Blunt abdominal trauma: changing patterns in diagnostic and treatment strategies

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Blunt Abdominal Trauma
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Blunt Abdominal Trauma
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Introduction and outline of the thesis
Trauma is the most common cause of death in people younger than 45 years of age and accounts for more years of life loss than cancer, heart disease, and stroke combined.\(^1\) In the Netherlands, yearly 2,5 millions people sustain any kind of injury leading to 980,000 Emergency Department visits, 170,000 hospital admissions, and 5,100 deaths.\(^2\) One of the main causes of death after trauma, with numbers ranging from 40 to 80%, is exsanguination due to injuries from abdominal organs. Blunt trauma (i.e. motor vehicle accidents and fall from heights) is still the most common mechanism of injury in the Netherlands although penetrating injuries are becoming more common due to increasing violence.

The spleen, liver and kidney are the most commonly injured abdominal organs\(^3\)-\(^5\) as a result of blunt trauma and a missed splenic injury is the most common cause of preventable death in trauma patients.\(^6\)

The management of patients with blunt abdominal injury has evolved greatly over the last few decades. Historically, surgical management was the preferential treatment for most blunt abdominal injury, because nonoperative management (NOM) was associated with a high mortality rate and significant risk of delayed rupture.\(^7\) However, a significant amount of the laparotomies were non-therapeutic and therefore possibly unnecessary.\(^8\)

Furthermore, as the severity of postsplenectomy infection became better understood, a trend from splenectomy towards splenic conservation has emerged.

Although initially controversial, NOM of patients with blunt abdominal injury is currently the treatment of choice in hemodynamically stable patients.\(^9\)-\(^13\) NOM can be divided in either observation (OBS) alone or angiography and embolization (AE) followed by close observation. Observational management involves admission to a unit with monitoring of vital signs, strict bed rest, frequent monitoring of haemoglobin concentration, and serial physical exams.\(^14\) In 1995 Sclafani described the first successful use of angiography and embolization in a patient with splenic injury.\(^15\) Many studies support the use of embolization as an adjunct to observation. AE has increased the success rate of nonoperative management both by stopping ongoing bleeding as well as by preventing delayed rupture.\(^16\)-\(^20\) Success rates up to 97% are described in the literature. Improved imaging techniques and advances in interventional radiology have helped to better differentiate patients who can be observed versus those needing AE. However, a lot of issues regarding the diagnostics and therapeutic management of patients with blunt abdominal injuries after trauma are still debated.

**The present study was initiated to answer the following questions:**

What are the results in the Netherlands of NOM in blunt abdominal injury (liver, spleen and kidney)?

What is the impact of AE on the success rate of nonoperative management?

What is the failure rate of NOM in children with blunt splenic or liver injury when a contrast blush is present on Computed Tomography (CT)?

What (CT) characteristics and what patient characteristics are associated with failure of NOM?

What are the complications of AE in patients with blunt abdominal injury?
OUTLINE OF THE THESIS

In this thesis several aspects of nonoperative management of patients with blunt abdominal injury are discussed. An overview of the literature regarding the changing patterns in diagnostic strategies and the treatment of blunt injury to solid abdominal organs is described in Chapter 2. Various aspects of diagnosis and treatment of patients with traumatic injury to the liver, spleen and kidney are described. Furthermore, future perspectives regarding diagnostics and treatment modalities are discussed.

In Part 1 of this thesis several modalities and current aspects of the diagnostics of patients with blunt abdominal injury are reviewed and discussed. In Chapter 3 a review of the literature assessing the significance of detection of a contrast blush on Computed Tomography in children with splenic and liver injury is described. In adults, it has been well established that the presence of an arterial blush on CT scan is a risk factor for failure of NOM. Therefore, adult treatment algorithms often include the presence of a contrast blush as an indication for AE or even surgical intervention.

Prior studies assessing whether or not the presence of a contrast blush is associated with failure of NOM presented controversial results. This chapter describes a systematic review in which the results of these prior studies were sampled to obtain a higher level of evidence for the significance of a contrast blush in children.

Chapter 4 describes three patients with seatbelt signs following a car accident are presented. The trauma mechanism, incidence and awareness of a seatbelt sign and the diagnostic workup and treatment options in these patients are described.

The most widely used grading system for blunt splenic injury is according to the organ injury scale of the American Association for the Surgery of Trauma (AAST). A few years ago a new grading system, incorporating vascular injuries, has been developed. This ‘Baltimore’ grading system was reported to be superior to the AAST system in predicting the need for angiography and embolization or surgery in patients sustaining blunt splenic injury. In Chapter 5 the inter- and intraobserver reliability between radiologists in classifying splenic injury according to both grading systems are described.

The spleen is the second most frequently injured organ following blunt abdominal trauma. Presently, nonoperative management of splenic injury is the most common management strategy in hemodynamically stable patients. Chapter 6 gives an overview of the diagnostic strategies and the role of AE in patients with blunt splenic injury.

In Part 2 of the thesis the focus lies on the outcome of treatment of patients with blunt abdominal injury treated in the Dutch level-1 trauma centers.

Current opinions with respect to treatment outcome following NOM in blunt abdominal injury are predominantly based on large volume studies from level-1 trauma centers in the United
States (US). Trauma patient volumes in European centers are often considerably lower than in the US. Therefore, it is questionable whether these results can be translated to centers with lower volumes of patients with blunt abdominal injury.

In Chapter 7 a retrospective cohort study has been performed on consecutive patients with blunt splenic injury admitted to the Academic Medical Center of Amsterdam to analyse results of NOM in a relatively low volume level-1 trauma center. The results are described and compared with the literature. Furthermore, the impact of AE on the success rates of nonoperative management is presented.

Chapter 8 presents the results of a multicenter cohort study of patients with blunt splenic injury treated nonoperatively in three level-1 trauma centers. The results of nonoperative management and the influence of AE are analysed. Secondly, the identification of risk factors for failure of NOM is investigated with uni- and multivariate logistic regression analysis.

In Chapter 9 a retrospective cohort study has been performed on consecutive patients with blunt hepatic injury admitted to the Academic Medical Center of Amsterdam. Aim of the study was to compare the failure rate of primary treatment before and after the introduction of angiography. Furthermore, the effects on clinical outcomes and complication rates are assessed.

In 2005 the European Association of Urology (EAU) has published the guidelines on urological trauma. In daily practice, however, guidelines are often not followed. Earlier research showed that only half of the urologists in the United Kingdom utilizes the guidelines in the management of renal trauma and furthermore, that there was variable adherence to the recommendations. Therefore, we performed a study comparing the diagnostics and treatment of patients with blunt renal injury applied in a Level-1 trauma center to the recommendations of the EAU guidelines. The results of this study are presented in Chapter 10.

Angiography and embolization have become the treatment of choice for (arterial) internal hemorrhage after abdominal trauma or pelvic injury in hemodynamically stable. Some studies however, report a high incidence of rebleeding (failure) and other complications. The type and incidence of the complications and failure rate in trauma patients undergoing such procedures are described and discussed in Chapter 11.

Finally, in Chapter 12 and 13 the findings of the preceding chapters are summarized and discussed.
REFERENCES

1. Krug EG, Sharma GK, Lozano R. The global burden of injuries. Am J Public Health. 2000; 90(4): 523-6
2. Centraal bureau van Statistiek. http://www.cbs.nl
3. Davis JJ, Cohn I, Nance FC, Diagnosis and management of blunt abdominal trauma. Ann Surg. 1976; 183(6):672-8.
4. Esposito TJ, Gamelli RL (2000). Injury to the spleen. In: Feliciano DV, Moore EE, Mattox KL. Trauma. Appleton and Lange, Stamford
5. Schroeppe1 TJ, Croce MA. Diagnosis and management of blunt abdominal solid organ injury. Curr Opin Crit Care. 2007; 13:399-404
6. Cales RH, Trunkey DD. Preventable trauma deaths. A review of trauma care systems development. JAMA. 1985;254:1059-1063
7. Richardson JD. Changes in the management of injuries to the liver and spleen. J Am Coll Surg. 2005; 200:648-669.
8. Sorkey AJ, Farnell MB, Williams HJ et al, The complementary roles of diagnostic peritoneal lavage and computed tomography in the evaluation of blunt abdominal trauma. Surgery. 1989; 106: 794-800
9. Velmahos GC, Toutouzas K, Radin R, Chan L, Rhee P, Tillou A et al. High success with nonoperative management of blunt hepatic trauma: the liver is a sturdy organ. Arch Surg. 2003; 138(5):475-480.
10. Frumento C, Vane DW. Changing patterns of treatment for blunt splenic injuries: an 11-year experience in a rural state. J Pediatr Surg. 2000; 35:985-988.
11. Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: a 5-year experience. J Trauma. 2005;58:492-498.
12. Santucci RA, Fisher MB. The literature increasingly supports expectant (conservative) management of renal trauma-a systematic review. J Trauma. 2005; 59:493-503
13. Stein DM, Scalea TM. Nonoperative management of spleen and liver injuries. J Intensive Care Med. 2006 Sep-Oct; 21(5):296-304. Review.
14. Konstantakos AK, Barnoski AL, Plaisier BR, Yowler CJ, Fallon WF, Jr., Malangoni MA. Optimizing the management of blunt splenic injury in adults and children. Surgery. 1999;126:805-812.
15. Sclafani SJ, Shafman GW, Scalea TM et al. Nonoperative salvage of computed tomography-diagnosed splenic injuries: utilization of angiography for triage and embolization for hemostasis. J Trauma. 1995; 39:818-825
16. Hagiwara A, Yukioka T, Ohta S, Nitatori T, Matsuda H, Shimazaki S. Nonsurgical management of patients with blunt splenic injury: efficacy of transcatheter arterial embolization. AJR Am J Roentgenol. 1996;167:159-166.
17. Liu PP, Lee WC, Cheng YF et al. Use of splenic artery embolization as an adjunct to nonsurgical management of blunt splenic injury. J Trauma. 2004;67:676-772.
18. Haan JM, Biffl W, Knudson MM et al. Splenic embolization revisited: a multicenter review. J Trauma. 2004;56:542-547.
19. Missetbeek TS, Teicher EJ, Cipolle MD, Pasquale MD, Shah KT, Dangleben DA et al. Hepatic angioembolization in trauma patients: indications and complications. J Trauma. 2009; 67(4):769-773.
20. Mohr AM, Lavery RF, Barone A, Bahramipour P, Magnotti LJ, Osband AJ et al. Angiographic embolization for liver injuries: low mortality, high morbidity. J Trauma 2003; 55(6):1077-1081.
21. Lynch TH, Martinez-Piêheiro L, Plas E, Serafetinides E, Türk1eri L, Santucci RA, Hohenfellner M; European Association of Urology. EAU guidelines on urological trauma. Eur Urol. 2005 Jan;47(1):1-15
22. European Association of Urology Guidelines on Urological Trauma (online), http://www.uroweb.org (2009)
23. Sharma D, Butt N, Barrass B, Dawson C, Examining the impact of renal trauma guidelines on urologists in UK. Eur J Trauma Emerg Surg. 2008;34:54-8
Changing patterns in diagnostic strategies and the treatment of blunt injury to solid abdominal organs

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Chapter 2

ABSTRACT

**Introduction:** In recent years there has been increasing interest shown in the nonoperative management (NOM) of blunt traumatic injury. The growing use of NOM for blunt abdominal organ injury has been made possible because of the progress made in the quality and availability Computed Tomography (CT) scan and the development of minimally invasive intervention options such as angio-embolization.

**Aim:** The purpose of this review is to describe the changes which have been made over the past decades in the management of blunt trauma to the liver, spleen and kidney.

**Conclusion:** The management of blunt abdominal injury has changed considerably. Focused assessment with sonography for trauma examination has replaced diagnostic peritoneal lavage as diagnostic modality in the primary survey. CT scanning with intravenous contrast is now the gold standard diagnostic modality in hemodynamically stable patients with intra-abdominal fluid detected with FAST. One of the current discussions in the literature is whether a whole body CT survey should be implemented in the primary survey. The progress in imaging techniques has contributed to NOM being currently the treatment of choice for hemodynamically stable patients. Angioembolization can be used as an adjunct to NOM and has increased the success rate to 95%. However, to date many controversies exist about the optimum patient selection for NOM, the proper role of angioembolization in NOM, the best technique and material to use in angioembolization, and the right follow-up strategy of patients sustaining blunt abdominal injury. Conducting a well-designed prospective clinical trial or a Delphi study would be preferable.
INTRODUCTION

Trauma is the leading cause of death among people who are younger than 45 years.\textsuperscript{1} One of the main causes of death after trauma, with numbers ranging from 40 to 80\%, is exsanguination caused by injuries to the abdominal organs. The spleen and liver are the most commonly injured organs as a result of blunt trauma. The kidney is also commonly injured.\textsuperscript{2} Over the past 40 years, many changes in the primary survey and treatment of patients with blunt abdominal trauma have occurred. Traditionally, emergent laparotomy was the standard of care. Currently, nonoperative management (NOM) is the most common management strategy in hemodynamically stable patients. The aim of this review is to describe the shift in management of blunt abdominal trauma over the past decades and to discuss recommendations for the future. We have focused on the following abdominal organs: the liver, spleen and kidney.

PRIMARY CARE

Before the 1970s, the structure of the diagnosis and treatment of life-threatening injury was very dependant upon the physician. The turning point of this management style came with the introduction of the Advanced Trauma Life Support (ATLS) principles by Steiner and Collicott in 1978.\textsuperscript{3} With this ATLS protocol, a clear guideline for the optimal primary clinical survey of patients with life-threatening injury was developed. The goal of the primary survey is to quickly assess and stabilize the trauma patient. Structure, simplicity and a multidisciplinary methodology are essential to this approach. An important ATLS principle is: ‘treat first what kills first’.

DIAGNOSTIC STRATEGIES

Major changes in the diagnostics of hemodynamically stable patients with blunt trauma have occurred. Currently, the primary survey consists of a chest X-ray, X-rays of the cervical spine and pelvis, blood and urine samples and a Focussed Assessment with Sonography for Trauma (FAST).

Diagnostic peritoneal lavage

Formerly, diagnostic peritoneal lavage (DPL) was the procedure of choice for the quick diagnosis of a hemoperitoneum in patients with blunt abdominal trauma. DPL, first described in 1965, resulted in a decrease in mortality and morbidity following abdominal trauma.\textsuperscript{4} In general, FAST examination has replaced the use of DPL, because DPL is an invasive procedure and provides no information about which organ is injured, resulting in a high rate of negative or non-therapeutic laparotomies.\textsuperscript{5}
FAST
FAST is useful in trauma evaluation to identify intra-abdominal fluid, a herald of significant organ injury, with a sensitivity of 90–93%.6,7 FAST can be performed simultaneously with resuscitation efforts during the initial trauma management and can be completed rapidly and is, therefore, also useful in hemodynamically unstable patients.8 One of the strengths of FAST in this patient group is that it helps to direct the surgeon to the abdomen as a major source of blood loss when positive, thereby leading to early laparotomy rather than Computed tomography (CT). Despite its efficacy and non-invasive character, FAST has several important disadvantages. First, FAST does not accurately detect the extent (grade) or the exact site of the organ injury. Hemoperitoneum detected with FAST in hemodynamically stable patients should be followed by a CT scan to evaluate the nature and extent of injury in more detail.9 Second, its sensitivity for direct demonstration of blunt abdominal injury is relatively low (between 34% and 55%), since the presence of free fluid in sufficient quantity indirectly indicates intraperitoneal injury.10 Other limitations of FAST include operator-dependence, limited retroperitoneal accuracy and poor scanning results in obese patients or patients with overlying wounds.
When the FAST is negative for hemoperitoneum, it is still debatable whether a CT scan is required. Estimates for the presence of intra-abdominal injury in the absence of hemoperitoneum on FAST can be as high as 29%.11 In a recent study, 13% of the patients with clinical signs of abdominal injury and a negative FAST for intra-abdominal fluid were shown to have significant injury upon CT scanning.12 Therefore, hemodynamically stable patients with a negative FAST and a high clinical suspicion of splenic injury, for example a seat belt sign or upper abdominal pain, should undergo routine CT scanning.13,14

Contrast Enhanced Ultrasound
An increase in the utilisation of another radiological modality, the Contrast Enhanced Ultrasound (CEUS) could contribute to the shift towards NOM. CEUS is a real-life, non-invasive, bedside, radiation free technique. Some studies suggest that CEUS is a good alternative to CT scanning for the evaluation of traumatic lesions in solid abdominal organs, especially in patients with contraindications for CT contrast agents and in hemodynamically compromised patients.15 The exact place of CEUS in the diagnostics of patients with blunt abdominal injury should be further determined in the future.

