury, data at presentation including shock (systolic blood pressure [SBP]<90 mmHg), Glasgow coma score, vital parameters, hemoglobin level, serum lactate, base deficit, and blood transfusion requirements were documented. The Injury Severity Score (ISS) was calculated for each patient. Liver injuries were diagnosed on computed tomography scan or during laparotomy and graded using the organ injury scale of the American Association for Trauma Surgery.[15] Grade 3 to 5 hepatic injuries were considered to be high grade injuries. All patients with suspected liver trauma were admitted at the trauma resuscitation unit and initially resuscitated and managed according the principles of the Advanced Trauma Life Support (ATLS®) including the treatment as described for hypovolemic shock management.[16] Indications for NOM and OM are presented in table 1.

Table 1. Indications for NOM and OM.

NOM:	
1.	Haemodynamic stable patients
2.	Responders to resuscitation (haemodynamic and/or metabolic)
3.	CT findings excluding intra-abdominal injuries (bowel perforation) requiring surgical repair
4.	Patients with intravenous contrast extravasation ± angiographic embolization in haemodynamic stable patients
OM:	
1.	Non-responders to resuscitation (haemodynamic and/or metabolic)
2.	Peritonitis.
3.	CT findings suggestive of bowel perforation.
4.	CT scan finding of free fluid without a solid organ injury in a patient with a head injury or a complete spinal cord injury, where the abdomen cannot be assessed clinically.

Operative Management(OM) and Nonoperative Management (NOM)

The decision to perform an angiography and embolization in the early management of patients with liver injuries was made by the attending trauma surgeon and interventional radiologist.

Liver related mortality was defined as death due to liver bleeding, liver failure, or thecomplications of massive fluid resuscitation. Liver related morbidity was defined as a liver injury related complication necessitating an intervention; these complications were subdivided into (a) bleeding if either angio-embolization or laparotomy was needed (blood transfusion was not considered a complication); (b) liver related infection included a liver, perihepatic abscess or hepatic necrosis; (c) biliary referred to a biloma (sterile or infected), biliary peritonitis, biliary fistula and bile duct injuries; (d) missed hollow visceral injury, actual or suspected if a laparotomy was performed; (e) development of abdominal compartment syndrome requiring decompressing laparotomy. The treatment of liver related complications was multidisciplinary and included angiography and angiographic embolization of pseudoaneurysm, ERCP and stenting of biliary leaks, and CT-guided drainage of hepatic and perihepatic abscesses or biliary collections. The primary outcomes of this study were survival, failed NOM and liver related complications. Secondary outcomes included general complications, and duration of hospital stay and ICU-stay. Results were presented as number (%) or as median (P25-P75). Patient groups were compared using the Pearson's chi- squared test or Fisher's exact test for categorical variables, and the Mann-Whitney test for non-normally distributed data. Statistical analyses were performed using SPSS statistical software, version 20. P values < 0.05 were considered statistically significant.

RESULTS

One-hundred-and-thirty-four patients who had sustained blunt liver trauma were admitted during the study period covering 52 months. Ninety six (72%) were male with a mean age of 29 years (range 24-38), with a median ISS of 25 (range 16-34). The distribution of extra abdominal injuries is presented in table 2. The mechanism of injury was a motor-vehicle accident in 57 patients, pedestrian vehicle accident in 49, blunt assault in 27 and a fall from a height in a single patient.

Table 2. Distribution of extraabdominal injuries

	Number of patients	
	OM	NOM
Body region		
Head and Neck	19	54
Face	8	21
Chest	24	63
Pelvic	7	29
Extremity	15	46

Operative Management(OM) and Nonoperative Management (NOM)

Patients treated with urgent surgery. Thirty five (26 %) patients required early surgical intervention, table 3. The indication for surgery was haemodynamic instability in 11 (31%) patients, an acute abdomen in 16 (46%), and 8 (23%) patients had CT findings of intra-abdominal injuries, other than the hepatic injury, that required surgical repair. On the CT scan intravenous contrast extravasation in a grade V kidney injury with a combined grade V liver injury (n=1) was found, enteric injuries (n=5) and free fluid without solid organ injuries (n=2). In the latter two patients a liver injury was diagnosed during laparotomy.

Table 3: Comparison of patients with blunt hepatic trauma who underwent an immediate operation vs those who underwent initial NOM.

	Overall (N=134)	NOM (N=99)	OM (N=35)	P-value
SBP <90mHg[1]	19 (14%)	13 (13%)	6 (17%)	0.559
Hb[2]	11.4 (9.1-12.7)	11.6 (9.6-12.8)	9.8 (7.0-12.0)	**0.006**
Transfusion requirements in units[2]	0 (0-2)	0 (0-0)	2 (0-7)	**<0.001**
Lactate[2]	2.1 (1.0-4.0)	1.8 (1.0-3.2)	3.6 (2.0-4.4)	**0.001**
Base excess[2]	-2.9 (-8.3- -0.5)	-1.8 (-5.1-1.0)	-7.8 (-11.5- -3.1)	**<0.001**
High grade liver injury[1]	65 (49%)	44 (44%)	21 (60%)	0.113
Associated intra-abdominal injury[1]	73 (55%)	46 (47%)	27 (77%)	**0.002**
Kidney injury[1]	27 (20%)	18 (18%)	9 (26%)	0.340
Spleen injury[1]	30 (22%)	18 (18%)	12 (34%)	**0.049**
Pancreas injury[1]	9 (7%)	3 (3%)	6 (17%)	**0.004**
Vascular injury[1]	2 (2%)	0 (0%)	2 (6%)	**0.017**
Hollow injury[1]	11 (8%)	0 (0%)	11 (31%)	**<0.001**
General complications[1]	82 (61%)	50 (51%)	32 (91%)	**<0.001**
Liver related complications[1]	14 (10%)	7 (7%)	7 (20%)	**0.032**
ICU-stay[2]	0 (0-6)	0 (0-4)	6 (1-15)	**<0.001**
Hospital-stay[2]	15 (8-25)	13 (7-20)	24 (12-33)	**<0.001**
Mortality[1]	7 (5%)	1 (1%)	6 (17%)	**<0.001**

Data are presented as [1]number with the percentages between brackets or as [2]median with the P_{25}-P_{75} between brackets. Data were analyzed with a [1]Pearson Chi-squared analysis or Fisher's Exact Test or a [2]Mann-Whitney Test analyses. Boldface fonts indicate statistically significant differences.

Hypotension on arrival. In comparing patients who underwent an immediate operation and the patients who were managed non-operatively there was no difference in patients presenting initially with shock. In total 19 patients presented initially with a systolic blood pressure below 90 mmHg. Six of these 19 patients were nonresponders and required urgent surgery. Thirteen patients were resuscitated successfully and were managed nonoperatively.

Operative management of liver injuries. In 22 (63%) of the 35 patients requiring urgent surgery the liver was actively bleeding at the time of surgery. Fourteen (40%) patients required packing to control the bleeding and in 2 of these patients the common hepatic artery was found to be injured and was ligated. Eight (23%) patients required direct liver suturing of the bleeding vessels for haemostasis. The remaining 13 (37%) of the 35 patients did not require any early surgical intervention specific for the liver and the injury was drained.

Isolated liver injuries. Eight patients had intra-abdominal isolated grade II (n=2), grade III (n=2) and grade IV (n=3) liver injuries. Three patients required no intervention for the liver injury except removal of haematoma and drainage of the injury. Two patients required temporary packing to control the liver bleeding. Three patients were managed with therapeutic packing of the injured bleeding liver. In this group of isolated intra-abdominal liver injuries a retroperitoneal hematoma was present in three patients. Several associated extra-abdominal injuries were present: head (n=2), pelvis (n=2), long bone fractures (n=1), and thoracic trauma (n=1). One patient with a grade III isolated liver injury re-presented on day 10 post surgery with hemobilia, and had successful angioembolization of the hepatic artery branches to segments 8 and 4. All patients with isolated liver injuries survived.

Associated injuries. Associated intra-abdominal injuries were diagnosed in 27 (77%) patients, spleen (n= 12), kidney (n= 9), pancreas (n=6), stomach (n=2), small-bowel (n=6), colon (n=3), IVC (2), gallbladder (n=2) and bladder (n=3). Associated intraabdominal injuries were more frequently seen in the operative group. Comparing patients who were managed operatively and NOM, there were 12 (34%) and 18 (18%) splenic injuries in the two groups respectively. Eleven (31%) patients had head injuries, and 24 (69%) patients had thoracic injuries. Seven (20%) patients sustained a pelvic fracture.

Postoperative complications. Liver related complications developed in 7 patients who underwent urgent surgery [necrosis (n=2), haemobilia (n=1), and external biliary fistula (n=4)], representing an incidence of 20 per cent. Patients who underwent an immediate operation developed liver related complications more frequently. The two patients who developed liver necrosis both had injuries of the common hepatic artery that were ligated. One patient died of multi-organ failure and refractory shock, and the second patient was successful managed with percutaneous drainage and survived. General complications including ICU-length of stay (ICLOS), hospital length of stay (HLOS), and mortality, were higher in the early operative group.

Patients managed with NOM. Conservative management was initiated for 99 (74%) (table 3). One patient with a grade V liver injury underwent angioembolization of a peripheral hepatic artery pseudoaneurysm as initial management. The indication for angioembolisation was a blush of contrast seen on the admission computed tomography angiography and a fall in haemoglobin serum level in haemodynamically stable patient. This patient was successful managed non-operatively. Five (5%) patients eventually required an operation between 5 and 15 days post admission. Liver related complications following NOM. Seven patients developed liver related complications (biloma (n=3), biliary peritonitis (n=2), liver haematoma (n=1), abdominal compartment syndrome (n=1). The patients with a biloma were treated with percutaneous drainage. One patient treated for a grade III liver injury was discharged home on day three post injury, and readmitted on day 5 with nausea, abdominal pain and a fall in haemoglobin level. A repeated CT-scan showed an increase in size of the haemoperitoneum. This patient required 2 units of packed cells and was managed successfully without surgery, and discharged home day 8 post injury. Three patients who developed liver related complications required delayed surgery.

Patients who failed NOM. The success rate of NOM for BLI was 95% (table 4). Higher grade liver injuries were not more frequently seen in the failed NOM group. A comparison of patients who failed NOM and patients where NOM was successful, showed that there was no difference between GCS, presentation in shock, severity of metabolic acidosis (base deficit), associated splenic or extraabdominal injuries. General complications, intensive care stay, and hospital stay were equal in the group of patients who failed NOM and patients who were successfully managed with NOM.

Liver related failure of NOM. Two patients, both with a grade III liver injury, developed biliary peritonitis on day 7 and 15 post admission. These patients presented with spiking temperature and peritonitis and underwent a laparotomy. Endoscopic cholangiopancreaticography (ERCP) demonstrated a leak and both patients were treated successful with endoscopic sphinctertomy and internal drainage with a plastic stent. There was 1 patient who presented initially haemodynamic unstable and failed NOM. This was a polytrauma patient with a grade IV liver injury, a vertical shear pelvic fracture, bilateral femur fractures and a severe degloving injury of the buttock. The pelvic fracture and bilateral femur fractures were stabilized and the severe degloving injury was debrided. In the first five days, a massive blood transfusion was required (17 units). On day 5 a decompressive laparotomy for sustained intraabdominal hypertension and a loop colostomy for sepsis control was performed. At laparotomy the liver was not actively bleeding, but 3 litres of old blood was evacuated. This haemoperitoneum was felt to be related to the pelvic fracture. This patient eventually succumbed on day18 due to multi-organ failure. Non liver related failure of NOM. Two patients with splenic injuries (grade 2 and 3), one with a grade I liver injury and 1 with a grade III liver injury, required splenectomy on day 12 and 13 respectively because of abdominal pain, a drop in blood pressure and a fall in haemoglobin level. The spleen and not the liver was bleeding at the time of laparotomy.

Deaths. The overall hospital mortality rate was 5 per cent (table 5). The causes of death were associated head injuries in 3 patients (Gr I, Gr II & Gr III liver injuries) and multiorgan failure in 4 patients (Gr I (1), III (2), Gr IV (1) liver injuries). Two of the patients with

Table 4: Comparison of NOM patients with blunt hepatic trauma in whom NOM succeeded vs those whom NOM failed.

	Overall (N=99)	Successful NOM (N=94)	Failed NOM (N=5)	P-value
Gender male[1]	71 (72%)	66 (70%)	5 (100%)	0.150
Age[2]	29 (23-38)	29 (23-38)	31 (22-37)	0.898
SBP < 90mmHg[1]	13(13%)	12(13%)	1(20%)	0,641
GCS[2]	15 (10-15)	15 (10-15)	15 (13-15)	0.448
RTS[2]	7.84 (6.67-7.84)	7.84 (6.64-7.84)	7.84 (6.54-7.84)	0.411
ISS[2]	22 (14-34)	22 (14-34)	18 (13-32)	0.666
Hb[2]	11.6 (9.6-12.8)	11.6 (9.4-12.7)	12.8 (10.6-14.4)	0.256
Lactate[2]	1.8 (1.0-3.2)	1.8 (1.0-3.2)	1.0 (0.0-8.5)	0.515
Base excess[2]	-1.8 (-5.1-1.0)	-1.9 (-5.2-0.6)	-1.0 (-11.8-2.0)	0.642
Transfusion requirements in units[2]	0(0-0)	0(0-0)	0(0-7)	0.353
Head injury[1]	33 (33%)	32 (34%)	1 (20%)	0.516
Thorax injury[1]	63 (64%)	61(65%)	2 (40%)	0.260
Pelvic injury[1]	29 (29%)	27 (29%)	2 (40%)	0.589
Long bone fracture[1]	24 (24%)	23 (25%)	1 (20%)	0.820
Associated intra-abdominal injury [1]	46 (47%)	43 (46%)	3 (60%)	0.533
Kidney injury[1]	18 (18%)	18 (19%)	0 (0%)	0.279
Spleen injury[1]	18 (18%)	16 (17%)	2 (40%)	0.194
Pancreas injury[1]	3 (3%)	3 (3%)	0 (0%)	1.000
High grade liver injury[1]	44 (44%)	41 (44%)	3 (60%)	0.473
General complications[1]	50 (51%)	47 (50%)	3 (60%)	0.663
Liver related complications[1]	7 (7%)	4 (4%)	3 (60%)	**0.002**
ICU-stay[2]	0 (0-4)	0 (0-4)	0 (0-9)	0.741
Hospital-stay[2]	13 (7-20)	12 (7-20)	22 (18-28)	**0.026**
Mortality[1]	1 (1%)	0 (0%)	1 (20%)	0.051

Data are presented as [1]number with the percentages between brackets or as

Table 5a: Comparison of patients with blunt hepatic trauma regarding survival.

	Overall (N=134)	Survived (N=127)	Deceased (N=7)	P-value
SBP <90mHg[1]	19 (14%)	16 (13%)	3 (43%)	**0.025**
Hb[2]	11.4 (9.1-12.7)	11.4 (9.3-12.7)	6.8 (6.0-12.8)	0.197
Transfusion requirements [2]	0 (0-2)	0 (0-2)	8 (2-17)	**<0.001**
Lactate[2]	2.1 (1.0-4.0)	2.0 (1.0-3.9)	4.1 (3.1-7.9)	**0.004**
Base excess[2]	-2.9 (-8.3- -0.5)	-2.5 (-6.8- -0.3)	-10.1 (-17.0- -7.8)	**0.001**
High grade liver injury[1]	65 (49%)	61 (48%)	4 (57%)	0.639
Associated intra-abdominal injury[1]	73 (55%)	66 (52%)	7 (100%)	**0.013**
Kidney injury[1]	27 (20%)	27 (21%)	0 (0%)	0.172
Spleen injury[1]	30 (22%)	27 (21%)	3 (43%)	0.182
Pancreas injury[1]	9 (7%)	7 (6%)	2 (29%)	**0.018**
Hollow injury[1]	11 (8%)	8(6%)	3 (43%)	**0.001**
Vascular injury[1]	2 (2%)	1 (1%)	1 (14%)	**0.004**
Liver packing[1]	16 (12%)	12 (9%)	4 (57%)	**<0.001**
Failed NOM[1]	5 (4%)	4 (3%)	1 (14%)	0.239
Open abdomen[1]	10 (8%)	7 (6%)	3 (43%)	**<0.001**
General complications[1]	82 (61%)	75 (59%)	7 (100%)	**0.030**
Liver related complications[1]	14 (10%)	10 (8%)	4 (57%)	**<0.001**

Data are presented as [1]number with the percentages between brackets or as [2]median with the P_{25}-P_{75} between brackets. Data were analyzed with a [1]Pearson Chi-squared analysis or Fisher's Exact Test or a [2]Mann-Whitney Test analyses. Boldface fonts indicate statistically significant differences.

Table 5b. Causes of death in 7 patients.

No.	OIS	Surgery	Associated Injuries	Liver related complication	Direct cause of death
1.	I	Early	Spleen Head Injury	-	Severe Head Injury
2.	II	Early	Haemothorax Small Bowel Head Injury	-	Severe head Injury
3.	III	Early	Pancreas Facial fractures	External Biliary Fistula (ERCP)	Sepsis/Multi Organ Failure
4.	III	Early Packing Ligation hepatic artery	Haemothorax Spleen IVC Scapula	-	Sepsis/Multi Organ Failure
5.	III	Early	Haemothorax Small Bowel Scapula Femur/Tibia Head Injury	-	Severe Head Injury
6.	I	Early	Spleen Colon Pancreas Tibia	-	Sepsis/Multi Organ Failure
7.	IV	Delayed	Cervical spine Pelvic Bilateral femur Severe degloving injury	Abdominal compartment syndrome	Sepsis/Multi Organ Failure

multi-organ failure developed liver related complications (high output biliary fistula and abdominal compartment syndrome). The liver related mortality for patients with blunt trauma was 2%. All patients who did not survive required surgery at some stage (early (n=5) and delayed (n=1)). The failed NOM mortality in this series was 20%.

DISCUSSION

Nonoperative management of severe blunt liver injury is on the increase with a similar increment in failure. Currently more than 95% of blunt hepatic trauma is managed with NOM with a success rate of between 80% and 100%.[1-9] Many of the series include milder liver injuries, which are known to have a success rate close to 100%. In this study 76% of patients were managed nonoperatively with a success rate of 95%. Due to a selective use of CT abdomen the number of diagnosed milder liver injuries managed nonoperatively is most likely lower in this study period comparing to the literature. The Groote Schuur Hospital functions as a level 1 trauma center and tertiary referral center for secondary hospitals in the region. Patients with minor blunt abdominal trauma are managed in secondary hospitals is another explanation that our percentage for NOM for blunt liver injuries is lower in comparison to the literature. While outside the scope of this report, in the same study period 95 (52%) patients with penetrating [stab wounds (41) and gunshot wounds (54)] liver injuries were managed nonoperatively, with a success rate of 100% and 94% for stab wounds and gunshot wounds respectively.

The great majority of haemodynamic stable patients with blunt liver injuries can be managed nonoperatively (up to 90%). Physiologic behavior or CT findings of intraabdominal injuries, other than the hepatic injury, requiring repair dictated the need for operative intervention. Grading of liver injury did not influence immediate management. The percentage of patients who underwent urgent surgery is similar to other series, while this study included all grades of liver injuries.[7,14,20] A non-therapeutic laparotomy was performed in 3 (9%) patients, and 37% of the patients did not require any liver related surgical intervention. Two patients underwent a laparotomy because of unexplained free fluid with no solid organ injury on CT scan and a liver injury was found at surgery. Our policy is to perform a laparotomy in patients with unexplained free fluid without solid organ injury and associated head or spinal cord injuries. This is an indication to perform a laparotomy in order to exclude a hollow viscus or mesenteric injury.[11] Missed hollow viscus injuries were not found in the failed nonoperative management group due to an active surgical management policy and identifying patients who required early surgical management.

There is concern about an overuse of NOM and increase in morbidity, with conflicting reports in the literature.[10,14,17-19] Several authors have described hypotension on admission as a predictor of failed NOM. For these reasons, NOM has been promoted with the caveat that patients must be haemodynamically stable.[10,14] In the current series hypotension on initial presentation itself was not a predictive factor for failed NOM. Thirteen patients who presented initially with a systolic blood pressure below 90 mmHg were managed nonoperatively, only one patient who presented initially haemodynamic unstable failed NOM.

A single center prospective study including all grades of liver injuries in 2003 by Velmahos et al presents 55 (71%) patients who were managed nonoperatively, with a 85% success rate. Eight (15%) patients failed NOM, and in none of the cases was the liver the cause of failure. Liver complication related failure is reported in the literature 0-6.5%.[1-14,17] In our series three (3%) patients failed NOM due to liver related complications. Two patients, who failed NOM due to liver related complications, developed biliary peritonitis. Routine follow-up CT's were not performed. Laparoscopy and internal drainage as treatment for biliary peritonitis would be an alternative, nevertheless we advocate an exploratory laparotomy for patients presenting with post traumatic peritonitis.

Considering the 65 (49%) patients in this series with a high grade liver injury only 44 (67%) patients were managed nonoperatively. Higher grade liver injuries did not occur more often in the failed NOM group in our series. In the literature there are convincing reports that complex and high grade liver injuries can be managed nonoperatively safely.[17-20] Nevertheless, predictive factors for patients with BLI who will develop liver related complications and potentially fail nonoperative management are lacking. We consider grade 3 liver injuries high grade liver injuries. In potential severe and lethal liver related complications can develop in patients with grade 3 liver injuries post OM and fail NOM.

The number of patients with a BLI in this single center prospective study is small and includes all grades of liver injuries in multiple injured patients. Physiologic behavior and failed NOM are influenced by associated intraabdominal injuries. A prospective study including patients with isolated liver injuries only would be of interest. The statistical outcome of comparison small groups of patients in this single center study should be interpreted in the light of a statistical error due too small sample size and considered as a supportive result of clinical practice, rather than a statement on its own.

In conclusion: Haemodynamic instability, generalized peritonitis, worsening metabolic acidosis during resuscitation or CT-findings showing associated intraabdominal injuries requiring surgical repair warrants early surgical exploration. NOM of blunt liver injuries in haemodynamic stable patients is feasible and safe. Liver related complications contribute to failure of NOM, but could not predict failure of NOM. Nonoperative management of BLI should be considered irrespective of the grade of liver trauma. Associated solid intra-abdominal and extra-abdominal injuries do not exclude nonoperative management.

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Nonoperative management of penetrating wounds of the liver

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Submitted

ABSTRACT:

Nonoperative management (NOM) of penetrating liver injuries is infrequently practised. The aim of this study was to assess the safety of selective NOM of penetrating liver injuries.

Patients and Methods: A prospective, protocol-driven study, which included patients with penetrating liver injuries admitted to a level I trauma center, was conducted over a 52- month period. Patients with right-side thoracoabdominal, and right upper quadrant (RUQ) penetrating wounds with or without localized RUQ tenderness underwent contrasted abdominal CT scan evaluation to detect the presence of a liver injury. Patients with confirmed liver injuries were observed with serial clinical examinations. Outcome parameters included need for delayed laparotomy, complications, length of hospital stay and survival.

Results: During the study period, 95 patients (54 gunshot and 41stabbed liver injuries), were selected for nonoperative management. The mean injury severity and PATI scores were, 20 (range 4-50) and 7(range 4-20), respectively. Simple liver injuries (Grades I and II) occurred in 49 (51.6%) patients and complex liver injuries occurred in 46 (48.4%) patients. Associated injuries included 23 (24.2%) kidney, 69 (72.6%) diaphragm, 23 (24.2 %) pulmonary contusion, 42 (66.7%) hemo/pneuomothoraces, and 28 (29.5%) rib fractures. Three patients required delayed laparotomy resulting in successful nonoperative management rate of 96.8%. Complications included: liver abscess (1), biliary fistula (9), retained hemothorax (3), and nosocomial pneumonia (4). The overall median hospital stay was 6 IQR: [4-11] days, with no mortality.

Conclusion: The nonoperative management of appropriately selected patients with penetrating liver injuries is safe and associated with minimal morbidity.

INTRODUCTION

The selective nonoperative management of penetrating abdominal trauma is gradually being embraced by the trauma fraternity. The selective nonoperative management (NOM) of abdominal stab wounds is widely accepted and typically considered the standard of care. Conversely, the NOM of gunshot wounds to the abdomen is slowly gaining momentum in the context of adjunctive use of computerised axial tomographic (CT) scanning in patients without peritonitis or sustained hypotension. Patients selected for nonoperative management of penetrating liver injuries are those who have sustained a penetrating abdominal injury without an immediate indication for an emergency laparotomy, who undergo CT imaging to confirm a liver injury and are managed without a laparotomy. This study attempts to validate the feasibility and safety of the SNOM of penetrating liver injuries.

METHODS

This prospective, local ethics board approved study was conducted in the Trauma Center in Groote Schuur Hospital in Cape Town, South Africa, over a 52-month period (September 2008 – December 2012). All patients presenting with penetrating abdominal trauma were initially assessed and resuscitated along standard guidelines. Indications for emergency laparotomy were: peritonitis (diffuse tenderness, rebound tenderness, guarding, rigidity), hemodynamic instability and patients with associated head and spinal cord injuries. Hemodynamically stable patients without signs of peritonitis with intact sensorium were selected for a trial of nonoperative management. Patients with right-sided thoracoabdominal, and right upper quadrant (RUQ) penetrating injuries with or without localized RUQ tenderness underwent a CT scan with intravenous contrast to identify or exclude a liver injury. All CT scans were performed using a 16-channel scanner with a high-power injection of 100 mL of intravenous contrast at 5mL/sec. Portovenous, arterial and delayed phases were routinely acquired. Patients with confirmed liver injuries were admitted to a high-care observation area for continuous hemodynamic monitoring, 4-hourly hemoglobin estimation and serial clinical examination. After 48 hours in the high-care observation area, once stabilized and tolerating oral diet, patients were transferred to a general trauma surgical ward. At any time, in the event of the development of peritonitis, hemodynamic instability or a significant reduction in hemoglobin requiring more than 2-4 units of blood transfusion in 24 hours, a laparotomy was performed. The injury severity was categorized using the revised trauma score (RTS), injury severity score (ISS) and American Association of Surgery for Trauma (AAST) grading for solid organ injury. Outcome was determined by the need for delayed laparotomy, liver-related morbidity, length of hospital stay and survival. All patients were followed up 2-weeks from discharge.