Computed Tomography
The introduction of helical tomography in the 1980s has improved the detection and classification of blunt abdominal injury.16 Currently, Multidetector Computed Tomography scanning with intravenous contrast is the gold standard diagnostic modality in hemodynamically stable patients with intra-abdominal fluid detected with FAST. CT scanning with intravenous contrast has numerous advantages. First, the detection of injuries related to the liver, spleen and kidney can be reliably determined, with a sensitivity of 90–100%. Second, active bleeding (a contrast
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extravasation), pseudoaneurysms and post-traumatic arteriovenous fistulas can be diagnosed and the localisation of these vascular injuries can also be established. Third, the CT scan plays a decisive part in the order of treatment if more than one injury is present.17 Because of the technical developments which have resulted in a higher degree of resolution of the CT scan and in quicker scanning, the effectiveness of conventional radiology (X-rays and FAST) in the clinical ATLS approach has been challenged. One of the main reasons for this is the lack of any research which prove that the mortality and disability rates of injured patients decreases after the implementation of the ATLS concept.18 One of the current discussions in literature is whether a whole body CT survey should be implemented in the primary survey. Some authors recommend conducting a whole body CT (the so-called imaging survey) as the standard diagnostic tool during the early resuscitation phase for patients with polytrauma. They report that a CT scan of the chest or abdomen results in a change of treatment in up to 34% of patients with blunt trauma.19 A 30% reduction in mortality using the whole body CT is also reported.20 Other arguments in favour of an imaging survey are the reduction in time from

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**Figure 1.** Diagnostic algorithm of patients with blunt abdominal injury

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•Abnormalities in physical examination of the abdomen, pelvis or lumbar spine
  Abnormal X-ray of pelvis, lumbar spine or chest
  Abnormal FAST
  Base excess < -3
  Systolic blood pressure < 90 mm Hg
  Long bone fractures 13

![Diagnostic algorithm of patients with blunt abdominal injury](image-url)
admission to intervention and the possibility of managing hemodynamically unstable patients in the same way. \(21\)

It is debatable whether a whole body CT survey is to be recommended considering its disadvantages. The need for iodine containing contrast and the radiation exposure, especially in the relatively young trauma population, are not negligible when one considers the lifetime risk of cancer. \(22\) Moreover, whole body CT as part of the primary survey can only be adopted if a CT scan is available in, or very close to, the emergency department. \(23\) For the moment the benefit of whole body CT scanning seems particularly high for patients with severe injury. The diagnostic algorithm for abdominal evaluation of hemodynamically stable patients after blunt trauma is depicted in figure 1.

TREATMENT

Historically, surgical management was the preferential treatment for most blunt abdominal injury, because NOM was associated with a high mortality rate. \(24\) However, a lot of the laparotomies were unnecessary and non-therapeutic. \(25\) With the wide availability and improved quality of CT scanning, and the more modern less invasive intervention options, such as angio-embolization, NOM has evolved into the treatment of choice for hemodynamically stable patients. \(26\) NOM consists of close observation of the patient completed with angio-embolization, if necessary. Observational management involves admission to a unit and the monitoring of vital signs, with strict bed rest, frequent monitoring of haemoglobin concentration, and serial abdominal examinations. \(27\) NOM, with or without angio-embolization is of benefit to trauma patients because the function in the organ concerned is preserved. In addition, the possible morbidity that may accompany a laparotomy such as incisional hernia, abscess formation, pneumonia, wound infection, multi organ failure, pancreatitis, bleeding, tromboembolic events, and paralytic ileus, is avoided. Angio-embolization has proven to be a valuable adjunct to observational management and has increased the success rate of NOM to 95%. \(28\) The foundation for angio-embolization was laid by Charles Theodore Dotter (1920–1985). In 1964 he performed the first transluminal angioplasty in a patient with peripheral occlusive disease. \(29\) Later on, the technique of embolization was introduced. The first application of embolization of the internal iliac artery in a patient with a pelvic fracture occurred in 1972 and from then on, the role of interventional radiology in the diagnosis and treatment of traumatic bleeding has increased significantly. Research demonstrates that angio-embolization is a well-tolerated and effective tool in the treatment of traumatic liver, splenic and kidney injury. \(30\)-\(33\)

The patients who can benefit the most from angio-embolization is still a controversial subject. CT features such as high grade of injury (AAST Grade 3–5), pseudoaneurysm or arteriovenous fistula, contrast extravasation contained within the spleen (Figure 2), liver or kidney and the presence of a hemoperitoneum just as patient characteristics such as age above 55 years old,
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**Figure 2.** Computed Tomography with intravenous contrast shows small amounts of haemoperitoneum around the spleen and a contrast ‘blush’, which is confined to the splenic parenchyma.

**Figure 3.** Liver injury with intraperitoneal contrast extravasation visible on Computed Tomography scan.
**Figure 4.** Computed Tomography with intravenous contrast showing haemoperitoneum, a fractured spleen with large haematoma and extravasation of contrast medium into the abdominal cavity.

**Figure 5.** Computed Tomography with intravenous contrast demonstrating large haematoma around the right kidney with contrast extravasation.
GCS <8 and male gender are associated with an increased failure rate of NOM. Angio-embolization could be advocated to improve the success rate of NOM in these patients. The single CT finding that warrants immediate angio-embolization (or a laparotomy) is a contrast blush within the peritoneal cavity (Figures 3–5).

LIVER

The liver is frequently injured after blunt abdominal trauma. Traditionally, a lesion of the liver was treated surgically. The major techniques which have been used over time are, in consecutive order, selective hepatic artery ligation and major liver resection using omental flaps for tamponade.

Ongoing bleeding, infections, and the high mortality rate after operative treatment, stimulated the search for alternative treatments and, in 1990 NOM was introduced as a treatment for liver injury. The high success rate (approximately 90%) combined with the lower mortality and complication rates, in comparison to surgical treatment, make NOM the treatment of choice for the majority of liver injuries, including high grade liver injury.

NOM consists of observation, supplemented by Endoscopic Retrograde CholangioPancreatography with the placement of a stent, or drainage by Percutaneous Transhepatic Cholangiography if injury to the bile ducts has taken place. For active bleeding, angio-embolization can be performed. Angio-embolization may also be applied to control the haemorrhage which may occur after damage-control operations using perihepatic packing in hemodynamically unstable patients.

Despite the reduction of mortality that using angio-embolization has achieved, some studies describe a rise in severe but treatable complications such as hepatic necrosis, abscesses or bile leakage. Gallbladder ischemia, hepatic parenchymal necrosis, and biloma may also occur, and in patients with a high grade liver injury (Grade 4 and 5) the incidence of complications can be high.

Spleen

The spleen is the most frequently injured organ in blunt abdominal trauma, and a missed splenic injury is the most common cause of preventable death in trauma patients. Formerly, in the early twentieth century, a splenectomy was nearly always performed. This invasive management was based on the following two findings: the first was the belief that the spleen could not heal spontaneously, the second was called the ‘latent period of Baudet’ which refers to the tendency of the spleen to rupture at a later stage.

Changes to this type of management occurred in the 1970s when data about postsplenectomy complications were published describing the risk of overwhelming postsplenectomy infection.
Chapter 2

(OPS) and its high mortality rate. In less than 10 years, NOM became the treatment of choice for splenic injury.

In 1995, Sclafani described the first successful use of angio-embolization in a patient with a splenic injury. Since the 1990s, angio-embolization has been frequently used to achieve better splenic salvages rates. To date, there is no consensus about the optimal localisation of embolization, either proximal (Figures 6 and 7) or distal (selective), in the splenic artery.

A recent development is proximal splenic artery embolization (PSAE). The surgical equivalent of PSAE for splenic injury was first described in 1979. PSAE is predominantly used in cases with multiple disseminated haemorrhage sites or when quick intervention is needed because of the condition of the patient. Arguments in favour of proximal embolization are: the low failure rate, its speed, and the decreased incidence of splenic abscess or infarction. PSAE does not significantly influence the splenic anatomy or the immune function in the long term. A disadvantage of PSAE, however, could be that selective embolization in case of rebleeding is difficult, if not impossible, because the splenic artery cannot be accessed. Furthermore, ischemia of the pancreas when embolization is performed proximally to the main pancreatic artery and dislodgement of coils resulting in infarction of the spleen are reported.

Figure 6. Selective digital subtraction angiogram of the celiac axis showing the intra-peritoneal contrast ‘blush’ in the spleen, confirming active bleeding.
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Selective embolization, used to stop focal bleeding, has also proved to be successful in NOM. This technique achieves hemostasis to the injured parts while preserving perfusion to the remainder of the spleen. Disadvantages include the possibility of subsequent bleeding out of vascular injuries that were unnoticed owing to vasospasm and the higher rate of minor complications. However, the clinical relevance of these infarctions is questionable. A recent meta-analysis showed that both techniques have an equivalent rate of major infarctions and infections requiring splenectomy. However, the results regarding major rebleeding, the most common reason for failure of SAE were inconclusive.

**KIDNEY**

The kidney are affected in nearly 10% of all trauma patients whereas blunt trauma is responsible for 90% of the renal injuries. The switch from operative to nonoperative management for the treatment of renal injuries occurred as a result of critical perceptions. Researchers noticed that patients who underwent a laparotomy had a significantly higher risk of nephrectomy than the
patients who were treated nonoperatively; it therefore seemed that maximal renal preservation, with a minimum of subsequent complications, could be better achieved with NOM.\textsuperscript{56}

In 2004, the Renal Trauma Committee and, in 2005 the European Association of Urology drew up guidelines for the optimum evaluation of patients with urological trauma.\textsuperscript{57,58} The decisive factor in the evaluation is hemodynamic stability. Hemodynamic instability related to renal bleeding, complete ureteral tears or pelvic avulsions or leakage of urine into peritoneal cavity are imperative indications for laparotomy. If the patient is hemodynamically stable, the distinction between gross or microscopic hematuria determines whether there is any further need for imaging and what the treatment options are. In case of gross hematuria, a CT scan is the gold standard for the evaluation of renal injury.\textsuperscript{58} Microscopic hematuria does not demand imaging. Exclusion of coexisting injuries is of overriding importance in the initiation of NOM. Currently, NOM is used in up to 90\% of renal injuries. This is because of the particularly high incidence of minor renal injury. Perinephric fluid collections or urinomas can be treated with percutaneous drainage. Patients with active haemorrhages detected on the CT scan can be treated with angio-embolization of the renal arteries.\textsuperscript{33} Kidney function can be preserved through recanalisation and stenting (Figure 9) even when a transection of the renal artery had been made (Figure 8).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure8.png}
\caption{Computed Tomography with intravenous contrast: transection of the renal artery without contrast in the left kidney.}
\end{figure}
Discussion

Even though NOM has proven to be of tremendous benefit, a couple of controversies regarding the current management of trauma patients should be discussed.

Advances in CT technology have improved the practitioner’s ability to determine the degree of injury and to identify patients who are more likely to fail NOM. However, until now, CT scanning has not been able to differentiate, in a precise manner, between which patients should be treated conservatively, which would benefit from angio-embolization and which would respond best to a surgical response. The decision for treatment should always be based on the clinical situation and the physiological response of the patient to initial resuscitation.

A determinant of the success of NOM is the level of cooperation between different specialists in the hospital. Good teamwork between the trauma surgeon, the anaesthesiologist, and the

**Figure 9.** Angiogram of the same patient in Figure 8 after recanalisation and placement of a stent in the renal artery, resulting in good perfusion of the kidney.
(interventional) radiologist leads to a quicker understanding of the underlying injuries and shortens the time between entering the hospital and the initiation of therapeutic interventions. This seems obvious in Level-1 trauma centers but can be a matter of concern, especially in level-2 or 3 trauma centers.

RECOMMENDATIONS FOR THE FUTURE

The exact position of angio-embolization in the NOM of blunt abdominal injury is still subject to discussion. Angio-embolization has been shown to be a valuable adjunct to observational management and has increased the success rate of NOM in many series of clinical trials. However, a lot of controversies regarding angio-embolization in patients with blunt abdominal trauma exist. The optimal technique (proximal, distal or a combination of both) nor the material to use has been compared in a prospective trial with regard to outcome (success rate) and complication rate. A recently published systematic review and meta-analysis of Schnüriger et al. is based on retrospective data and the results regarding major bleeding, the most important reason for failure of SAE were inconclusive. The optimal follow-up strategy of patients sustaining blunt abdominal injuries has not been elucidated either. Up to now, the length of hospital stay, the need for, frequency of and best modality of follow-up imaging as well as discharge instructions with regard to resuming of activities are at the discretion of the physician. Research shows that practice patterns between physicians are quite variable. Although difficult to conduct because of the nature of the trauma population, prospective (clinical) trials are necessary to determine the optimum patient selection for angiography and embolization, the optimal technique and material used for angio-embolization, and the follow-up strategy in patients with traumatic blunt injury. One way of tackling this issue would be to conduct a Delphi study. The Delphi method is a systematic interactive forecasting method for obtaining experience-based agreement from a panel of independent experts. The process allows anonymous, non-biased consensus building and has been well validated for systematically assessing and organising expert opinion. Although low in level of evidence, we hold this study design appropriate since a lot of controversies regarding the clinical decision making could be resolved by an international expert panel, selected on the basis of extensive clinical and/or research experience. We recommend a study such as this to be performed. Furthermore, we advocate the improvement of logistic factors. If CT scans were present and available in trauma resuscitation rooms, the ‘one hour rule’ would be easier to fulfil. The CT scan could also play a part in the diagnostics of hemodynamically unstable patients. At present, these patients go straight to the operating room but in future however, they might also be treated with angio-embolization.
CONCLUSION

Over the past several years, major changes in the management of blunt abdominal injury have occurred. Because of the progress which has been made in the quality and wide availability of the CT scan combined with minimally invasive intervention options like angio-embolization, NOM has evolved to be the treatment of choice for hemodynamically stable patients. NOM is a safe treatment for stable patients with traumatic liver, splenic, or kidney injuries and success rates of up to 95% are described in the literature. However, to date a lot of controversies exist about the optimum patient selection for NOM, the proper role of angio-embolization in NOM and the right follow-up strategy.
REFERENCES

1. Sauaia A, Moore FA, Moore EE et al. Epidemiology of trauma deaths: a reassessment. J Trauma. 1995; 38: 185-93
2. Zwingmann J, Schmal H, Sudkamp NP, Strohm PC. Injury severity and localisations seen in polytrauma-
matised children compared to adults and the relevance for emergency room management. Zentralbl Chir. 2008;133: 68-75.
3. Carmont MR. The Advanced Trauma Life Support course: a history of its development and review of related literature. Postgrad Med J. 2005;81: 87-91.
4. Root HD, Hauser CW, Mckinley CR, Lafave JW, Mendolia RP Jr., Diagnostic Peritoneal lavage. Surgery. 1965;57: 633-a7.
5. Gonzalez M, Bucher P, Ris F, Anderegen E, Morel P. Spleenic trauma: predictive factors for failure of non-operative management. J Clin Ultrasound. 2005;33: 155-63.
6. Bode PJ, Edwards MJ, Kruit MC, van Vugt AB. Sonography in a clinical algorithm for early evaluation of 1671 patients with blunt abdominal trauma. AJR Am J Roentgenol. 1999;172: 905-11
7. Schnuriger B, Kilz J, Inderbitzin D et al. The accuracy of FAST in relation to grade of solid organ injuries: a retrospective analysis of 226 trauma patients with liver or splenic lesion. BMC Med Imaging. 2009;9: 3.
8. Deunk J, Brink M, Dekker HM et al. Predictors for the Selection of Patients for Abdominal CT After Blunt Trauma: A Proposal for a Diagnostic Algorithm. Ann Surg. 2010 Mar; 251(3): 512-20.
9. Deunk J, Brink M, Dekker HM et al. Routine versus selective computed tomography of the abdomen, pelvis, and lumbar spine in blunt trauma: a prospective evaluation. J Trauma. 2009;66: 1108-17.
10. Miller MT, Pasquale MD, Bromberg WJ, Wasser TE, Cox J. Not so FAST. J Trauma. 2003;54: 52-9.
11. Catalano O, Aliani L, Barozzi L, Bokor D, De Marchi A, Faletti C, Maggioni F, Montanari N, Orlandi PE, Siani A, Sidhu PS, Thompson PK, Valentino M, Ziosi A, Martegani A. CEUS in abdominal trauma: multicenter study. Abdom Imaging. 2009 Mar-Apr; 34(2): 225-34.
12. Mullinix AJ, Foley WD, Multidetector computed tomography and blunt thoracoabdominal trauma. J Comput Assist Tomogr. 2004 Jul-Aug;28 Suppl 1:S20-7
13. Miller LA, Shanmuganathan K. Multidetector CT evaluation of blunt trauma, Radial Clin North Am. 2005;43: 1079-95.
14. Jayaraman S, Sethi D. Advanced trauma life support training for hospital staff. Cochrane Database Syst Rev. 2009;CD004173.
15. Deunk J, Dekker HM, Brink M, Vugt vR, Edwards MJ, Vugt vAB. The value of indicated computed tomography scan of the chest and abdomen in addition to the conventional radiologic work-up for blunt trauma patients. J Trauma. 2007;63: 757-63.
16. Huber-Wagner S, Lefering R, Visscher K, Quick LM et al. Effect of whole-body CT during trauma resuscitation on survival: a retrospective, multicentre study. Lancet. 2009;373: 1455-61.
17. Chan O. Primary computed tomography survey for major trauma. Br J Surg. 2009;96: 1377-8.
18. Brenner DJ, Hall EJ, Computed Tomography — An Increasing Source of Radiation Exposure. N Engl J Med. 2007;357: 2277-84.
19. Saltzherr TP, Fung Kon Jin PH, Bakker FC et al. An evaluation of a Shockroom located CT scanner: a randomized study of early assessment by CT scanning in trauma patients in the bi-located trauma center North-West Netherlands (REACT trial). BMC Emerg Med. 2008;8: 10.
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24. Richardson JD. Changes in the management of injuries to the liver and spleen. J Am Coll Surg. 2005; 200: 648-69.
25. Sorkey AJ, Farnell MB, Williams HJ et al., The complementary roles of diagnostic peritoneal lavage and computed tomography in the evaluation of blunt abdominal trauma. Surgery. 1989; 106: 794-800
26. Malangoni MA, Cue Ji, Fallat ME, Willing SJ, Richardson JD. Evaluation of splenic injury by computed tomography and its impact on treatment. Ann Surg. 1990;211: 592-7.
27. Pachter HL, Guth AA, Hofstetter SR, Spencer FC. Changing patterns in the management of splenic trauma: the impact of nonoperative management. Ann Surg. 1998;227: 708-17.
28. Stein DM, Scalea TM. Nonoperative management of spleen and liver injuries. J Intensive Care Med. 2006;21: 296-304.
29. Dotter CT, Judkins MP, Transluminal treatment of arteriosclerotic obstruction. Description of a new technic and preliminary report of its application. Circulation. 1964; 30: 654-70
30. Hagiwara A, Murata A, Matsuda T et al. The efficacy and limitations of transarterial embolization for severe hepatic injury. J Trauma. 2002; 52: 1091–6.
31. Brugere C, Arvieux C, Dubuisson V et al. Early embolization in the nonoperative management of blunt splenic injuries: a retrospective multicenter study. J Chir (Paris). 2008, 145: 126–32.
32. Nijhof HW, Willemssen FE, Juikema GN. Transcatheter arterial embolization in a hemodynamically unstable patient with grade IV blunt liver injury: is nonsurgical management an option? Emerg Radiol. 2006; 12: 111–5.
33. Krämer SC, Görich J, Rilinger N, Gottfried HW, Mattes R, Aschoff AJ., The percutaneous transarterial embolization therapy of traumatic kidney hemorrhages, Rofo. 1998, Sep;169(3): 297-301.
34. Fang JF, Chen RJ, Wong YC et al. Classification and treatment of pooling of contrast material on computed tomographic scan of blunt hepatic trauma. J Trauma. 2000;49: 1083-8.
35. Marmery H, Shanmuganathan K, Alexander MT, Mirvis SE. Optimization of selection for nonoperative management of blunt splenic injury: comparison of MDCT grading systems. Am J Roentgenol. 2007; 189: 1421-7.
36. Schurr MJ, Fabian TC, Gavant M et al. Management of blunt splenic trauma: computed tomographic contrast blush predicts failure of nonoperative management. J Trauma. 1995;39: 507-12.
37. Harbrecht BG, Peitzman AB, Rivera I et al., Contribution of age and gender to outcome of blunt splenic injury in adults: Multicenter study of the eastern association for the surgery of trauma, J Trauma. 2001; 51: 887-95
38. Knudson MM, Maull KI. Nonoperative management of solid organ injuries. Past, present, and future. Surg Clin North Am. 1999;79: 1357-71.
39. Buckman RF, Jr., Miraliakbari R, Badellino MM. Juxtahepatic venous injuries: a critical review of reported management strategies. J Trauma. 2000;48: 978-84.
40. Dabbs DN, Stein DM, Scalea TM. Major hepatic necrosis: a common complication after angioembolization for treatment of high grade liver injuries. J Trauma. 2009;66: 621-7.
41. Kozar RA, Moore JB, Niles SE et al. Complications of nonoperative management of high grade blunt hepatic injuries. J Trauma. 2005;59: 1066-71.
42. Mohr AM, Lavery RF, Barone A et al. Angiographic embolization for liver injuries: low mortality, high morbidity, J Trauma. 2003;55: 1077-81.
43. Misselbeck TS, Teicher EJ, Cipolle MD et al. Hepatic angioembolization in trauma patients: indications and complications. J Trauma. 2009;67: 769-73.
44. Cales RH, Trunkey DD. Preventable trauma deaths. A review of trauma care systems development. JAMA. 1985;254: 1059-63.
45. Peitzman AB, Ford HR, Harbrecht BG, Potoka DA, Townsend RN. Injury to the spleen. Curr Probl Surg. 2001;38: 932-1008.
46. Holdsworth RJ, Irving AD, Cuschieri A. Postsplenectomy sepsis and its mortality rate: actual versus perceived risks, Br J Surg. 1991;78: 1031-8.
Sclafani SJ, Shaftan GW, Scalea TM et al. Nonoperative salvage of computed tomography-diagnosed splenic injuries: utilization of angiography for triage and embolization for hemostasis. J Trauma. 1995; 39: 818-25.

Keramidas DC. The ligation of the splenic artery in the treatment of traumatic rupture of the spleen. Surgery. 1979;85: 530-3.

Smith HE, Biffi WL, Majercik SD, Jednacz J, Lambiase R, Cioffi WG. Splenic artery embolization: Have we gone too far? J Trauma. 2006;61: 541-4.

Bessoud B, Denys A, Calmes JM et al. Nonoperative management of traumatic splenic injuries: is there a role for proximal splenic artery embolization? Am J Roentgenol. 2006;186: 779-85.

Malhotra AK, Carter RF, Lebman DA, Carter DS, Riaz OJ, Aboutanos MB, Duane TM, Ivatury RR. Preservation of splenic immunocompetence after splenic artery angioembolization for blunt splenic injury, J Trauma. 2010, 69: 1126- 31.

Schnuriger B, Inaba K, Konstantinidis A, Lustenberger T, Chan LS, Demetriades D. Outcomes of proximal versus distal splenic artery embolization after trauma: a systematic review and meta-analysis. J Trauma, 2011; 70: 252-60

Raikhlin A, Baerlocher MO, Asch MR, Myers A. Imaging and transcatheter arterial embolization for traumatic splenic injuries: review of the literature, J Can Chir. 2008; 61: 464-72

Haan JM, Biffi W, Knudson MM, et al. Splenic embolization revisited: a multicenter review. J Trauma. 2004;56: 542-7

Taviloglu K, Yasar H. Current trends in the management of blunt solid organ injuries. Eur J Trauma Emerg Surg. 2009; 35: 90-4

Bergen CT, Chan TN, Bodzin JH. Intravenous pyelogram results in association with renal pathology and therapy in trauma patients. J Trauma. 1987; 27: 515

Santucci RA, Wessells H, Bartsch G, Descotes J, Heyns CF, McNinch JW, Nash P, Schmidlin F. Evaluation and management of renal injuries: consensus statement of the renal trauma subcommittee. BJU Int. 2004 May;93(7): 937-54.

Lynch TH, Martinez-Piñeiro L, Plas E, Serafetinides E, Türkeri L, Santucci RA, Hohenfellner M; European Association of Urology. Eur Urol. 2005 Jan; 47(1): 1-15

Fata P, Robinson L, Fakhry SM. A survey of EAST member practices in blunt splenic injury: a description of current trends and opportunities for improvement, J Trauma. 2005; 59: 836-42

Ludlow, J. (1975). Delphi enquiries and knowledge utilisation. In H.A. Linstone, and M. Turoff (Eds.). The Delphi method: techniques and applications (pp.102-123). Reading, MA: Addison-Wesley publishing company

Lin WC, Chen YF, Lin CH, Tzeng YH, Chiang HJ, Ho YJ, Shen WC, Chen JH. Emergent transcatheter arterial embolization in hemodynamically unstable patients with blunt splenic injury. Acad Radiol. 2008 Feb;15(2): 201-8.
Diagnostic strategies in blunt abdominal trauma
The failure rate of nonoperative management in children with splenic or liver injury with contrast blush on computed tomography: a systematic review

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Chapter 3

ABSTRACT

Introduction: Nonoperative management (NOM) is the treatment of choice for hemodynamically stable pediatric patients with spleen or liver trauma. The aim of this study was to assess the failure rate of NOM in children with blunt liver and/or splenic injury when a contrast blush is present on a CT scan.

Methods: A systematic review of the literature published between 1985 and 2009 was performed by searching the EMBASE and MEDLINE database for English and German articles. Articles were eligible if they reported the failure rate of NOM with or without angio-embolization (AE) in pediatric patients with splenic and/or liver injuries with a contrast blush on CT and included two or more trauma patients. Two reviewers independently assessed the eligibility and the quality of the articles and performed the data extraction. Interrater differences were resolved by discussion.

Results: Nine studies were included describing 117 pediatric patients. The median sample size was five (range 2-44). Seven studies (including 71 patients) reported a total of 16 patients with failure after NOM without AE. Failure rates across these studies ranged from 4.5 to 100%; the pooled percentage was 28.2% (95% CI: 8.9-61.3%). The failure percentages after NOM with or without AE ranged from 0 to 100%; the pooled percentage was 21% (95% CI: 7.5-46.8%). Two studies (including 46 patients) reported a total of 3 patients with failure after NOM with primary AE: a percentage of 6.5%.

Conclusion: Despite the current low level of evidence on failure rate of NOM when a contrast blush is present on CT we emphasize that there is a significant number of patients in whom NOM fails. We therefore recommend that the management of splenic and hepatic injury in children should not only be based on the physiological response, but should include consideration of the presence of a contrast blush.
INTRODUCTION

Blunt abdominal trauma is an important cause of death in children older than one year of age.\(^1\) The spleen and liver are the most commonly injured intraabdominal organs, accounting for up to 70\% of all visceral injuries.\(^1\) The best method to diagnose liver and splenic injuries is an intravenous contrast-enhanced Computed Tomography (CT). CT has the ability to provide accurate information about the severity of sustained injuries and also gives information about the presence and location of active bleeding sites.

Reported success rates for nonoperative management (NOM) of blunt liver and splenic injuries are 90\% or higher for pediatric patients. Due to this high success rate NOM is considered the standard of care in hemodynamically stable children.\(^2\)-\(^4\) In the literature there are no reliable indicators other than hemodynamic instability that predict the failure of NOM in pediatric trauma patients.\(^5\) Several recent studies in adults suggest that the presence of a contrast blush on CT is associated with an increased failure rate of NOM of blunt splenic and/or liver injury.\(^6\)-\(^8\) However, the clinical implication of a contrast blush on CT with liver and/or splenic injury in the pediatric population has not yet been assessed.

The primary aim of this systematic review was to assess the failure rate of NOM without AE (observational management) in children with blunt liver and/or splenic injury in the presence of a contrast blush on CT scan. The second goal was to determine the failure rate after NOM with angio-embolization (AE).

METHODS

A systematic search of the literature was conducted to identify studies assessing the significance of a contrast blush on CT and the failure of NOM (with or without AE) in children with liver and/or splenic injuries.

Data sources and search strategy

We searched the MEDLINE and EMBASE databases for English and German articles published between 1985 and 2009. The medical subject heading terms, title words and free text were searched for the following terms: (injury OR injuries OR trauma OR rupture OR rupture*) AND (child OR childr* OR childh* OR paediatric* OR paediatric OR pediatric OR pediatric* OR infant* OR newborn OR adolescent*) AND (liver OR hepatic OR biliary OR spleen OR splenic* OR visceral* OR intestinal OR intestine* OR abdominal OR abdomen) AND (angiography OR angiography* OR embolization OR embolization* OR embolization OR angioembolization OR angioembolization* OR angioembolization* OR ((extravasation* OR extravasation)) OR ((blush OR leak*)) AND contrast)). Additionally, the reference list of each eligible article was screened for other relevant
publications (cross-reference search) to identify studies not found in the computerized search. Furthermore, a manual search of the following journals was performed (CHV, TPS) that reported most frequently about the topic of interest: Journal of pediatric surgery, Pediatric Surgery International, European Journal of Pediatric Surgery, Journal of Trauma, Annals of Emergency Medicine, Injury, Journal of Emergency Medicine, Radiology, Emergency Radiology, American Journal of Roentgenology. For the manual search we used the same publication year restriction. The last search was performed in May 2009 and was conducted with the help of a clinical librarian.

**Study selection**

The selection procedure was performed by two independent reviewers (CHV and TPS). The inclusion criteria were: (1) pediatric trauma patients (age <18 year); (2) English or German language; (3) original data (no review or editorials) (4) randomized clinical trials (RCT’s), prospective or historical studies including at least two trauma patients; (5) clinical data concerning splenic and/or liver injuries with a contrast blush on CT; (6) the primary treatment was nonoperative; (7) the aim of the selected studies was to assess the failure rate of NOM with or without AE.

Meeting abstracts, unpublished data, and theses were excluded. Trauma was defined as a physical injury or wound caused by an external force which may cause death or permanent disability. NOM was defined as treatment without operative interventions and included both clinical observation and/or AE. Failure of the initial treatment (NOM with or without AE) was defined as (1) the need for abdominal exploration, (2) the need for an (re-)AE after clinical observation or earlier AE for an ongoing bleeding or rebleeding, and (3) death due to uncontrollable hemorrhage.

Both reviewers independently assessed the titles of the literature search to determine whether they were potentially relevant. Subsequently, the abstracts were assessed and the eligible articles were retrieved. If abstract relevancy was questionable, the full text article was reviewed. The final step of inclusion was always based on the full text article. Interrater differences were resolved by discussion. During the selection process no concealment of authors and institutions was used.

**Data Extraction**

Data extraction was performed independently using a standardised checklist for the following characteristics: number of patients, mean age at time of trauma, mechanism of trauma, Injury Severity Score (ISS), Abbreviated Injury Score abdomen (AIS abd.), type of NOM (with or without AE) and organ specific failure of initial treatment. Interrater differences were resolved by discussion. All corresponding authors were contacted if the reported data was unclear or incomplete for data extraction.
Methodological quality

The methodological quality of the studies was assessed using a scale that was based on a checklist of the Dutch Cochrane Centre for evaluating cohort studies (http://www.cochrane.org). The scoring system consisted of the following eight items: (1) description of demographic details of the investigated patient groups; (2) description of the selection criteria for treatment; (3) prospective study design; (4) consecutive inclusion of patients; (5) description of treatment; (6) definition of failure reported; (7) follow-up period > 30 days; (8) no selective loss to follow-up. If a study fulfilled the item, one point was awarded. If it was unclear whether the study fulfilled the item, no point was awarded. All items were assumed to be of equal importance and were not weighted. Studies with a score of 0–5 were classified as “poor quality” reports and those with a methodological score of 6–8 as “moderate to good”.

Statistical analysis

For each study, patient characteristics and failure rate were summarized using descriptive statistics. Pooled failure rates accounting for inter-study variation were analyzed using a nonlinear random effects model, implemented (proc nlmixed) in SAS version 9.1 (SAS Institute Inc., Cary, NC, USA). Statistical uncertainties were expressed in 95% confidence intervals (CI).

RESULTS

Search strategy and selection

The computerized literature search resulted in 447 titles from the EMBASE database and 957 titles from the MEDLINE database (Figure 1). After reviewing the titles and eliminating the duplicates from both databases 95 titles were selected for further evaluation. Based on the abstract 77 papers were excluded because they did not match the inclusion criteria resulting in 18 full text articles. The manual search and cross-reference search added two additional papers which made a total of 20 articles for full text review. In total, five authors were contacted for additional information on the data. After reviewing the full-length text, another 11 studies were excluded for various reasons leaving nine eligible studies.9–17 During quality assessment one study was rated poor quality and eight as moderate to good. No studies were excluded because of quality assessment.

Data extraction

All nine studies were observational studies, eight of them had retrospective data collection and one had a prospective design. All studies provided specific data about the failure rate of NOM with or without AE.

The patient and injury characteristics, type of nonoperative treatment and failure rates of the nine included studies are shown in table 1. A total of 117 patients was included with a median
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MEDLINE identified titles 957
abstract selected 95
full text selected 18
full text data extraction 9

EMBASE identified titles 477
268 double titles 1071 not relevant
77 abstracts not relevant

2 cross-references
0 manual search
articles for review 20

2 case report
4 no data on blush
5 authors contacted:
1 no data on children
4 no response

Figure 1. Flowchart of the reviewing process

Table 1. Patients demographics and outcome

|          | Mayglothling (14) | Fang (18) | Eubanks (11) | Lutz (13) | Cloutier (9) | Cox (10) | Ohtsuka (16) | Nwomeh (15) | Taylor (17) |
|----------|-------------------|-----------|---------------|-----------|--------------|----------|--------------|-------------|-------------|
| n        | 44                | 5         | 22            | 6         | 5            | 2        | 27           | 4           |
| age mean | n.a.              | 12.0      | 5.9           | n.a.      | 9.5          | 11.0     | 11.1         | n.a.        |
| ISS mean | 23.6              | n.a.      | 25.8          | 24        | n.a.         | 24       | n.a.         | 20.7        | n.a.        |
| organ injured | spleen | liver | liver | spleen | spleen | both | liver | spleen | both |
| AIS abd. | 3.2               | 4.0       | 4.1           | 3.7       | 3.0          | 4.5      | 3.5          | 3.3         | n.a.        |
| NOM without AE n= | n.a. | 5 | 22 | 6 | 5 | 2 | n.a. | 27 | 4 |
| failure n= | n.a. | 2 | 1 | 1 | 2 | n.a. | 6 | 3 |
| % | 40% | 4.5% | 16.7% | 20% | 100% | n.a. | 22% | 75% |
| AE=NOM with AE n= | 44 | n.a. | n.a. | n.a. | n.a. | n.a. | 2 | n.a. | n.a. |
| failure n= | 3 | n.a. | n.a. | n.a. | n.a. | n.a. | 0 | n.a. | n.a. |
| % | 6.8% | n.a. | n.a. | n.a. | n.a. | n.a. | 0% | n.a. | n.a. |

ISS = Injury Severity Score, AIS abd. = Abbreviated Injury Score abdomen, AE= AE angio-embolization
n.a. = no data available
The failure rate of NOM in children with splenic or liver injury with contrast blush on CT: a systematic review

sample size of 5 (range 2–44). For the five studies specifically describing the age of their patient population, the median age was 11.0 years (range 5.9–12). All patients had sustained blunt trauma. Median Abbreviated Injury Score of the abdomen was 3.6 with a range from 3.0–4.5. Seven studies, including 71 patients, reported a total of 16 patients with failure after NOM without AE. The failure rates across the studies ranged from 4.5% to 100% with a pooled percentage of 28.2% (95% CI: 8.9-61.3%). Figure 2 shows the forest plot for these studies. The failure percentages after NOM with or without AE ranged from 0% to 100% with a pooled percentage of 21 (95% CI: 7.5-46.8%) (Figure 3) Two studies (46 patients) reported a total of 3 patients (6.5%) with failure after NOM with primary AE.