RESULTS

During the study period, 278 patients with penetrating liver injuries were admitted. Of these, 183 (65.8%) had an indication for emergency laparotomy. Table 1 summarizes the management of these 183 liver injuries and of these, 115 (62.8%) patients had no liver-related surgical intervention. Ninety-five patients, (GSW 54, SW 41) with CT confirmed liver injuries were selected for a trial of nonoperative management and form the basis of further analysis for this study. There were 88 men and seven women with a mean age of 27.7 (range 14-88) years. All patients were hemodynamically stable on admission. In addition, 30 of these patients had associated hematuria. Computerized tomography revealed 95 liver and 23 kidney injuries: 72 patients with isolated liver injuries and 23 with combined liver and kidney injuries. The mean RTS and ISS was 7.841 and 19.6 (range 4-34), respectively. The liver and kidney injury grading is shown in Table 2. Simple liver injuries (Grades I and II) occurred in 49 (51.6%) patients and complex liver injuries (Grades III, IV and V) occurred in 46 (48.4%) patients. Associated injuries are listed in Table 3. Right-sided diaphragm injuries were accepted as being present when either lung contusion and/or hemo/pneuomthoraces were diagnosed with a liver injury caused by the same missile trajectory. Three patients with liver gunshot injuries failed abdominal observa-

Table 1. Management of 183 patients with liver injuries undergoing emergency laparotomy

Procedure	Stab	GSW	Total
Definitive packing (damage control)	5	40	45
Drain	16	39	55
Suture	7	16	23
Temporary packing	8	16	24
Nil	10	26	36
Total	46	137	183

Table 2. Liver and kidney injury according to AAST-OIS

	GI		GII		GIII		GIV		GV	
	SW	GSW	SW	GSW	SW	GSW	SW	GSW	SW	GSW
Liver (95)	9	6	19	15	13	19	0	13	0	1
Kidney (23)	0	1	5	3	3	6	3	2	0	0

AAST-OIS, American Association of Surgery for Trauma organ injury scale

Table 3. Associated injuries (same trajectory causing liver injury)

Viscera	SW	GSW
Diaphragm	26	43
Lung contusion	3	20
Hemothorax /pneumothorax	35	60
Rib fractures	4	24
Kidney	11	12

AAST-OIS, American Association of Surgery for Trauma organ injury scale

tion and underwent delayed laparotomy. No hollow-viscus injuries were detected at laparotomy. Table 4 summarizes the indications for surgery and findings at laparotomy. Liver-related complications occurred in 10 (10.5%) patients. There were 9 biliary fistulae: 3 biliary cutaneous fistulae through drains placed at surgery in patients 1, 2 and 3 undergoing delayed laparotomy (see above) and two pleurobiliary fistula in patients undergoing successful nonoperative management (one SW and one GSW). Two intrahepatic culture negative bilomas underwent successful percutaneous drainage. Four patients underwent an endoscopic retrograde cholangiogram for persistent bile leaks (> 50 mL for > 14days) which showed peripheral bile leaks, a sphincterotomy was done and a 10 Fr biliary stent placed. The outcome in these patients was further uneventful apart from a

Table 4. Patients undergoing delayed laparotomy N=3

No.	CT findings	Indication for laparotomy	Delay	Findings / Procedure
1	Grade 2 liver injury	Peritonism & Fever	18 hours	300mL haemperitoneum Diaphragm repair Liver drained Hospital stay 7 days
2	Grade 4 liver and Grade 1 kidney Injuries	Peritonism & Fever	12 hours	300mL haemperitoneum Diaphragm repair Liver drained Hospital stay 13 days
3	Grade 4 liver injury	Bile peritonitis	15 days	Lavage Liver drained Hospital stay 57 days
			48 hours	250 mL blood Liver drained Diaphragm repair

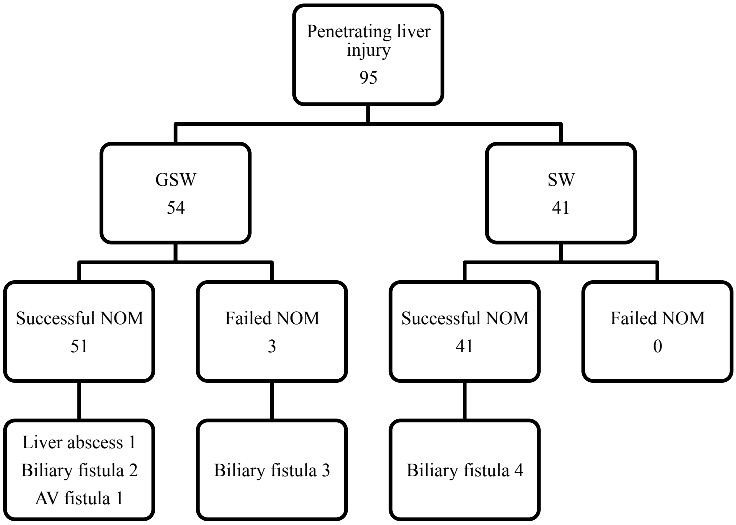

Fig 1. Outcome of patients with penetrating liver injuries managed nonoperatively

prolonged mean 22 day hospital stay. One patient developed a liver abscess treated by ultrasound guided percutaneous drainage. Cultures grew cloxacillin sensitive Staphylococcus aureus. In one GSW patient, admission CT revealed an arterio-venous fistula that underwent immediate successful angioembolisation. Non-liver related complications included 3 right-sided retained or residual hemothoraces that were treated conservatively or with repeat tube thoracostomy. None of these required operative intervention. Four patients developed nosocomial pneumonias or infected lung contusions which were successfully treated with parenteral antibiotics. The overall median hospital stay was 6 IQR: [4-11] days. There were no deaths. A two-week clinical follow-up of 100% had no new complications or patients requiring readmission. Figure 1 summarizes the final outcome of the 95 patients with penetrating liver injuries selected for NOM.

DISCUSSION

The selective nonoperative management of penetrating abdominal trauma has evolved over the last two decades. While clinically evaluable patients with abdominal stab wounds can be safely managed with serial clinical examination[1], the same approach to low-velocity abdominal gunshot wounds has not been readily accepted. There is, however, increasing evidence that the SNOM of abdominal gunshot wounds is practical and safe, and up to one third of all abdominal gunshot wounds can be managed successfully nonoperatively[2-8]. The nonoperative management of blunt solid organ injuries is widely accepted with success rates of up to 90%. Conversely, selective nonoperative management of penetrating solid organ injuries, and in particular, penetrating liver injuries has not been widely practised[9-11]. Renz and Feliciano[12] reported the first prospective study on the NOM of liver gunshot injuries. In their series of 13 patients with right-sided thoracoabdominal gunshot wounds, seven patients had CT confirmed liver injuries, with a 100% nonoperative management success rate. Similarly, Chmielewski et al [13], in series of 12 patients with lower right chest gunshot wounds, confirmed eight hepatic injuries (Grades II-III) in those undergoing ultrasound or CT. One patient required delayed laparotomy without any adverse outcome. Ginzburg et al[14] managed 4 patients with liver gunshot injuries successfully nonoperatively. In their retrospective series Demetriades et al [15] proposed the notion that only selected patients with Grade I-III injuries should be managed nonoperatively. In a previous prospective study of SNOM of liver gunshot injuries from our center, increasing injury severity was associated with an increasing rate of complications, however injury grade itself was not shown to be an independent predictor of nonoperative management failure [16]. Overall, of the 313 cases of nonoperatively managed penetrating liver injuries identified in the English literature [11-20], a success rate of greater than 90% has been reported (Table 5). This is comparable to our success rate of 96%. This high success rate could be attributed to the fact that most penetrating injuries to the liver require no treatment[21]. In the current study of 278 penetrating liver injuries, 91/183 (49.7%) of these injuries required no treatment at laparotomy, and 95/278

Table 5. Reported results of the treatment of nonoperative management of penetrating liver injuries

Author, year	Mechanism SW / GSW	Study design	N	Success (%)
Renz, 1994	GSW	Prospective	7	100
Chmielewski, 1995	GSW	Prospective	8	88
Ginzburg, 1998	GSW	Prospective	4	100
Demetriades, 1999	GSW	Retrospective	16	69
Omoshoro-Jones , 2005	GSW	Prospective	33	97
Pal, 2000	GSW	Case reports	2	100
Shanmuganathan, 2001	GSW	Prospective	9	100
Demetriades, 2006	GSW&SW	Prospective	36	84
DuBose, 2007	GSW	Retrospective	10	90
Navsaria, 2009	GSW	Prospective	63	92
Schnurger, 2011	GSW	Retrospective	30	96
Current series	GSW&SW	Prospective	95	96
TOTAL			**313**	**93**

GSW *gunshot wound,* SW *stab wound*

(34.1%) patients were considered for nonoperative management without laparotomy. Hence, a total of 186/278 (66.9%) of all penetrating liver injuries in this series were managed 'conservatively'. Although seen only once in this study, a contrast 'blush' on CT scan is considered a significant finding of a bleeding, false aneurysm or arteriovenous fistula, and in the hemodynamically stable patient should be followed immediately by angiography and possible embolization to increase the success rate of NOM[19,22]. One of the major concerns regarding the nonoperative management of abdominal gunshots wounds is missing a hollow viscus injury. Although modern imaging performed by experienced radiologists using state of the art modern scanners can demonstrate ongoing hemorrhage and corroborate evidence of hollow viscus injury (free air, free fluid in absence of solid organ injury, localized bowel wall thickening, mesentery stranding, hematoma surrounding hollow viscus), the level of accuracy and sensitivity for diagnosing bowel injuries following penetrating trauma remains a source of concern [22-24]. It is therefore essential that serial clinical examination be used to identify such injuries in patients who are considered for nonoperative management. The complications of liver injury which include rebleeding, bile leaks and infected fluid collections can be managed by interventional radiological and endoscopic techniques. While only one septic liver-related complication occurred, it is possible that the 4 patients treated for nosocomial pneumonias or infected pulmonary contusions with intravenous antibiotics may have masked or had inadvertently treated septic liver-related complications. While outside the scope of this report, all (100%) associated renal injuries were successfully managed nonoperatively. While reports of nonoperatively treated penetrating kidney injuries are few[19, 20, 25, 26,27], this study further provides some evidence that this too is highly feasible, and when associated with liver injuries, does not preclude the NOM of either solid organ. In conclusion , this study demonstrates the efficacy of NOM of penetrating liver injuries in a select group of clinically evaluable, hemodynamically stable patients. Selective CT scanning for right thoracoabdominal and RUQ gunshot wounds with localized tenderness detects liver injuries for NOM. In the current series, 34.2% of all penetrating liver injuries were managed nonoperatively without laparotomy with a 96% success rate, irrespective of severity of injury. A reasonable liver-related complication rate of 10.5% is acceptable. The surgeon must recognize the risks of NOM of penetrating liver injuries and possess the resources (angioembolization, percutaneous interventional techniques, endoscopic interventional cholangiography) to address potential complications. However, SNOM of patients with penetrating abdominal wounds, with or without solid-organ injury, with or without advanced CT technology, is still based largely on the findings from serial clinical examinations.

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Chapter 3

OPERATIVE MANAGEMENT OF LIVER INJURIES

Packing for control of hemorrhage in major liver trauma

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ABSTRACT

Background: Packing for complex liver injuries has been associated with an increased risk of abdominal sepsis and bile leaks. The aim of the present study was to determine the optimum timing of pack removal and to assess whether the total duration of packing increases the incidence of these complications.

Methods: The study was based on a retrospective review of all patients requiring liver packing over an 8-year period in a level 1 trauma center.

Results: Ninety-three (17%) of 534 liver injuries identified at laparotomy required perihepatic packing. Penetrating and blunt trauma occurred in 72 (77%) and 21 (23%), respectively. The mean total duration of packing was 2.4 days (range: 0.5–6.0 days). There was no association between the total duration of packing and the development of liver-related complications (P = 0.284) or septic complications (P = 0.155). Early removal of packs at 24 h was associated with a higher rate of re-bleeding than removal of packs at 48 h (P = 0.006).

Conclusions: The total duration of liver packing does not result in an increase in septic complications or bile leaks. The first re-look laparotomy should only be performed after 48 h. An early re-look at 24 h is associated with re-bleeding and does not lead to early removal of liver packs.

INTRODUCTION

The use of liver packing for complex liver injuries with a subsequent re-look laparotomy and removal of the packs has resulted in the control of bleeding from coagulopathy in up to 80% of patients presenting with these injuries.[1–11] The leading cause of death in severe liver injuries remains uncontrollable bleeding, whereas sepsis and multiple organ dysfunction are the primary causes of morbidity and late death.[12] Mortality also appears to be higher in older patients, those with higher grade injuries, and those with hemodynamic instability on presentation and with blunt trauma.[13] Over half of patients surviving grade 3–5 liver injuries will be at risk for the development of complications including hemorrhage, intra-abdominal abscess formation, and bile leaks.[14] Sepsis is a major source of morbidity following packing, and this has led to the recommendation that liver packs be removed as soon as possible. Others have stated that the timing of pack removal is not as critical as ensuring that hemodynamic stability has been achieved. These opposing viewpoints have resulted in concern about the timing of the planned re-look laparotomy with removal of the liver packs, which can vary from as early as 12 h to as late as 7 days after the original liver injury.[4,10,15] There appears to be little consensus on the optimum timing for re-look and removal of liver packs. The aim of the present study was to determine when liver packs should be removed following packing for complex liver trauma and whether the total length of time that liver packs are in situ is related to the development of subsequent complications.

PATIENTS AND METHODS

Patients presenting between January 1996 and May 2004 to Groote Schuur Hospital Trauma Unit with liver injuries that required laparotomy were identified. An emergency laparotomy was performed on patients with persistent hemodynamic instability, an acute abdomen, ongoing blood transfusion requirements, a denervated abdomen with penetrating abdominal injuries, and the finding of free fluid on computed tomographic (CT) scan without any solid organ injury in the unconscious patient. Laparoscopy was used to exclude tangential gunshot wounds, but the finding of peritoneal penetration was used as an indication for laparotomy. Since January 2000 isolated low-velocity gunshot wounds of the liver have been treated conservatively provided the patient was hemodynamically stable, fully conscious to allow for serial clinical examinations, and if there was no active liver bleeding apparent on the CT scan.[16] All patients were resuscitated according to Advanced Trauma Life Support[17] (ATLS) recommendations. At laparotomy the liver injury was graded according to the liver injury scale of the American Association of Surgery in Trauma.[18] On-going bleeding from the liver led to liver packing in conjunction with the Pringle maneuver and selective ligation of any visible bleeders and large bile leaks. In such circumstances, the Pringle maneuver was employed for a period of 20 min, after which the clamp was released and the liver was re-examined for any further bleeding. Selective ligation of any arterial bleeders was then undertaken. Failure to control bleeding led to packing the liver with approximately 6 abdominal swabs so as to restore liver continuity and to provide compression. This technique was employed as part of the strategy of damage-control surgery. Abdominal swabs were never placed into a laceration, and the liver was never merely sutured over a bleeding vessel. After liver packing, the abdomen was left open if there was any concern about the intra-abdominal pressure. All patients were then transferred to the intensive care unit for correction of acidosis, coagulopathy, and hypothermia. A re-look laparotomy was performed when the patient's temperature

had normalized, shock had been corrected, and the International Normalized Ratio (INR) was less than 1.5. A re-bleed was defined as bleeding from the liver after pack removal and requiring re-packing. A liver-related complication was defined as a biloma or a biliary fistula and an infected intra-abdominal collection was a collection (serosanguinous or purulent) identified at laparotomy with positive pus swabs or requiring percutaneous drainage after CT scan associated with positive swabs. Blood collections on and around the prosthetic plastic bag were not considered significant. The total duration of packing was the total amount of time that the liver packs were left in the patient's abdomen. Statistical analysis was performed using the Fisher's exact test for noncontinuous variables and the nonparametric analysis of variance (ANOVA) and Wilcoxon ranksum test for continuous variables. SAS System Package version 8.2 software (SAS Systems International, Cary, North Carolina, USA) was used for this analysis. A P value < 0.05 was considered statistically significant.

RESULTS

During the 8 years of the retrospective study, 534 patients presented to Groote Schuur Hospital with liver injuries identified at laparotomy. In 369 (69%) patients the liver was not bleeding at the time of operation; in 306 (57%) the liver was drained, and the remaining 63 patients were managed without drainage (Table 1). Fortysix patients required suturing of their liver injury to obtain hemostasis. A liver resection was performed in 22 patients. This consisted of non-anatomic resection and debridement in 21 patients and a right lobectomy and a Roux-en-Y hepaticojejunostomy in a single patient for a gunshot wound through the porta hepatis with an injury to the intrahepatic portion of the right hepatic duct. Four patients required temporary packing of the injury in conjunction with the Pringle maneuver, which controlled the bleeding, allowing removal of

Table 1.
Surgical management of 534 liver injuries at laparotomy

Surgical management	Number of patients
Drainage	306
No drainage	63
Suturing of liver	46
Liver resection	22
Temporary packing	4
Liver packing	93

the liver packs before the abdomen was closed. Definitive liver packing with subsequent re-laparotomy and removal of packs was used in 93 of the 534 patients (17%). The mean age of the 93 patients that required liver packing was 30 years (range: 14–68 years). The mean revised trauma score was 6.4 (range: 0.6–7.8). Seventytwo patients sustained penetrating trauma, most commonly from gunshot wounds (Table 2). Liver packing was required predominantly for the higher-grade 3, 4, and 5 injuries (Table 3). Twenty-one of the 93 patients who underwent liver packing died in the first 24 h. Eleven of these deaths were on the operating table and 10 patients died later in the surgical intensive care unit. At autopsy the predominant causes of death appeared to hypovolemia and irreversible shock in 10, and multiple injuries in 8 patients. Two patients died from head injuries and 1 from an associated cardiac injury. The early operative mortality (< 24 h) was 23%. All twenty-one patients who died within the first 24 h after arrival at the hospital were excluded from further analysis. The remaining 72 patients, who survived more than 24h, were divided into three groups, depending on whether the first re-look laparotomy and removal of packs was performed at 24 h, 48 h, or 72 h (Table 4). Twenty-five patients underwent first re-look laparotomy at 24 h. Eleven of these patients were taken to the operating room for decompression of the abdomen after they developed signs of abdominal compartment syndrome. Another 2 patients had associated cardiac injuries that required sternotomy and repair; of these 13 patients, 9 required re-packing of the liver. The remaining 12 of the 25 patients were hemodynamically stable. They

Table 2.
Mechanism of injury in 93 patients with liver packing

Mechanism of Injury	Number of patients
Gunshot wound	66
Stab	6
Motor vehicle accident	15
Train accident	3
Blunt assault	3

Table 3.
Grade of liver injuries and numbers packed and not packed

Grade	Packed	Not packed
1	0	40
2	1	123
3	20	151
4	58	123
5	14	4
Total	93	441

Table 4.
Timing of the first re-look laparotomy and re-bleeding rate requiring packing in hemodynamically stable patients with an INR < 1.5

Re-look (h)	No. of patients	Exclusions[a]	No. of patients INR < 1.5	Re-bleeding
24	25	11 ACS 2 Cardiac	12	8
48	44	1 ACS	43	5
72	3		3	0

[a] Patients excluded as the reason for their re-look laparotomy was either ACS (abdominal compartment syndrome) or in two cases a re-look was performed as the patient was being taken to the operating room for a cardiac injury.
INR: International Normalized Ratio.

had been re-warmed, and their coagulopathy was corrected (INR of less than 1.5), and they were taken to the operating room for removal of their liver packs at 24 h. Eight of these patients required re-packing of their liver injuries due to bleeding that occurred during removal of the packs. Forty-four patients had their first re-look laparotomy at 48 h. One patient developed abdominal compartment syndrome, but the remaining 43 patients were all hemodynamically stable with an INR corrected to less than 1.5. Of these patients only 5 had bleeding on removal of the liver packs that required re-packing. In the remaining 38 patients, of this group, the liver packs were successfully removed. Three patients were taken for their first re-look laparotomy at 72 h, and in all 3 cases the packs were removed without any further bleeding. Early removal of packs at 24 h was associated with a higher rate of re-bleeding than removal of packs at 48 h (P = 0.006). The mean total duration of packing was 2.4 days (range: 0.5–6.0 days). To summarize, In 8 patients the liver packs were left in for a total of 24 h (Table 5), and 44 patients had their liver packs left in for a total of 48 h. In the latter group there were 17 intra-abdominal collections and 6 liver-related complications. Another 20 patients were packed for a total duration of 3 days or longer. In that group, there were 9 intra-abdominal collections and 3 liver-related complications. The total duration of packing, whether 2 or 3 days, did not appear to be related to the development of either intra-abdominal collections (P = 0.284) or liver-related complications (P = 0.155). The presence of a small bowel or colon injury was an important factor with regard to the development of an intra-abdominal collection (P = 0.001). There were only 15 intra-abdominal collections in the 52 patients without bowel injuries, whereas 16 intra-abdominal collections were recorded in 20

Table 5.
Total duration of liver packing and the development of complications

Duration (days)	No. of patients	Intra-abdominal collections	Liver-related complications
1	8	6	5
2	44	17	6
3 or longer	20	9	3
		P = 0.284	*P* = 0.155

patients with associated small bowel or colon injury. The other factor that was important in the development of an intra-abdominal collection was an open abdomen. Eighteen of the 72 patients who survived more than 24 h had an open abdomen. There were 13 intra-abdominal collections in these 18 patients. Only 18 of the 54 patients in whom primary closure of the abdomen was possible developed an intra-abdominal collection. Thus the presence of an open abdomen appeared highly significant (P = 0.004) with respect to the development of an intraabdominal collection. Twenty-one of the surviving 72 patients required repacking. There was no increase in liver-related (P = 0.120) or septic complications (P = 0.246) in the patients who were re-packed compared to the 51 patients who did not require re-packing. Re-packing did not appear to result in an increased incidence of liver-related or septic complications.There were 27 intra-abdominal collections detected in the 54 patients with penetrating abdominal injuries compared to 5 in the 18 patients with blunt abdominal trauma (P = 0.210). Fourteen liver-related complications occurred in the penetrating trauma group, compared to nil in the blunt trauma group (P = 0.002). Prolonged packing in the presence of blunt liver trauma was not associated with an increased complication rate with respect to liver-related (there were none) and septic complications (P = 0.963). There were a further 7 deaths from multiple organ dysfunction in the intensive care unit. Including the deaths in the first 24 h, 28 patients died from their injuries to give an overall mortality rate of 30% in the cohort of patients with complex liver injuries that required packing.

DISCUSSION

Ninety-three (17%) of 534 patients with liver injuries identified at laparotomy required liver packing. The vast majority of injuries could be handled by drainage or suturing. The incidence of liver injuries requiring liver packing varies from 5%[19] to 36%[20] in the literature. This figure is expected to be higher in level 1 trauma centers because of more complex injuries and referrals with packs in situ. Our incidence of 17% appears high when compared to Feliciano et al.,[10] who reported in 1986 on 1,348 liver injuries of whom only 66 (5%) required liver packing. This higher incidence is most likely due to an increased awareness of the need to institute damage control procedures in the unstable patient. It has been stated that liver packs should be removed as soon as the patient is stable and coagulopathy, hypothermia, and acidosis have been corrected.[10,12,21] This usually takes 12–36 h to achieve, yet liver packs have been removed as long as 7 days after the initial packing.[15] Leaving packs around the liver is also known to cause significant cardiopulmonary compromise,[22,23] and abdominal compartment syndrome appears to be an independent predictor for the development of multiple organ failure.[24,25] There is obviously a desire to remove the liver packs as soon as possible, but the cardiopulmonary benefits of pack removal have to be weighed against the risk of a re-bleed requiring repeat liver packing.

Caruso et al.[25] demonstrated that re-bleeding from the liver was greater when liver packs were removed within 36 h than after 36 h. In the present series the optimum time for the removal of packs was at least 48 h after the initial surgery. If liver packs are removed at 24 h in the stable patient the risk of bleeding from the liver requiring re-packing is significantly higher ($p = 0.006$) than if the packs are left in to the 48-h point. In this series 8 of 12 hemodynamically stable patients who had been rewarmed and their coagulopathy corrected, required re-packing of the liver injury when the first re-look was performed at 24 h. In contrast, only 5 of 43 patients who had the packs removed at 48 h required re-packing. This would seem to indicate that in the majority of patients packing of the liver for a period of at least 48 h is required to achieve hemostasis. It would appear that it takes time for the liver tamponade to take effect and for any clot to become stable and not to become dislodged on the removal of the packs. It is important to recognize that liver packing will not control arterial bleeding and that any bleeding artery should be suture ligated prior to liver packing. The abdomen should be closed if possible, provided closure is not performed under tension. The presence of an open abdomen was associated with a higher chance of developing an intra-abdominal collection ($P = 0.004$). At the same time, patients require close observation in the intensive care unit because a significant number will develop abdominal compartment syndrome and require decompression. In the present series early decompression (< 24 h) was required in 11 patients. The mean total duration of liver packing was 2.4 days (0.5–6.0 days). There was no association between the total duration of packing and the development of liver-related complications ($P = 0.284$) or intra-abdominal collections ($P = 0.155$). The concern that the longer that liver packs are left in situ the higher the rate of complications such as intra-abdominal collections and bilomas will be, does not appear to be warranted. A multidisciplinary approach is required in the management of complex liver injuries. Angiography and embolization was performed in our series only in those patients in whom the second attempt to remove the liver packs was unsuccessful because of liver bleeding. Hepatic angioembolization has been recommended immediately post-packing, and certainly this may prove to be a useful adjunct in controlling hepatic hemorrhage. [26]

Our data show that the total duration of liver packing does not appear to result in an increase in septic complications or bile leaks. The first re-look laparotomy following packing for a liver injury should only be performed after 48 h and when hypotension, hypothermia, coagulopathy, and acidosis have been corrected. An early re-look at 24 h is associated with re-bleeding and does not lead to the successful removal of the liver packs.

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Liver Packing for Complex Trauma

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Submitted

ABSTRACT

Background: Increased awareness of the need to institute damage control surgery has led to a higher incidence of liver packing. The safety and efficacy of perihepatic packing to control liver hemorrhage were studied.