**Figure 2.** Forest plot showing the failure rate after NOM without AE

**Figure 3.** Forest plot showing the failure rate after NOM with and without AE
DISCUSSION

The primary aim of this systematic review was to assess the failure rate of NOM in children with blunt liver and/or splenic injury with a contrast blush on CT scan. Currently, hemodynamic stability is the main parameter decisive for the initiation of NOM in children with splenic and/or liver injuries.\textsuperscript{2,18-21} However, although the failure rates of NOM are assumed small, potential risk factors for failure in these children are unknown. Improved imaging techniques and the advances in interventional radiology have led to a better selection of adult patients who are eligible to NOM. Several recent studies in adults have suggested that vascular injuries including active bleeding (contrast blush) are associated with an increased failure rate of NOM of splenic and liver injury.\textsuperscript{2,22-25} For pediatric patients there is controversial evidence in the literature whether or not the presence of a contrast blush is associated with failure of NOM. Analysis of factors for failure of NOM in pediatric patients is relevant because children have a high ability for physiologic compensation. As a result, hypotension is usually a late sign signifying catastrophic hemorrhage and there is concern that delayed operations in unstable children may result in significant morbidity and mortality.\textsuperscript{26}

Our analysis showed on average a failure rate of 28.2\% after NOM without AE in pediatric patients with a contrast blush on CT scan. This suggests that almost one of the three children with liver or splenic injuries and a blush on CT scan required an intervention to treat the ongoing bleeding or rebleeding with all the potential adverse effects. However, it should be stressed that this aggregated point estimate is statically imprecise as most of the reviewed studies were retrospective nonrandomized studies of moderate quality with a large fluctuation of failure rates between the studies (from 4.5–100\%). Moreover, the estimates were based on a small number of patients leading to wide confidence intervals.

Although no randomized controlled trials have been published, several studies of adult patients concluded that primary AE increased the success rate of NOM.\textsuperscript{27-32} However, the precise role of AE in children is still unclear. The combined data of all studies reporting on NOM with or without AE showed a failure rate to 21\%. But here again, the differences in study populations and suboptimal study methods and quality hamper the interpretation of the results.

If only the two studies that reported on NOM supplemented with angio-embolization were analyzed we found a failure rate of 6.5\%. This seems to suggest that the adjunction of AE leads to fewer failures. A critical note has to be made on this assumption because Mayglothling et al\textsuperscript{14} described 44 adolescent patients (aged 13–17 years) with splenic injuries in whom AE seemed to be a valuable and safe treatment. However, it is questionable if these results also apply to younger patients in their childhood and to children with liver injuries. In addition to this, AE is an invasive and time-consuming procedure in young children and carries the risk for complications. This increased risk is supposed to be due to the small size of the femoral artery which may be difficult to cannulate and the higher vaso-reactivity in children which makes accessing the
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splenic artery or deploying the coil more difficult. However, these are all theoretical risks and the reviewed studies demonstrated no major complications and vascular injuries.\textsuperscript{14,16} Besides the small sample sizes and heterogeneity of the studies, our review has the limitation that it specifically focused on the presence of a contrast blush on the CT scan. The localisation (intraparenchymal, intraperitoneal) of the contrast extravasation, imaging evidence of the liver or splenic capsule and the presence and quantity of hemoperitoneum were not separately assessed. Studies in adult patients suggest that evidence of intraperitoneal bleeding and a large hemoperitoneum predict failure of observational management.\textsuperscript{12,18} Finally, as stressed before, the results of our systematic review should be interpreted with caution due to the wide variation in populations and study methods. As a result of the found low level of evidence the definitive answer about the optimal management strategy should come from a well-designed randomized clinical trial in which NOM without an NOM with primary AE should be compared for failure rate in hemodynamically stable children with liver or splenic injuries. Furthermore, all the above mentioned CT characteristics should be prospectively evaluated to assess if there are any CT findings that can predict failure of nonoperative management and when AE could be beneficial.

CONCLUSION

Despite the current low level of evidence on failure rate of NOM when a contrast blush is present on CT we emphasize that there is a significant number of patients in whom NOM fails. We therefore recommend that the management of splenic and hepatic injury in children should not only be based on the physiological response, but should include consideration of the presence of a contrast blush. AE could be a valuable adjunct to nonoperative management and its application should be assessed in future studies.
REFERENCES

1. Tataria M, Nance ML, Holmes JH, Miller CC, III, Mattox KD, Brown RL, et al. Pediatric blunt abdominal injury: age is irrelevant and delayed operation is not detrimental. J Trauma. 2007 Sep;63(3): 608-14.

2. Bond SJ, Eichelberger MR, Gotschall CS, Sivit CJ, Randolph JG. Nonoperative management of blunt hepatic and splenic injury in children. Ann Surg. 1996 Mar;223(3): 286-9.

3. Oldham KT, Guice KS, Ryckman F, Kaufman RA, Martin LW, Noseworthy J. Blunt liver injury in childhood: evolution of therapy and current perspective. Surgery. 1986 Sep;100(3): 542-9.

4. Stylianos S. Compliance with evidence-based guidelines in children with isolated spleen or liver injury: a prospective study. J Pediatr Surg. 2002 Mar;37(3): 453-6.

5. Ochsner MG. Factors of failure for nonoperative management of blunt liver and splenic injuries. World J Surg. 2001 Nov;25(11): 1393-6.

6. Fang JF, Chen RJ, Wong YC, Lin BC, Hsu YB, Kao JL, et al. Classification and treatment of pooling of contrast material on computed tomographic scan of blunt hepatic trauma. J Trauma. 2000 Dec;49(6): 1083-8.

7. Schurr MJ, Fabian TC, Gavant M, Croce MA, Kudsk KA, Minard G, et al. Management of blunt splenic trauma: computed tomographic contrast blush predicts failure of nonoperative management. J Trauma. 1995 Sep;39(3): 507-12.

8. Marmery H, Shanmuganathan K, Alexander MT, Mirvis SE. Optimization of selection for nonoperative management of blunt splenic injury: comparison of MDCT grading systems 8. AJR Am J Roentgenol. 2007 Dec;189(6): 1421-7.

9. Cloutier DR, Baird TB, Gormley P, McCarten KM, Bussey JG, Luks FI. Pediatric splenic injuries with a contrast blush: successful nonoperative management without angiography and embolization. J Pediatr Surg. 2004 Jun;39(6): 969-71.

10. Cox CS, Jr., Geiger JD, Liu DC, Garver K. Pediatric blunt abdominal trauma: role of computed tomography vascular blush. J Pediatr Surg. 1997 Aug;32(8): 1196-200.

11. Eubanks JW, Ill, Meier DE, Hicks BA, Joglar J, Guzzetta PC. Significance of ‘blush’ on computed tomography scan in children with liver injury. J Pediatr Surg. 2003 Mar;38(3): 363-6.

12. Fang JF, Chen RJ, Wong YC, Lin BC, Hsu YB, Kao JL, et al. Pooling of contrast material on computed tomography mandates aggressive management of blunt hepatic injury. Am J Surg. 1998 Oct;176(4): 315-9.

13. Lutz N, Mahboubi S, Nance ML, Stafford PW. The significance of contrast blush on computed tomography in children with splenic injuries. J Pediatr Surg. 2004 Mar;39(3): 491-4.

14. Mayglothling JA, Haan JM, Scalea TM. Blunt Splenic Injuries in the Adolescent Trauma Population: The Role of Angiography and Embolization. J Emerg Med. 2011 Jul;41(1): 21-8.

15. Nwomeh BC, Nadler EP, Meza MP, Bron K, Gaines BA, Ford HR. Contrast extravasation predicts the need for operative intervention in children with blunt splenic trauma. J Trauma. 2004 Mar;56(3): 537-41.

16. Ohtsuka Y, Iwasaki K, Okazumi S, Yoshida H, Matsunaga T, Kouchi K, et al. Management of blunt hepatic injury in children: usefulness of emergency transcatheter arterial embolization. Pediatr Surg Int. 2003 Apr;19(1-2): 29-34.

17. Taylor GA, Kaufman RA, Sivit CJ. Active hemorrhage in children after thoracoabdominal trauma: clinical and CT features. Am J Roentgenol. 1994 Feb;162(2): 401-4.

18. Fang JF, Chen RJ, Wong YC, Lin BC, Hsu YB, Kao JL, et al. Classification and treatment of pooling of contrast material on computed tomographic scan of blunt hepatic trauma. J Trauma 2000 Dec;49(6): 1083-8.

19. Gandhi RR, Keller MS, Schwab CW, Stafford PW. Pediatric splenic injury: pathway to play? J Pediatr Surg. 1999 Jan;34(1): 55-8.

20. Mehall JR, Ennis JS, Saltzman DA, Chandler JC, Grewal H, Wagner CW, et al. Prospective results of a standardized algorithm based on hemodynamic status for managing pediatric solid organ injury. J Am Coll Surg. 2001 Oct;193(4): 347-53.
21. Stylianos S. Compliance with evidence-based guidelines in children with isolated spleen or liver injury: a prospective study. J Pediatr Surg. 2002 Mar;37(3): 453-6.
22. Davis KA, Fabian TC, Croce MA, Gavant ML, Flick PA, Minard G, et al. Improved success in nonoperative management of blunt splenic injuries: embolization of splenic artery pseudoaneurysms. J Trauma. 1998 Jun;44(6): 1008-13.
23. Federle MP, Courcoulas AP, Powell M, Ferris JV, Peitzman AB. Blunt splenic injury in adults: clinical and CT criteria for management, with emphasis on active extravasation. Radiology. 1998 Jan;206(1): 137-42.
24. Gavant ML, Schurr M, Flick PA, Croce MA, Fabian TC, Gold RE. Predicting clinical outcome of nonsurgical management of blunt splenic injury: using CT to reveal abnormalities of splenic vasculature. Am J Roentgenol. 1997 Jan;168(1): 207-12.
25. Shanmugarathan K, Mirvis SE, Boyd-Kranis R, Takada T, Scalea TM. Nonsurgical management of blunt splenic injury: use of CT criteria to select patients for splenic arteriography and potential endovascular therapy. Radiology. 2000 Oct;217(1): 75-82.
26. Velmahos GC, Chan LS, Kamel E, Murray JA, Yassa N, Kahaku D, et al. Nonoperative management of splenic injuries: have we gone too far? Arch Surg. 2000 Jun;135(6): 674-9.
27. Davis KA, Fabian TC, Croce MA, Gavant ML, Flick PA, Minard G, et al. Improved success in nonoperative management of blunt splenic injuries: embolization of splenic artery pseudoaneurysms. J Trauma. 1998 Jun;44(6): 1008-13.
28. Haan J, Ilahi ON, Kramer M, Scalea TM, Myers J. Protocol-driven nonoperative management in patients with blunt splenic trauma and minimal associated injury decreases length of stay. J Trauma. 2003 Aug;55(2): 317-21.
29. Hagiwara A, Yukioka T, Ohta S, Nitatori T, Matsuda H, Shimazaki S. Nonsurgical management of patients with blunt splenic injury: efficacy of transcatheter arterial embolization. Am J Roentgenol. 1996 Jul;167(1): 159-66.
30. Liu PP, Lee WC, Cheng YF, Hsieh PM, Hsieh YM, Tan BL, et al. Use of splenic artery embolization as an adjunct to nonsurgical management of blunt splenic injury. J Trauma. 2004 Apr;56(4): 768-72.
31. Myers JG, Dent DL, Stewart RM, Gray GA, Smith DS, Rhodes JE, et al. Blunt splenic injuries: dedicated trauma surgeons can achieve a high rate of nonoperative success in patients of all ages. J Trauma. 2000 May;48(5): 801-5.
32. Sclafani SJ, Shaftan GW, Scalea TM, Patterson LA, Kohl L, Kantor A, et al. Nonoperative salvage of computed tomography-diagnosed splenic injuries: utilization of angiography for triage and embolization for hemostasis. J Trauma. 1995 Nov;39(5): 818-25.
A seatbelt sign following a car accident: look for internal abdominal injury

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Chapter 4

ABSTRACT

We present three patients, a 55 year old man, a 69 year old woman and a 25 year old man, all with seatbelt signs following a car accident. The 3 patients exhibited a range of injuries that can all occur with blunt trauma, such as rib fractures. In one patient, however, the symptoms of internal abdominal injury occurred several days after the accident. The presence of a seatbelt sign is associated with an increased risk of internal abdominal injury. We therefore advise that a computed tomography CT scan of the abdomen is made in patients who present with a seatbelt sign, even if an abdominal ultrasound does not reveal any signs of injury.

Ladies and gentlemen,
A ‘seat belt sign’ consists of ecchymosis and excoriations of the abdominal wall caused by compressive stress and the shear forces of the seat belt. This phenomenon was described for the first time in 1962.1 Since the introduction of the three-point seat-belt, this type of injury can also be found on the thorax and neck. The presence of a ‘seat belt sign’ should alert doctors to be aware of the possibility of intra abdominal injury.

In this lecture we will present three patients with blunt abdominal injury who exhibited a ‘seat belt sign’ when physically examined. The management issues related to this physical diagnostic finding will be discussed in this article.

Patient A, a 55 year old Polish man, was involved in a one-sided car accident as substitute driver. The driver ran head-on into a tree. Immediately after the accident the patient was transported to the trauma unit and evaluated according to the ATLS protocol where he was found to be A,B,C-stable with a Glasgow Coma Score (D) of 14 (E4M6V4) after an obvious use of alcohol. Physical examination (E) revealed a ‘seat belt sign’ on the abdomen (Figure 1). Except for a rib fracture of the first left and right ribs, no abnormalities were found on radiological findings (X-ray of the pelvis, ultrasound of the abdomen, CT scan of the brain, cervical spine, thorax [with intravenous contrast]). The patient was admitted to the hospital for observation and on the next day he was discharged after a ‘tertiary survey’ (a second complete physical examination conducted with the aim of detecting any injuries which may have been missed earlier). After 8 days, the patient reported to the hospital with a swollen abdomen, nausea and vomiting. On physical examination the patient appeared unwell; he had a distended abdomen without peristalsis. Laboratory investigation revealed there were no infections.

A CT scan with an intravenous contrast of the abdomen revealed a caliber jump at the terminal ileum, possibly caused by an internal herniation of the intestines caused by a tear in the mesentery (Figure 2). An ischemic terminal ileum was encountered during explorative laparotomy and, for that reason, an ileocecal resection was performed. A herniation was not detected. The patient left hospital 10 days later in a good physical condition.
Patient B, a 45 year old man drove into the back of a lorry after having fallen asleep. The patient was evaluated A, B, C, D stable during assessment in the shock room in accordance with the guidelines. Physical examination showed a 'seat belt sign' on the left side of the lower part of the abdomen and a tender abdomen. The ultrasonography revealed free fluid in the cavum Douglasi, we therefore, decided to perform a CT scan of the abdomen with intravenous contrast. At the mesocolon of the sigmoid, extravasation of contrast fluid was detected (Figure 3) and a sigmoid resection with primary anastomosis was executed. The postoperative period went well and after 5 days the patient left hospital in a good condition.
Figure 3. CT scan of the abdomen with intravenous contrast (venous phase) showed extravasation of contrast fluid at the mesocolon of the sigmoid.

Figure 4. CT scan showed a contrast extravasation localized near the left mammalian artery and a traumatic arteriovenous fistula between the left colic artery and the superior mesenteric vein.
Patient C, a 69 year old woman, was involved in a car-accident. She was reviewed in the trauma room following the ATLS criteria. On arrival the patient was A, B, C, D stable. During the physical examination a seat belt sign was detected and the abdomen was slightly tender. An X-ray of the thorax revealed a fracture of the first rib on both sides and a hemothorax on the right side. When a thorax drain was inserted, 200 ml of blood was evacuated. The ultrasound showed no abnormalities. After preparation with Tavegil® and Dexamethason®, which were used because of an iodine allergy, a CT of the thorax and abdomen with intravenous contrast was performed. These revealed multiple rib fractures on both sides, with a drained hemothorax on the right, a fracture of the sternum, and multiple fractures of the pelvis. Liquid was present near the duodenum and in the retroperitoneum. Intra-abdominal blood and air were both absent. Moreover, contrast extravasation was found in a localized area near the left mammalian artery and a traumatic arteriovenous fistula was discovered between the left colic artery and the superior mesenteric vein (Figure 4). Both were treated with angiography and embolization with coils (Figures 5 a, b). The patient did not develop complications and 1 week after the accident she was discharged from hospital in a good condition.

Figure 5. Angiography of the traumatic arteriovenous fistula between left colic artery and superior mesenteric vein. Before (a) and after (b) treatment with coil embolisation.
Blunt trauma to the abdomen accompanied by mesenterial injury arises from the mechanisms of deceleration and compression. A wide spectrum of injuries, varying from contusions to lacerations of the abdominal wall and the mesenterium, can occur. Even full blown devascularisation of fragments of the intestines may be manifest.

**TRAUMA MECHANISM**

Blunt trauma to the abdomen accompanied by mesenterial injury arises from the mechanisms of deceleration and compression. A wide spectrum of injuries, varying from contusions to lacerations of the abdominal wall and the mesenterium, can occur. Even full blown devascularisation of fragments of the intestines may be manifest.

**EPIDEMIOLOGY**

The presence of a ‘seat belt sign’ is associated with a higher risk of intra-abdominal injury. The prevalence of intra-abdominal injury in the presence of a ‘seat belt sign’ is 10–21% and 2% if a seatbelt sign is not present.²,³

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**Figure 6.** Flow chart of the diagnostic and treatment process in patients with blunt abdominal injury. Minimal: minimal free fluid intra-abdominal and/or small tear in the mesenterium.
A seatbelt sign following a car accident: look for internal abdominal injury

**DIAGNOSTIC**

From the case histories described above, it appears that diagnosing intra-abdominal injury on the basis of clinical and radiological presentation can be difficult. Physical examination can offer some useful indications, but symptoms such as abdominal pain, a distended abdomen, decreased peristalsis, hypotension or shock are present in only 13–64% of patients in the acute phase. Making an ultrasound of the abdomen is a non-invasive, quick investigation, but it is only suitable for detecting free fluid. The sensitivity and specificity for the detection of a hemoperitoneum by using an ultrasound are 26 and 96% respectively. The sensitivity for the identification of an injury to a solid organ is even lower (40–50%). In the latter case a hemoperitoneum is observed in 29–44%. In every trauma patient a screening ultrasound of the abdomen is performed. A CT scan is executed if free fluid is present as it is a sign of possible organ injury. The sensitivity and specificity of a CT scan is 82 and 99% respectively. A CT scan is recommended if there is any clinical evidence of intra-abdominal injury, such as a ‘seat belt sign’. It is even speculated that an ultrasound is redundant if a ‘seat belt sign’ is present as the seat belt sign is usually indicative of more extensive injuries being present which cannot be detected with the ultrasound (because of its low sensitivity). Therefore, the only correct course of action is to perform a CT scan.

**TREATMENT**

An imperative indication for a laparotomy is the intra-abdominal presence of free air. Patients with a limited amount of free fluid without (parenchymatous) organ injury, (judged on the basis of a CT scan), or patients with minimal mesenterial damage can be treated conservatively. A DPL (diagnostic peritoneal lavage) can be carried out on these patients to differentiate between an injury to a hollow organ (intestine, gallbladder), an active bleeding or an injury to the pancreas. Any deterioration in the condition of the patient is an indication that a new CT scan or laparotomy should be performed. Extensive mesenterial injuries accompanied by a lot of free fluid demands direct surgical intervention. In the case of the vascular injuries (Patient C), an endovascular treatment performed by an intervention radiologist is preferable. Currently this latter treatment is not available in every hospital but, because of the progress in interventional radiology, this may change in the coming years. Because of the high sensitivity of a CT scan, a cooperative patient who has a ‘seat belt sign’, and no indicative signs of injury on the CT scan, can be safely discharged from hospital. Comprehensive information about any possible complications is essential. If a general practitioner detects a ‘seat belt sign’ during the physical examination of a patient who has had a car accident, this patient should be referred to hospital
for additional investigations. The Flowchart (Figure 6) illustrates our strategy for the diagnostic and therapeutic pathway.

Ladies and gentlemen, after the introduction of the obligation to wear a seat belt, the morbidity and mortality rates of car accident related injuries have drastically declined. However, a new phenomenon has now appeared: ‘the seat belt sign’. If a ‘seat belt sign’ is present, one should be aware of the presence of intra-abdominal injury and therefore a CT scan should be performed accessible.
REFERENCES

1. Garrett JW, Braunstein PW. The seat belt syndrome. J Trauma. 1962;2: 220-38.
2. Chandler CF, Lane JS, Waxman KS. Seatbelt sign following blunt trauma is associated with increased incidence of abdominal injury. Am Surg. 1997;63: 885-8.
3. Velmahos GC, Tatevosian R, Demetriades D. The „seat belt mark“ sign: a call for increased vigilance among physicians treating victims of motor vehicle accidents. Am Surg. 1999;65: 181-5.
4. Wotherspoon S, Chu K, Brown AF. Abdominal injury and the seat-belt sign. Emerg Med. 2001;13: 61-5.
5. Shanmuganathan K, Mirvis SE, Sherbourne CD, Chiu WC, Rodriguez A. Hemoperitoneum as the sole indicator of abdominal visceral injuries: a potential limitation of screening abdominal US for trauma. Radiology. 1999;212: 423-30.
6. Chiu WC, Cushing BM, Rodriguez A, Ho SM, Mirvis SE, Shanmuganathan K et al. Abdominal injuries without hemoperitoneum: a potential limitation of abdominal sonography for trauma (FAST). J Trauma. 1997;42: 617-23.
7. Stassen NA, Lukan JK, Carrillo EH, Spain DA, Richardson JD. Abdominal seat belt marks in the era of focused abdominal sonography for trauma. Arch Surg. 2002;137: 718-22.
8. Menegaux F, Tresallet C, Gosgnach M, Nguyen-Thanh Q, Langeron O, Riou B. Diagnosis of bowel and mesenteric injuries in blunt abdominal trauma: a prospective study. Am J Emerg Med. 2006;24: 19-24.
9. Stuhlfaut JW, Soto JA, Lucey BC, Ulrich A, Rathlev NK, Burke PA et al. Blunt abdominal trauma: performance of CT without oral contrast material. Radiology, 2004;233: 689-94.
10. Rutledge R, Lalor A, Ollier D, Hansen A, Thomason M, Meredith W et al. The cost of not wearing seat belts. A comparison of outcome in 3,396 patients. Ann Surg. 1993;217: 122-7.
Reliability of injury grading systems for patients with blunt splenic trauma

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Accepted Injury
ABSTRACT

Introduction: The most widely used grading system for blunt splenic injury is the American Association for the Surgery of Trauma (AAST) organ injury scale. A few years ago a new grading system was developed. This ‘Baltimore CT grading system’ is superior to the AAST system in predicting the need for angiography and embolization or surgery. The present study assessed inter - and intraobserver reliability between radiologists in classifying splenic injury according to both grading systems.

Methods: Computed Tomography (CT) scans of 83 patients with blunt splenic injury admitted between 1998 and 2008 to an academic Level 1 trauma center were retrospectively reviewed. Inter and intrarater reliability were expressed in Cohen’s or weighted Kappa values.

Results: Overall weighted interobserver Kappa coefficients for the AAST and ‘Baltimore CT grading system’ were respectively substantial (kappa =0.80) and almost perfect (kappa= 0.85). Average weighted intraobserver Kappa’s values were in the ‘almost perfect’ range (AAST: kappa=0.91, ‘Baltimore CT grading system’: kappa = 0.81).

Conclusion: The present study shows that overall the inter – and intraobserver reliability for grading splenic injury according to the AAST grading system and ‘Baltimore CT grading system’ are equally high. Because of the integration of vascular injury, the ‘Baltimore CT grading system’ supports clinical decision making. We therefore recommend use of this system in the classification of splenic injury after blunt trauma.
INTRODUCTION

The spleen is the most commonly injured solid organ in blunt abdominal trauma.\(^1,\,^2\) Contrast-enhanced multidetector computed tomography is the gold standard diagnostic examination for splenic trauma because of its speed, widespread availability, diagnostic accuracy, and relatively non-invasive nature. The most widely used grading system for blunt splenic injuries is the American Association for the Surgery of Trauma (AAST) organ injury scale.\(^3,\,^4\) This grading system, first introduced in 1989, is based on anatomic disruption of the spleen, as found during laparotomy (Appendix 1). CT-based injury grading systems, derived from the AAST scale, also exist.\(^5\)

Prior studies showed that grade of injury on the CT scan alone is a poor predictor for successful outcome of nonoperative management (NOM).\(^6\,^8\) Recent evidence suggests that vascular injuries including active splenic haemorrhage (the so-called ‘contrast blush’), pseudoaneurysms and post-traumatic arteriovenous fistulas are associated with an increased failure rate of NOM.\(^9\,\,^10\) Furthermore, it was shown that the higher the grade of splenic injury according to the AAST, the greater the risk of vascular injury.\(^11\) To date, vascular injuries are not integrated in the AAST grading system. Therefore, in 2007 Marmery and colleague radiologists validated a new grading system for the classification of splenic injury\(^12\) (Appendix 2). The presence of a contrast blush is a key factor in this grading system (further referred to as ‘Baltimore CT grading system’). The ‘Baltimore CT grading system’ is superior to the AAST system in predicting the need for angiography and embolization or splenic surgery in patients sustaining blunt splenic injury and therefore its use may be preferred over the AAST grading system.\(^5\)

The objective of the present study is to assess inter- and intraobserver reliability between radiologists in classifying blunt splenic injury according to the AAST and ‘Baltimore CT grading system’.

PATIENTS AND METHODS

All patients with blunt splenic injuries admitted between 1998 and 2008 to the level-1 trauma center of the Academic Medical Center, the Netherlands, were identified from the hospital’s trauma registry. The presence and quality of CT images, made during initial trauma screening in the shock room, were verified by a senior radiologist (LB).

Contrast-enhanced CT scans with 8 mm slices or thinner collimation and with images obtained during the portal-venous phase were selected.

Computed Tomography scanning (protocol)

CT scans were obtained on a 4 slice scanner (Sensation 4, Siemens Medical Solutions, Forcheim, Germany) before 2008 and a 64 slice scanner (Siemens Sensation 64) after 2008. Images were
acquired 70 seconds after intravenous administration of 100 ml contrast material (mainly Ultravist 300). The CT scans were independently scored by two senior radiologists (>10 years of experience, observer 1 and 2) and one radiology resident (4 years of experience, observer 3) on a PACS system (Impax 4, 5, AGFA Gevaert, Belgium). The CT scans were scored twice with a time interval of ≥2 months. The scans were presented to the observers in a random order. Since observers could have been involved in initial trauma screening in the shock room of a number of the clinical cases included in the study, observers were blinded for patients’ name, identity number and his or her clinical course.

**Investigated Parameters**

Splenic Injury was scored according to the ordinal grading systems of the AAST (Appendix 1) and the ‘Baltimore CT grading system’ (Appendix 2). AAST grades 1-3 and grades 4 and 5 were additionally dichotomized into low versus high grade splenic injury, respectively. This distinction is commonly applied in literature and has therapeutic implications. Since low reliability for scoring the presence (or absence) of a contrast blush can negatively influence the reliability of the ‘Baltimore CT grading system’, we additionally assessed the reliability of this parameter. The presence of a contrast blush was documented according to the following nominal categories: intraparenchymal (in the splenic parenchyma or subcapsular space) or intraperitoneal (into the peritoneum). A contrast blush was defined as a well-circumscribed, peri-splenic or intra-parenchymal contrast collection that was hyperdense with respect to the rest of the splenic parenchyma. Lastly, we assessed if in our study population a relation was observed between the grade of splenic injury (scored according to the AAST grading system) and the presence of vascular injury. In addition to the presence and type of contrast blush, this includes the presence of pseudoaneurysms and post traumatic arteriovenous fistulas.

**Statistical analysis**

Relevant patient characteristics (sex, age and Injury Severity Score) and the relation between vascular injury and splenic injury grade were summarized using descriptive statistics. For reporting vascular injury in relation to splenic injury grade, the mean value of the three observers (round 2) was calculated. Inter- and intraobserver reliability were expressed in Kappa coefficients. The Kappa statistic estimates the proportion of agreement among or within observers after chance agreement has been removed. Binary and nominal data were expressed in Cohen’s Kappa values, whereas ordinal data were expressed in weighted Kappa values. Average (weighted) Kappa values of pair of observations were considered as an overall index for concordance among or within observers. Kappa values were arbitrarily classified according to Landis and Koch with values <0 indicating no agreement, 0–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1 as almost perfect agreement. Statistical uncertainty of kappa of pair of observations was expressed in a 95% confidence interval.
RESULTS

CT scans of 88 patients were analyzed. Five patients were excluded due to incomplete data. The study population consisted of 83 patients. 88% of the patients was male. Median age was 29 years (range 17–86). Median Injury Severity Score was 24 (range 4–66).

Interobserver reliability

The interobserver reliability values of all parameters are shown in Table 1. The overall Kappa coefficients for the AAST and ‘Baltimore CT grading system’ were substantial (kappa = 0.80) and almost perfect (kappa = 0.85), respectively. The average Cohen’s Kappa for the presence or absence of a contrast blush was substantial (kappa = 0.76). Average Cohen’s Kappa’s for the subtypes of blushes (intraperitoneal and intraparenchymal) were ‘substantial’ (kappa = 0.68; data not presented) and ‘fair’ (kappa = 0.41; data not presented) respectively.

In general, the point estimates of the Kappa values of the most experienced observers (observer 1 and 2) were higher, indicating better interobserver agreement. The point estimates of the Kappa values of observer 2 against observer 3 were lower. Appendix 3 shows where disagreement was predominantly situated. 23 out of 34 CT scans graded as AAST splenic injury grade 3 by observer 2 were graded differently by observer 3. 9 out of the 14 CT scans graded as AAST splenic injury grade 4 by observer 2 were graded as AAST splenic injury grade 5 by observer 3. CT scans that were graded as splenic injury grade 4A by observer 2 according the ‘Baltimore

Table 1. Interobserver reliability: (weighted) Kappa values with 95% confidence intervals (n = 83 CT scans)

| Parameter                          | Overall Kappa a | (weighted) Kappa of pair of observations (95% confidence interval) |
|------------------------------------|-----------------|-------------------------------------------------------------------|
| AAST *                             | 0.80            | 1,2: 0.83 (0.77 - 0.90)                                            |
|                                   |                 | 2,3: 0.75 (0.65 - 0.84)                                            |
|                                   |                 | 1,3: 0.81 (0.70 - 0.91)                                            |
| AAST low vs high grade splenic injury ** | 0.75            | 1,2: 0.74 (0.60 - 0.89)                                            |
|                                   |                 | 2,3: 0.72 (0.57 - 0.87)                                            |
|                                   |                 | 1,3: 0.78 (0.64 - 0.91)                                            |
| ‘Baltimore CT grading system’ **   | 0.85            | 1,2: 0.91 (0.87 - 0.95)                                            |
|                                   |                 | 2,3: 0.79 (0.71 - 0.88)                                            |
|                                   |                 | 1,3: 0.84 (0.77 - 0.91)                                            |
| Contrast blush **                  | 0.76            | 1,2: 0.83 (0.70 - 0.96)                                            |
|                                   |                 | 2,3: 0.69 (0.52 - 0.86)                                            |
|                                   |                 | 1,3: 0.75 (0.59 - 0.90)                                            |

1: observer 1; 2: observer 2; 3: observer 3; *: ordinal data expressed in weighted Kappa values; **: binary and nominal data expressed in Cohen’s Kappa values.
a: overall Kappa indicates the average (weighted) Kappa values of pair of observations.
grading system' was graded as grade 2 (n=3), grade 3 (n=4) or grade 4B (n=1) by observer 3. Interobserver Kappa values after a time interval of ≥2 months showed the same patterns (data not presented).

**Intraobserver reliability**

Overall Kappa’s were in the ‘almost perfect’ range except for the presence of a contrast blush (substantial: kappa=0.77). Apart from the ‘Baltimore CT grading system’, the point estimates of the intraobserver agreements (Table 2) were higher compared to the interobserver agreements (Table 1). The intraobserver agreement of the third observer (resident) on the ‘Baltimore CT grading system’ was relatively low (kappa =0.66; 95% CI: 0.45-0.88), whereas the first observer showed almost perfect intraobserver Kappa values ≥0.89 for all parameters.