Methods: A prospective, protocol driven study, including all patients with a liver injury conducted over a period 2008-2013. All patients who underwent surgery for abdominal trauma with a major liver bleeding were further analyzed. Visible bleeding vessels were ligated and the liver packed for control of ongoing venous bleeding. Removal of packs was planned after 48-72 hours. The outcome was survival and vascular complications.

Results: Two-hundred-eighteen patients with a liver injury underwent operative management for abdominal trauma. Eighty-two (38%) patients had a major liver bleeding. In 19 patients bleeding was controlled after simple ligation of visible bleeding vessels. Fifty-nine patients required perihepatic packing to control bleeding. Inflow occlusion was performed in 19 patients, visible bleeding vessels were ligated in 11 patients and 8 patients had juxtahepatic venous injury. Four patients exsanguinated, and 11 patients died later during hospital stay. Repair of juxtahepatic venous injuries was delayed. Early relook and removal of packs was related to a higher rate of rebleeding ($p < 0{,}0001$). Nine patients developed delayed intrahepatic vascular complications, regardless the complexity of liverinjury and surgical intervention ($p=0{,}327$).

Conclusion: Ligation of visible bleeding vessels and liver packing are safe surgical techniques to control major liver bleeding, and definitive repair of juxtahepatic venous injuries may be delayed.

INTRODUCTION

A major reason for the reduced in mortality from hepatic injuries during the last three decades has been a shift from performing liver resections to therapeutic packing.[1,2,3] Packing is effective in controlling major venous bleeding with suture ligation of visible arterial bleeding from the liver.[4] Control of deep arterial intrahepatic bleeding may be difficult to achieve.[5] Some authors report successful management of penetrating liver injuries with a Sengstaken-Blakemore intrahepatic balloon[6,7] and routine hepatic angiography has been reported as a useful adjunct to perihepatic packing[8]. An increased awareness of the need to institute damage control surgery in the unstable patient has most likely led to a higher incidence of patients who undergo liver packing. There also appears to be little consensus on the optimum timing for re-look and removal of liver packs.[2,9] Despite the succes of packing complex liver injuries, recently some authors advocate performing resections [10], and concern has been expressed about management of highly lethal juxtahepatic venous injuries[11]. Optimal surgical management of patients with a bleeding liver injuries remains a topic of contention.

Liver bleeding at our institution is initially managed surgically by manual compression and temporary packing or inflow occlusion. This is followed by definitive control by the ligation of visible bleeding vessels and liver packing to control ongoing venous bleeding. The removal of packs was planned after 48-hours and postoperative angiography was only indicated for failure of removal of packs due to ongoing bleeding.

The aim of this protocol driven study was to assess the safety and efficacy of perihepatic packing and ligation of visible bleeding vessels to control liver bleeding in patients undergoing operative management of liver trauma.

PATIENTS AND METHODS

A prospective evaluation of 412 patients with liver trauma admitted to Groote Schuur Hospital Trauma Centre in Cape Town, South Africa, was performed from 2008 to 2013. Ethics approval was granted from the Human Research Ethics Committee of the Faculty of Health Sciences of the University of Cape Town. The study was conducted in a level-1 Trauma Centre and tertiary hepatobiliary referral hospital serving a population of 2.5 million people. All patients were resuscitated and managed according to the Advanced Trauma Life Support (ATLS®) principles.[12] The indications for surgery for liver injuries were hemodynamic instability or generalized peritonitis. Liver injuries were graded according the Organ Injury Scale of the American Association of Surgery for Trauma.[13] Patient demographics, mechanism of injury, operative intervention, intra-abdominal associated injuries, morbidity, and mortality were documented.

Inclusion criteria: Due to diagnosic challenges initially all patients with active bleeding in the right upper quadrant were identified. Patients with intrahepatic or juxtahepatic bleeding as the main source of bloodloss were then included in this study and further analysed. A major hepatic bleed was defined as a bleeding not controlled after temporary packing of the liver.

Exclusion criteria: patients with liver injuries that were managed non-operatively, patients with a liver injury requiring simple surgical repair or stopped bleeding spontaneously, and patients with a liver injury in which associated perihepatic injuries caused the main source of bloodloss were excluded from further analyses.

Outcome parameters.

The primary outcome of this study was liver related mortality. Liver related mortality was defined as death due to ongoing liver bleeding, liver failure, or death related to complications of massive fluid resuscitation, initiated as a result of major bleeding.

The secondary outcome include all liver injury related morbidity.

Morbidity was classified as the occurrence of liver related complications or surgical complications. Liver related complications were divided in vascular (delayed hemorrhage, pseudoaneurysm and liver necrosis) and biliary complications.

Biliary complications and surgical complications were graded according the Clavien Dindo classification of surgical complications.[15] Severe general surgical complications were defined as complications graded as 3 or higher.

Operative Management: Bleeding from the liver was initially controlled by manual and temporary compression with packs in all patients that needed operative interventions. Intrahepatic visible bleeding from vessels was ligated. Superficial suture closing of liver lacerations was avoided. If there was ongoing bleeding through the liver packs, intermittent inflow occlusion was performed as described by Pringle[14] with a vascular clamp placed across the hepatoduodenal ligament. The clamp was then removed and any visible vessels and bile leaks were suture ligated. In the case of an injury near the free edge of the liver, a finger fracture technique was used to open the tract of the injury followed by ligation of the involved vessel. A formal liver resection was not considered as part of the initial surgical management. Persistent posterior dark venous bleeding after inflow conclusion was indicative of a juxtahepatic vena caval injury. For persistent bleeding, abdominal swabs were placed anterior and posterior to the liver to staunch blood loss and provide hemostasis by tamponade. These packs were not forced into the liver injury but were used to restore the normal anatomical continuity of the liver. Typically 6 packs or more were used to provide a firm tamponade of the injury. Arterial bleeders were controlled prior to therapeutic perihepatic packing and this involved removing the vascular inflow occlusion. Patients with liver packing were managed as patients with an open abdomen. Patients who underwent liverpacking were transferred to the intensive care unit (ICU) for further resuscitation as part of the damage control strategy. Patients were returned to the operating room after 48-72 hours for removal of the packs. Indications for postoperative angiography were: clinical suspicion for ongoing intrahepatic bleeding with intrahepatic contrast extravasation seen on computed tomography and rebleeding requiring repacking at the first relook laparatomy.

Treatment of liver related complications was multidisciplinary when appropriate and included angiography and angioembolization, ERCP and stenting of biliary leaks, CT-guided drainage of hepatic and perihepatic abscesses or biliary collections. Surgical interventions included either laparotomy or laparoscopy.

Statistical analysis. Results were presented as number (%) or as median (P_{25}-P_{75}). Patient groups were compared using the Pearson's chi-squared test or Fisher's exact test for categorical variables, and the Mann-Whitney or Kruskal-Wallis test for non-normally distributed data. Statistical analyses were performed using SPSS statistical software, version 20. P values < 0.05 were considered statistically significant. Multivariable forward stepwise logistic regression analysis including factors with univariable $p<0.10$.

RESULTS

Four hundred and twelve patients presented with a liver injury, the type of management, and the indications for 218 patients who were selected for surgery are presented in table 1. A management flow chart presenting the methods of hemorrhage control is presented in figure 1.

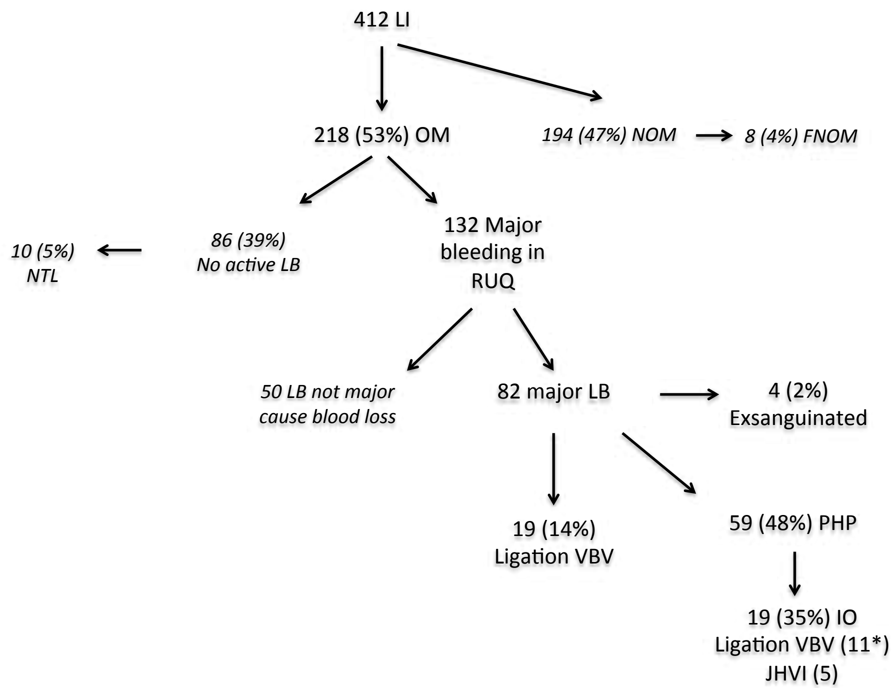
One hundred thirty and two of the 218 (61%) patients were identified with a major bleeding in right upper quadrant of the abdomen. Eighty six (39%) patients had no obvious major liverbleeding, and hemosstasis was controlled after simple surgical interventions or spontaneously.

Eighty two of the 132 operated liver injured patients (62%) patients (75 men, 7 women; mean age 28, range; 13-74, years) had a major hepatic bleeding causing the main source of blood loss. Fifteen patients (18%) sustained blunt trauma, and 67 (82%) sustained penetrating trauma, 11 (13%) due to stab wounds and 56 (68%) due to gunshot wounds. Seventy four patients had intrahepatic bleeding and eight patients had juxtahepatic bleeding. The median ISS was 22 (interquartile range 16-29).

Packing and selective ligation of visible intrahepatic bleeding vessels.

In all patients an attempt was made to pack the liver and control bleeding. In 19 patients bleeding was controlled after temporary packing and ligation of a visible bleeding vessel. Sixty three patients had a major liver injury in which the bleeding could not be controlled by temporary packing or simple suture and required more complicated procedures. Twenty patients required intermittent inflow occlusion to identify the bleeding

Figure 1: Management of Patients with a liver injury following abdominal trauma.



LI: Liver Injuries
RUQ: Right Upper Quadrant
IO: Inflow Occlusion
NTL: Non-Therapeutic-Laparotomy
OM: Operative Mangement
VBV: Visible Bleeding Vessel
JHV: Juxtahepatic Venous Injury
LB: Liver Bleeding
PHP: Peri Hepatic Packing

Table 1. Grading of liver injuries in 412 patients according the Organ Injury Scaling of the American Association of Surgery in Trauma.[13]

OIS	Total	NOM	**OM**	**Indications for surgery**			**Surgical Intervention**	
				Unstable	P	CT	Sutures	PHP
I	65	35	**30**	5	21	4	0	-
II	140	69	**71**	9	56	6	10	7
III	133	56	**77**	13	57	7	5	28
IV	59	27	**32**	2	26	4	4	12
V	15	7	**8**	-	8	-	-	5
	412	*194*	***218***					

OIS=Organ Injury Scale, NOM=nonoperative management, OM=operative management, P=peritonitis, CT=computed tomography, PHP=peri-hepatic packing.

Table 2. Timing of the first re-look laparotomy in 59 therapeutically packed patients.

Re-look (h)	No. of patients (n=59)	ACS	PBL	Transfered	Planned removal of packs	Rebleeding
< 48	13	4	6	3		6(67%)
48	33				33	3(9%)
72	13				13	0(0%)
P-value						**P<0.001**

Data were analyzed with a Pearson Chi-squared analysis or Fisher Exact Test. Boldface fonts indicate statistically significant differences.
Removal of packs was planned after 48-72 hours. Indications for early removal of packs (<48 hours) were abdominal compartment syndrome (ACS), proximal small bowel ligation (PBL), and transfer from a secondary hospital.

site. Of these patients eight had a juxtahepatic venous injury and in 11 patients a visible bleeding vessel was suture ligated. Finger fracture technique was applied for adequate exposure in only a single case. In one other patient balloon tamponade of the bullet tract was used to control bleeding, a subsequent CTA did not reveal intrahepatic blush. Four patients died during operations due to exsanguination. The liver was therapeutically packed the remaining 59 patients with major liver bleeding. Thirteen of these 59 patients returned to the operating theatre within 48 hours; the indications for an early relook are presented in table 2. Early removal of packs was associated with a higher rate of re-bleeding than removal of packs after 48 h : 6 of 13 versus 3 of the 46 after 48 hours re-operated patients.

Table 3. Predictive factors for hospital mortality in patients with liver trauma, results of a multivariable forward stepwise logistic regression analysis including factors with univariable p<0.10.

	Odds Ratio	95% CI	P-Value
Shock	4.6	1,3-17	0.019
Packing	37	4.6-300	0.001

CI = confidence interval

Resections.

In 6 of the 59 patients devitalized tissue was debrided during the relook laparotomy and removal of packs, formal hepatic resections were not performed.

Juxtahepatic venous injuries.

Eight patients of the 63 patients with major hepatic bleeding had complex juxtahepatic venous injuries. Primary repair was not attempted and all liver injuries were packed. All definitive repairs of juxtahepatic venous injuries were delayed 48 hours after secondary resuscitation. Three patients died within 24 hours during operation due to exsanguination. Five patients who underwent initial abdominal packing returned to the operating theatre 48 hours later for removal of packs and direct hepatic venous repair. Control of liver inflow with hepatoduodenal vascular clamping was used in all of these patients, with total hepatic isolation in 1 patient.

In the remaining 50 of 132 (38%) patients with a major bleeding in the right upper quadrant of the abdomen not the liverbleeding but associated perihepatic injuries caused the main source of bloodloss. *Perihepatic injuries included:* the common hepatic artery (2) and right hepatic artery (2), aortic injuries (2), juxtarenal (2) and infrarenal (4) vena caval injuries, and 38 patients had right kidney injuries. The surgical interventions to control bleeding were: ligation of the common hepatic artery (2) and right hepatic artery (2) and subsequent cholecystectomy. Primary aortic repair and aortic repair with interposition graft in a single patient. Two IVC injuries were primarily repaired, 2 infrarenal IVC injuries ligated, 2 IVC injuries were packed and definitive repair was delayed. Sixteen nephrectomies were performed.

*Primary Outcome of patients with a liver injury selected for operative management***.**

Fifteen of the 218 (7%) operatively treated liver injury patients died. Predictive factors for mortality were shock on admission (p=0.02) and liver injuries requiring packing to control hemorrhage (p=0.001) (table 3). Four patients with high grade (IV(1) & (V(3)) liverinjuries due to gunshot wounds exsanguinated in the operating theatre and mortality was directly attributable to the liver injury. Eleven patients (5 GLI and 6 blunt) died in the intensive care unit. Three patients died due to severe traumatic brain injuries. Eight patients developed multi organ failure. Three of these patients had liver related complications (biliary fistula (2), liver necrosis (1)). Liver related operative mortality was 3% (7/218).

*Secondary Outcome***.**

The incidences of the vascular and general complications are presented in table 4. Nine of the 218 (4%) liver injured and operated patients had vascular complications (pseudoaneurysm (6), livernecrosis (3). Three patients had sustained blunt trauma and 6 patients penetrating trauma (SLI (2) and GLI (4)). No different complication rates were found for patient who had surgical repair of the liver and those who had no intervention on the liver or had only packing. Specifically, there was no significance difference in patients who required ligation of a visible intrahepatic bleeding vessel and patients who did not, with respect to vascular complications.

Table 4. Complications and hospital stay in 218 operatively treated patients with a liver Injury.

	No intervention, simple surgical technique, or hemostasis achieved after temporary packing (n=136)	Sutures only(n=19)	Sutures + Packing (n=11)	Packing only(n=52)	P-Value
Vascular complications	4 (2.9%)	1 (5.3%)	1 (9.1%)	3 (5.8%)	0.327 [2]
General complications	47 (34.6%)	10 (52.6%)	11 (100%)	52 (100%)	<0.0001 [2]
I	11	1	2	8	
II	17	4	2	8	
III	8	3	4	20	
IV	3	1	2	11	
V	8	1	1	5	
Hospital stay [1]	12 [7-19]	10 [7-15]	27 [14-41]	23 [13-30]	<0.0001 [3]

Vascular complications were classified as delayed bleeding, pseudoaneurysm or liver necrosis.
General Surgical complications were graded according the Clavien Dindo Classification.
Hospital Stay was presented in days, median [25th-75th percentile][1.]
Data were analyzed with a Pearson Chi-squared analysis or Kruskal-Wallis Test. Boldface fonts indicate statistically significant differences.

Vascular complications.

Six pseudoaneurysms were diagnosed between 15-51 days post injury. All six patients initially underwent early initial surgery. In one of the six patients a suture was used to ligate an intraparenchymal vessel. Indications for postoperative angiography were: radiological findings in combination with a fall in hemoglobin serum level (n=1), drainage of fresh blood via the percutaneous drain (n=2) and hemobilia (n=3). All pseudoaneurysms were successfully angioembolized. One patient had a concomitant major bile leak, which was managed with endoscopic sphincterotomy and temporary biliary stenting.

Three patients were diagnosed with liver necrosis on CT. In all patients the hepatic artery was ligated during initial surgery, after injuries of the common hepatic artery (2) and right hepatic artery (1). Two of these patients were successful managed with percutaneous drainage, and one patient required a relaparotomy. One patient with a grade III liver injury had a complete transection of the common hepatic artery underwent a laparotomy for abdominal sepsis. This patient died because of multiple organ failure on day 5 post injury.

General surgical complications.

The incidence of general surgical complications is presented in table 4. Sixty three (31%) patients who underwent initial operative management had postoperative intraabdominal septic complications (table 5). There was a difference in septic complications related to the mechanism of injury. Seventeen (8,3%) patients required one or more relooks for intraabdominal septic complications (pancreatic fistula (5), duodenal fistula (3), enteric fistula (3), mechanical obstruction (3), missed bowel perforation (1), acalculous cholecystitis (1), necrotizing fasciitis (1)). General complications, hospital stay and mortality were higher in patients with major hepatic bleeding requiring packing to control bleeding.

Table 5: Septic complications in 218 patients who were managed operatively.

	Overall (N=218)	Blunt (N=35)	GSW (N=137)	SW (N=46)	P-value
Septic complications [1]	63 (29%)	18 (51%)	38 (28%)	7 (15%)	**0.002**

DISCUSSION

Uncontrolled bleeding is the main cause of early death in patients with a liver injury. Despite improvement in resuscitation and critical care facilities the mortality of complex hepatic injuries remains high. The overall operative mortality rate in consecutive adult liver injuries in our study was 7%. Overall mortality in liver injuries ranges from 10 to 42%, and depends on the mechanism of injury.[16] Seven of the deaths were directly attributable to the liver injury, liver related operative mortality was 3%, and the remainder were due to associated injuries.

The results of this study showed that suture ligation and liver packing are effective surgical tools to achieve hemostasis. Due to direct suture repair of visible intrahepatic bleeding vessels, the use of angiography as adjunct to perihepatic packing in this study was limited, and only indicated in selective cases. The repair of juxtahepatic venous injuries can wel be delayed when initial abdominal and perihepatic packing is performed. A first relook laparotomy and removal of packs only after 48-hours was associated with the lowest risk on rebleed.

Perihepatic packing has become the most widely used and successful method for management of severe liver injury.[1,2,3] There is concern about the timing of the planned re-look laparotomy and when the liver packs should be removed. Similar to the results of an earlier retrospective study from our institution, removal of liver packs should be performed after 48 hours, as this is associated with the lowest risk of rebleeding.[3] Although the evidence that supports the efficacy of damage control surgery compared to traditional laparatomy is limited, and there has been an increase in incidence of patients who undergo damage control.[17,18] Surgeons should be aware of the increase of morbidity in patients who unnecesarily undergo a damage control laparotomy.

In damage control surgery for the liver, severe parenchymal damage has initally been left untreated. We feel that all vissible bleeding vessels should be ligated prior to packing, in order to limit the need for adjuvant postoperative angiography and subsequent embolization. Direct suturing of the liver edges with large, blunt tipped o chromic suture is controversial and not recommended, because complications due to direct suture repair may lead to intrahepatic hematomas or haemobilia. Alternative techniques include hepatotomy which potentially can lead to extensive additional parenchymal bleeding while searching for the intrahepatic bleeding vessel.[19] Hepatotomy or the finger fracture technique was applied in only 1 patient in this series. Hirschberg and Mattox advocate this technique only in patients who are well resuscitated and can tolerate additional blood loss.[5]

Recently some authors suggested that resection of the injured portion of the liver can definitively control bleeding, eliminate devitalized tissue, and avoid bile leak and should be considered as a surgical option in patients with complex injuries, and can be accomplished with low mortality and liver related morbidity. In this series we did not perform anatomical or non-anatomical resection to control bleeding. During a relook laparotomy 6 non-anatomical liver resections or debridement of devitalized liver parenchyma were performed.

Penetrating tracts through the hepatic tissue can be challenging. Recently a series of patients with penetrating liver injuries have been managed successfully with a Sengstaken- Blakemore balloon.[6,7] Although this alternative surgical technique is viable in the present series in 1 of the 183 patients with penetrating liver injuries balloon tamponade of the tract was used.

Currently angiography is recommended as an adjuvant to perihepatic packing.[8] Mortality following embolization is reported to be low, but concern has been expressed about a significant morbidity[.20,21] Furthermore angiography and subsequent embolization is not readily available in all operating theatres and performing a routine angiography in a postoperative critical ill patient is not a benign procedure. Although angioembolization is available in our hospital, in this series of patients the role of postoperative angiography is very limited and was used for treatment of delayed bleeding, and hepatic artery pseudoaneurysms. Post traumatic hepatic artery pseudoaneurysm is an uncommon delayed complication. Pseudoaneurysm detected by CT should be treated as early as possible, since occasionally hepatic artery pseudoaneurysm may become symptomatic.[22,23] A follow up CT scan in a 'young' trauma population for a rarely seen, but potential lethal complication is controversial. The high number needed to treat and negative effects of radiation exposure are matters of concern, and clinical examination and follow up might be the preferred method.

Juxtahepatic venous injuries are the most devastating liver injuries with a high mortality. Buckman *at al* outlined three main surgical strategies (direct venous repair, anatomic resection and tamponade with containment) and recently reports of using fenestrated grafts have been reported. These advanced radiological intervention techniques are not widely available. While a few authors report successful results on shunting, direct repair of venous injuries without the necessity performing a sternotomy has been reported as being more successful.[24] But direct repair of venous injuries requires full mobilization of the liver and places the patient at risk when not performed in a well-resuscitated patient.

The approach of juxtahepatic venous injuries in this series is a damage control strategy, containment by tamponade using packs followed by a direct repair, when feasible after initial resuscitation and an experienced team has been mobilized.

While this prospective series of patients is large the number of vascular complications is low. The comparison of small groups in this paper by means of significance testing needs to be interpreted in the light of the very low power to detect statistically significant differences.

In conclusion; early recognition of the magnitude of complex liver injuries and a clear treatment strategy for peri- and intra-hepatic injuries is essential. Suture ligation and liver packing are effective surgical tools to achieve hemostasis. Direct suture repair of visible intrahepatic bleeding seems successfull with subsequent limited need for postoperative angiography. Repair of juxtahepatic venous injuries can be delayed, while patients are being resuscitated and an experienced surgical team is mobilized The first relook laparotomy and removal of packs should be performed after 48-hours.

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CHAPTER 4

TRAUMATIC BILE LEAKS

Management of biliary complications in 412 patients with liver injuries

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ABSTRACT

Background: Bile leaks occur in 4% to 23% of patients after major liver injuries. The role of conservative management versus internal biliary drainage has not been clearly defined. The safety and efficacy of nonoperative management of bile leaks were studied.

Methods: Four hundred twelve patients with liver injuries were assessed in a prospective study between 2008 and 2013. All patients with clinically significant injuries to the intrahepatic biliary tract were evaluated. Bile leaks were classified as minor or major (400 mL/d or persistent drainage for 14 days). Minor leaks were managed conservatively, and major leaks underwent ERCP and endoscopic biliary stenting.

Results: Fifty-one patients (12%) developed a bile leak after liver trauma. Eleven patients (22%) with an extrahepatic duct injury underwent open surgery. Forty patients (78%) had an intrahepatic bile leak. Twenty-six patients (65%) with minor bile leaks were treated conservatively, and 14 patients (35%) with major leaks underwent endoscopic retrograde cholangiogram and internal drainage. All bile leaks resolved. There was no significant difference in the two groups with respect to septic complications ($p = 0.125$), intensive care unit stay ($p = 0.534$), hospital stay ($p = 0.164$), or mortality ($p = 1.000$).

Conclusion: Sixty-five percent of the intrahepatic bile leaks following trauma are minor and easily managed conservatively. Endoscopic retrograde cholangiogram and internal drainage should be reserved for major leaks.

INTRODUCTION

Non-operative management (NOM) of the injured liver in the hemodynamically stable patient, in the absence of an acute abdomen, has gained universal acceptance. This concept is applicable regardless of the severity of parenchymal damage and the mechanism of injury.[1-2] In patients in whom surgery is required, current operative management emphasizes the need for damage control surgery (DCS) and perihepatic packing in the hemodynamically unstable patient. [3-4] These management strategies may result in severe parenchymal damage being untreated and may potentially result in larger and more complicated bile leaks that may not resolve with simple drainage. The priority in DCS is to control bleeding and prevent any obvious contamination, and attention should be given during the relook to ligating any visible bile ducts that are leaking. Endoscopic retrograde cholangiography (ERC) with internal drainage of complicated bile leaks has proven successful.[5-10] The timing of the ERC has been open to debate with some authors suggesting that this should be as soon as the bile leak is evident.[11] This, however, does not take into account the natural history of a bile leak after severe trauma in which spontaneous resolution is the norm, irrespective of the mechanism, provided there is adequate drainage.[11,12] All reports to date on the role of ERC have been retrospective and data about conservative management of a bile leak with simple drainage lacking.

The aim of this study was to assess the role and safety of conservative management of minor bile leaks compared to the treatment of major bile leaks with endoscopic sphincterotomy and biliary stenting.