**Table 2. Intraobserver reliability: (weighted) Kappa values with 95% confidence intervals (n = 83 CT scans)**

|                      | Overall Kappa a | (weighted) Kappa per observer (95% confidence interval) |
|----------------------|----------------|--------------------------------------------------------|
| AAST *               | 0.91           | 1: 0.96 (0.92 - 1.00)                                  |
|                      |                | 2: 0.86 (0.80 - 0.92)                                  |
|                      |                | 3: 0.91 (0.85 - 0.97)                                  |
| AAST low vs high grade splenic injury ** | 0.84           | 1: 0.95 (0.88 - 1.00)                                  |
|                      |                | 2: 0.74 (0.59 - 0.90)                                  |
|                      |                | 3: 0.83 (0.70 - 0.95)                                  |
| ‘Baltimore CT grading system’ * | 0.81           | 1: 0.97 (0.84 - 0.98)                                  |
|                      |                | 2: 0.80 (0.67 - 0.93)                                  |
|                      |                | 3: 0.66 (0.45 - 0.88)                                  |
| Contrast blush **    | 0.77           | 1: 0.89 (0.78 - 0.96)                                  |
|                      |                | 2: 0.73 (0.57 - 0.88)                                  |
|                      |                | 3: 0.70 (0.53 - 0.86)                                  |

1: observer 1; 2: observer 2; 3: observer 3; *, ordinal data expressed in weighted Kappa values **, binary and nominal data expressed in Cohen’s Kappa values.

a, overall Kappa indicates the average (weighted) Kappa values per observer

**Vascular injury**

No post-traumatic arteriovenous fistulas and 3 pseudoaneurysms were detected on the CT scans. In 28 out of the 83 patients (33%) a contrast blush was detected. In 11 patients an intraparenchymal blush was present, in 14 an intraperitoneal blush and in three patients a combination of both an intraparenchymal and intraperitoneal blush was observed. The number of patients with a contrast blush visible on CT scan in relation to the (total) number of patients with the corresponding grade of splenic injury increased from 0 out of the 10 (0%) patients with grade 1 splenic injury to 10 out of the 14 (71%) patients with grade 5 splenic injury. Figure 1 depicts the different types of contrast blushes per grade of splenic injury.
Reliability of injury grading systems for patients with blunt splenic trauma

**DISCUSSION**

The present study shows that overall the interrater reliability between radiologists in classifying splenic injury after blunt trauma is substantial for the AAST grading system and almost perfect for the ‘Baltimore CT grading system’.

A contrast blush, a sign of vascular injury, is a key factor in the ‘Baltimore CT grading system’. In this system the presence of a contrast blush is responsible for an upgrade of the splenic injury to grade 4, even in patients with splenic injury categorized as grade 1 or 2 according to the AAST system. Although interobserver reliability for the presence or absence of a contrast blush was accurate, additional analyses were performed for the different subtypes of contrast blushes because what really matters is how frequently or infrequently different observers come to clinically important different assessments. Possibly, more accurate scoring of mainly an intraparenchymal blush (Baltimore grade 4a) could result in a further improvement of interobserver reliability of the ‘Baltimore CT grading system’. Because of the low occurrence of arteriovenous fistulas and pseudoaneurysms, also scored as Baltimore grade 4a, these types of vascular injury were not entered into analysis.

The interobserver reliability of the AAST low versus high grade of splenic injury was not higher than the more detailed standard AAST and ‘Baltimore CT grading system. This is in contrary to our expectations because in theory a smaller number of categories facilitates the scoring process for the observers. In the dichotomised AAST classification (low versus high grade splenic injury) observers make a distinction between severe and less severe splenic injury instead of choosing a grade that differs only slightly from the grade above or below.

The observers were consistent in their performance, reflected by high overall intraobserver Kappa’s for all parameters. However, point estimates of the Kappa values seem to indicate a

![Figure 1. Number of patients with a contrast blush visible on CT scan in relation to the AAST grade of splenic injury (n=83)](image-url)
difference between the most experienced radiologist and the resident, mainly for the ‘Baltimore CT grading system’ and the presence of a contrast blush. Furthermore, the results of earlier research were confirmed showing that the higher the grade of splenic injury according to the AAST, the greater the risk vascular injury.\(^\text{11, 17}\) The most important advantage of the ‘Baltimore CT grading system’ is that it integrates vascular injury into the score. Awareness of the presence of vascular injury is important since a leading cause of death after trauma is exsanguination. Moreover, the presence of vascular injury is associated with higher rates of failure of NOM, which can be prevented by splenic artery embolization.\(^\text{10, 13}\) Several studies point out that angioembolization is reserved for those patients with active bleeding on admission CT scan and higher grade splenic injuries thus confirming that the presence of vascular injury is therapy guiding.\(^\text{18, 19}\)

A number of limitations of this study need to be considered. First, CT scanning protocols changed during the study period. Although all images were of good quality (qualitatively poor images were excluded from the study), images of 2008 were qualitatively better because the CT scanner was replaced by a newer model. Second, the sample size of three observers was small. Third, no time limits were set for evaluation of the images. In an actual trauma situation time restraints could impair adequate scoring, and will favour a more simple approach. Fourth, radiologists no time limits were set for evaluation of the images. In an actual trauma situation time restraints could impair adequate scoring, and will favour a more simple approach. Third, radiologists were more experienced in grading splenic injury according to the AAST system since it was introduced approximately 20 years ago and is widely used whereas the ‘Baltimore CT grading system’ has only recently been introduced and still has to gain acceptance. This could have possibly influenced the results, in favour of the AAST grading system. Lastly, we did not establish the association between the two grading systems and the modality of treatment that was elected and the outcome. Future studies, should point out whether subcategories of blushes can be defined that are helpful to formulate a prognosis of nonoperative management. The characteristics of blushes that are likely to stabilize and eventually regress or disappear should be distinguished from blushes that require arterial embolization or surgery. A study about the prognostic value of a contrast blush in the hierarchy of treatment options, particularly in polytrauma patients, would be of considerable value.

**Conclusion**

The present study shows that the inter- and intraobserver reliability for grading splenic injury according to the AAST grading system and ‘Baltimore CT grading system’ are equally high. Because of the integration of vascular injury, the ‘Baltimore CT grading system’ supports clinical decision making. We therefore recommend use of the ‘Baltimore CT grading system’ in the classification of splenic injury after blunt trauma.
Reliability of injury grading systems for patients with blunt splenic trauma

REFERENCES

1. Esposito T.J. and Gamelli R.L. Injury to the spleen. 2000. Appleton and Lange. Trauma. Feliciano D.V., Moore, E. E., and Mattox K.L.
2. Tsugawa K, Koyanagi N, Hashizume M et al. New insight for management of blunt splenic trauma: significant differences between young and elderly. Hepatogastroenterology. 2002;49:1144-1149.
3. Moore EE, Shackford SR, Pachter HL et al. Organ injury scaling: spleen, liver, and kidney. J Trauma. 1989;29:1664-1666.
4. Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni MA, Champion HR. Organ injury scaling: spleen and liver (1994 revision). J Trauma. 1995;38:323-324.
5. Marmery H, Shanmuganathan K, Alexander MT, Mirvis SE. Optimization of selection for nonoperative management of blunt splenic injury: comparison of MDCT grading systems. AJR Am J Roentgenol. 2007;189:1421-1427.
6. Becker CD, Spring P, Glattli A, Schweizer W. Blunt splenic trauma in adults: can CT findings be used to determine the need for surgery? AJR Am J Roentgenol. 1994;162:343-347.
7. Sutyak JP, Chiu WC, D’Amelio LF, Amorosa JK, Hammond JS. Computed tomography is inaccurate in estimating the severity of adult splenic injury. J Trauma. 1995;39:514-518.
8. Kohn JS, Clark DE, Isler RJ, Pope CF. Is computed tomographic grading of splenic injury useful in the nonsurgical management of blunt trauma? J Trauma. 1994;36:385-389.
9. Thompson BE, Munera F, Cohn SM et al. Novel computed tomography scan scoring system predicts the need for intervention after splenic injury. J Trauma. 2006;60:1083-1086.
10. Shanmuganathan K, Mirvis SE, Boyd-Kranis R, Takada T, Scalea TM. Nonsurgical management of blunt splenic injury: use of CT criteria to select patients for splenic arteriography and potential endovascular therapy. Radiology. 2000;217:75-82.
11. Omert LA, Salyer D, Dunham CM, Porter J, Silva A, Protetch J. Implications of the “contrast blush” finding on computed tomographic scan of the spleen in trauma. J Trauma. 2001;51:272-277.
12. Marmery H, Shanmuganathan K. Multidetector-row computed tomography imaging of splenic trauma. Semin Ultrasound CT MR. 2006;27:404-419.
13. Schurr MJ, Fabian TC, Gavant M et al. Management of blunt splenic trauma: computed tomographic contrast blush predicts failure of nonoperative management. J Trauma. 1995;39:507-512.
14. Feinstein AR. Clinimetrics. New Haven: Yale University Press . 1987.
15. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977; 33:159-174.
16. Brenner H, Kliebsch U. Dependence of weighted kappa coefficients on the number of categories. Epidemiology. 1996;7:199-202.
17. Anderson SW, Varghese JC, Lucey BC, Burke PA, Hirsch EF, Soto JA. Blunt splenic trauma: delayed-phase CT for differentiation of active hemorrhage from contained vascular injury in patients. Radiology. 2007;243:88-95.
18. Haan J, Ilahi ON, Kramer M, Scalea TM, Myers J. Protocol-driven nonoperative management in patients with blunt splenic trauma and minimal associated injury decreases length of stay. J Trauma. 2003;55: 317-321.
19. Franco F, Monaco D, Volpi A, Marcato C, Larini P, Rossi C. The role of arterial embolization in blunt splenic injury. Radiol Med. 2011;116:454-465.
Chapter 5

APPENDIX

Appendix 1. American Association for the Surgery of Trauma Organ Injury Scale Spleen (1994 revision) [10]

| Grade | Injury type   | Description of injury                                                                 |
|-------|---------------|---------------------------------------------------------------------------------------|
| I     | Hematoma      | subcapsular: <10% surface area                                                        |
|       | Laceration    | capsular tear: <1 cm parenchymal depth                                                |
| II    | Hematoma      | subcapsular: 10%-50% surface area; intraparenchymal. <5 cm in diameter                |
|       | Laceration    | capsular tear. 1-3 cm parenchymal depth that does not involve a trabecular vessel     |
| III   | Hematoma      | subcapsular: >50% surface area or expanding; ruptured subcapsular or                  |
|       | Laceration    | parenchymal hematoma; intraparenchymal hematoma >5 cm or expanding                    |
|       |               | >3 cm parenchymal depth or involving trabecular vessels                                |
| IV    | Laceration    | laceration involving segmental or hilar vessels producing major devascularisation     |
|       |               | (>25% of spleen)                                                                      |
| V     | Laceration    | completely shattered spleen                                                            |
|       | Vascular      | hilar vascular injury with devascularized spleen                                      |

Appendix 2. ‘Baltimore CT grading system’ [9]

| Grade | Criteria                                                                 |
|-------|--------------------------------------------------------------------------|
| 1     | Subcapsular hematoma < 1 cm thick                                        |
|       | Laceration < 1 cm parenchymal depth                                      |
|       | Parenchymal hematoma < 1 cm diameter                                     |
| 2     | Subcapsular hematoma 1-3 cm thick                                        |
|       | Laceration 1-3 cm in parenchymal depth                                   |
|       | Parenchymal hematoma 1-3 cm in diameter                                  |
| 3     | Splenic capsular disruption                                              |
|       | Subcapsular hematoma > 3 cm thick                                        |
|       | Laceration > 3 cm in parenchymal depth                                   |
|       | Parenchymal hematoma > 3 cm in diameter                                  |
| 4a    | Active intraparenchymal and subcapsular splenic bleeding                 |
|       | Splenic vascular injury (pseudoaneurysm or arteriovenous fistula)        |
|       | Shattered spleen                                                         |
| 4b    | Active intraperitoneal bleeding                                          |
## Appendix 3. Cross-tabulations for observer 2 against observer 3 for the AAST grading system and ‘Baltimore grading system’

### AAST grading system

| Observer 2 | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | Total |
|------------|---------|---------|---------|---------|---------|-------|
| Grade 1    | 6       | 1       | 0       | 0       | 0       | 7     |
| Grade 2    | 9       | 11      | 0       | 1       | 1       | 22    |
| Grade 3    | 2       | 7       | 11      | 12      | 2       | 34    |
| Grade 4    | 0       | 0       | 0       | 5       | 9       | 14    |
| Grade 5    | 0       | 0       | 0       | 0       | 6       | 6     |
| Total      | 17      | 19      | 11      | 18      | 18      | 83    |

### ‘Baltimore grading system’

| Observer 2 | Grade 1 | Grade 2 | Grade 3 | Grade 4A | Grade 4B | Total |
|------------|---------|---------|---------|----------|----------|-------|
| Grade 1    | 6       | 1       | 0       | 0        | 0        | 7     |
| Grade 2    | 8       | 9       | 1       | 1        | 0        | 19    |
| Grade 3    | 2       | 2       | 16      | 6        | 0        | 30    |
| Grade 4A   | 0       | 3       | 4       | 5        | 1        | 13    |
| Grade 4B   | 0       | 0       | 0       | 4        | 10       | 14    |
| Total      | 16      | 19      | 21      | 16       | 11       | 83    |
Literature review of the role of ultrasound, computed tomography, and transcatheter arterial embolization for the treatment of traumatic splenic injuries

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ABSTRACT

**Introduction:** The spleen is the second most frequently injured organ following blunt abdominal trauma. Trends in management have changed over the years. Traditionally, laparotomy and splenectomy was the standard management. Presently, non operative management (NOM) of splenic injury is the most common management strategy in hemodynamically stable patients. Splenic injuries can be managed via simple observation (OBS) or with angiography and embolization (AE). AE has shown to be a valuable alternative to observational management and has increased the success rate of nonoperative management in many series.

**Diagnostics:** Improved imaging techniques and advances in interventional radiology have led to a better selection of patients who are amenable to nonoperative management. In spite of this, there is still a lot of debate going on which patients are prone to NOM.

**Angiography and embolization:** The optimal patient selection is still a matter of debate and the role of CT and AE have not yet fully evolved. The role of FAST and CT features such as contrast extravasation, pseudoaneurysms, arteriovenous fistulas or hemoperitoneum to determine the optimal patient selection for AE are discussed. Also the efficiency, technical considerations (proximal or selective embolization), logistics and complication rates of AE for blunt traumatic splenic injuries are reviewed.
INTRODUCTION

The spleen is behind the liver the second most frequently injured organ following abdominal trauma, occurring in 32% of abdominal injuries. Splenic injuries are most often observed in blunt abdominal trauma such as in motorcycle accidents, assaults, fall from height and sports. During the last two decades, major changes in the management of splenic injuries have occurred. Traditionally, operative management (OM) was the standard management for patients with splenic injury. Once the spleen has been mobilized, a decision must be made regarding splenectomy or splenic salvage procedures (mesh splenorraphy, partial resection, adhesive and/or coagulation techniques). Due to the increased risk of infections, in particular fatal overwhelming post-splenectomy sepsis, a trend from splenectomy towards splenic conservation has emerged. Presently, nonoperative management (NOM) of splenic injury is the most common management strategy in hemodynamically stable patients. NOM can be divided in either observation (OBS) or angiography and embolization (AE). Observation involves admission to an unit with monitoring of vital signs, strict bed rest, frequent monitoring of red blood cell count, and serial abdominal exams. Improved imaging techniques and advances in interventional radiology have helped better differentiate patients who can be observed versus those needing AE. Nevertheless, the optimal patient selection is still a matter of debate and the role of CT and AE has not yet fully evolved.

The aim of this article is to review the current literature pertaining to the diagnosis and transcatheter therapy of traumatic splenic injuries.

DIAGNOSTICS

FAST

The primary goal in the initial management of abdominal trauma is to detect and treat life-threatening injuries, in the majority of cases bleeding related, as quickly as possible. The method of choice for rapid evaluation of the abdomen for free fluid is the Focused Abdominal Sonography for Trauma (FAST). In European trauma centers sonography has replaced diagnostic peritoneal lavage as the primary screening test for intra abdominal haemorrhage. FAST can be performed simultaneously with resuscitation efforts during the initial trauma management and only takes two minutes to perform. For this reason it is also useful in hemodynamically unstable patients. FAST is especially useful for detecting the presence or absence of a hemoperitoneum, a herald of significant organ injury with a sensitivity of 90–93%. However, FAST has a low sensitivity for detecting and grading splenic injury. Injuries to bowel and mesentery without hemoperitoneum and retroperitoneal hematomas may also be missed by FAST. In addition to this, FAST is unable to detect the presence of active haemorrhage. For patients...
who are hemodynamically stable, a FAST detecting hemoperitoneum should lead to a CT scan for further evaluation of the nature and extent of injury. When the FAST is negative for hemoperitoneum, debate exists regarding whether a CT scan is required. Estimates for the presence of intra-abdominal injuries in the absence of hemoperitoneum on FAST can be as high as 29%.\textsuperscript{16,21-23}

Most trauma centers that use FAST as a primary screening modality rely on the assumption that any missed injuries are low-grade lesions without serious clinical consequence.\textsuperscript{24,25} However, some studies demonstrated that the use of FAST examination as a screening tool for blunt abdominal injury in the hemodynamically stable trauma patient results in underdiagnosis of intra-abdominal injuries. Routine CT scan frequently reveals additional injuries, which results in a change of treatment in 6.4–16% of these patients.\textsuperscript{20,26-28} That may have an impact on treatment and outcome in trauma patients. Therefore, hemodynamically stable patients with a negative FAST and a high clinical suspicion for splenic injury, for example a seat belt sign or upper abdominal pain, should undergo routine CT scanning.