METHODS

This study, of which ethical approval was granted from the Human Research Ethics Committee of the Faculty of Health Sciences of the University of Cape Town, was a prospective observational cohort study of 412 consecutive patients with liver trauma admitted to Groote Schuur Hospital Trauma Center in Cape Town, South Africa, between 2008 and 2013. The setting was a level-1 Trauma Centre and a referral centre for hepatobiliary surgery serving a population of 2,5 million people. Patients with a suspected liver injury were initially resuscitated and managed according the Advanced Trauma Life Support (ATLS®) principles.[14] The indications for surgical intervention for liver injuries were hemodynamic instability and generalized peritonitis. Liver injuries were diagnosed on CT-scan or during an exploratory laparotomy. Liver injuries were graded using the Organ Injury Scale of the American Association of Surgery for Trauma.[15] Patient demographics, Revised Trauma Score (RTS), Injury Severity Score (ISS), mechanism of injury, type of management (operative management (OM) versus NOM)), morbidity and mortality were documented. Morbidity was defined of any liver related complication or the presence of intra-abdominal sepsis. The length of total hospital and critical care unit stay were measured in days.

All patients with bile leaks were identified and included in the study. A bile leak was defined as drainage of bile through the wound tract, or via an intra-abdominal or chest drain placed at surgery, or following CT-guided percutaneous drainage of a perihepatic or pleural collection. Bile leaks were classified as minor or major leaks. A major leak was defined as drainage of > 400 ml/Day, or persistent drainage of > 50 ml/Day for longer then 14 days. A minor leak was defined as drainage of bile < 400 ml/Day or > 50 ml/Day not longer then 14 days. The range for minor leaks was [15cc/Day-50cc/Day]. Minor leaks were managed conservatively. Major leaks underwent ERC and sphincterotomy within 24 hours after diagnosis. On the basis of the cholangiogram findings during ERC, the site of the bile leak was classified as either central or peripheral. Central intrahepatic biliary injuries were defined as those involving the proximal right and left hepatic ducts within 5 cm of the hepatic duct confluence. Peripheral biliary injuries were defined as those within the hepatic parenchyma more than 5 cm from the hepatic duct confluence.[10] If a leak was identified, a 10-Fr plastic biliary stent was inserted. Removal of the internal stent was performed 4-6 weeks after the cessation of bile drainage.

The primary outcomes were the efficacy of conservative treatment of minor bile leaks and endoscopic drainage in major bile leaks. The secondary outcomes included septic complications, hospital stay and ICU-stay.

Results were presented as number (%) or as median (P_{25}-P_{75}). Patient groups were compared using the Pearson's chi-squared test or Fisher's exact test for categorical variables, and the Mann-Whitney test for non-normally distributed data. Statistical analyses were performed using SPSS statistical software, version 20. P values< 0.05 were considered statistically significant.

RESULTS

Four hundred and twelve patients with a liver injury were treated between 2008 and 2013. One hundred thirty four (33%) patients sustained blunt trauma and 278 (67%) penetrating injuries. Two hundred eighteen (53%) patients required surgery as initial management for abdominal trauma. Fifty one (12%) patients with injuries to the biliary tract were identified. Forty patients had intrahepatic biliary injuries. Eleven patients sustained extra hepatic biliary injuries, 9 patients had injuries to the gallbladder and two patients had injuries to the common bile duct. One patient had a complete mid common bile duct transection. The liver was initially packed and a hepaticojejunostomy was performed as definitive repair 48 hours later. A second patient had an injury of the right hepatic artery and the proximal common bile duct involving the hepatic confluence. As initial treatment the right hepatic artery was ligated, the liver was packed and bile drained to prevent contamination. During the relook 48 hours later a cholecystectomy and primary repair of the right and left hepatic duct was performed.

Forty (10%) patients (38 men, 2 women, mean age 28, range 17-58 years) had intrahepatic biliary complications. Seven (19%) patients sustained blunt trauma and 33 (81%) penetrating, 10 (29%) due to stab wounds and 23 (71%) gunshot wounds. *The median RTS-score was 7,841 (interquartile range 7,841-7,841). The median ISS was 25 (interquartile range 16-32).*

Nine (23%) patients had been managed nonoperatively, and 31 (77%) patients underwent an operation. In the patients who were managed nonoperative successful, 6 patients developed fever, had an increasing white cell count without generalized peritonitis. Computed tomography showed in these patients an intraabdominal collection and the bilomas were drained percutaneously. In 1 patient, bile was leaking through the wound tract. Two patients had a pleurobiliary fitusla following penetrating trauma. Twenty four (35%) of the patients who were operated required damage control surgery and the liver was packed to control the bleeding, in 3 patients in combination with sutures (2) or a resectional debridement (1). Seven patients underwent definitive repair of their injuries, in 4 patients the liver was temporary packed and surgical drains were left in place.

Forty intrahepatic biliary complications were diagnosed. A biloma was drained percutaneously under ultrasound guidance in seven patients. Thirty-three patients developed a biliary fistula. Biliary peritonitis developed in three patients who were managed nonoperatively following blunt trauma (2) and a gunshot wound of the liver (1). Twenty-two patients presented with bile leak via the surgical drain (18), wound tract (3) and persistent drainage (> 3 days) following percutaneous drainage of an abscess (2). A pleuro-biliary fistula was diagnosed in eight patients following thoracoabdominal penetrating trauma (GSW (6) and stab wounds (2).

Bile leaks occurred in patients who underwent operative management ($p< 0.001$), damage control surgery and packing of the liver ($p < 0.001$), higher-grade liver injury ($p< 0.001$), and penetrating trauma ($p= 0.030$) [Table 1].

Twenty six (65%) patients had a minor bile leak, and 14 (35%) patients a major bile leak. The 26 patients with minor bile leaks (drainage < 400 ml/Day) were managed conservatively and did not undergo endoscopic intervention, all external drains were removed within 14 days. The 14 patients with major bile leaks underwent endoscopic sphincterotomy and internal temporary biliary stenting. In two patients it was not possible to cannulate the common bile duct deeply and only a sphincterotomy was performed. In

TABLE 1. Incidence of Bile Leaks Categorized According to Mechanism of Trauma, Management, and Grading of Liver Injury

A. Trauma Mechanism				
	Overall (n = 408)	Blunt (n = 134)	Penetrating (n = 274)	p
Bile leaks*	40 (10%)	7 (5)	33 (12)	**0.030**
B. OM and NOM				
	Overall (n = 408)	OM (n = 169)	NOM (n = 239)	p
Bile leaks*	40 (10%)	31 (18)	9 (4)	**<0.001**
C. DR and DCS				
	Overall (n = 214)	DR (n = 155)	DCS (n = 59)	p
Bile leaks*	31 (15%)	7 (5)	24 (41)	**<0.001**
D. Low-Grade (I, II) and High-Grade (III, IV, V) LI				
	Overall (n = 408)	Low-grade LI (n = 198)	High-grade LI (n = 210)	P
Bile leaks*	40 (10%)	8 (4)	32 (15)	**<0.001**

*Data are presented as number (percentage) and were analyzed with Pearson χ^2 analysis.
Values in boldface indicate statistically significant differences.
DR, definitive repair; LI, liver injury.

the other twelve patients the ERC demonstrated a leak from the right hepatic duct (5 patients), peripheral branches of the right hepatic duct (5), peripheral branches of the left hepatic duct (2). These 12 patients underwent an endoscopic sphincterotomy and insertion of a plastic 10 fr biliary stent.

The ERC for the major leaks demonstrated 5 central leaks and 7 peripheral leaks. The mean time of closure of the fistula after ERC was 9 days. There were no significant differences in grade of injury (p= 0.702), injury severity score (p= 0.679) and type of management (p= 0.563) in the two groups comparing conservative management or the patients who underwent an ERC. All bile leaks resolved and there was no significant difference in septic complications (p= 0.125), length of intensive care stay (p= 0.534), length of hospital stay (p= 0.164) and mortality (p= 1.000). There were no ERC-related complications. Two patients died because of multi-organ dysfunction, one treated conservatively and one managed with ERC. [Table 2]

TABLE 2. Outcome of Patients With a Bile Leak, Categorized According to Management in ERC and Internal Drainage and Conservative Treatment

	Overall (n = 40)	ERC (n = 14)	Conservative (n = 26)	p
ISS*	25 (16–32)	23 (17–32)	25 (16–34)	0.679
OM**	28 (70)	9 (64)	19 (73)	0.563
High-grade injury**	30 (75)	11 (79)	19 (73)	0.702
Septic complication**	18 (45)	4 (29)	14 (54)	0.125
ICU stay*	1 (0–5)	1 (0–4)	1 (0–11)	0.534
HLOS*	26 (14–33)	28 (18–40)	24 (12–31)	0.164
Mortality**	2 (5)	1 (7)	1 (4)	1.000

*Data are presented as median (P_{25}–P_{75}) and were analyzed with Mann-Whitney U-test analyses.
**Data are presented as number (percentage) and were analyzed with Pearson χ^2 analysis or Fisher's exact test.
Values in boldface indicate statistically significant differences.
HLOS, hospital length of stay.

DISCUSSION

There has been a paradigm shift from operative to NOM in recent decades in the management of liver trauma. Interventional techniques such as arteriography and selective embolization, percutaneous drainage of infected collections, and endoscopic sphincterotomy and biliary stenting are successful in the management of complications in up to 85 % of patients.[5-10]. The reports on ERC have all been retrospective and data about conservative management of a bile leak with simple drainage are missing. The major issue that is now faced is when and at what stage to intervene. The incidence of bile leaks secondary to liver trauma in the literature is reported 4-23 per cent.[13] In this series the overall incidence is 10 per cent (minor bile leaks 7 %, and major bile leaks 3%). The natural history of biliary cutaneous fistulae reported in the literature is spontaneous closure within 3 weeks provided that biliary drainage is maintained regardless of the type of injury.[12] Cogbill et al suggested that a biliary fistula requires further evaluation when bilious drainage was at least 50ml per day continuing after two weeks or a drainage of over 300-400 cc per day.[13]

While the use of endoscopic sphincterotomy and biliary stenting for management of major bile leaks is successful, little is known about bile leaks that resolve by simple external drainage. In this study bile leaks were considered to be significant when drainage was more then 400 ml per day or longer then 14 days. The use and timing of endoscopic retrograde cholangiogram has been a subject of controversial debate.[12] The theory behind the effectiveness of ERC is that stenting reduces the pressure gradient between the bile duct and the duodenum by eliminating the physiological role of the sphincter of Oddi. Bile drains preferentially into the duodenum, allowing the disrupted duct to heal spontaneously. In our series of 14 patients with a major bile leak, 5 patients had a central duct lesion and 7 patients had a peripheral duct injury. In two patients, it was not possible to cannulate the common bile duct and only a sphincterotomy was performed with resolution of the bile leak.

Whether patients with a minor bile leak would benefit from an intervention, ERC, sphincterotomy and stenting in order to resolve the bile leak earlier and to pursue a decrease in hospital stay cannot be addressed by analysis of the present data. Nevertheless these patients did not require an ERC, repeated ERC and subsequent stent removal after 4 weeks. It is likely that patients with a major bile leak, who develop a large volume fistula, will benefit from an early ERC. For the persistent fistula it remains unclear whether the persistent fistula will close after 3-6 weeks spontaneously.

In conclusion, 26 patients with minor bile leaks were managed conservatively thus avoiding an ERC. This confirms the concept that minor bile leaks usually resolve with conservative management alone. Septic complications, length of hospital stay, and mortality were not increased in these patients. Fourteen patients with a high output biliary fistula underwent endoscopic sphincterotomy and internal stenting. Intrahepatic complications were most commonly seen in patients who were managed surgically for high grade liver injuries due to penetrating trauma. The surgical approach to complex liver injuries can be challenging even for experienced surgeons. Inflow occlusion and direct repair with selective vascular and biliary ligation is recommended in order to decrease the risk of intrahepatic complications.[16-20] At the relook laparotomy attention should be given to ligating any visible bile ducts that are leaking. This is best done with a figure of eight suture and using a 2-0 polypropylene suture. The liver must be adequately drained in patients who require surgery and so as to prevent any biloma formation. In patients managed nonoperatively, fever and a rise in white cell count without generalized peritonitis warrant a computed tomography and subsequent drainage of an intraabdominal collection.

Physicians need to be cognizant that ERC is not a benign procedure, especially in a multiple injured, post-operative patient in a surgical intensive or high care unit. In case of postoperative care, we feel it is safe to wait for up to 14 days and most of the bile leaks resolve spontaneously. Source control, drainage of bile through the wound tract, via an intra-abdominal drain after surgery, following percutaneous drainage of a perihepatic or pleural collection is essential. Conservative management of bile leaks is safe provided the patients have been adequately drained and they remain apyrexial. Internal drainage should be considered when drainage of bile is more than 400ml per day or when the bile leak has persisted beyond 14 days.

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Management of biliary complications following damage control surgery for liver trauma

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ABSTRACT

Background: The liver is the most frequently injured solid intra-abdominal organ. The major cause of early death following severe liver trauma is exsanguination. Although perihepatic packing improves survival in severe liver trauma, this leaves parenchymal damage untreated, often resulting in post-traumatic biliary leakage and a subsequent rise in morbidity. The aim of this study was to analyze the incidence and treatment of biliary leakage following the operative management of liver trauma.

Methods: Patients presenting between 2000 and 2009 to Erasmus University Medical Centre with traumatic liver injury were identified. Data from 125 patients were collected and analyzed. Sixty-eight (54 %) patients required operation. All consecutive patients with post-operative biliary complications were analyzed. Post-operative biliary complications were defined as biloma, biliary fistula, and bilhemia.

Results: Ten (15 %) patients were diagnosed with postoperative biliary leakage following liver injury. Three patients with a biloma were treated with percutaneous drainage, without further intervention. Seven patients with significant biliary leakage were managed by endoscopic stenting of the common bile duct to decompress the internal biliary pressure. One patient had a relaparotomy and right hemihepatectomy to control biliary leakage and injury of the right hepatic duct.

Conclusion: Biliary complications continue to occur frequently following damage control surgery for liver trauma. The majority of biliary complications can be managed without an operation. Endoscopic retrograde cholangiopancreatography (ERCP) and internal stenting represent a safe strategy to manage post-operative biliary leakage and bilhemia in patients following liver trauma. Minor biliary leakage should be managed by percutaneous drainage alone.

INTRODUCTION

Liver injury is common in patients with abdominal trauma[1]. Early deaths in patients with liver trauma are often related to uncontrolled bleeding and associated injuries. Later deaths are predominantly related to septic complications. In the majority of patients with blunt abdominal trauma, hepatic bleeding stops spontaneously or can be stopped with abdominal packing[2]. This perihepatic packing is a safe damage control maneuver which improves survival [3–7]. However, it leaves parenchymal damage untreated and may lead to persistent low-volume hemorrhage, abscesses, hemobilia, and bile leaks [8]. Three types of acute complications following biliary

trauma are biloma, biliary fistula, and bilhemia. The incidence of post-traumatic biliary complications vary from 4 to 22 % [8–10]. Bilhemia occurs in 1 % of liver trauma patients [11, 12]. Some bile duct injuries will be obvious intra-operatively, with significant bile staining and a visible disrupted bile duct. However, it may be difficult to diagnose the presence of traumatic bile leak during operation[13]. Many persistent fistulae may manifest from smaller peripheral bile ducts, which retract into the liver parenchyma and are not visualized intra-operatively [14]. Subsequent peritonitis caused by bile leakage can give rise to substantial morbidity, leading to prolonged hospital stay [9, 15, 16]. Reduction of the pressure gradient between the bile duct and duodenum by endoscopic retrograde cholangiopancreatography (ERCP) has been reported to be successful in the cessation of bile leakage and may prevent relaparotomies to control biliary leakage [14, 15, 17–19]. The aim of this study was to analyze the incidence and treatment of biliary leakage following the operative management of liver trauma.

METHODS

All consecutive patients, 16 years and older with blunt or penetrating liver injuries presented between 2000 and 2009 at a major level 1 trauma center and a tertiary referral center for hepatobiliary surgery and liver transplantation in the Netherlands, were identified from the trauma registration database. The electronic records and imaging studies of all patients, diagnosed a liver injury during laparotomy or on computed tomography (CT) scan, were reviewed. All liver trauma patients who subsequently underwent damage control surgery and developed a post-operative biliary leak were included.

Operative management. Initial management of the injured patient was carried out according the guidelines of the Advanced Trauma Life Support (ATLS)[20]. Hemodynamic instability and signs of peritonitis were indications for an exploratory laparotomy according to the algorithm and guidelines for abdominal trauma[19]. Initially, the injured liver was compressed manually to control the bleeding and subsequent packs were placed above and below the liver temporarily. Whenever the bleeding was controlled after temporarily packing, the packs were removed at the initial operation. Nevertheless, patients with prolonged hemodynamic instability, hypothermia, severe acidosis, onset of coagulopathy, and massive transfusion requirement were managed following a damage control surgery strategy[21]. This strategy included perihepatic packing to control bleeding, spillage control, temporary abdominal closure, resuscitation in an intensive care environment, if feasible and necessary angioembolization, and planned reoperation for definitive treatment after 24–48 h [4–7]. In general, in the damage control setting, the falciform ligament is transected and dry packs were placed above the liver to restore the anatomical

relationship. Thereafter, the liver is cautiously retracted in the caudocephalad direction to the pack below, while being aware of the risks of too much traction on the vena cava inferior [22]. If necessary, an acute partial liver resection was performed as part of the damage control procedure. Other techniques of packing the liver as described in the literature (i.e., mesh wraps or omental flaps) were not used in this series [23]. Following an explorative laparotomy and in case of suspected ongoing bleeding post-operatively, an on-demand angiogram was performed, including subsequent selective angioembolization. Classification of liver injuries and complications The localization and extent of the liver injuries were classified according to the segmental and functional anatomy described by Couinaud[24]. The severity of all liver injuries was graded according to the Organ Injury Scale (OIS) of the American Association for the Surgery of Trauma (AAST) (Table 1)[25]. Post-operative biliary leakage was subdivided into biloma, biliary fistula, or bilhemia. A biloma was defined as an intra-abdominal collection of bile, diagnosed with ultrasound or CT scan. A biliary fistula was defined as leakage of bile via the surgical wound, gunshot wound opening, stab wound opening or percutaneous drain of more than 50 mL/day for 2 weeks or more than 400 cc daily, confirmed by a bilirubin fluid level

Table 1 The liver Organ Injury Scale (OIS) of the American Association for the Surgery of Trauma (AAST)

Grade of liver injury	Type of injury	Description of injury
I	Haematoma	Subcapsular, <10 % surface area
	Laceration	Capsular tear, <1 cm parenchymal depth
II	Haematoma	Subcapsular, 10–50 % surface area
		Intraparenchymal, <10 cm in diameter
	Laceration	1–3 cm parenchymal depth, <10 cm length
III	Haematoma	Subcapsular, >50 % surface area or expanding. Ruptured subcapsular or parenchymal haematoma
		Intraparenchymal haematoma >10 cm or expanding
	Laceration	>3 cm parenchymal depth
IV	Laceration	Parenchymal disruption involving 25–75 % hepatic lobe or 1-3 Couinaud's segments in a single lobe
V	Laceration	Parenchymal disruption involving >75 % of hepatic lobe or >3 Couinaud's segments within a single lobe
	Vascular	Juxtahepatic venous injuries, i.e., retrohepatic vena cava/central major hepatic veins
VI	Vascular	Hepatic avulsion

exceeding the normal bilirubin serum level[26]. Bilhemia was defined by a communication between intrahepatic bile ducts and the hepatic venous system, clinically characterized by jaundice and increased serum bilirubin level. All patients with a biloma were initially managed by percutaneous drainage. Patients with biliary fistulae and significant leakage of bile and patients with bilhemia were treated endoscopically. An endoscopic retrograde cholangiogram was performed within 24 h after diagnosis. If the bile leak was localized and confirmed on cholangiography, internal transpapillary stenting, using 7- or 10-Fr plastic stents, was performed with or without a sphincterotomy. The intention was to maintain all patients on enteral nutrition. The primary outcome was the success rate of controlling biliary leakage. This was defined as the cessation of bile leakage following internal stenting or percutaneous drainage alone. Follow-up continued until 6 months after discharge. Failure of percutaneous or endoscopic treatment was defined as the need for surgical intervention, such as a relaparotomy with partial liver resection to control biliary leakage.

Statistics Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 16.0. Normality of continuous data was tested with the Shapiro–Wilk and Kolmogorov–Smirnov tests and by inspecting the frequency distributions (histograms). Homogeneity of variances was tested using Levene's test. Descriptive analysis was performed to assess the patient characteristics. For continuous data, the mean ± standard deviation (SD) (parametric data) or medians and percentiles (non-parametric data) were calculated. For categorical data, frequencies were calculated.

RESULTS

General study group.

A total of 125 liver trauma patients were identified from the trauma database. The mean age was 33 years (range 16–81). Sixty-three percent of the liver injuries were caused by blunt trauma. The median Injury Severity Score (ISS) of these patients was 22 (interquartile range 17–34). The median length of hospital stay was 10 days (interquartile range 4–18). Sixty-eight (54 %) of the 125 liver trauma patients needed operative management of their abdominal traumatic injuries (Fig. 1). The mechanism of trauma was blunt in 53 %. The median ISS was 26 (interquartile range 17–42). Associated intra-abdominal injuries in the operative group of 68 patients were lacerations of the spleen, stomach, small bowel, and colon (Table 2). The median length of hospital stay was 11 days (interquartile range 6–36). Thirteen of the 125 liver trauma patients (10 %) died because of exsanguination or associated injuries within 48 h (early deaths). Ten of the 125 liver trauma patients (1 %) developed post-traumatic biliary complications (Table 3).

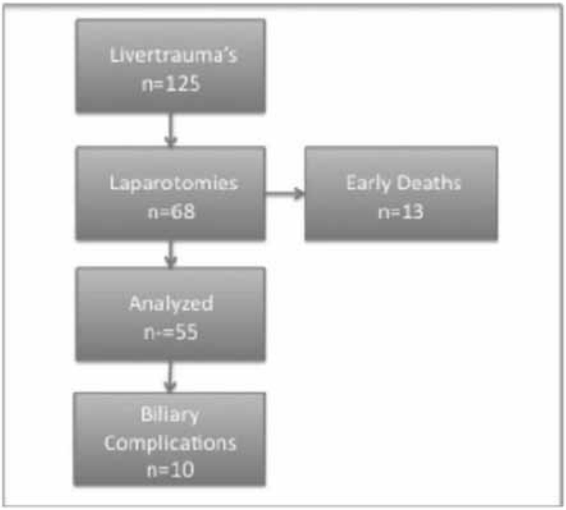

Fig. 1 Sixty-eight patients needed operative management. Thirteen patients died because of exsanguinations or associated injuries within 48 h. Ten patients developed post-traumatic biliary leakage

Table 2 Associated intra-abdominal injured organs, diagnosed peri-operatively

Organ	*n*
Diaphragm	6
Stomach	9
Duodenum	2
Gallbladder	2
Small bowel	9
Colon	8
Spleen	10
Pancreas	3
Kidney	4
Vascular	5

Biliary complications.

Ten patients presented with biliary leakage, biloma (n = 3), biliary fistula (n = 6), and bilhemia (n = 1), and were further analyzed in this study. Their mean age was 36 years (range 20–55). The mechanism of injury was blunt trauma in five patients and penetrating trauma in the other five. The median ISS was 19 (interquartile range 17–25). Initial operative management consisted of perihepatic packing (n = 7), resections and packing (n = 2), intra-operative placement of an endovascular juxtahepatic stent (n = 1) [12], and adjuvant embolization of the proper hepatic artery in the angiosuite following exploratory laparotomy (n = 1). Nine out of the ten patients with post-traumatic biliary leakage were diagnosed as high-grade liver injuries, with grades V and IV (Table 3). Time of diagnosis, length of hospital stay, and mortality. At a mean of 8 days (range 1–15 days) after removal of the packs and secondary resuscitation in the intensive care unit (ICU), patients were diagnosed with biliary complications. Three patients were diagnosed with non-significant biliary leakage (\50 mL/day for 2 weeks or\400 cc daily) and six patients were diagnosed with significant biliary leakage. One patient was diagnosed with bilhemia on day 10. The median length of hospital stay was 50 days (interquartile range 21–61, there was no late mortality, and all patients were discharged home or for rehabilitation.

Table 3 Ten patients with post-traumatic biliary leakage following the operative management of liver trauma

No.	Trauma mechanism	Associated injuries	Segments	Grade	Surgical management	Adjuvant radiological intervention	Bile leak	Management biliary complications	Outcome
1	Blunt	Pneumothorax	5, 6, 7, 8	4	Packing		Fistula	ERCP	Successful
2	Penetrating	Cardiac, thoracal spine	3, 7	3	Temporary packing	Embolizing proper hepatic artery	Fistula	ERCP	Successful
3	Penetrating	Colon	4, 5, 6	5	Packing	–	Fistula	ERCP	Successful
4	Blunt	Spleen, vena cava inferior	5, 6, 7, 8	5	Packing	–	Fistula	ERCP	Successful
5	Blunt	–	5, 8	4	Packing	–	Fistula	ERCP	Right hemihepatectomy
6	Penetrating	–	2, 3, 4	4	Packing	–	Fistula	ERCP	Successful
7	Penetrating	Humerus left	5, 8	5	Packing/deep liver suture	Stenting juxtahepatic vein	Biliovenous fistula	ERCP	Successful
8	Penetrating	Kidney, gallbladder, vena portae	2, 3, 4	5	Packing	–	Fistula	Percutaneous drainage	Successful
9	Blunt	Spleen, pelvic, traumatic brain injury	5, 6, 7, 8	5	Right hemihepatectomy/ packing	–	Biloma	Percutaneous drainage	Successful
10	Blunt	–	1, 2, 3	4	Left hemihepatectomy/ packing	–	Biloma	Percutaneous drainage	Successful

Trauma mechanism, associated injuries, segments involved, liver injury grade, initial surgical management, adjuvant radiological management, type of bile leak, management of biliary complications [endoscopic retrograde cholangiopancreatography (ERCP) or percutaneous drainage], and outcome are presented in this table

Management of biliary complications.

Three patients were managed with percutaneous drainage only. The bile leakage resolved spontaneously without the need for internal decompression. Two of these patients had been initially managed by performing a partial liver resection and subsequent perihepatic packing. Seven patients were managed endoscopically by stenting with or without sphincterotomy, after demonstration of the defect on the cholangiogram (Fig. 2). In six patients, biliary leakage was controlled after internal decompression with a 7- or 10-Fr plastic stent and sphincterotomy. Internal stents were placed to reduce the pressure gradient and not with the intention to bridge the defect in the bile duct. Persistent bile leakage from the right intrahepatic duct was present in one patient, despite bridging of the defect by means of a 10-Fr stent. In this patient, a right hemihepatectomy was performed after 8 weeks to successfully control biliary leakage.

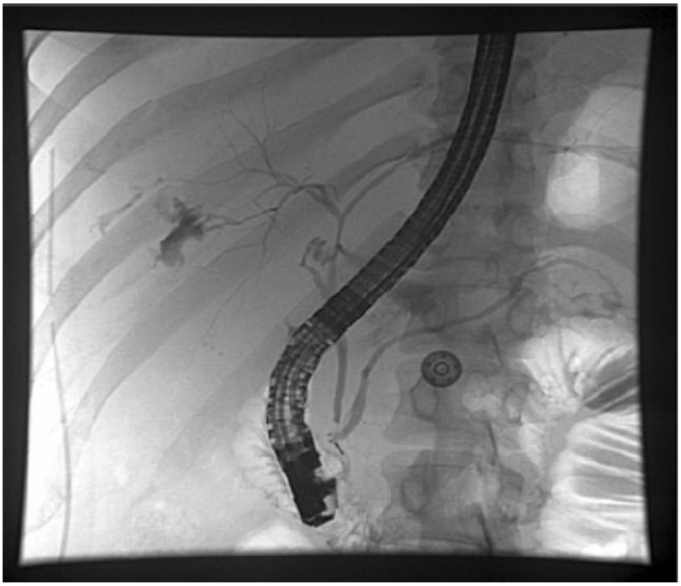

Fig. 2 Endoscopic retrograde cholangiopancreatography (ERCP) reveals biliary leakage from the right intrahepatic bile system

DISCUSSION

In this series, the overall biliary complications rate was 1%. The incidence of biliary leakage in the operative group was 15%. Eighty-five percent of the patients with biliary complications after liver trauma were managed successfully by ERCP or percutaneous drainage. Biliary leakage was not related to post-operative mortality in this series. Previous series documented an incidence of overall biliary fistulas in about 4–22% of the patients[9]–[18]. In the current study, the incidence of biliary leakage in the operative group was 15%. Earlier studies also showed that the majority of complications following liver trauma can be successfully managed with non-operative techniques in up to 85% of the patients[9]. The role and safety of endoscopic management for bile leaks following complex hepatic trauma was analyzed in a previous report. Eleven patients underwent biliary sphincterotomy and stent insertion, leading to complete resolution of all bile leaks without the need for a relaparotomy [10]. Previous reports on the management of post-traumatic biliary leakage following liver trauma are limited and series are small. The results documented in the current study and those found in the literature recommend ERCP and internal stenting as a safe and effective strategy for the management of bile leaks following blunt and penetrating liver trauma[9–14, 17, 18]. One patient in this series has been reported earlier in this journal and presented with intravascular biliary leakage following penetrating trauma and implantation of an endovascular stent in the juxtahepatic vena cava as adjuvant to perihepatic packing, and was successfully treated with stenting of the bile duct[12].

In this series, two patients had, during the procedure of damage control surgery, a partial liver resection as initial surgical therapy. Nowadays, acute hepatic resection is controversial in the management of hepatic injury, because of the high mortality and better survival following perihepatic packing only[4–8]. In our two cases, clinical judgement and partial liver resection was performed by an experienced hepatobiliary surgeon. These two patients presented with minor bile leaks and could be managed with percutaneous drainage alone. In this series of patients, finger fracture technique or hepatotomy in combination with intermittent inflow control by performing a Pringle maneuver[27] were not used routinely in order to ligate lacerated bile ducts and eventually lower risk for post-operative bile leaks. Non-operative techniques as percutaneous drainage and ERCP represent to be successful in the management of post-traumatic biliary leakage. Although biliary leakage did not directly attribute to mortality, the mean length of ICU stay was 18.3 days (range 4–30) and the mean length of hospital stay was 52.3 days (range 20–115), reflecting a substantial morbidity and a considerable demand on hospital facilities [emergency room (resuscitation), operating theater facilities (damage control surgery), ICU (secondary resuscitation), intervention radiology unit, and ERCP facilities]. The consequential chance that liver trauma will develop biliary leakage after damage control surgery should be taken into account by the treating physicians and discussed with the patients and their relatives postoperatively. In this series, an angiography was performed in only three patients. One patient was managed successfully nonoperatively without the development of liver related complications such as hepatic necrosis or biliary leakage. Two patients in the operatively treated group underwent an angiography, of which one patient was positive. This patient underwent angioembolization of the right hepatic artery. This patient developed a bile leak. To what extent angioembolization of the proper hepatic artery and subsequent risk of biliary ischemic events attributed to an increased morbidity and a complicated follow-up such as the development of a biliary fistula is difficult to determine. Nevertheless, in this case, angioembolization was successful in controlling the bleeding in addition to operative management.

The retrospective character limits this study, i.e., the small number of patients included and the lack of a standardized protocol for the management of post-traumatic biliary leakage during the study period. Further research should be undertaken with preferably a multicenter study design with standardized protocols in order to overcome these limitations.

In conclusion, post-operative biliary leakage following liver trauma is a significant problem. Endoscopic sphincterotomy and internal stenting represent a successful strategy to manage significant post-operative biliary leakage and bilhemia in patients following liver trauma. Minor biliary leakage should be managed by percutaneous drainage alone.

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CHAPTER 5.

PERIHEPATIC ASSOCIATED INJURIES

The Indications for Damage Control Laparotomy in major trauma with a concomitant Liver Injury

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Submitted

ABSTRACT:

Background: Damage control surgery (DCS) is a well-established surgical strategy in the management of the severely injured and shocked patient, but selection of patients for DCS remains controversial. The aim of this study was to assess the criteria for selection of patients requiring a damage control laparotomy.

Methods: Eighty-two severely injured patients with a complex pattern of injuries were treated in a 52-month period. Patients were divided into two groups according to operative strategy; Group I Definitive Repair (DR). Group II. DCL. Factors identifying patients who underwent a DCL were analyzed and evaluated.

Results: Twenty five (%) patients underwent a DCL and 55 (%) patients had DR. The number and severity of overall abdominal injuries were equally distributed in the two groups of patients. Patients who underwent a DCL presented more frequently hemodynamic unstable ($p=0.02$), required more units of blood and required more often intubation to secure the airway. Onset of metabolic failure was more profound in patients who underwent a DCL comparing to patients who had DR. The mean Base deficit was -7,0 and -3,8 respectively ($p=0.003$). Vascular abdominal ($p=0.001$) and major liver injuries ($p=0.006$) were more frequently diagnosed in the DCL group. Mortality, general complications ($p<0.0001$), hospital stay ($p<0.0001$) and ICU stay ($p<0.009$) were increased in patients who underwent DCS.

Conclusion: In severely injured patients with a complex pattern of injuries 33% of the patients required a damage control strategy with 84% survival rate. Physiologic behavior, abdominal vascular injuries and major liver injuries dictated the need for a damage control strategy.

INTRODUCTION

Damage control strategies are useful for a subset of trauma patients. Recognition of patients who are likely to benefit from a damage control laparotomy are those with gunshotwounds of the abdomen and major blunt abdominal trauma. The extension of this approach has also been described in the general emergency surgery population.[1,2] Patients with, coagulopathy, acidosis and hemodynamic instability are likely to benefit from a damage control laparotomy.[3,4,5] This approach resulted in improved survival of critical injured and shocked patients based on retrospective case series and when compared with historical controls (table 1). However there is concern about the lack of research relating to indications for a DCL.[6]

Table 1. Criteria for Damage Control Surgery in patients who sustained blunt abdominal trauma or abdominal gunshotwounds.

Criteria for DCS
Complex Pattern of Injuries [4,5,22,23]
Operating Time for DR of injuries > 60-90 minutes [22,23,24]
Initial hypothermia: T < 35° C [25,26,27,28]
Initial Acid Base Status: pH<7,2; BE < 10-15; lactate < 5mmol/L [27,28,29,30,31]
Non-surgical bleeding, onset of coagulopathy [20,32,33,34]
Transfusion requirements > 10 units packed cells [18,32,33,35,36]

DCS: Damage Control Surgery; DR:Definitive Repair; T: Temperature; BE: Base Excess.

The liver is the most common injured intraabdominal organ following trauma.[7] The mortality associated with severe hepatic injury is 10% with an isolated liver injury, but if three major organs are injured mortality approaches 70%.[8,9] The effectiveness and decrease in mortality of liver packing to control a major liver bleeding has been well established, and a damage control approach in patients with a vascular injury and two or more visceral injuries shows a survival benefit.[5,10] An early decision to initiate a damage control strategy is imperative after rapid assessment of internal injuries and before metabolic failure has set in. But concern has been expressed about identifying patients who might benefit from a damage control approach and patients who could tolerate definitive repair of injuries.[11,12] Appropriate selection for DCS is critical in order to decrease morbidity, unnecessary use of hospital facilities and costs.

We compared two groups of patients with major abdominal injuries who were treated with definitive repair of injuries or patients who were selected for a damage control laparotomy. The aim of this study was to assess the criteria for selection of severely injured patients for a damage control laparotomy.

METHODS

From September 1, 2008, to December 31, 2012, all patients with a liver injury requiring emergency surgery at the level-1 Trauma Center of the Groote Schuur Hospital University of Cape Town were considered for inclusion in the study.

Patients were identified in a prospective trauma database. Major abdominal trauma was defined as two or more organs injured in the right upper quadrant of the abdomen in patients with an Injury Severity Score[13] (ISS) > 15, and Abbreviated Injury Score[14] (AIS) (Abdomen) ≥ 3. Patients with major abdominal were included and further analysed. Patients with a single injury in the right upper quadrant, or ISS < 15, or AIS < 3 were excluded. Patients who died in the operating theatre or within 24 hours in the ICU were excluded for further analysis.

Outcome:

Primary outcome was survival till discharge. Secondary outcome was morbidity. Morbidity was defined as general and organ specific complications, duration of intensive care stay and hospital stay in days. Complications were graded by using the Clavien-Dindo grading system for the classification of surgical complications.[18]

Grading of injuries:

Intra-abdominal injuries were graded according the Organ Injury Scale of the American Association of Surgery for Trauma[15]. High grade injuries were considered to be grade 3 to 5.

Operative management:

Following initial resuscitation and management according the principles of the Advanced Trauma Life Support (ATLS®)[16], physiological parameters were documented. Potential candidates for a damage control laparotomy were non-responders to shock management, hypothermia, onset of metabolic failure, or a combination of these. Metabolic failure was defined as worsening metabolic acidosis (Base deficit), with or without the onset of coagulopathy (non-mechanical bleeding).

Indications for surgery were continued haemodynamic instability, peritonitis or CT-findings suggestive of bowel injury requiring surgical repair.

Operative management included definitive repair of injuries or damage control surgery (DCS). Operative management was based on institutional and Definitive Surgical Trauma Care[17] (DSTC®) guidelines. A DCL was defined as a limited operation for control of hemorrhage and contamination, secondary resuscitation in the ICU and definitive repair during a reoperation. The decision to perform or to convert to a damage control laparotomy was based on preoperative physiologic status, the severity of abdominal injuries and estimated time for repair of intra-abdominal injuries exceeding total operating time > 60-90 minutes. Massive fluid resuscitation, a decrease in Base Deficit after hemorrhage control, and the use of inotropes to improve hemodynamics were indication for conversion to a damage control strategy.

Damage control techniques included perihepatic packing. Splenectomy was undertaken for bleeding splenic injuries. An injury to the renal artery was treated with ligation and nephrectomy in the presence of a normal contralateral kidney. Injuries of the aorta were managed with primary repair or interposition graft. Injuries to the major abdominal veins were ligated or packed. In the patient with a limited number of small or large bowel injuries a rapid one layer, continuous, full thickness closure was used. Multiple large perforations within a short segment of the small bowel or colon were treated with segmental resection. In unstable patients or patients on inotropes, the bowel was ligated and neither an end-to end anastomosis nor the maturation of a colostomy was performed at the initial operation. Injuries to pancreatic head of the pancreas were packed. Parenchymal defects not involving the duct were drained. Ductal transections to the left of the mesenteric vessels that did not involve the splenic vessels were packed and drained. Major parenchymal or ductal injuries in the head or neck of the pancreas were also packed and drained, once bleeding from the pancreas or underlying vessels was controlled. Distal pancreatectomy, and pancreaticoduodenectomy were delayed until the relook laparotomy.

When severe shock, hypothermia, acidosis, and massive transfusion have led to coagulopathy and diffuse non-mechanical bleeding, the intraabdominal cavity was packed. Patients with intra-abdominal packing were managed as an open abdomen.

Patients were transferred to the intensive care unit for reversal of metabolic failure. The endpoints of resuscitation were defined as; temperature > 36 Celsius, Base deficit > -2, normal serum lactate, INR < 1,5, platelets > 50.000/ul, weaned off inotropes, fraction of inspired oxygen < 0.50 and O_2 Saturation > 95%.

Emergency reoperation was undertaken for the development of abdominal compartment syndrome or failure to attain the endpoints of resuscitation due to continuing hemorrhage.

Treatment of complications was multidisciplinary when appropriate and included endovascular, endoscopic interventions, and CT-guided drainage of abscesses.

Statistics:

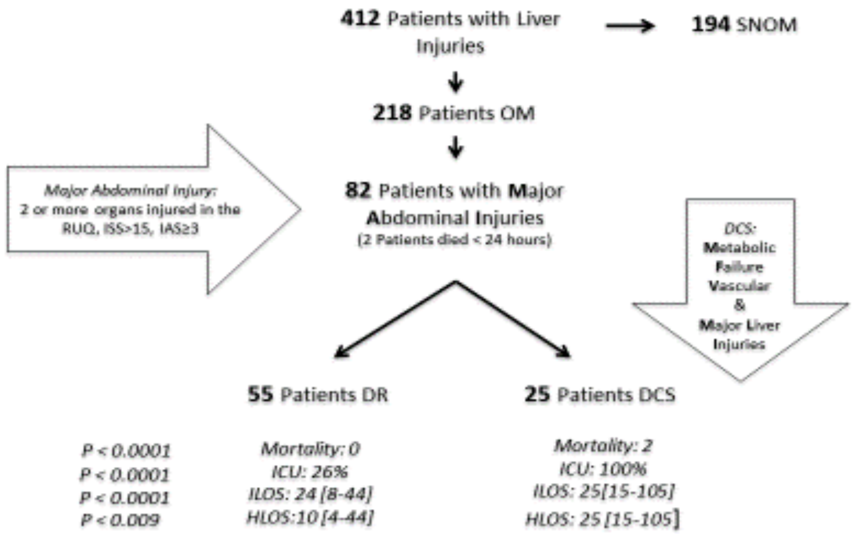
Results were presented as number (%) or as median (P_{25}-P_{75}). Patient groups were compared using the Pearson's chi-squared test or Fisher's exact test for categorical variables, and the Mann-Whitney test for non-normally distributed data. Statistical analyses were performed using SPSS statistical software, version 20. P values< 0.05 were considered statistically significant.

RESULTS

Four hundred and twelve patients were diagnosed a liver injury following abdominal trauma between 2008 and 2013. One hundred and ninety four were selected for nonoperative management. Two hundred and eighteen patients with a liver injury underwent surgery. Eighty-two (38%) patients with a complex pattern of injuries were identified. Figure 1 presents a management flow chart of all patients with abdominal trauma and a concomitant liver injury.

Two patients died on table or in the SICU within 24 hours. The first patient was a 19 year old male who sustained multiple thoracoabdominal gunshotwounds. He arrived hemodynamic stable (SBP 118), GCS 15 core temperature 35,1°C, BE -5,7, lactate 3,4, pH 7,22, and Hb 9,2 g/dl. RTS:7,108, ISS:25, PATI:25, During initial resuscitation he detoriated (abdominal distension and hypovolemic episodes) and was taken to the operating theatre immediately. He had a Gr III liver injury, stomach perforation, small bowel and colon laceration, a pancreatic tail injury and transection of the inferior mesenteric vein (IMV). The IMV was the main source of bleeding, and ligated. Non-surgical bleeding was controlled with packing of the liver and pancreas. Stomach lacerations were repaired with sutures, small bowel and colon were ligated. Perioperatively the patient received 14 packed cells, 4 FFP and 1 platelets. Despite control of surgical bleeding this patient

Figure 1. Management flow-chart patients with abdominal trauma and a concomitant liver injury.



SNOM: Selective nonoperative management, OM: operative management, RUQ: Right upper Quadrant, ISS: Injury Severity Score, AIS: Abdominal Injury Score, DCS: Damage Control Surgery, DR: Defitive repair, ILOS: Intensive care unit length of stay, HLOS: Hospital length of stay.

developed severe coagulopathy and ischemic SB and colon. The patient's condition could not tolerate an extended hemicolectomie and small bowel resection. He died in the operating room.

The second patient was a 54 year old male who was involved in a motor vehicle accident. He arrived intubated, heamodynamic unstable (SBP 68), GCS 7, core temperature 35,8 °C, BE -11,2, lactate 9,2, pH7,29 and Hb 6,3g/dl. RTS: 4,502, ISS: 34. He sustained an open skull fracture. He responded to initial resuscitation, and received 6 PC and 1 FFP. An urgent computed tomography revealed the following injuries; severe TBI, and Gr III LI, stomach, spleen, pancreas and kidney injuries and a lumbal spine, pelvic fracture, right femur and left tibial fracture. Although this patients was a transient responder to resuscitation the decision was made to withdrawal further treatment because of the extent of injuries and physiologic derangement.

Eighty patients (73 men, 7 women, mean age 26, range 13-57 years) who survived more than 24 -hours were included and further analyzed. Eleven (14%) patients sustained blunt trauma and 69 (86%) penetrating, 7 (10%) due to stab wounds and 62 (90%) gunshot wounds. The median ISS was 21.5 (range 16-32).

In 80 patients 108 high grade injuries in the right upper quadrant of the abdomen were diagnosed, liver (46), extra hepatic biliary tract (2), major vascular (12), right kidney (26), duodenum (10) and pancreas (12). Other associated intra-abdominal injuries diagnosed were stomach (21), diaphragm (15), small bowel (26), colon (17), spleen (13), left kidney (13), ureter (5), bladder (4), vascular (10) and pelvic fractures (4).

Thirty-four (42.5%) patients had isolated abdominal injuries. Forty six (58%) patients sustained injuries in body regions other than the abdomen, included head and neck (n=9), face (n=5), thorax (n=36), and extremities (n=18).

The indications for surgery were hemodynamic instability in 17 (21%) patients, an acute abdomen in 56 (70%) patients, and 7 (9%) patients had CT findings of intra-abdominal injuries that required surgical repair. Fifty-five patients had definitive repair of their injuries, and 25 patients underwent a damage control laparotomy.

The operative procedures in 25 patients who underwent a damage control laparotomy are presented in table 2a. General surgical complications and organ specific complications are presented in table 2b.

Magnitude of Injuries:

Comparing the magnitude of injuries between patients who underwent a damage control laparotomy and patients who had definitive repair, the Injury Severity Score was higher, more abdominal vascular injuries and more high grade liver injuries were diagnosed in patients who underwent a damage control laparotomy, table 3.

Table 2a. Damage control surgical techniques in 25 patients.

- Perihepatic packing: 20
- IVC packing: 4
- Drainage Common Bile Duct Injury
- Kidney packing: 1
- Duodenal primary repair: 3
- Nefrectomy: 6
- Infrarenal IVC ligation: 2
- Distal pancreatectomy: 3
- Colon ligation: 5
- Small bowel ligation: 1

Table 2b. Hundred and four surgical complications occurred in 25, complications classified according Clavien-Dindo classification.

General complications:	**Organ specific complications:**
Grade I: 18	Liver related complications:
Grade II: 29	Biliary fistula: 7
Grade III a: 11	Pseudoaneurysm: 1
Grade III b: 10	Hepatic necrosis:1
Grade IV a: 25	Stricture Common BileDuct:1
Grade IV b: 7	Pancreatic related complications:
Grade V: 4	Peri-pancreatic collection: 1
	Pancreatic Fistula: 2
	Urogenital related complications:
	Urinoma: 1
	Duodenal related complications:
	Anastomic breakdown: 3

Physiological State:

Patients who required a damage control laparotomy were older, presented more often with hypotension, required more frequently intubation to secure the airway, and had greater units of blood transfused. Comparing patients who underwent definitive repair and patients who underwent damage control surgery, a more profound metabolic acidosis was found in patients who required a damage control laparotomy, table 4.

Outcome:

Patients who underwent a DCL had an increased mortality, more surgical complications, liver related complications and duodenal complications. Hospital stay and the number of patients requiring ICU and ICU stay were increased in patients who underwent a DCL, table 5.

Deaths:

Two patients died later during hospital stay (HLOS 12 and 15 days). The first patient was a 35 year old male who sustained multiple gunshotwounds (abdominal, groin and buttocks and extremities). He arrived hemodynamically stable, SBP 138, GCS 15 core temperature 36,5°C, BE:-4,9 , lactate: 4,3 , pH:7,21 , and Hb: 6,6 . RTS:7,841, ISS:26, PATI:38. During surgery he deteriorated and a decision to bail out and perform a damage control laparotomy initiated. He had a Gr V LI, right kidney injury. A nephrectomy was performed and the bleeding liver was controlled with packing. Perioperative the patient received 5 packed cells and 5 FFP. Despite control of surgical bleeding this patient developed

Table 3. General patient`s characteristics and magnitude of injuries.

	DR N=55 (69%)	DCL N= 25 (31%)	P-Value
Sex, N (%)			
M	51 (93%)	22 (88%)	0,67[1]
F	4 (7%)	3 (12%)	
Age in years	**25**	**30**	**0,03[2]**
Mechanism, N (%)			
Blunt	7 (13%)	4 (16%)	0.73[1]
Penetrating	48 (87)	21 (84%)	
Gunshot wound	42/48 (87%)	20/21 (95%)	0.43[1]
Stab wound	6/48 (13%)	1/21 (5%)	
Injury Severity Score	**19**	**26**	**0.002[2]**
Liver Injury, N (%)			
Low	**29/55 (53%)**	**5/25 (20%)**	**0.006[4]**
High	**26/55 (47%)**	**20/25 (80%)**	
Abdominal Vascular Injury, N (%)			
All	**9 (16%)**	**13 (52%)**	**0.001[4]**
Low	2/9 (22%)	3/13 (23%)	1.00[1]
High	7/9 (78%)	10/13 (77%)	
Extrahepatic biliary tree injury, N (%)			
Low	3/3 (100%)	0/2 (0%)	1.00[1]
High	0/3 (0%)	2/2 (100%)	
Pancreatic Injury, N (%)			
Low	12/20 (60%)	7/11 (64%)	1.00[1]
High	8/20 (40%)	4/11 (36%)	
Duodenal Injury, N (%)			
Low	7/14 (50%)	2/5 (40%)	1.00[1]
High	7/14 (50%)	3/5 (60%)	
Right Kidney Injury, N (%)			
Low	10/28	2/10	0.45[1]
High	18/28	8/10	
Bowel Injury, N (%)			
All	22 (40%)	11(44%)	0.74[4]
Small Bowel	18 (33%)	8 (32%)	0.95[4]
Large Bowel	10 (18%)	7 (28%)	0.32[4]
Abdominal Injuries, N (%)			
3 organs	14 (25%)	2 (8%)	0.16[4]
4 organs	11 (20%)	9 (36%)	
5 organs	17 (31%)	6(24%)	
> 5 organs	13 (24%)	8(32%)	

severe abdominal sepsis and required 3 relook laparotomies. Eventually this patient died due to multi organ failure on day 15.

The second patient was a 23 year old male who sustained an abdominal gunshot-wound and precordial stab. He arrived unstable (SBP 89), GCS 14, core temperature 35,8 °C, BE -3, lactate: 4,6, pH:7,31 and Hb:12,2. RTS: 7,108 , ISS:25 PATI:29. He sustained an open

Table 4. Physiologic parameters in 80 patients with severe abdominal trauma comparing patietns undergoing DR versus DCS.

	Definitive repair N=55 (69%)	Damage Control laparotomy n=25 (31%)	P-Value
Blood pressure < 90 mmHg on admission, N (%)	3 (5)	6(24)	**0.02**[1]
Intubation on admission, N (%)	8 (15)	16 (64)	**< 0.0001**[4]
Glascow Coma Scale ≤ 8 on admission, N (%)	1(2)	3 (12)	0.09[1]
Hemoglobin in g/dl, mean (SD)	11 (2)	10 (3)	0.06[2]
pH, mean (SD)	7.34 (0.09)	7.28 (0.08)	**0.01**[2]
Lactate in mmol/L, mean (SD)	2.6 (2.1)	3.9 (2.8)	**0.03**[2]
Base deficit, mean (SD)	- 3.8 (4.0)	-7.0 (4.9)	**0.003**[2]
Blood Transfusion			
N (%)	18 (33%)	21 (84%)	**< 0.0001**[4]
Units of Blood, median, range	0 (0-7)	4 (0-12)	**< 0.0001**[3]

DR: Definitive Repair, DCS: Damage Control Surgery

Table 5. Morbidity in 80 patients undergoing DR versus DCS.

	Definitive Repair n=55 (69%)	Damage Control Laparotomy n=25 (31%)	P-Value
Patients with surgical complications	27 (49%)	24 (96%)	**< 0.0001**[3]
Number of Liver related complications	10 (18%)	10 (40%)	**0.04**[4]
Number of Pancreatic related complications	6/20 (30%)	3/11 (27%)	1.00[1]
Number of Duodenal related complications	0/14 (0%)	3/5 (60%)	**0.01**[1]
Number of Kidney related complications	3/28 (11%)	1/10 (10%)	1.00[1]
Hospital stay in days	10 (4-44)	25 (15-105)	**< 0.0001**[3]
ICU stay in days			
Patients requiring ICU	14 (26%)	25 (100%)	**< 0.0001**[4]
ICU-stay in days	24 (8-44)	25 (15-105)	**0.009**[3]
Mortality	0 (0%)	2 (8%)	0.10[1]

DR: Definitive Repair, DCS: Damage Control Surgery.

skull fracture. He responded to initial resuscitation, was take to the operating room, a laparotomy and sternotomy were performed. The patient arrested 3 times during surgery. A cardiac injury was sutured with pledgets, a diaphragm injury, a grade 5 liver injury, and a pancreatic and gastric injury were identified. He received 12 PC, 7 FFP, and 1 platelets. Despite control of bleeding with packing, this patient developed abdominal sepsis and died due to multi organ failure on day 15 post injury.