**Computed Tomography and grading systems**

CT before and during the arterial and delayed phase of intravenous contrast enhancement is now considered the gold standard for diagnosing splenic injuries after trauma and is preferred in hemodynamically stable patients. CT is the most accurate test to assess the grade of injury to the spleen, as well as other intraperitoneal and retroperitoneal organs and it can give a relatively accurate estimation of the volume of hemoperitoneum. It can also detect the presence and

**Figure 1.** Hemodynamically stable patient (patient A) with blunt abdominal trauma after fall from horse. CT with intravenous contrast shows small amount of hemoperitoneum around the spleen and a contrast “blush”, which is confined to the splenic parenchyma. (AAST grade 3, Baltimore grade 4a)
location of active arterial haemorrhage as well as the presence of a pseudoaneurysms or arte- riovenous fistulas in the spleen.\textsuperscript{29, 30} Active contrast extravasation is usually seen on CT scan as an irregular or linear area of contrast extravasation in the splenic parenchyma (Patient A; figure 1), subcapsular space or in the peritoneum (Patient B; figure 2).\textsuperscript{28} It may be difficult to accurately distinguish pseudoaneurysms from extravasation if monophasic scanning is performed during CT. If multi-phasic CT is done, washout from the false aneurysm in the delayed phase enables reliable differentiation from extravasation.\textsuperscript{31} CT can also play a role in hemodynamically unstable patients when the logistic situation is organised in such a way that CT scanning during initial trauma resuscitation and evaluation is directly available in or very close to the emergency room.\textsuperscript{32, 33} Limitations of the early trauma CT include its modest sensitivity for assessing injury to pancreas, bowel and mesentery, as well as its relative inability to detect venous haemorrhage.

The most widely used grading system for blunt splenic injuries is the American Association for the Surgery of Trauma (AAST) injury scale.\textsuperscript{34, 35} This grading system (table 1) is based on the anatomic extention of disruption of the spleen, as shown on CT scans or during laparotomy. However, this grading system is not reliable in the prediction of the outcome of splenic injuries and not decisive whether surgery of conservative treatment should be applied.\textsuperscript{2, 36-39} Previous studies have shown that the CT injury grade alone is a poor predictor for the success of NOM.\textsuperscript{36, 40, 41} Recent literature has suggested that vascular injuries including active splenic bleeding (contrast blush), pseudoaneurysms and post-traumatic arteriovenous fistulas are associated with an increased failure rate of nonoperative management.\textsuperscript{7, 10, 13, 28, 38, 42-44}

**Figure 2.** Hemodynamically stable patient (patient B) with blunt abdominal trauma after motor vehicle accident. CT with intravenous contrast shows hemoperitoneum, fractured spleen with large hematoma and extravasation of contrast medium into the abdominal cavity. (AAST grade 4, Baltimore grade 4b)
However, these injuries are not included in the AAST grading system. Because of the risk of failure of nonoperative management of patients with these injuries on CT scan, it is important to identify these vascular injuries. Marmery and colleagues have developed a new grading system (‘Baltimore’ grading system) (table 1), which was based on experience from multiple trauma centers, indicating that CT evidence of a contrast blush or vascular injuries predicts the need for AE or surgical management. This ‘Baltimore’ CT grading system seems to be better than the AAST system for predicting which patients are the most likely candidates for embolization or splenic surgery. However, prospective randomized studies are needed to validate these results.

**ANGIOGRAPHY AND EMBOLIZATION**

**Indications**

In 1995 Sclafani described the first successful use of AE for hemodynamically stable patients with a splenic injury as adjunct to observational management. Since the late 1990’s AE has been applied more frequently to achieve better splenic salvage rates in the treatment of patients with splenic injuries. Simple observation alone has been reported to have a failure rate as high as 34%; the failure rate is even higher among patients with high grade splenic injuries (AAST grade 3–5).
Many studies support the use of embolization as an adjunct to observation. AE has increased the success rate of nonoperative management both by stopping ongoing bleeding as well as by preventing delayed rupture of the spleen.\(^7\)-\(^{47}\),\(^{52-57}\) Success rates up to 97% are described in the literature. However, these results must be interpreted with some caution, because these results are based on cohort studies which were compared with results of historical studies. Prospective randomized controlled trials have never been published.

Recent studies advocate the use of AE in the presence of the following CT findings: active contrast extravasation, pseudoaneurysm or arteriovenous fistula, large hemoperitoneum and a higher grade of injury (grade 3–5).\(^9\),\(^{10}\),\(^{28}\),\(^{49}\),\(^{55}\),\(^{58-63}\)

Several authors and also the clinical practical guideline for the NOM of blunt splenic injury of the Eastern Association for the Surgery of Trauma suggest that the presence of a contrast blush or vascular injury on the CT scan may portend a higher failure rate after observational management.\(^9\),\(^{10}\),\(^{38}\),\(^{43}\),\(^{46}\)

Schurr et al.\(^{46}\) described 89 patients who were initially managed nonoperatively. Twelve patients failed NOM. Upon review of the initial computed tomography scans, a contrast blush was noted in 8 of 12 (67%) patients who failed and in 5 of 77 (6%) of those who were successfully managed nonoperatively (\(p <0.0001\)). Another study demonstrated that both a contrast blush and traumatic vascular injuries (pseudoaneurysms and arteriovenous fistula) were associated with a high failure rate (82%) of nonoperative management.\(^{43}\)

Omert et al. have questioned the significance of a contrast blush. They suggested that a contrast blush is not an absolute indication for an operative or angiographic intervention. Factors such as patient age, grade of injury, and presence of hypotension need to be considered in the clinical management of these patients.\(^{64}\)

Splenic embolization has also been used successfully in patients with AAST grade 3–5 splenic injuries.\(^9\),\(^{10}\),\(^{55}\),\(^{59}\),\(^{65}\) Haan et al. published results demonstrating success rates from 87–100% after embolization.\(^9\),\(^{10}\) Another study demonstrated increases in NOM success rate from 74 to 89% with embolization in patients with high grade lesions.\(^{55}\)

Presence of a large hemoperitoneum predicted failure of NOM in the EAST study\(^{49}\) and also in a study of Velmahos et al.\(^{51}\) However, in other studies a significant hemoperitoneum did not affect the success rate.\(^9\) The combination of a contrast blush within the peritoneal cavity and a significant hemoperitoneum indicates active and massive bleeding and predict a high failure rate and thus warrant a low threshold for AE or a splenectomy.\(^{55}\),\(^{62}\),\(^{66}\)

The overall success rate (defined by preservation of the spleen) of splenic embolization ranges from 73–97% with most studies reporting success rates greater than 90%.\(^7\),\(^{9}\),\(^{10}\),\(^{47}\),\(^{54}\),\(^{55}\),\(^{57}\),\(^{58}\),\(^{62}\),\(^{65}\),\(^{67}\),\(^{68}\) Several authors also successfully re-embolized patients in whom initial embolization failed, which further increased the splenic salvage rate.\(^9\),\(^{58}\),\(^{68}\) Some studies, in contrast, showed no benefit of splenic artery embolization. A study of Harbrecht et al.\(^{69}\) concluded that patients who underwent splenic arteriography did not have improved nonoperative splenic salvage rates compared with a contemporaneous control group of similarly injured patients. In two
other studies, the authors show their concern that embolization may be overutilized for blunt splenic injury, resulting in still high failure rates (27%) after embolization.\textsuperscript{62,70} They recommend a low threshold to operate if bleeding persists in an embolized patient who had the combination of a high grade injury and large hemoperitoneum or contrast blush on CT. Figure 3 depicts our strategy for the diagnostic and therapeutic management.

* abnormalities in physical examination of the abdomen, pelvis or lumbar spine
base excess $<-3$
systolic blood pressure $<90$ mm Hg
long bone fractures\textsuperscript{27}

\textbf{Figure 3.} Flowchart for the diagnostic and therapeutic management of blunt splenic injury.

\textbf{Technique}

Splenic arterial catheterization is commonly performed using the common femoral artery access. Placement of a 5–6 French introducer sheath suffices in most cases. A flush aortogram may be performed to evaluate anatomy of the visceral vessels, but is not mandatory, particularly when a contrast-enhanced CT-scan is available. Selective angiography of the splenic artery should always be performed to evaluate arterial injury. Diagnostic series of the splenic artery should be obtained using a 4 or 5 French catheter, but for selective catheterization of splenic artery branches co-axial microcatheters and micro-guidewires may be required. Techniques
and materials used for embolization depend on anatomical considerations, the hemodynamic situation of the patient and the type and distribution of vascular injuries. Coils are usually the embolic agents of choice and gelfoam may in some situations also be used. Other types of embolic agents are rarely needed. Occasionally, the use of an Amplatzer® vascular plug may be useful.71

Occlusion after coil embolization usually occurs as a result of coil-induced thrombosis rather than mechanical occlusion of the lumen by the coil and therefore this technique works best when the coagulation profile of the patient is normal or only mildly abnormal. In case of serious clotting disturbances addition of another embolic agent such as gelfoam is indicated. Gelfoam is a sterile gelatin sponge intended for use as a temporary intravascular embolic material. It can be used in the shape of a “torpedo” or as pledgets. It can be injected through both standard 4–5 French angiographic catheters and micro-catheter systems. The major advantage of coils over gelfoam is the ability to provide permanent embolization which is most desirable in treating vascular injuries. Gelfoam is a bio-degradable material, but splenic artery recanalization rates after embolization are not known. However, occlusive agents such as gelfoam seem to have a higher failure rate (50%) compared with coil embolization (23%).72 The routine use of antibiotic prophylaxis for splenic artery embolization is not indicated.

**Proximal versus Selective Embolization**

Both proximal splenic artery embolization (PSAE) and selective distal splenic artery embolization have been applied and are described in the literature.10,47 The surgical equivalent of PSAE

![Figure 4](image1.png) **Figure 4.** Same patient (patient A) as in figure 1. Selective digital subtraction angiogram of the celiac axis showing the intra-parenchymal contrast “blush” in the spleen. Note tortuous anatomy of the splenic artery.

![Figure 5](image2.png) **Figure 5.** Same patient (patient A) as figures 1 and 4. Selective embolization was not possible as a result of the tortuous anatomy and proximal coil embolization of the splenic artery was performed. Check angiogram after embolization shows occlusion of the proximal splenic artery. Perfusion of the spleen by collaterals is not shown in this image.
for splenic injury, splenic artery ligation, was first described in 1979.\textsuperscript{73} PSAE (patient A; figure 4 and 5) is based on the theory that the intrasplenic blood flow and blood pressure decrease, as a result of which the bleeding stops.\textsuperscript{74} Sufficient perfusion of the spleen for salvage of the organ is preserved through the collateral flow of the short gastric arteries. PSAE involves occluding the proximal splenic artery using coils or in some specific situations using the Amplatzer\textsuperscript{®} vascular plug. It can often be performed using standard 4–5 French catheters and is usually less time-consuming than distal embolization.\textsuperscript{75, 76} The technique of selective distal embolization (patient B; figure 6 and 7) involves embolizing only the injured blood vessels. This often involves smaller branches of the splenic artery and is inside the spleen itself. Typically a micro-catheter system is required for this type of embolization, particularly when there is significant tortuosity of the splenic artery.

Proximal embolization is mostly used when there is diffuse bleeding of the spleen, when there are multiple focal bleeding vessels in the spleen, when there is time-pressure as a result of the hemodynamic situation of the patient or when tortuosity of the splenic artery prevents selective distal embolization. PSAE may also used in some situations where the site of hemorrhage is not identified on the angiogram and the clinical situation of the patient suggests ongoing bleeding form the spleen. Selective distal embolization is usually reserved for patients who have one or only a few focal bleeding vessels in the spleen and in whom the anatomy and hemodynamic situation allow employment of this.

The current literature provides little evidence whether PSAE or selective embolization is a better treatment. Although no prospective studies comparing the results of proximal or selective embolization are described, the use of PSAE seems to have some advantages. PSAE is faster, is
associated with a lower failure rate of NOM in some studies and a lower incidence of splenic abcess or infarction as compared to selective distal embolization. However, it has to be noted, that splenic infarcts after selective distal embolization rarely lead to clinical sequelae and splenic abcess can usually be treated percutaneously. Several studies have shown that PSAE and selective embolization have no major long-term impact on the splenic anatomy and immune function.

A potential disadvantage of PSAE could be the fact that in case of rebleeding, repeat embolization is difficult due to the inaccessibility of the splenic artery. Nevertheless, both techniques have been used successfully. The choice for either of the two techniques depends on the considerations mentioned above as well as on operator preference.

**VACCINATION**

The lifetime risk of overwhelming postsplenectomy sepsis is 1–2%, with a mortality rate of 33%. For that reason, the current recommendation is to treat patients after splenectomy with H. Influenzae (Hib), pneumococcal and meningococcal vaccination. Several studies have shown that proximal ligation of the splenic artery, proximal and selective splenic embolization has no major long-term impact on the splenic anatomy and immune function. Only one recent study suggest that the immunologic profile of embolized patients is reduced to controls. These studies, however state, that large controlled studies will be needed to make definitive vaccination recommendations. We apply vaccination in patients after extensive distal embolization or embolization (proximal or distal) for a shattered spleen.

**LOGISTICS**

For an effective application of AE as a treatment modality, CT scanning should be available 24 hours a day to triage patients between observation, angio-embolization and surgery. Early assessment using CT scanning in the emergency room, may further improve these logistics. Also, the hospital interventional radiology suite and personnel should be set up for rapid response at any time.

The success rate of NOM depends on the time between the initial intake at the emergency room and the AE, as a result of the decreasing clinical condition and coagulation state of the patient. Because embolization can be time-consuming and there is a risk for hemodynamic deterioration, the patient should be monitored carefully. Therefore, AE requires good teamwork among the trauma surgeon, the anaesthesiologist and the interventional radiologist.
Chapter 6

**COMPLICATIONS**

Major complications following splenic artery embolization have been reported in 6–20%.\(^9,^{10,85}\) In a small study of Ekeh and colleagues major complications such as bleeding, abscess and contrast nephropathy occurred in 27%.\(^70\) Minor complications, fever, pleural effusions and coil migration occurred in 53%. Other studies have demonstrated lower complication rates.\(^9,^{10,85}\) In the Western Trauma Association multi-institutional trial \(^9\) 140 patients underwent proximal and distal embolization and combination of both techniques in 83, 48 and 9 patients, respectively. Mean AAST splenic injury grade was 3.5. The following vascular injuries were seen on the CT scan: hemoperitoneum (59%), contrast extravasation (44%), pseudoaneurysm (33%) and an AV fistula in 4% of the patients. This trial reported a major complication rate of 20%. These complications included persistent bleeding or rebleeding (11%), missed injury (3%), and splenic abscess (4%). Two percent of the patients had coil migration at the time of angiography, without sequelae in any of these patients. Infarctions following embolization occurred in 21% of patients in this study. Similar infarction rates have been described in other series.\(^9,^{62,77,85}\) In one study, the infarction rate was 100% following distal embolization and 63% following proximal embolization.\(^67\) Most of patients with splenic infarcts are asymptomatic and could be managed conservatively.\(^67,72\) Abscess usually presents at contrast-enhanced CT as a hypodens fluid collection with or without air or an air-fluid level. However, the presence of gas in the spleen after embolization is not a specific sign for infection. In general, post-embolization splenic abscesses can be treated with percutaneous drainage. Puncture-site related complications (hematoma, dissection, trombosis) after angiography are relatively rare.\(^47,67\)

**CONCLUSION**

AE is widely accepted in the management of hemodynamically stable patients with splenic injury, due to the improved CT techniques, their direct availability in early trauma management and the advances in interventional radiology. CT scanning with intravenous contrast help to select hemodynamically stable patients for AE, but the optimal patient selection is still controversial. The single CT finding that warrants immediate AE is a contrast extravasation within the peritoneal cavity, particularly in patients who are not hemodynamically stable or who have other clinical signs of ongoing bleeding. Other CT-features such as false aneurysm, AV-fistula, contrast extravasation contained within the spleen and the presence of a hemoperitoneum are associated with an increased failure rate of NOM but whether angio-embolization for such findings increase the success rate of NOM remains a matter of debate. Angio-embolization has shown to be a valuable adjunct to observational management and has increased the success rate of NOM in many series. PSAE and selective embolization can both be performed and there is currently no evidence favoring either technique. However,
these results must be interpreted with caution, as they are based on cohort studies which were compared with results of historical studies. Prospective randomized controlled trials comparing observational management versus embolization have never been published. Although difficult to conduct due to the nature of the trauma population, such trials are needed to further determine the optimal patient selection for AE for traumatic splenic injury.
REFERENCES