DISCUSSION

In a small minority of patients, definitive organ repair cannot be undertaken safely in a patient with a critical physiological status. These patients are more likely to die from their intraoperative metabolic failure than they are from the failure to complete organ repairs. Physiologic behavior, abdominal vascular injuries and major liver injuries dictated the need for a damage control strategy in patients with major abdominal trauma evaluated in our study. Since the introduction of damage control it has been generally accepted that patients with severe injury and physiological derangements are selected for a DCS.[3,4,5,9,19] On the other hand DCS should not be performed in patients who can tolerate DR of their injuries, causing an increase in morbidity and subsequent increase in use of hospital facilities and costs.[10,11]

In liver trauma perihepatic packing has been a well established surgical technique to control liver bleeding.[9] In patients with a complex pattern of injuries control of bleeding is essential, and the severity of trauma and physiological derangements influence the decision to pack and delay definitive organ repair. The first step is recognition of patients in the resuscitation room likely to need a damage control laparotomy. The second step is an exploratory laparotomy and after control of bleeding a rapid assessment to classify the severity of trauma and estimate the time required for definitive repair. At this stage timing to initiate DCS is depending on physiological derangement. Previous studies demonstrated that changes in core temperature, acidosis and coagulation are essential, and initial preoperative temperature, Ph, BE, transfusion requirements, and haemodynamic status are vital, table 1.

Although there is no consensus on a validated definition of polytrauma[20], in this study we defined severely injured patients with a complex pattern of injuries as: three or more organ injuries in the right upper quadrant of the abdomen, AIS >3, and ISS> 15.

This study was performed in a busy level 1 trauma center. The incidence of DCS in this group of patients was 33%. A much higher incidence comparing to the literature 6 -18%.[21] The reason for a higher incidence is most likely influenced by selection, due to the fact that we only selected patients who sustained major abdominal trauma to the right upper quadrant. The overall mortality in patients undergoing DCS was 16%. In the literature the mortality rates for DCS varies from 26% to 67%.[20] The high rate of personal violence, in this series the majority of patients sustained abdominal gunshotwounds comparing to severe abdominal trauma, may be responsible for the better outcome. Mortality following penetrating abdominal trauma is 10%, whereas mortality following severe blunt abdominal exceeds 40%.[7] This may explain a lower overall mortality rate in our study comparing with the literature. However all patients who were selected for damage control surgery and reached the operating room had a 84% survival.

While the number of patients in this prospective series of severely injured patients with a complex injury pattern is low, comparison of small groups in this paper by means of significance testing needs to be interpreted in the light of the very low power to detect statistically significant differences. A clinical interpretation and familiarity with surgical strategies and techniques taught in the DSTC or similar course has to be put upon the comparisons and not just a statistical interpretation.

While an increase in incidence of patients who undergo damage control surgery has been noted, we should be aware for the increase in morbidity in patients who unnecessarily undergo a damage control laparotomy. Despite reports of increased survival after the introduction of damage control surgery and implementation of a damage control strategy in the field of emergency surgery[1,2] few authors conclude that evidence that supports the safety and efficacy of damage control is limited.[21] They call for the need of randomized controlled trials. An RCT would be confronted with the same dilemma, at first overuse of DCS in patients who could also tolerate DR, or vice versa an increase in mortality or morbidity in patients who are selected for DR.

This current prospective single center study did focus on criteria for selection of patients who might benefit from DCS. In conclusion 33% of the severely injured patients with a complex pattern of injuries required a damage control strategy with 84% survival rate. A moderate onset of metabolic failure or hypotension on arrival are not strict indications to perform a DCL. No improvement after hemorrhage control and perioperative resuscitation should alert the operating surgeon to perform a DCL. Physiologic behavior, abdominal vascular injuries, and major liver injuries dictate the need for a damage control strategy.

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Subxiphoid pericardial window to exclude occult cardiac injury after penetrating thoracoabdominal trauma

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ABSTRACT:

Background: An occult cardiac injury may be present in patients with an acute abdomen after penetrating thoracoabdominal trauma. This study assessed the use of a subxiphoid pericardial window (SPW) as a diagnostic manoeuvre in this setting.

Methods: This was a retrospective review of a trauma database (2001–2009). Patients presenting with a penetrating thoracoabdominal injury with an acute abdomen, and in whom there was concern about a potential cardiac injury from the site or tract of the injury, were included.

Results: Fifty patients with an indication for emergency laparotomy underwent a SPW for a possible cardiac injury. An occult haemopericardium was present at SPW in 14 patients (28 per cent) mandating, median sternotomy. Nine cardiac injuries (18 per cent) were identified including five tangential injuries and four perforations. The specific complication rate relating to the SPW was 2 per cent.

Conclusion: The SPW is a useful technique at laparotomy to identify cardiac injuries in patients with penetrating thoracoabdominal injuries.

INTRODUCTION

The reported incidence of combined thoracic and abdominal injuries following penetrating chest trauma is between 6 and 42 per cent1–5. This wide variation reflects the proportion of gunshot wounds (GSWs) included in a particular series. Patients with penetrating thoracoabdominal injuries have a 20–30 per cent risk of cardiac injury where the tract overlies the cardiac silhouette[6]–[10]. The diagnosis of haemopericardium can be made by ultrasonography of the pericardial sac, but the sensitivity and specificity of the test is variable and there is concern about the number of false-negative reports, particularly in association with haemothorax[11]. A subxiphoid pericardial window (SPW) can be performed at laparotomy if there is concern about an occult cardiac injury. The manoeuvre is quick, simple and easy to learn. However, it is invasive and the negative consequences have not been defined. This study investigated how often an occult haemopericardium occurs in patients with thoracoabdominal injuries, and determined adverse effects of SPW.

METHODS

All patients presenting to the Groote Schuur Hospital Trauma Centre between October 2001 and February 2009 with a penetrating thoracoabdominal injury in close proximity to the heart, and an indication for emergency laparotomy but no immediate indication for thoracotomy, were included in the study. All patients were resuscitated according to the Advanced Trauma Life Support (ATLS®) guidelines[12]. The Revised Trauma Score (RTS) was calculated for each patient. Abdominal injuries were graded using the Penetrating Abdominal Trauma Index (PATI), and cardiac injuries by means of the Cardiac Injury Scale in accordance with the American Association for the Surgery of Trauma as outlined[13]. A thoracoabdominal injury was defined as an injury to both the thoracic and abdominal cavities,with or without a concomitant diaphragmatic injury,confirmed either clinically, radiologically or at operation. Indications for emergency laparotomy after penetrating thoracoabdominal trauma were: presence of an acute abdomen, complete spinal cord injury with a penetrating abdominal wound, an unconscious patient with a penetrating thoracoabdominal wound, bowel evisceration, and rectal blood loss. Pneumoperitoneum without abdominal signs was not considered an indication for exploration in a conscious patient in the absence of abdominal signs. Exclusion criteria were: suspicion of cardiac injury but no need for exploratory laparotomy, obvious cardiac injuries presenting with hypovolaemic shock and cardiac tamponade, emergency department thoracotomies, and any indication for urgent thoracotomy. Indications for urgent thoracotomy were: drainage of more than 1·5 litres of blood from an intercostal drain or ongoing bleeding of more than 200 ml/h. A SPW was undertaken when there was concern about the possibility of a cardiac injury, based on the presence of a pericardial effusion on ultrasound examination, a bullet tract in close proximity to the heart, or clinical suspicion because of a raised central venous pressure (CVP) greater than 12cmH2O, electrocardiographic changes, an enlarged heart on chest X-ray or unexplained haemodynamic instability. The SPW was performed via a 6-cm vertical midline incision over the xiphoid process. A Langenbeck retractor was placed under the sternum and elevated. A sponge on a stick was found to be particularly useful for wiping away the fat pad from the inferior portion of the pericardium. The pericardium was incised under direct vision vertically for approximately 4 cm. If the SPW was negative and the patient stable, this wound was closed before laparotomy to limit possible contamination of the pericardium. A positive SPW was defined as the presence of blood in the pericardial sac in the form of active bleeding, blood clots or blood staining of the pericardial fluid. A falsepositive ultrasound examination was defined as presence of fluid in the pericardial sac without haemopericardium at SPW and in the absence of pre-existing pericardial disease. A median sternotomy was performed if a haemopericardium was found atSPWin the acute setting. Sternotomywas done before laparotomy if there was active bleeding from the pericardial sac. If there was no active bleeding from the pericardium in a haemodynamically unstable patient, laparotomy was undertaken first, before sternotomy. When sternotomy was indicated, full inspection of the heart was carried out, including the posterior surface. The anaesthetist was warned before elevating the heart of the circulatory collapse that accompanies this manoeuvre.

RESULTS

Between October 2001 and February 2009, a total of 348 patients underwent surgery for an obvious or suspected penetrating cardiac injury. Some 157 patients required either an emergency department thoracotomy or emergency surgery. Fifty of the 157 patients had sustained thoracoabdominal trauma with an indication for emergency laparotomy, and underwent a SPW to exclude possible cardiac injury. The indication for the emergency exploratory laparotomy was an acute abdomen in 48 patients, bowel evisceration in one patient, and a penetrating abdominal injury in an unconscious patient. There were 47 men and three women, with a mean age of 25·6 (range 15–44) years. Forty-one patients (82 per cent) sustained GSWs and nine (18 per cent) had stab wounds in the thoracoabdominal region. The median RTS was 7·84 (range 2·93–7·84). The site of the stab wounds was: left thoracoabdominal (3), upper epigastrium (2) and multiple sites (4). The low-velocity GSWs were left thoracoabdominal (17), right thoracoabdominal (5), transmediastinal (5) and at multiple sites (14). Twenty-one patients were shocked on

Table 1 Indications for subxiphoid pericardial window

	No. of patients	SPW positive	SPW negative
Bullet tract in proximity to heart	22	2	20
Ultrasonography showing haemopericardium	6	5	1
Clinical suspicion based on ECG, CVP or chest X-ray	20	7	13
Unexplained haemodynamic instability	2	0	2
Total	50	14	36

SPW, subxiphoid pericardial window; ECG, electrocardiography; CVP, central venous pressure.

presentation, four had distended neck veins, 11 had a CVP greater than 12cmH2O, five had an enlarged heart on chest X-ray, and non-specific ST-segment electrocardiographic changes were present in 13 patients. Pericardial ultrasonography (focused assessment with sonography for trauma, FAST) was performed in nine patients and in six there appeared to be blood in the pericardial sac. Indications for the SPW are shown in Table 1. The commonest reasons were a bullet tract in proximity to the heart (22 patients), clinical suspicion (20) and a positive ultrasound examination (6). The SPW was positive for blood in the pericardial sac in 14 of the 50 patients (28 per cent). Of these, two had multiple stab wounds, one had been stabbed in the epigastrium, seven patients had multiple GSWs, two had been shot in the left thoracoabdominal area and two had sustained a transmediastinal GSW. Nine patients had the SPW incision extended into a median sternotomy (Fig. 1). In these nine patients there were three tangential injuries to the right and two to the left ventricle (grade 2), three perforating injuries to the right ventricle (grade 4), and one hole in the left ventricle (grade 5). Median sternotomy was not undertaken in five of the 14 patients despite the SPW being positive for blood. Two patients had sustained stab wounds and three had GSWs. Three patients had a positive FAST, and in one computed tomography of the chest documented a pericardial effusion. In the three patients with GSWs the surgeon felt that the positive haemopericardium was due to a cardiac contusion as the tract of the bullet through the diaphragm was well away from the heart. One patient had a stab wound to the epigastrium with an acute abdomen, and FAST showed a10-mm effusion. At laparotomy there were injuries to the stomach and left diaphragm. The SPW was positive for blood, but on irrigation of the sac there was no active bleeding and no injury to the anterior surface of the heart was visualized through the SPW wound. The other patient had multiple stab wounds with a 15-mm effusion on FAST and an acute abdomen. The laparotomy was negative but the SPW was positive for blood. There was no active bleeding on irrigation and the surgeon decided against a sternotomy. During laparotomy 110 intra-abdominal injuries were diagnosed. The liver was the most frequently injured organ (25 patients), followed

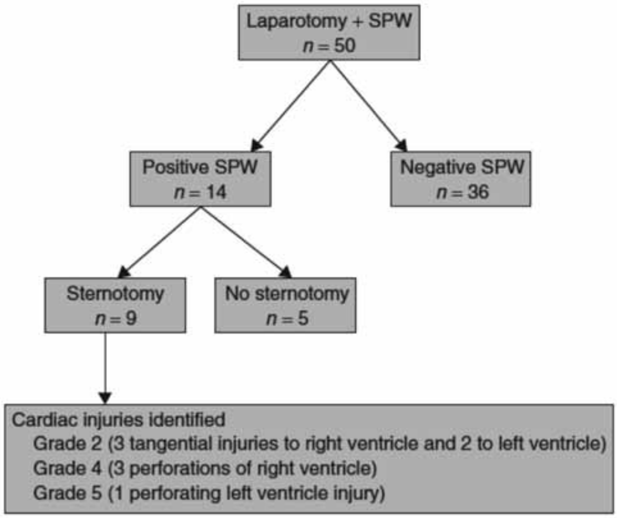

Fig. 1 Surgical management of the 50 patients. SPW, subxiphoid

by the colon (16) and the stomach (15). The mean PATI was 14·7 (range 0–37). Associated thoracic injuries were found in 37 patients (74 per cent), including 13 haemothoraces (26 per cent) and 11 pneumothoraces (22 per cent) (Table 2). The median duration of hospital stay for patients with a positive SPW was 7 (range 4–23) days, and the median length of ICU stay was 1 (0–20) days. The 36 patients who underwent a negative SPW had a median hospital stay of 6 (4–15) days, and the median ICU stay was 0 (0–9) days. One patient (2 per cent) suffered a cardiac-related complication (tension pneumopericardium) after a negative SPW. This necessitated a second SPW to relieve the cardiac tamponade. The patient was discharged after 6 days without the need for surgical intensive care. There were no cardiac complications among the five patients who merely had drainage of the pericardial sac after a positive SPW. Their mean hospital stay was 6 (4–7) days. One of these patients contracted pneumonia that responded to treatment, and another developed an ileus that settled with conservative management. The complication rate associated with the performance of SPW was 2 per cent. The overall mortality rate in this series was 8 per cent (4 patients). All of these patients died as a result of massive blood loss within 24 h after admission following a damage control strategy to deal with the major intra-abdominal injuries. One patient had a hole in the right ventricle, with an extensive parenchymal liver injury (grade 5) as well as stomach, colon and small bowel perforations. The other three had no cardiac injury.

Table 2 Thoracoabdominal injuries

	No. of patients
Chest	
Cardiac	14
Haemothorax	13
Pneumothorax	11
Abdomen	
Solid organ	32
Bowel	29
Diaphragm	19
Vascular	4
Other region	
Maxillofacial	4
Neurological	2

DISCUSSION

Diagnosing a cardiac injury can be difficult, especially in patients with hypovolaemia and associated abdominal injury. Beck's triad, the classical presentation of cardiac tamponade comprising hypotension, raised jugular venous pressure and muffled heart sounds14, may be present, and ultrasonography of the pericardial sac as part of the FAST is safe, precise and quick. The results of cardiac ultrasound examination depend on the experience of the investigator, machine resolution, and presence of chest wall injuries, surgical emphysema, obesity, pneumothorax and haemothorax[15]. Ultrasonography was used to detect pericardial effusion in only nine patients in the present series owing to lack of expertise in the emergency room. Asensio and colleagues[16] published a series of thoracoabdominal trauma and only 16 per cent of their patients underwent ultrasonography before surgery. This low figure may also represent concern over whether a negative ultrasound examination was in fact truly negative, when over two-thirds of patients had associated haemopneumothoraces. According to the medical literature the sensitivity and negative predictive value for SPW is close to 100 per cent. The present study demonstrated a sensitivity of 100 per cent and a negative predictive value of 100 per cent for SPW in excluding cardiac injuries. The complication rate following a SPW has been described as neglible[6,7,17,18] . In the present series the cardiac-related morbidity rate was 2 per cent with no negative chest explorations. The mortality rate was only 8 per cent despite the fact that 82 per cent of patients had sustained GSWs. Other studies have reported mortality rates as high as 59 per cent where there have been combined procedures, although this also obviously relates to the severity of the injury and the physiological status of the patient. Although it is not possible to draw firm conclusions from the data presented, the low mortality rate of 8 per cent may be related to the screening ability of the SPW to exclude cardiac injury and prevent the chest from being opened unnecessarily. There is concern over the fact that 72 per cent of the SPW procedures were negative, but at the same time it was essential to exclude cardiac injury. It remains unresolved whether to have a two-team approach, with one managing the chest and the other the abdomen. Furthermore, it is unclear which cavity should be managed in the first instance if there is only one surgeon. Saadia and colleagues[19] have suggested that intra-abdominal haemorrhage should take precedence over cardiac tamponade. Certainly any intra-abdominal bleeding should take precedence but, if this is not encountered, a cardiac reason for the shock should be considered with a proximity wound and a SPW done. The present authors favour the classical (as opposed to the transdiaphragmatic) approach because it may prevent contamination of the pericardial sac from peritoneal soiling. The authors have completed a randomized clinical study to determine whether a sternotomy is required in stable patients presenting with haemopericardium, or whether they can be managed purely with a SPW and washout of the pericardial sac. This study was conducted over the same interval as the present study and included a highly selected group of patients, namely haemodynamically stable individuals who could be observed for 24 h in a high-care unit after which a SPW was done. The results suggest that this specific group of stable patients can be managed successfully without a sternotomy, as documented previously in small pilot study[20]. Thorson and co-workers[10] from Miami in the USA have also questioned the need for mandatory sternotomy in every stable patient diagnosed with haemopericardium[10]. However, the present authors would like to stress, in patients presenting with an acute abdomen and a positive SPW, that sternotomy should be performed unless a very experienced surgeon is confident that the tract is away from the heart.

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CHAPTER 6

ILLUSTRATIONS

Blunt abdominal trauma leading to traumatic transection of the liver without massive hemorrhage

Hommes M, Goslings JC, van Gulik TM

J Trauma 2008

INTRODUCTION.

The liver is the most commonly injured organ after abdominal trauma. Nonoperative management of blunt liver trauma in hemodynamic stable patients has now evolved into a common practice. In this case, we report a patient who sustained blunt abdominal trauma leading to a high grade liver trauma dividing the liver along the middle intersegmental line (Cantilie's line) without massive hemorrhage. This phenomenon supports the policy of nonoperative management of liver injuries in hemodynamically stable patients, regardless of the American Association for the Surgery of Trauma (AAST) grade of the injury.

CASE REPORT

A 20-year-old cyclist sustained blunt abdominal trauma with handlebar impact. She presented at the emergency department hemodynamically stable and was managed according to the Advanced Trauma Life Support. Contrast-enhanced computed tomography (CT) scan (Fig. 1) of the abdomen revealed a fracture of the liver along the border between the medial segment of the left liver lobe (segment IV) and the medial segments of the right liver lobe (segments V and VIII). The fracture line corresponds to Cantilie's line, which, according to surgical anatomy of the liver, divides the liver into the anatomic right and left halves. Besides the severe liver trauma, there were signs of concomitant injury of the pancreatic body. Additional injuries included a pneumothorax, severe head injury, an unstable fracture of the spine (T10), and a fracture of the right femur. Then, 24 hours posttrauma, an exploratory laparotomy was performed

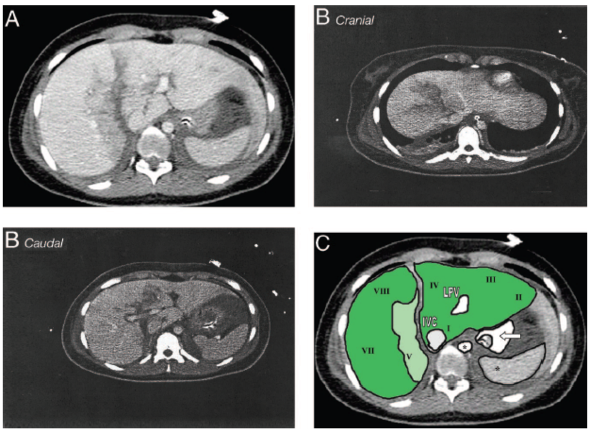

Fig. 1. *(A) Contrast-enhanced computed tomography (CT) scan of the abdomen revealed a fracture of the liver along the border between the medial segment of the left liver lobe (segment IV) and the medial segments of the right liver lobe (segments V and VIII). (B) Two additional CT cuts, cranial and caudal of the CT section shown in A, respectively. (C) IVC, inferior vena cava; LPV, left portal vein; arrowhead, stomach with nasogastric tube; *, aorta; +, spleen.*

because of suspicion of pancreatic disruption in a patient who had otherwise remained hemodynamically stable since admission. Remarkably, no intra-abdominal blood was found at laparotomy. The Glissonian capsule of the liver was intact showing signs of an intraparenchymal hematoma in segments IV, V, and VIII. Resection of pancreatic body and tail was performed for total disruption of the pancreaticbody. Further exploration excluded any additional intra-abdominal injuries. After a total hospital stay of 30 days, the patient was discharged in good clinical condition.During the follow-up period of 1 year, no complications were recorded. Follow-up imaging studies were not obtained to avoid unnecessary irradiation.

DISCUSSION

This patient had sustained a grade III pancreatic injury and a grade V liver injury according to the Organ Injury Scale of the AAST.[1,2] In spite of high grade hepatic trauma virtually splitting the liver along the line of Cantilie, no major hemorrhage or bile leakage occurred demonstrating the separate segmental vascular and biliary anatomy of the liver as established by Couinaud. In 1953, Couinaud, a French surgeon, provided the basis of surgical anatomy of the liver. Through numerous dissections of the liver, he defined the segmental anatomy of the liver as dictated by the distribution of the hepatic veins and Glissonian pedicles (Fig. 2). Each segment has a separate pedicle consisting of afferent branches of the portal vein and hepatic artery, and efferent veins draining into the hepatic venous system. The bile is drained through the segmental biliary ducts, eventually flowing into the hepatic duct confluence. The middle hepatic vein defines the plane through the anatomic middle of the liver dividing the liver in a right and left liver lobe. Thus, the liver segments are separate functional units with a relatively avascular plane in between.[3] During partial liver resections, this segmental division of the liver is respected and the lines of parenchymal dissection are preferably chosen according to the avascular intersegmental planes to minimize blood loss. Sherlock et al. described two mechanisms of liver injury resulting from blunt abdominal trauma. First, deceleration injuries usually cause tears between the posterior sector (segment VI and VII) and anterior sector (V and VIII) of the right liver lobe. Secondly, a direct blow to the abdomen can lead to a crush injury of the central anterior portion of the liver (segments IV, V, and VIII), whereas compression of the lower ribs and spine can cause liver injuries of the caudate lobe.[4] The patient presented here had a liver laceration incidentally running along the plane between the right and left hemi-liver in between the Couinaud segments V and VIII on the right and segment 4 on the left side. The image on CT showed a complete fracture of the liver with an intraparenchymal hematoma at the fracture site, however, without any extravasation of contrast as evidence of massive bleeding. This was confirmed during laparotomy, at which time no blood was present in the abdomen and the liver capsule was found to be intact. Complications such as major bleeding or hemobilia, biliary fistula, or biloma after bile leakage in thishigh-grade liver injury did not occur. The lesson learned from this case of a major liver trauma dividing the liver along the middle intersegmental line (Cantilie's line) is that, owing to segmental anatomy, the patient sustained a contained intraparenchymal liver bleed without massive hemorrhage. This phenomenon supports the policy of nonoperative management of liver injuries in hemodynamically stable patients, regardless of the AAST grade of the injury.

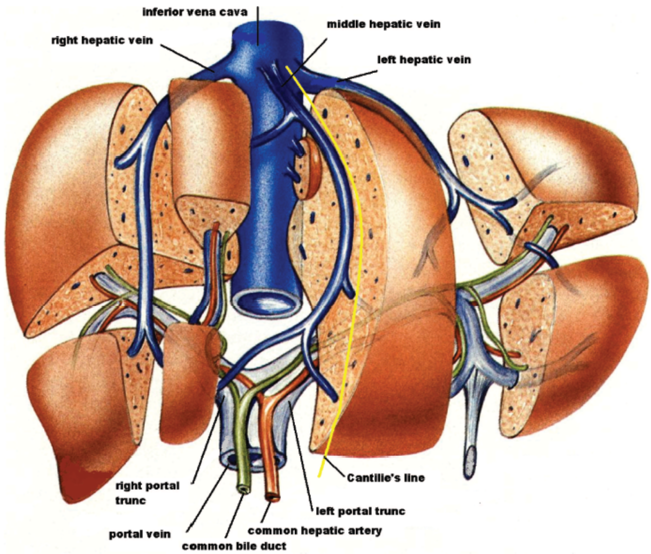

Fig. 2. *Segmental anatomy of the liver. Each segment (I–VIII) has a separate pedicle consisting of afferent branches of the portal vein and hepatic artery, and efferent veins draining into the hepatic venous system. Cantilie's line indicating the plane of the middle hepatic vein defines the anatomic middle of the liver and divides the liver into a right and left liver lobe.*

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Complex liver trauma with bilhemia treated with perihepatic packing and endovascular stent in the vena cava

Hommes M, Kazemier G, van Dijk LC, Kuipers EJ, van Ijsseldijk A, Vogels LM, Schipper IB

J Trauma 2009

INTRODUCTION.

Liver trauma associated with juxtahepatic venous injury is the most challenging form of all cases of liver trauma. There is still controversy as to the best operative approach for controlling this bleeding and to prevent the patient from an unsalvageable metabolic state of hypothermia, coagulopathy, and acidosis. This case report supports the intraoperative implantation of a stent graft in the juxtahepatic inferior vena cava (IVC) as adjuvant for perihepatic packing in the unstable patient suffering liver trauma with juxtahepatic venous injury. Because of the better survival of the patients with severe liver trauma, more complications such as biliary leakage are seen. As a result of the injury, this patient suffered bilhemia successfully treated with temporary endoscopic biliary stenting and sphincterotomy.

CASE REPORT

A 29-year-old female presented at the emergency department a Level I trauma center. The patient was stabbed with a knife in the right upper quadrant of the abdomen and subsequently jumped of a tree meters high balcony. The patient was managed according to the principles of the "advanced trauma life support" and treatment started with a chest tube for a pneumothorax on the right side. In the emergency room, she developed significant tachycardia and prolonged hypotension irresponsive to fluid resuscitation. The patient was transferred to the operating theater. During laparotomy, a parenchymal laceration was seen through segment V and VIII of the liver also affecting the intraparenchymal right hepatic and portal vein. On palpation, the liver injury extended to the bare area of the liver, indicating juxtahepatic IVC injury. Packing of the right liver lobe in combination with vascular inflow occlusion of the portal triad "Pringle Maneuver" diminished hemorrhage considerably, but there was ongoing retrohepatic bleeding from the laceration of the juxtahepatic IVC. Intraoperative endovascular implantation of a stent graft in the IVC was successful to control this bleeding. The IVC was reached by cannulation of the right femoral vein. By means of selective cannulation and contrast injection, the exact location of both the renal veins and the three major hepatic veins was established with (mobile C-arm) fluoroscopy. The !7-cm long part of the IVC between the hepatic and renal veins was covered with two overlapping stent grafts each with a diameter of 32 mm and a length of 45 mm. Those stents are normally used as proximal aortic extenders for endovascular treatment of abdominal aortic aneurysms (GorePXA320400, W.L. Gore Inc., Flagstaff, AZ). The liver parenchyma was sutured on the anterior side to control bleeding from the right hepatic and portal vein. Subsequently, the liver was packed, and on table angiography showed no additional bleeding from the right hepatic artery. The patient was transferred to the surgical intensive care for secondary resuscitation. Because of excessive blood loss (14 L) and transfusion with blood products, leading to evident coagulopathy, the patient was treated with recombinant activated factor VII. Forty-eight hours after the primary intervention and after the correction of acidosis, hypothermia, and coagulation disorders, a second look was performed and the packing removed. Secondary survey had revealed a mid shaft fracture of the left humerus, which was immobilized with a plaster cast. A computed tomography scan of the liver showed an intrahepatic portosystemic shunt between the right portal vein and right hepatic vein. A patent stent was visualized in the juxtahepatic IVC (Fig. 1). On the 10th postoperative day, she developed high fever (42.5°C) with severe hyperbilirubinemia (933!mol/L, upper limit of normal 20 !mol/L). Investigation by means of an endoscopic retrograde cholangiopancreaticogram (ERCP) revealed an intrahepatic biliovenous fistula between the right nterior bile duct and the right hepatic vein. Therefore, the patient was treated with endoscopic papillotomy and retrograde introduction of a 15 cm, 7 Fr plastic stent in this right anterior bile duct with the proximal end of the stent placed at the location of the fistula (Fig. 2, A and B). The serum bilirubin level subsequently dropped below 250 !mol/L within 12 hours after stent placement and became normal within 3 days. The bile duct stent was removed after 13 days. Because the patient developed fever, there was the suspicion of an infected stent. During this ERCP, the biliovenous fistula was no longer visible, and no new stent was introduced. The patient was discharged in good clinical condition 61 days after hospital admission with normal liver biochemistry.

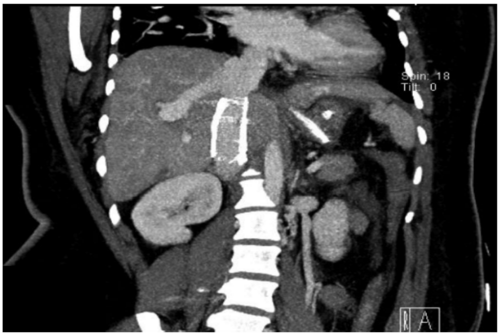

Figure 1. Computed tomogram: endovascular stent is present in the juxtahepatic inferior vena cava.

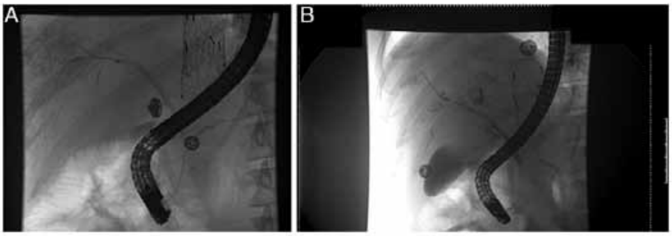

Figure 2. (*A*) ERCP reveals an biliary leakage from the right anterior bile duct. (*B*) Endoscopic retrograde cholangiopancreaticogram biliary stent present in the anterior right hepatic duct.

DISCUSSION

This patient sustained a complex liver injury with damage to the retrohepatic IVC, the portal and hepatic vein, and the intrahepatic biliary tract. The discussion is divided into two parts. First, the treatment of traumatic injuries of the IVC, and second, biliary complications such as bilihemia after trauma are discussed. First, injuries of the IVC are often fatal. The majorities of patients arrive in shock and fail to respond to initial resuscitative measures. Most are still actively bleeding at the time of laparotomy and have a low probability of survival.[1] According the American Association for the Surgery of Trauma, grade V liver injuries are defined as parenchymal disruption involving "75% of hepatic lobe or more than three Couinaud's segments within a single lobe and vascular laceration of the juxtahepatic venous structures such as the retrohepatic IVC or hepatic veins.[2] High mortality rates of juxtahepatic venous injuries are caused by the surgically inaccessible anatomic location of this area.[3] An attempt to mobilize the right liver half to expose the juxtahepatic veins tends to increase hemorrhage. For the critically injured exsanguinating patient approaching the triad of hypothermia, acidosis, and coagulopathy, damage control surgery requires to control arterial bleeding and perihepatic packing to save the patients' life. Direct juxtahepatic venous repair with or without vascular isolation is associated with high mortality. Performing lobar resections for exploration of the juxtahepatic IVC is not recommended to control bleeding. Perihepatic gauze packing is prescribed as the preferred method to control hepatic venous bleeding.[3] The successful use of endovascular stenting for the injured juxtahepatic IVC has been described in few publications.[4,5] In 1997, Denton et al.[6] reported the use of an endovascular stent to repair the injured juxtahepatic IVC, days after perihepatic packing. Second, as a result of improved survival after severe extensive hepatic parenchymal damage, there is an increased incidence of complications resulting from extensive liver parenchymal damage that has intentionally been left untreated, including persistent hemorrhage, intrahepatic and perihepatic abcesses, bile leakage as biloma, biliary fistula, bilihemia, and hemobilia. Many of these problems can be managed by interventional techniques that are less invasive than a laparotomy, including arteriography and selective embolization, a computed tomography-guided drainage of infected collections, and an ERCP combined with biliary stenting and sphincterotomy.[7] Biliary leakage is often defined as the presence of bile in the abdominal drainage fluid or the presence of free bile in the peritoneal cavity. Adequate drainage is an important measure to control biliary leakage. An excessively high serum level of direct bilirubin and only moderately elevated liver enzymes indicate bilihemia in trauma patients. Successful use of an ERCP and stenting of the papilla in patients with bile leak after liver trauma has been described.[8] In this case, a biliovenous shunt was diagnosed.because the goal in the management of post-traumatic bilihemia is to decrease the intraluminal pressure in the bile ducts to avoid shunting of bile into the bloodstream, endoscopic therapy of bilhemia using an ERCP endostenting and sphincterotomy is a therapy that can be performed safely for patients with bilhemia.

CONCLUSION

The unstable patient with a grade V liver injury associated with a laceration of the juxtahepatic IVC carries an inordinately high mortality. In desperate cases where packing will not control bleeding, the implantation of an endovascularstent as adjuvant for perihepatic packing to control bleeding can be a life saving option. Bile leaks are seen more often after severe liver trauma. First because of progress in the treatment and better survival of complex liver injuries and second because the intentionally untreated hepatic parenchyma including the vascular and biliar components. In this case, intravascular biliary leakage was successfully treated with temporary stenting of the bile duct combined with a sphincterotomy.

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CHAPTER 7.

GENERAL DISCUSSION AND FUTURE PERSPECTIVES

The liver is the most commonly injured organ following abdominal trauma.[1,2] Following the results of this thesis nonoperative management, perihepatic packing and delayed direct repair of juxtahepatic venous injuries have reduced mortality associated with liver bleeding. In order to pursue the right management strategy for each individual patient, the surgeon treating a severely injured patient with a liver injury will rapidly have to make several critical decisions. Most liver injuries can be managed nonoperative and do not require a surgical intervention by explorative laparotomy. A minority of bleeding liver injuries requires surgical repair, and direct repair of visible bleeding vessels and leaking bile ducts is recommended to reduce the risk of intrahepatic complications. The optimal management of patients with serious liver injuries therefore is still debated.[16,17,18,19,20] During the last two decades a paradigm shift in the management of liver trauma has occurred, from operative management - repairing liver injuries - to nonoperative management. The introduction of intermittent inflow occlusion[3] facilitates direct repair of liver injuries, but high mortality was noted in operative management of the high grade liver injuries.[4,5,6,7] The observation that many non-therapeutic laparotomies were performed after the introduction of diagnostic peritoneal lavage[8], and the introduction of computed tomography for the purpose of preoperative diagnostics, has led to a more conservative approach, which resulted in with better outcomes.[9,10] However, advanced surgical and radiological techniques, improvement of surgical critical care and the concept of damage control surgery have also helped to increase survival in patients with a serious liver injury.[11] Various studies have shown an improved outcome both after nonoperative management and damage control surgery.[12,13,14,15]

The central theme of this thesis is how to assess patients with liver injury and how to select the best treatment: nonoperative management, definitive repair or damage control laparotomy. First the preoperative assessment of patients and selection of the optimal treatment will be discussed, then the surgical techniques and strategies to achieve hemostasis. Lastly the treatment of liver related complications will be discussed.

Preoperative assessment of patients and selection of optimal treatment

Various symptoms warrant surgery in patients with abdominal trauma: Haemodynamic instability, generalized peritonitis, worsening metabolic acidosis during resuscitation or CT findings showing associated intraabdominal injuries requiring surgical repair. The role and added value of preoperative computed tomography in patients with abdominal trauma with the abovementioned symptoms is unclear.

In the beginning of the previous century local tenderness and hemodynamic instability were used as indicators to perform an exploratory laparotomy.[5,21,22,23] In the mid-sixties a positive for blood DPL was also used as an indicator.[8] While DPL is very sensitive, a high rate of non-therapeutic laparotomies for solid organ injuries in patients with blunt abdominal trauma was noted. Current diagnostic imaging techniques used are ultrasound (FAST) and CT scanning. CT scan of the abdomen is the optimal diagnostic method to aid in both the diagnosis and management of blunt hepatic trauma in hemodynamically stable patients[24] CT scanning is more specific than ultrasound, which does not predict the source of bleed, and is therefore essential for surgeons, who need to decide on nonoperative treatment of patients with blunt or penetrating solid organ injuries.[25,26] In this thesis only 10 % of patients selected for operative management had a preoperative CT scan showing injuries requiring surgical repair, the other 90 % presented with hemodynamic instability or generalized peritonitis and underwent surgery without preoperative computed tomography. In the literature hemodynamic instability and generalized peritonitis[27] after abdominal trauma is a level 1 recommendation for urgent laparatomy.[28] CT scanning greatly facilitates diagnosis and grading of solid organ injuries, but the main concern remains missing a hollow organ injury.[10,29,30,31]

Some authors recommend a preoperative computed tomography in all hemodynamically stable patients regardless of clinical findings such as generalized peritonitis.[32] We do not support this recommendation. A preoperative CT scan in a patient with peritonitis should be based on the surgeon's experience and preference for preoperative planning. In our experience 90 % of patients with a clinical indication for an urgent laparotomy did not have a preoperative CT scan. With this approach an acceptable 5% of the patients underwent unnecessary laparotomies.

Nonoperative management of severe blunt liver injuries is on the increase with a similar increment in failure and the need for a delayed laparotomy. Several authors have described hypotension on admission as a predictor of failing NOM. For this reason, NOM has been prompted with the caveat that patients must be hemodynamically stable.[33,34,35,36,37] In this study hypotension on arrival itself was not a predictive factor for failing NOM in patients who respond to resuscitation. Although encouraging results from pioneers treating selected hemodynamically unstable patients under hypotensive resuscitation[38], persistent hemodynamic instability warrants an urgent laparotomy. Nonoperative management of BLI should be considered irrespective of the grade of liver trauma. In our study liver related complications contributed to failure of NOM, but could not predict failure of NOM. Other authors reported no liver related failure of NOM.[39] The presence of associated intraabdominal and extraabodminal injuries do not render nonoperative management inapplicable for patients with a liver injury, although associated intraabdominal injuries (spleen) do contributed to failing NOM.

Nonoperative management of blunt solid organ injuries is widely accepted. Conversely, SNOM of penetrating solid organ injuries and penetrating liver injuries has not been widely practiced, but it use has evolved over the last two decad es.[40,41,42,43,44,45,46,47,48,49,50] The use of CT scanning permits the missile tract to be outlined, and detects liver injuries for NOM, irrespective of the grade of injury.

Nevertheless, despite the modern imaging techniques, the level of accuracy and sensitivity for diagnosing bowel injuries following penetrating abdominal trauma remains a source of concern. The surgeon must appreciate the risks of NOM of penetrating liver injuries and possess the resources to address potential complications without delay. Contrary to blunt abdominal injury, successful NOM of penetrating abdominal injuries, with or without advanced CT technology present, is still largely based in the findings from serial clinical complications.

Surgical Technique & Strategy

Despite the high success rate of selective nonoperative management of liver injuries, an exploratory laparotomy is indicated in the majority (75%) of patients following penetrating abdominal trauma and minority (25%) of patients following blunt abdominal trauma.[38, 51,52] The liver is the most commonly injured organ following abdominal trauma and subsequently there is a considerable chance that the general surgeon will be confronted with an injured liver, when performing an exploratory laparotomy.[1,2] Early recognition of the magnitude of complex liver injuries, and excluding or treating perihepatic injuries is essential. Once inside the abdomen, the first priority is to achieve temporary hemostasis, evacuate blood, and eviscerate the bowel. With blunt trauma, begin with packing and with penetrating trauma eviscerate and determine where the bleeding is coming from.[53] When there is a significant liver injury pack the liver temporarily and rapidly assess the rest of the abdomen before focusing on the liver injury. In the following section, the surgical approach to a bleeding liver, the surgical strategy in patients with penetrating thoracoabdominal trauma and patients with a complex pattern of injuries will be discussed.

The options for initial hemorrhage control described in textbooks and instructed at courses are manual compression, temporary packing and inflow occlusion–Pringle maneuver.[54,55,56,57] Perihepatic packing does not control arterial bleeders. Ligation of visible vessels has been used to treat arterial bleeding from the liver, control of deep arterial intrahepatic bleeding is often very difficult to achieve.[58,59,60,61] Inflow occlusion described by Pringle, facilitates the diagnosis and surgical management of arterial and venous bleeding.[62,63] In this thesis the results of ligation of visible bleeding vessels in combination with or without inflow control was successful and limits the use of postoperative angiography and subsequent embolization.

Diffuse bleeding from a damaged or devitalized liver requires surgical treatment. Some authors advocate performing resections[33,64] but the high mortality rate led to discontinuation of this treatment in most centers.[65,66] In our experience non-anatomical hepatic resection or debridement was reserved as surgical treatment during re-look and return to the operating theatre for removal of packs. Resections should not be used not as primary surgical tool to achieve hemostasis due to the risk of unexpected blood loss in an already uncompromised trauma patient.

An increased awareness of the need to institute damage control procedures in the unstable patient has most likely led to a higher incidence of patients who undergo liver packing. There is a desire to remove the liver packs as soon as possible, but the risk of septic complications[67,68] the cardiopulmonary benefits[69,70] and the risk of re-bleed requiring repeat liver packing have to be weighed against each other. The results of the retrospective study were incorporated in the prospective study and showed that the first re-look laparotomy should be performed only after 48 hours, creating a minimum risk of rebleeding and keeping risks of septic complications as low as possible.

When dark blood is flowing from behind the liver after inflow occlusion, a venous bleeding is highly suspected. Juxtahepatic venous injuries are uncommon, but tend to be highly lethal. Widely mentioned is the application of atriacaval shunts in the management of these injuries. Few authors report successful results on shunting[71,72] and others have reported successful direct repair of venous injuries without the necessity performing a sternotomy[73,74]. A safe surgical approach is starting out with damage control, containment by tamponade using packs, followed by direct repair, when feasible after resuscitation and after an experienced team has been mobilized.[75] When in the near future the availability of hybrid operating theatres will increase, more advanced techniques such as endovascular stenting of the juxtahepatic vena cava will be included in the trauma surgeon's toolbox. This will most probably again change the surgical approach to abdominal trauma.

Injuries of the abdomen and chest can be a double jeopardy for the trauma surgeon. Most patients with thoracoabdominal trauma are successfully managed by thorax drainage followed by laparotomy. About one-third of the patients will need a surgical intervention in both chest and abdomen.[76] In patients with penetrating thoracoabdominal injuries with suspicion of occult cardiac injury and acute abdomen, it remains unresolved whether to have a two team approach, with one managing the chest and the other the abdomen. Furthermore, it is unclear which cavity should be managed in the first instance if there is only one surgeon. Any intraabdominal bleeding should take precedence but if, this is not encountered, a cardiac reason for the shock should be considered and a SPW done.[77]

A trauma operation follows a generic sequence of reproducible steps – access to abdomen, control of bleeding, prevent contamination, define injury pattern, urgency and time for repair, and physiological impact - followed by a strategic decision; definitive repair or damage control surgery.[78] Evidence that supports safety and efficacy of DCS compared with traditional laparotomy is supported by Class 2 and 3 level of evidence.[11,79,80,81,82,83,84,85,86] While an increase in incidence of patients who undergo damage control surgery has been noted, we should be aware of the increase in morbidity in patients who unnecessarily undergo a damage control laparotomy. Despite reports of increased survival after the introduction of damage control surgery and implementation of damage control strategies in the field of emergency surgery [87,88,89] few authors conclude that evidence that supports the safety and efficacy of damage control is limited.[90] They call for the need of randomized controlled trials. An RCT would be confronted with the same dilemma, at first overuse of DCS in patients who could also tolerate definitive repair (DR), or vice versa an increase in mortality or morbidity in patients who are selected for DR. Approval of such RCTs by a Human Research Ethics Committee would not be granted. Currently the indication for DCS is dictated by the patient's physiologic behavior, the presence or absence of major liver injuries and vascular injuries, and concomitant injuries.

Angiography and embolization

Hepatic angiography is a useful addition to perihepatic packing or nonoperative management.[91,92,93,94] Although mortality related to angioembolization is reported to be low, concern has been expressed about the considerable morbidity.[15,95,96] Indications for angiography in abdominal trauma patients vary among institutions, but often include the presence of contrast blush on CT scans and patients who have required multiple blood transfusion. A contrast blush on a CT scan is considered a significant sign of bleeding, and should be followed immediately by angiography and possible embolization, despite the potential liver related sequels. Other researchers describe that 50% of patients with a contrast blush required an intervention, and hypotension on arrival. Severe abdominal trauma and a blush diameter of 1,5 cm or greater predicted the need for intervention.[97]

The role of postoperative angiography described in this thesis is limited. This is owing to the fact that, an active surgical management policy with ligation of visible vessels, rendered early postoperative angiography rarely necessary. In this study we did not perform routine angiography either. This adjunct diagnostic tool was used only on indication. Embolising a blush seen on a routine computed tomography should be related to clinical and radiological signs (blush diameter > 1,5 cm)[94]. Furthermore physicians need to recognize that an angiography is not a benign procedure - contrast nephropathy and risk of acute renal failure - especially in a multiple injured, postoperative critically ill patient admitted for secondary resuscitation in a surgical intensive care or high care unit. In our studies an early postoperative angiography was performed in only one of the 183 patients with penetrating liver injuries. The angiography was performed after a Sengstaken-Blakemore balloon was used to tamponade the wound tract, without signs of intravenous contrast extravasation (IVCE). This alternative technique has been presented as a successful treatment to control liver hemorrhage by several authors.[98,99]

Liver related complications

Biliary leakage and delayed bleeding following to blunt or penetrating hepatic trauma and severe damage to the intrahepatic parenchyma remain challenging problems. Delayed complications can occur days to weeks after trauma and they include delayed vascular and biliary complications, which can mostly be treated safely with less invasive techniques than laparotomy.[38,100,101,102]

Post traumatic hepatic artery pseudo aneurysm is an uncommon delayed complication. Pseudo aneurysm detected by CT should be treated as early as possible,[10,103] since occasionally hepatic artery pseudo aneurysms can become symptomatic.[93,96,104] In this thesis all six patients with pseudo aneurysm presented with symptoms (a fall in hemoglobin serum level (n=1), drainage of fresh blood via percutaneous drain(n=2) and hemobilia (n=3)) and were treated successfully with embolization. A follow up CT scan in this study population was not included as part of the protocol. Nevertheless a follow up CT scan in a "young" trauma population for a rarely seen, but potentially lethal complication is a topic of debate. The high number needed to treat and negative effects of radiation exposure are matters of concern. Clinical examination and follow up might be the preferred method.

Biliary leakage following liver trauma is a significant problem. Endoscopic retrograde cholangiography (ERC), biliary sphincterotomy and temporary internal stenting represent a safe and effective strategy for management of bile leaks following both blunt and penetrating trauma. ERC with internal drainage of complicated bile leaks has proven successful.[36,37,105,106,107,108] The timing of the ERC has been open to debate with some authors suggesting that this should be done as soon as the bile leak is evident.[109] This, however, does not take into account the natural history of a bile leak after severe trauma in which spontaneous resolution is the norm, irrespective of the mechanism, provided there is adequate drainage.[12,109] Minor bile leaks usually resolve with conservative management alone. Internal drainage should be considered when external drainage of bile is more than 400 ml per day or when the bile leakage has persisted beyond 14 days (this thesis).

Nonoperative Management of hemodynamically stable patients following blunt and penetrating hepatic trauma is safe in adequately selected patients. Use of damage control techniques is recommended in patients with a major hepatic bleeding or in patients with a minor liver injury with associated vascular injury and before the onset of metabolic failure. As a result of improved survival following severe hepatic parenchymal damage an increase in intrahepatic vascular and biliary complications has become evident. Many of these complications can be prevented by surgical ligation if a laparotomy is warranted, or can be managed by less invasive, percutaneous techniques in the acute (vascular) or secondary (biliary) stage.

Future perspectives. Trauma is a global problem, and carries a high price that is paid by individuals, communities, and nations. The liver is the most frequently injured intra-abdominal organ following trauma, although the incidence of patients with a severe bleeding liver injury is low. Clinical suspicion, decision making, repeated clinical examination, and surgical experience play a crucial role in the management and outcome of patients with severe liver injuries. However, most of the world's population does not have direct access to such high level trauma centers and first class operating and surgical critical care facillities.[110] Further research should therefore not only focus on the role and use of advanced techniques, such as preoperative computed tomography, angiography and embolization, advanced endoscopic and endovascular techniques. Other more easily accessible tools that are also of influence on mortality and morbidity of trauma patients, should be explored, especially for the less well equipped countries and hospitals.

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CHAPTER 8

Summary and answers to the questions

Chapter 1 provides a general introduction to the management of liver trauma and poses the questions to be answered in this thesis.

In general, for the management of patients with liver trauma three options exists: 1) nonoperative management; 2) operative management and primary definitive repair and 3) staged repair, also known as damage control surgery.

The safety and feasibility of nonoperative management of patients who sustained blunt and penetrating liver injuries was evaluated. To answer the question „*Which factors might indicated the need for a surgical intervention in patients who sustained blunt liver trauma?*" the first part of **chapter 2** presents 134 severely injured patients with a blunt liver injury. Physiologic parameters (haemodynamic instability, generalized peritonitis, and worsening metabolic acidosis during resuscitation) or CT-findings showing associated intraabdominal injuries requiring surgical repair, warrants early surgical exploration in 25 % of patients with a blunt liver injury. Seventy five per cent of the patients with blunt liver injuries could be managed nonoperative. Associated solid intra-abdominal and extra-abdominal injuries do not exclude nonoperative management. Nonoperative management should be considered irrespective of the grade of liver trauma. The conclusions of the evaluation provide an answer to the question „*How efficient is NOM in patients who sustained blunt liver trauma?*", and support the efficacy with a 95 % success rate of nonoperative management in patients who sustained blunt liver trauma. In the second part of **chapter 2,** 95 patients with penetrating liver injuries (54 gunshot wounds and 41 stabbed liver injuries) were analysed. Forty seven per cent of the patients with stabbed liver injuries, and 28 % of the patients with gunshot wounds of the liver were managed nonoperative irrespective the grade of liver injury. The results provide an answer to the question „ *How often do patients who sustained penetrating wounds to the liver require a delayed laparotomy?*". Three (6%) of 54 patients with liver gunshot injuries failed abdominal observation (suffering from peritonism and fever (2), or biliary peritonitis (1)) and underwent delayed laparotomy (non hollow-organ injuries were detected at laparotomy), and all (100%) 41 patients with stabbed liver injuries were successfully treated nonoperatively.

In view of the overall results, the answer to the fourth question, „*What is the incidence of liver related complications in patients undergoing NOM?*" is that the liver related complication rate is 7% and 11% for blunt and penetrating liver injuries respectively. Liver related complications contribute for 50% to failure of NOM.

Even in an era with computed tomography available in fairly every hospital, in 25 % (blunt) and 66% (penetrating) of the patients with liver injuries an explorative laparotomy is indicated. About 40% of the liver injuries stop bleeding spontaneously or do require simple drainage and a laparotomy is indicated for repair of associated injuries. But in 60% of the patients undergoing operative management a major liver bleeding is suspected. To diagnose a major liver injury or perihepatic injury as the main source of bleeding is challenging. After haemorrhage control 40 % of the patients undergoing operative management with a concomitant liver injury had a perihepatic injury, which caused the major source of blood loss. In **chapter 3** the methods of haemorrhage control of liver injuries in patients undergoing operative management were studied. Answering the question *" Is direct suture repair, perihepatic packing and selective use of angiography a safe strategy and efficient in order to control liver bleeding?"* 82 patients with a major liver bleeding were analysed. Suture ligation, perihepatic packing and selective use of postoperative angiography to treat the liver bleeding is efficient and safe. In case of perihepatic packing for major hepatic and juxtahepatic venous trauma return to the operating theatre should be delayed. **Chapter 3** also provides an answer to the question *" What is the optimal time of pack removal, in order to minimise the risk of rebleeding and lower the risk of septic complications?"*. Retrospective analysis of 93 patients shows that the total duration of liver packing does not result in an increase in septic complications or bile leaks. The first re-look laparotomy should only be performed after 48 hours. An early re-look is associated with a re-bleeding and does not lead to early removal of packs. Prospective analysis of 63 patients confirmed that in the case of major hepatic injuries a return to the operating theatre after therapeutic packing should be delayed after 48 hours.

Nonoperative management and damage control surgery for liver trauma leaves severe parenchymal damage initially untreated and may potentially result in larger and more complicated bile leaks that may not resolve with simple drainage. **Chapter 4** focuses on what is the optimal treatment for patients presenting with a traumatic bile leak will be and provides answers to the questions *What the incidence of bile leaks following blunt and penetrating trauma is* and *whether conservative management of intrahepatic bile leaks in patients who sustained liver trauma is safe.* The incidence of bile leaks is about 10%, and developed more often following penetrating trauma, operative management, damage control surgery and high grade liver injuries. Most intrahepatic bile leaks can be managed conservatively without the need for a re-laparotomy. The question *"Do all patients with a traumatic bile leak require endoscopic drainage?"* was answered by classifying 40 patients with a biliary leak in the intrahepatic biliary tree. Bile leaks were classified as minor and major (>400mL/d or persistent drainage > 14 days). Sixty five per cent of the intrahepatic bile leaks following trauma are minor and easily managed conservatively. Endoscopic cholangiography and internal drainage should be reserved for major leaks.

Damage control surgery is well established surgical strategy in the management of the severely injured and shocked patient, but selection of patients for DCS remains controversial. Liver packing as a surgical technique to control liver haemorrhage and a delayed return to the operating theatre has been described in chapter 3**.** Isolated liver injuries in patients following abdominal trauma are not that common. Simultaneous treatment of the most severe injuries is mandatory to optimise survival chances. In

chapter 5 we describe the treatment of patients with major multiple injuries and concomitant liver injury in which mortality approaches 70%. A major abdominal injury was defined as two or more organs injured in the right upper quadrant of the abdomen in patients with an injury Severity Score (ISS) > 15 and Abbreviated Injury Scale (AIS) > 3. Patients were divided into two groups according to operative strategy; group I Definitive Repair (DR) and Group II Damage Control Laparotomy. Factors identifying patients who underwent DCL were analysed and evaluated in order to answer the question *"Which criteria dictate the need for a damage control laparotomy in patients with a major abdominal injury?"*. Onset of metabolic failure (BE<5), abdominal vascular injuries and major liver injuries in patients with major abdominal trauma and multiple organs injured require a damage control laparotomy. A specific group of trauma patients are those who sustain penetrating thoracoabdominal trauma and the risk of a cardiac injury. The diagnosis can be made by ultrasonography, but the sensitivity and specificity of the test is variable. Therefore we present the results of the use of a subxiphoid pericardial to exclude occult cardiac injury after penetrating thoracoabdominal trauma. To answer the last question *"Is the subxiphoid window an efficient and safe manoeuvre to perform in patients with thoracoabdominal injuries?"* we evaluated 50 patients with thoracoabdominal trauma and indication for a laparotomy. An occult cardiac injury was present in 14 patients mandating sternotomy. Nine cardiac injuries were identified including five tangential injuries and four perforations. The SPW is a useful technique at laparotomy to identify cardiac injuries in patients with penetrating thoracoabdominal injuries.

In **chapter 6** two clinical illustrations are presented: One patient sustained blunt liver trauma and one patient had a stabbed injury of the liver. The first patient with a grade V liver injury, sustained a contained intraparenchymal liver bleed without massive haemorrhage. This phenomenon supports the policy of nonoperative management of liver injuries in hemodynamic stable patients, regardless of the American Association for the Surgery of Trauma (AAST) grade of injury. The second illustration presents a desperate case where packing did not control a major liver bleeding in a patient with a penetrating grade V liver injury. Implantation of a retro hepatic endovascular stent in the inferior vena cava as adjuvant to perihepatic packing did control bleeding. While bile leaks are not uncommon and discussed in chapter 4, bilhemia is a rare complication following liver trauma. Our patient with complex liver trauma developed bilhemia; intravascular biliary leakage was successfully treated with temporary stenting of the bile duct, combined with sphincterotomy.

Appendices

NEDERLANDSE SAMENVATTING

In deze studie worden de resultaten gepresenteerd van een onderzoek naar de behandeling van lever trauma's. In het algemeen bestaan er drie verschillende behandelopties voor patiënten met een levertrauma: 1) conservatieve, niet-operatieve therapie; 2) operatieve therapie en primair chirurgisch herstel en 3) een gefaseerde operatieve ingreep, beter bekend als "damage control surgery".

Na de algemene inleiding in hoofdstuk 1 wordt in hoofdstuk 2 de veiligheid en toepasbaarheid van de conservatieve behandeling van patiënten met stompe en penetrerende leververwondingen geëvalueerd. Het eerste deel van hoofdstuk 2 presenteert 134 patiënten met stompe leververwondingen. Fysiologische parameters (hemodynamische instabiliteit, gegeneraliseerde peritonitis en verslechterende metabole acidose gedurende initiële resuscitatie) of CT-bevindingen welke geassocieerde intra-abdominale letsels tonen die een operatieve behandeling vergen, zijn in 25 % van de patiënten een indicatie voor een exploratieve laparotomie bij patiënten met stomp levertrauma. Vijfenzeventig procent van de patiënten met stomp levertrauma kunnen conservatief behandeld worden. Geassocieerde soliede intra-abdominale en extra-abdominale orgaanletsel zijn geen exclusie criterium voor een succesvolle nonoperatieve behandeling. Een nonoperatieve behandeling kan in overweging worden genomen onafhankelijk van de graad leververwonding. Het succes van een conservatieve behandeling bij patiënten met een lever trauma is 95 %. In het tweede deel van hoofdstuk 2 zijn 95 patiënten met penetrerende leververwondingen (54 schotverwondingen en 41 steekverwondingen) geanalyseerd. Zevenenveertig procent van de patiënten met steekverwondingen van de lever, en 28 % van de schotverwondingen van de lever zijn conservatief behandeld, onafhankelijk van de graad leververwonding. Alle (100%) van de 41 patiënten met een steekverwonding van de lever waren succesvol conservatief behandeld. Bij 3 (6%) van de 54 patiënten met een schotverwonding van de lever was een exploratieve laparotomie geïndiceerd na een in opzet initiële conservatieve therapie (gegeneraliseerde peritonitis (2), biliaire peritonitis (1)).

De incidentie van levergerelateerde complicaties in de conservatief behandelde groep patiënten was 7 en 11 %, voor stompe en penetrerende leverletsels respectievelijk. Levergerelateerde complicaties droegen voor 50 % bij aan het falen van een conservatieve behandeling van patiënten met een schotverwonding van de lever.

In 25 % en 66 % van de patiënten met een leverletsel was een exploratieve laparotomie geïndiceerd, na stomp en penetrerend trauma respectievelijk. Ongeveer 40 % van de leververwondingen stoppen spontaan of kunnen met simpele chirurgische technieken behandeld worden en een laparotomie is meestal geïndiceerd voor geassocieerd abdominaal letsel. Echter in 60 % van de patiënten die een operatieve behandeling ondergaan kan men een complexere leverbloeding verwachten. Het diagnosticeren van een complexere leverbloeding of een bloedende perihepatische verwonding kan uitdagend zijn. Na initiële hemostase bleek dat 40 % van de patiënten met een leverletsel een perihepatische verwonding hadden die de belangrijkste oorzaak van de leverbloeding was. In hoofdstuk 3 worden de verschillende chirurgische technieken om de leverbloeding te controleren bestudeerd. Tweeëntachtig patiënten met een complexe leverbloeding werden verder geanalyseerd. Ligeren van bloedende intrahepatische vaten, leverpacking en het selectief gebruik van een postoperatieve angiografie om een leverbloeding te controleren bleek een veilige en efficiënte strategie. Ook bleek packing van een leververwonding met retrohepatisch letsel als initiële therapie en een later geplande definitieve operatieve ingreep veilig. Een retrospectieve analyse van 93 patiënten toonde aan dat de duur van leverpacking niet resulteerde in een toename van septische of biliaire complicaties. De eerste re-look laparotomie zou ideaal gezien niet vroeger dan 48 uur plaatsvinden. Een vroege relaparotomie en verwijderen van gazen was geassocieerd met een verhoogde kans op een bloeding. De prospectieve analyse van 63 patiënten bevestigde dat bij patiënten met een complexe leverbloeding, een relook laparotomie na 48 uur na leverpacking zou moeten worden uitgevoerd, met de kleinste kans op bloeding en "re-packing" en zonder een verhoogde kans op septische complicaties.

Conservatieve therapie van leververwondingen en leverpacking laten ernstige parenchymschade initieel onbehandeld. Dit kan resulteren in een verhoogde kans op gallekkage die niet goed behandeld kan worden met simpele percutane drainage.

In hoofdstuk 4 ligt het accent op de optimale behandeling van patiënten met posttraumatische gallekkage. De incidente van posttraumatische gallekkage is ongeveer 10 % en werd vaker waargenomen na penetrerend trauma, operatieve behandeling, damage control surgery en bij hooggradige leverletsels. De meeste intrahepatische gallekages konden worden behandeld zonder dat een relaparotomie was geïndiceerd. Gallekages werden geclassificeerd als niet significant en significant (>400mL/d of persisterende gal drainage > 14 dagen). Vijfenzestig procent van de posttraumatische intrahepatische gallekages waren niet significant en konden conservatief worden behandeld. Endoscopische cholangiografie en inwendige drainage werd slechts toegepast bij de minder voorkomende significante (majeure) gallekages.

Damage control surgery is een geaccepteerde chirurgische techniek voor de behandeling van ernstig verwonde patiënten en patiënten in hemodynamische shock, maar de selectie van patiënten voor een damage control strategie blijft controversieel.

Leverpacking om een bloeding te controleren en gefaseerde latere relaparotomie is beschreven als techniek in hoofdstuk 3. Geïsoleerde leverletsels in patiënten na abdominaal trauma worden niet vaak gezien. Gelijktijdige behandeling van de meest ernstige geassocieerde letsels is van groot belang om de overlevingskansen te vergroten. In hoofdstuk 5 wordt de behandeling van patiënten met een leverletsel en geassocieerde ernstige multipele verwondingen besproken, waarbij de mortaliteit kan oplopen tot 70 %. Ernstig abdominaal trauma werd als volgt gedefinieerd; twee of meer orgaanletsels in de rechter boven buik in patiënten met een ISS > 15 en AIS > 3. Patiënten werden in twee groepen verdeeld, de eerste groep onderging een laparotomie en primaire definitieve operatieve verzorging van intra-abdominale letsels, en de tweede groep onderging een gefaseerde damage control strategie. Metabool falen (BE<5), abdominale vasculaire verwondingen en complexe leververwondingen in patiënten met majeure buikverwondingen zouden een damage control strategie moeten ondergaan.

Een specifieke groep van trauma patiënten zijn die met penetrerende thoracoabdominale letsels, verdacht voor cardiaal letsel. De diagnose kan met behulp van een echografie (FAST) worden gesteld, maar de sensitiviteit en specificiteit van dit aanvullend onderzoek zijn variabel. Daarvoor presenteren we de resultaten van het gebruik van een subxiphoid pericardiaal venster om occult cardiaal letsel uit te sluiten of aan te tonen. Vijftig patiënten met thoracoabdominaal trauma en een indicatie voor een laparotomie werden geëvalueerd. Een occult cardiaal letsel werd aangetoond in 14 patiënten en slechts deze patiënten ondergingen een sternotomie. Negen cardiale letsels werden gediagnosticeerd, vijf tangentiele letsels en vier perforaties. Een subxiphoid pericardiaal venster is een eenvoudige bruikbare techniek om cardiale letsels in patiënten aan te tonen of uit te sluiten met penetrerende thoracoabdominale verwondingen.

In hoofdstuk 6 worden twee patiënten cases beschreven: een patiënt met stomp lever trauma en een patiënt met een steekverwonding van de lever. De eerste patiënt met een graad V leververwonding, had een intraparenchymale verwonding zonder massieve bloeding. Dit fenomeen ondersteunt een conservatieve behandeling van patiënten met een leververwonding onafhankelijk de graad leververwonding. De tweede patiënt toont een casus waar packing een graad V leverbloeding niet kon controleren. Implantatie van een endovasculaire stent in de retrohepatische vena cava als adjuvante therapie naast packing kon de bloeding controleren. Terwijl gallekkage niet ongewoon is en besproken is in hoofdstuk 4, ontwikkelde deze patiënt bilhemie, een zeldzame complicatie na levertrauma. De intravasculaire gallekkage kon succesvol behandeld worden met een tijdelijke inwendige stent, gecombineerd met een sfincterotomie.

De conservatieve therapie van hemodynamisch stabiele patiënten na stomp en penetrerend leverletsel is veilig in adequaat geselecteerde patiënten. Het gebruik van damage control technieken wordt aanbevolen in patiënten met een complexe leverbloeding of in patiënten met een minder ernstige leververwonding maar met geassocieerd abdominaal vasculair letsel. Als gevolg van verbeterde overleving na ernstig parenchymateus leverletsel een toename van intrahepatische vasculaire en biliaire complicaties wordt waargenomen. Veel van deze complicaties kunnen voorkomen worden door ligatie van intrahepatische beschadigde structuren, of kunnen minimaal invasief, met percutane technieken in de acute (vasculair) of in een latere fase (biliaire) behandeld worden.

Trauma is een globaal probleem, en draagt vaak een hoge prijs die wordt betaald door individuen, gemeenschappen en op nationaal niveau. De lever is het vaakst verwonde intraabdominal orgaan na abdominaal trauma, hoewel de incidentie van ernstige complexe leverbloedingen laag is. Klinische verdenking, besluitvorming, herhaalde klinische lichamelijk onderzoek en chirurgische ervaring spelen een cruciale rol in de behandeling en uitkomsten van patiënten met ernstig leverletsel. Een groot deel van de wereldbevolking heeft geen directe toegang tot "high level" trauma centra en "first class" chirurgische en intensive care faciliteiten. Ondanks de aangetoonde veiligheid en efficiëntie zal verder onderzoek zich niet alleen moeten concentreren op de "high tech" technieken, zoals CT-Scan, angiografie en embolisatie, endoscopische technieken en endovasculaire technieken. Andere meer toegankelijke hulpmiddelen waaronder eenvoudige chirurgische technieken, die de mortaliteit en morbiditeit beïnvloeden zullen systematisch en wetenschappelijk onderzocht moeten blijven worden. De ervaringen en uitkomsten van deze studies zullen vooral in het voordeel zijn voor die landen met minder goed uitgeruste ziekenhuizen.

DEUTSCHE ZUSAMMENFASSUNG

Grundsätzlich bestehen drei Optionen zum Management von Patienten mit einem Lebertrauma / einer Verletzung der Leber.
1, konservatives Vorgehen
2, operatives Vorgehen mit primärer Versorgung
3, stufenweises Vorgehen im Sinne von „damage control surgery"

Die Sicherheit und Durchführbarkeit der konservativen Therapie von Patienten mit stumpfen und penetrierenden Leberverletzungen wurde evaluiert. Der erste Teil des zweiten Kapitels präsentiert 134 schwer verletzte Patienten mit stumpfem Lebertrauma. Physiologische Parameter wie hämodynamische Instabilität, generalisierter Peritonismus sowie eine zunehmende metabolische Azidose während der Reanimation, sowie CT-graphisch diagnostizierte, assoziierte intraabdominale Verletzungen, welche einer operativen Therapie bedürfen, rechtfertigen eine frühzeitige operative Exploration in 25% der Patienten mit stumpfem Lebertrauma. 25% der Patienten mit stumpfem Lebertrauma konnten konservativ behandelt werden. Assoziierte intra- sowie extraabdominale Verletzungen, abgesehen von Hohlorganverletzungen, schliessen ein konservatives Vorgehen nicht aus. Ein konservatives Management muss unabhängig des Schweregrades der Leberverletzung in Betracht gezogen werden, da die diesbezügliche Erfolgsrate bei stumpfen Traumata bei 95% liegt.

Im zweiten Teil des zweiten Kapitels wurden 95 Patienten mit penetrierenden Lebertraumata (54 Schuss- und 41 Stichverletzungen) analysiert. 47% der Patienten mit Stichverletzungen bzw. 28% mit Schussverletzungen wurden unabhängig des Schweregrades des Traumas konservativ therapiert. Bei 3 (6%) der 54 Schussverletzungen musste im Verlauf auf ein operatives Vorgehen gewechstelt werden (2 Patienten mit Peritonismus und Fieber, 1 Patient mit biliärer Peritonitis) wobei im Rahmen der Laparotomie keine Hohlorganverletzungen gefunden werden konnten. Bei der Gruppe der Stichverletzungen konnten alle 41 Patienten (100%) erfolgreich konservativ therapiert werden.

Zusammenfassend traten Komplikationen in 7% bzw. 11% bei stumpfen bzw. penetrierenden Leberverletzungen auf. Leber assoziierte Komplikationen tragen zu 50% zum Versagen der konservativen Therapie bei.

Auch in Zeiten mit guter Verfügbarkeit einer weiteren Bildgebung mittels CT ist bei 25% (stumpf) sowie 66% (penetrierend) der Patienten mit Lebertraumata eine explorative Laparotomie indiziert. Bei ca. 40% der Leberverletzungen sistiert die Blutung spontan bzw. es bedarf einer Drainage wobei die Laparotomie zur Versorgung von Begleitverletzungen indiziert ist. Bei 60% der operierten Patienten wurde eine schwere Leberblutung vermutet. Die Diagnosefindung eines schweren Leber- bzw. perihepatischen Traumas als Hauptquelle der Blutung ist schwierig. Nach Blutungskontrolle präsentierte sich bei

40% der operierten Patienten mit Begleitverletzungen der Leber, eine perihepatische Verletzung als Hauptblutungsquelle.

Im dritten Kapitel wurden die Optionen der Blutungskontrolle bei den operierten Patienten mit Leberverletzungen analysiert. Diese Gruppe umfasst 82 Patienten. Ligaturen, perihepatisches „packing" im Sinne einer Tamponade sowie die postoperative Angiographie stellen effiziente und sichere Methoden dar. Im Falle des perihepatischen "packings" für schwere Leber sowie juxtahepatische venöse Verletzungen sollte die 2nd look Operation erst nach 48 Stunden erfolgen. Dies zeigte eine prospektive Analyse von 63 Patienten. Die retrospektive Analyse von 93 Patienten zeigte kein erhöhtes Risiko für Infekte oder „bile leak" in Zusammenhang mit der Dauer des "packings". Eine frühzeitige Revision führt zu erneuten Blutungen und hiermit zu keiner verfrühten Entfernung der Tamponaden.

Beim konservativen Vorgehen sowie bei "damage control" Operationen bleiben parenchymale Verletzungen unbehandelt und können zu grösseren „bile leaks", welche nicht mittels Drainage kontrollierbar sind, führen.

Das vierte Kapitel konzentriert sich auf die optimale Behandlung für Patienten mit traumatischen Gallengangsverletzungen. Die diesbezügliche Inzidenz liegt bei 10% und tritt gehäuft nach penetrierenden Verletzungen, operativem Vorgehen, "damage control" Operationen sowie schwergradigen Leberverletzungen auf. Die meisten intrahepatischen Gallengangsverletzungen können konservativ behandelt werden. Diese wurden in leichte und schwere Verletzungen je nach Drainagemenge (>400ml/d bzw. persistierende Fördermenge >14d bei schweren Formen) eingeteilt. 65% der intrahepatischen Gallengangsverletzungen sind leichtgradig und gut konservativ behandelbar. Die endoskopische Cholangiographie in Kombination mit Drainageanlage sind für schwere Formen reserviert.

Das stufenweise Vorgehen im Sinne des „damage controls" ist eine gut etablierte Strategie im Management von schwer verletzten und schockierten Patienten wobei die Patientenselektion kontrovers diskutiert wird. Die perihepatische Tamponade mit 2nd look Operation nach frühestens 48 Stunden wurde bereits im dritten Kapitel beschrieben. Da isolierte Leberverletzungen bei Patienten mit Abdominaltrauma selten sind, ist die zeitgleiche Versorgung der Begleitverletzungen unumgänglich zur Optimierung der Überlebenschancen.

Im fünften Kapitel beschreiben wir Patienten mit schweren Mehrfachverletzungen und Begleitlebertrauma bei welchen die Mortalität bis zu 70% beträgt. Als schweres Abdominaltrauma wurden Verletzungen von zwei oder mehr Organen im rechten oberen Quadranten bei Patienten mit einem ISS (injury severety score) >15 und AIS (abbreviated injury scale) >3 gewertet. Es erfolgte die Aufteilung in zwei Gruppen. Gruppe 1 mit definitiver Versorgung und Gruppe 2 mit „damage control" Vorgehen. Das Einsetzen eines metabolischen Versagens (BE<5), abdominale Gefässverletzungen und schwere

Leberverletzungen bei Patienten mit schweren Abdominaltraumata bei Mehrfachverletzung verlangen nach einem stufenweisen Vorgehen. Eine spezielle Patientengruppe stellt jene mit penetrierendem thorakoabdominalem Trauma, und dem Risiko einer kardialen Verletzung dar. Zur Diagnose kann eine Sonographie beitragen wobei die Sensitivität sowie Spezifität variabel sind.

Wir stellen die Resultate des subxiphoidalen perikardialen Fensters zum Ausschluss eines Perikardergusses im Rahmen penetrierender thorakoabdominaler Traumata vor. Von fünfzig Patienten mit thorakoabdominalem Trauma und bestehender Indikation zur Laparotomie zeigte sich eine okkulte kardiale Verletzung bei 14 Patienten welche eine Sternotomie zur Folge hatte. Hierbei bestätigten sich 9 kardiale Verletzungen (5 tangential, 4 Perforationen). Das subxiphoidale perikardiale Fenster stellt eine sinnvolle chirurgische Intervention im Rahmen einer Laparotomie zur Identifizierung von penetrierenden thorakoabdominalen Herzverletzungen dar.

Im sechsten Kapitel werden 2 klinische Fälle dargestellt. Ein Patient erlitt ein stumpfes Lebertrauma, der andere eine penetrierende Stichverletzung. Bei Patient 1 resultierte dies in einer Grad V Verletzung der Leber mit intraparenchymaler Blutung ohne wesentlichen Blutverlust. Dieses Beispiel unterstützt die Theorie der konservativen Therapie stumpfer Lebertraumata bei kreislaufstabilen Patienten, unabhängig des AAST - Schweregrades (American Association for Surgery of Trauma). Bei Patient 2 konnte mittels Tamponade eine schwere Leberblutung welche durch eine penetrierende Grad V Verletzung verursacht wurde nicht gestoppt werden. Erst durch die zusätzliche Implantation eines retrohepatischen endovaskulären Stents in die V. cava inferior konnte die Blutung kontrolliert werden. Währen „bile leaks“ nicht unüblich sind und bereits in Kapitel 4 besprochen wurden, stellt die Bilhämie eine seltene Komplikation im Rahmen von Lebertraumata dar. Patient 2 entwickelte eine Bilhämie. Diese konnte mittels temporärem Stenting des Gallenganges sowie einer Sphinkterotomie behoben werden.

Das konservative Vorgehen bei stabilen Patienten ist bei genauer Selektion eine sichere Therapieform sowohl für stumpfe, als auch penetrierende Traumata. “Damage control” wird für Patienten mit schweren Leberblutungen sowie für Patienten mit assoziierten Gefässverletzungen vor dem Eintritt der metabolischen Azidose empfohlen. Durch die verbesserte Überlebensrate nach schweren parenchymalen Verletzungen konnten vermehrt intrahepatische Gefäss- und Gallengangsverletzungen diagnostiziert werden. Viele dieser Komplikationen können mittels chirurgischer Ligatur im Rahmen der Laparotomie behoben werden bzw. durch weniger invasive Massnahmen wie perkutane Techniken in der Akutsituation (Gefässverletzungen) oder im späteren Verlauf (Biliär) therapiert werden.

Unfälle stellen ein globales Problem dar, welches hohe Kosten für Patienten, Spitäler und zuletzt Länder verursacht. Auf allen Kontinenten ist die Leber das am häufigsten betroffene intraabdominale Organ nach Unfällen obwohl die Inzidenz von schweren

Leberhämorrhagien niedrig ist. Die klinische Untersuchung und Reevaluation des Behandlungskonzeptes spielen eine wichtige Rolle im Management und Outcome von schweren Lebertraumata. Dem Grossteil der Weltbevölkerung fehlt der Zugang zu spezialisierten Traumazentren mit adäquat ausgestatteten Operationseinheiten sowie der Möglichkeit einer intensivmedizinischen Betreuung. Trotz des heutigen Wissensstandes benötigt es weitere Studien welche den Hauptfokus nicht auf hochspezialisierte, schwer zugängliche Therpieformen wie die präoperative Computertomographie, Angiographien mit Embolisation oder endoskopische und endovaskuläre Techniken legen. Auch andere, leichter zugängliche Modalitäten, welche einen Einfluss auf die Morbidität und Mortalität haben sollten in zukünftigen Studien Berücksichtigung finden, speziell für die weniger weit entwickelten Regionen und Spitäler dieser Welt.

LIST OF PUBLICATIONS

Nicol AJ, Navsaria PH, Beningfield S, **Hommes M**, Kahn D. **S**creening for occult penetrating cardiac injuries. *Ann Surg. 2015 Mar;261(3):573-8.*

Nicol AJ, Navsaria P, **Hommes M**, Ball C, Edu S, Kahn D. **S**ternotomy or Drainage for a Hemopericardium After Penetrating Trauma: A Safe Procedure? *Ann Surg. 2015 Feb 2 Epubhead of Print.*

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