1. Smith J, Caldwell E, D’Amours S, Jalaludin B, Sugrue M. Abdominal trauma: a disease in evolution. ANZ J Surg. 2005;75: 790-4.
2. Malangoni MA, Cue Ji, Fallat ME, Willing SJ, Richardson JD. Evaluation of splenic injury by computed tomography and its impact on treatment. Ann Surg. 1990;211: 592-7.
3. Gopal V, Bisno AL. Fulminant pneumococcal infections in ‘normal’ asplenic hosts. Arch Intern Med. 1977;137: 1526-30.
4. Holdsworth RJ, Irving AD, Cuschieri A. Postsplenectomy sepsis and its mortality rate: actual versus perceived risks. Br J Surg. 1991;78: 1031-8.
5. Pachter HL, Hofstetter SR, Spencer FC. Evolving concepts in splenic surgery: splenorrhaphy versus splenectomy and postsplenectomy drainage: experience in 105 patients. Ann Surg. 1981;194: 262-9.
6. Pachter HL, Spencer FC, Hofstetter SR, Liang HG, Hoballah J, Coppa GF. Experience with selective operative and nonoperative treatment of splenic injuries in 193 patients. Ann Surg. 1990;211: 583-9.
7. Davis KA, Fabian TC, Croce MA et al. Improved success in nonoperative management of blunt splenic injuries: embolization of splenic artery pseudoaneurysms. J Trauma. 1998;44: 1008-13.
8. Frumento C, Vane DW. Changing patterns of treatment for blunt splenic injuries: an 11-year experience in a rural state. J Pediatr Surg. 2000;35: 985-8.
9. Haan JM, Biffi W, Knudson MM et al. Splenic embolization revisited: a multicenter review. J Trauma. 2004;56: 542-7.
10. Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: a 5-year experience. J Trauma. 2005;58: 492-8.
11. Harbrecht BG, Zenati MS, Ochoa JB et al. Management of adult blunt splenic injuries: comparison between level I and level II trauma centers. J Am Coll Surg. 2004;198: 232-9.
12. Pachter HL, Guth AA, Hofstetter SR, Spencer FC. Changing patterns in the management of splenic trauma: the impact of nonoperative management. Ann Surg. 1998;227: 708-17.
13. Rutledge R, Hunt JP, Lentz CW et al. A statewide, population-based time-series analysis of the increasing frequency of nonoperative management of abdominal solid organ injury. Ann Surg. 1995;222: 311-22.
14. Konstantakos AK, Barnoski AL, Plaisier BR, Yowler CJ, Fallon WF, Jr., Malangoni MA. Optimizing the management of blunt splenic injury in adults and children. Surgery. 1999;126: 805-12.
15. Bode PJ, Edwards MJ, Kruit MC, van Vugt AB. Sonography in a clinical algorithm for early evaluation of 1671 patients with blunt abdominal trauma. AJR Am J Roentgenol. 1999;172: 905-11.
16. Miller MT, Pasquale MD, Bromberg WJ, Wasser TE, Cox J. Not so FAST. J Trauma. 2003;54: 52-9.
17. Stengel D, Bauwens K, Sehouli J et al. Systematic review and meta-analysis of emergency ultrasonography for blunt abdominal trauma. Br J Surg. 2001;88: 901-12.
18. Stengel D, Bauwens K, Sehouli J et al. Emergency ultrasound-based algorithms for diagnosing blunt abdominal trauma. Cochrane Database Syst Rev. 2005;CD004446.
19. Rozycki GS, Ochsner MG, Schmidt JA et al. A prospective study of surgeon-performed ultrasound as the primary adjuvant modality for injured patient assessment. J Trauma. 1995;39: 492-8.
20. Schnuriger B, Kilz J, Inderbitzin D et al. The accuracy of FAST in relation to grade of solid organ injuries: a retrospective analysis of 226 trauma patients with liver or splenic lesion. BMC Med Imaging. 2009;9: 3.
21. Bisharat N, Omar H, Lavi I, Raz R. Risk of infection and death among post-splenectomy patients. J Infect. 2001;43: 182-6.
22. Lentz KA, McKenney MG. Quantitative sensitivity of ultrasound in detecting free intraperitoneal fluid. J Trauma. 1996;40: 1052-4.
23. Shanmuganathan K, Mirvis SE, Sherbourne CD, Chiu WC, Rodriguez A. Hemoperitoneum as the sole indicator of abdominal visceral injuries: a potential limitation of screening abdominal US for trauma. Radiology. 1999;212: 423-30.
Literature review of the role of FAST, CT scan and angio-embolization for the treatment of splenic injury

24. Boulanger BR, Brenneman FD, McLeLLan BA, Rizoli SB, Culhane J, Hamilton P. A prospective study of emergent abdominal sonography after blunt trauma. J Trauma. 1995;39: 325-30.
25. Boulanger BR, McLeLLan BA, Brenneman FD et al. Emergent abdominal sonography as a screening test in a new diagnostic algorithm for blunt trauma. J Trauma. 1996;40: 867-74.
26. Deunk J, Dekker HM, Brink M, van VR, Edwards MJ, van Vugt AB. The value of indicated computed tomography scan of the chest and abdomen in addition to the conventional radiologic work-up for blunt trauma patients. J Trauma. 2007;63: 757-63.
27. Deunk J, Brink M, Dekker HM et al. Routine versus selective computed tomography of the abdomen, pelvis, and lumbar spine in blunt trauma: a prospective evaluation. J Trauma. 2009;66: 1108-17.
28. Shanmuganathan K, Mirvis SE, Boyd-Kranis R, Takada T, Scalea TM. Nonsurgical management of blunt splenic injury: use of CT criteria to select patients for splenic arteriography and potential endovascular therapy. Radiology. 2000;217: 75-82.
29. Miller LA, Shanmuganathan K. Multidetector CT evaluation of abdominal trauma. Radiol Clin North Am. 2005;43: 1079-95.
30. Yao DC, Jeffrey RB, Jr., Mirvis SE et al. Using contrast-enhanced helical CT to visualize arterial extravasation after blunt abdominal trauma: incidence and organ distribution. AJR Am J Roentgenol. 2002; 178: 17-20.
31. Anderson SW, Varghese JC, Lucey BC, Burke PA, Hirsch EF, Soto JA. Blunt splenic trauma: delayed-phase CT for differentiation of active hemorrhage from contained vascular injury in patients. Radiology. 2007;243: 88-95.
32. Goslings JC, van Delden OM. Angiography and embolization to control bleeding after blunt injury to the abdomen or pelvis. Ned Tijdschr Geneeskd. 2007;151: 345-52.
33. Lin WC, Chen YF, Lin CH et al. Emergent transcatheter arterial embolization in hemodynamically unstable patients with blunt splenic injury. Acad Radiol. 2008;15: 201-8.
34. Moore EE, Shackford SR, Pachter HL et al. Organ injury scaling: spleen, liver, and kidney. J Trauma. 1989;29: 1664-6.
35. Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni MA, Champion HR. Organ injury scaling: spleen and liver (1994 revision). J Trauma. 1995;38: 323-4.
36. Becker CD, Mentha G, Terrier F. Blunt abdominal trauma in adults: role of CT in the diagnosis and management of visceral injuries. Part 1: liver and spleen. Eur Radiol. 1998;8: 553-62.
37. Brasel KJ, DeLisle CM, Olson CJ, Borgstrom DC. Splenic injury: trends in evaluation and management. J Trauma. 1998;44: 283-6.
38. Federle MP, Courcoulas AP, Powell M, Ferris JV, Peitzman AB. Blunt splenic injury in adults: clinical and CT criteria for management, with emphasis on active extravasation. Radiology. 1998;206: 137-42.
39. Mirvis SE, Whitley NO, Gens DR. Blunt splenic trauma in adults: CT-based classification and correlation with prognosis and treatment. Radiology. 1989;171: 33-9.
40. Kohn JS, Clark DE, Isler RJ, Pope CF. Is computed tomographic grading of splenic injury useful in the nonsurgical management of blunt trauma? J Trauma. 1994;36: 385-9.
41. Sutyak JP, Chiu WC, D’Amelio LF, Amorosa JK, Hammond JS. Computed tomography is inaccurate in estimating the severity of adult splenic injury. J Trauma. 1995;39: 514-8.
42. Bessoud B, Duchosal MA, Siegrist CA et al. Proximal splenic artery embolization for blunt splenic injury: clinical, immunologic, and ultrasound-Doppler follow-up. J Trauma. 2007;62: 1481-6.
43. Gavant ML, Schurr M, Flick PA, Croce MA, Fabian TC, Gold RE. Predicting clinical outcome of nonsurgical management of blunt splenic injury: using CT to reveal abnormalities of splenic vasculature. AJR Am J Roentgenol. 1997;168: 207-12.
44. Shanmuganathan K. Multi-detector row CT imaging of blunt abdominal trauma. Semin Ultrasound CT MR. 2004;25: 180-204.
45. Marmery H, Shanmuganathan K, Alexander MT, Mirvis SE. Optimization of selection for nonoperative management of blunt splenic injury: comparison of MDCT grading systems. AJR Am J Roentgenol. 2007;189: 1421-7.
46. Schurr MJ, Fabian TC, Gavant M et al. Management of blunt splenic trauma: computed tomographic contrast blush predicts failure of nonoperative management. J Trauma. 1995;39: 507-12.

47. Sclafani SJ, Shaftan GW, Scalea TM et al. Nonoperative salvage of computed tomography-diagnosed splenic injuries: utilization of angiography for triage and embolization for hemostasis. J Trauma. 1995; 39: 818-25.

48. Cogbill TH, Moore EE, Jurkovich GJ et al. Nonoperative management of blunt splenic trauma: a multi-center experience. J Trauma. 1989;29: 1312-7.

49. Peitzman AB, Heil B, Rivera L et al. Blunt splenic injury in adults: Multi-institutional Study of the Eastern Association for the Surgery of Trauma. J Trauma. 2000;49: 177-87.

50. Sharma OP, Oswanski MF, Singer D, Raj SS, Daoud YA. Assessment of nonoperative management of blunt spleen and liver trauma. Am Surg. 2005;71: 379-86.

51. Velmahos GC, Toutouzas KG, Radin R, Chan L, Demetriades D. Nonoperative treatment of blunt injury to solid abdominal organs: a prospective study. Arch Surg. 2003;138: 844-51.

52. Haan J, Bocchicchio G, Kramer M, Scalea T. Air following splenic embolization: infection or incidental finding? Am Surg. 2003;69: 1036-9.

53. Haan JM, Boswell S, Stein D, Scalea TM. Follow-up abdominal CT is not necessary in low-grade splenic injury. Am Surg. 2007;73: 13-8.

54. Hagiwara A, Yukioka T, Ohta S, Nitatori T, Matsuda H, Shimazaki S. Nonsurgical management of patients with blunt splenic injury: efficacy of transcatheter arterial embolization. AJR Am J Roentgenol. 1996;167: 159-66.

55. Liu PP, Lee WC, Cheng YF et al. Use of splenic artery embolization as an adjunct to nonsurgical management of blunt splenic injury. J Trauma. 2004;56: 768-72.

56. Myers JG, Dent DL, Stewart RM et al. Blunt splenic injuries: dedicated trauma surgeons can achieve a high rate of nonoperative success in patients of all ages. J Trauma. 2000;48: 801-5.

57. Sclafani SJ, Weisberg A, Scalea TM, Phillips TF, Duncan AO. Blunt splenic injuries: nonsurgical treatment with CT, arteriography, and transcatheter arterial embolization of the splenic artery. Radiology. 1991;181: 189-96.

58. Dent D, Alsabrook G, Erickson BA et al. Blunt splenic injuries: high nonoperative management rate can be achieved with selective embolization. J Trauma. 2004;56: 1063-7.

59. Haan J, Ilahi ON, Kramer M, Scalea TM, Myers J. Protocol-driven nonoperative management in patients with blunt splenic trauma and minimal associated injury decreases length of stay. J Trauma. 2003;55: 317-21.

60. Rajani RR, Claridge JA, Yowler CJ et al. Improved outcome of adult blunt splenic injury: a cohort analysis. Surgery. 2006;140: 625-31.

61. Shammasganathan K, Mirvis SE, Sherbourne CD, Chiu WC, Rodriguez A. Hemoperitoneum as the sole indicator of abdominal visceral injuries: a potential limitation of screening abdominal US for trauma. Radiology. 1999;212: 423-30.

62. Smith HE, Biffi WL, Majercik SD, Jednacz J, Lambiase R, Ciolfi WG. Splenic artery embolization: Have we gone too far? J Trauma. 2006;61: 541-4.

63. Wei B, Hemmila MR, Arbabi S, Taheri PA, Wahl WL. Angioembolization reduces operative intervention for blunt splenic injury. J Trauma. 2008;64: 1472-7.

64. Omert LA, Salyer D, Dunham CM, Porter J, Silva A, Protetch J. Implications of the “contrast blush” finding on computed tomographic scan of the spleen in trauma. J Trauma. 2001;51: 272-7.

65. Bessoud B, Denys A, Calmes JM et al. Nonoperative management of traumatic splenic injuries: is there a role for proximal splenic artery embolization? AJR Am J Roentgenol. 2006;186: 779-85.

66. Fang JF, Chen RJ, Wong YC et al. Classification and treatment of pooling of contrast material on computed tomographic scan of blunt hepatic trauma. J Trauma. 2000;49: 1083-8.

67. Haan J, Scott J, Boyd-Kranis RL, Ho S, Kramer M, Scalea TM. Admission angiography for blunt splenic injury: advantages and pitfalls. J Trauma. 2001;51: 1161-5.
68. Haan JM, Marmery H, Shanmuganathan K, Mirvis SE, Scalea TM. Experience with splenic main coil embolization and significance of new or persistent pseudoaneurysm: reembolize, operate, or observe. J Trauma. 2007;63: 615-9.

69. Harbrecht BG, Ko SH, Watson GA, Forsythe RM, Rosengart MR, Peitzman AB. Angiography for blunt splenic trauma does not improve the success rate of nonoperative management. J Trauma. 2007;63: 44-9.

70. Duchesne JC, Simmons JD, Schmieg RE, Jr., McSwain NE, Jr., Bellows CF. Proximal splenic angiembolization does not improve outcomes in treating blunt splenic injuries compared with splenectomy: a cohort analysis. J Trauma. 2008;65: 1346-51.

71. Widlus DM, Moeslein FM, Richard HM 3rd. Evaluation of the Amplatzer® vascular plug for proximal splenic artery embolization. J Vasc Interv Radiol 2008;19(5): 652-6.

72. Smith HE, Biffi WL, Majercik SD, Jednacz J, Lambiase R, Cioffi WG. Splenic artery embolization: Have we gone too far? J Trauma. 2006;61: 541-4.

73. Keramidas DC. The ligation of the splenic artery in the treatment of traumatic rupture of the spleen. Surgery. 1979;85: 530-3.

74. Bessoud B, Denys A. Main splenic artery embolization using coils in blunt splenic injuries: effects on the intrasplenic blood pressure. Eur Radiol. 2004;14: 1718-9.

75. Anderson JH, VuBan A, Wallace S, Hester JP, Burke JS. Transcatheter splenic arterial occlusion: an experimental study in dogs. Radiology. 1977;125: 95-102.

76. Keramidas DC, Kelekis D, Dolatzas T, Alivazoglou T, Voyatzis N. The collateral arterial network of the spleen following ligation of the splenic artery in traumatic rupture of the spleen; an arteriographic study. Z Kinderchir. 1984;39: 50-1.

77. Killeen KL, Shanmuganathan K, Boyd-Kranis R, Scalea TM, Mirvis SE. CT findings after embolization for blunt splenic trauma. J Vasc Interv Radiol. 2001;12: 209-14.

78. Tominaga GT, Simon FJ, Jr., Dandan IS et al. Immunologic function after splenic embolization, is there a difference? J Trauma. 2009;67: 289-95.

79. Falimirski M, Syed A, Prybilla D. Immunocompetence of the severely injured spleen verified by differential interference contrast microscopy: the red blood cell pit test. J Trauma. 2007 Nov;63(5): 1087-91

80. Davies JM, Barnes R, Milligan D. Update of guidelines for the prevention and treatment of infection in patients with an absent or dysfunctional spleen. Clin Med. 2002 Sep-Oct;2(5): 440-3.

81. Nakae H, Shimazu T, Miyachi H, Morozumi J, Ohta S, Yamaguchi Y, Kishikawa M, Ueyama M, Kitano M, Ikeuchi H, Yukoia T, Sugimoto H. Does splenic preservation treatment (embolization, splenorrhaphy, and partial splenectomy) improve immunologic function and long-term prognosis after splenic injury? J Trauma. 2009 Sep;67(3): 557-63.

82. Huber-Wagner S, Lefering R, Vqwick LM et al. Effect of whole-body CT during trauma resuscitation on survival: a retrospective, multicentre study. Lancet. 2009;373: 1455-61.

83. Saltsher TP, Fung Kon Jin PH, Bakker FC et al. An evaluation of a Shockroom located CT scanner: a randomized study of early assessment by CT scanning in trauma patients in the bi-located trauma center North-West Netherlands (REACT trial).BMC Emerg Med. 2008;8:10.

84. Agolini SF, Shah K, Jaffe J, Newcomb J, Rhodes M, Reed JF, III. Arterial embolization is a rapid and effective technique for controlling pelvic fracture hemorrhage. J Trauma. 1997;43: 395-9.

85. Ekeh AP, McCarthy MC, Woods RJ, Haley E. Complications arising from splenic embolization after blunt splenic trauma. Am J Surg. 2005;189: 335-9.
PART
Treatment of blunt abdominal trauma
Impact of splenic artery embolization on the success rate of nonoperative management for blunt splenic injury

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Chapter 7

ABSTRACT

Introduction: Nonoperative management (NOM) has become the treatment of choice for hemodynamically stable patients with blunt splenic injury. Results of outcome following NOM are predominantly based on large volume studies from Level-I trauma centers in the United States. The aim of this study was to assess the results of NOM in a relatively low volume Dutch Level 1 trauma center.

Methods: An analysis of a prospective trauma registry was performed for a 6-year period before (period 1) and after the introduction and implementation of SAE (period 2). Primary outcome was the failure rate of initial treatment.

Results: 151 patients were reviewed. An increased use of SAE and a reduction of splenic operations in the second period was observed. In comparison with period 1, the failure rate after observation in period two decreased from 25% to 10%. The failure rate after SAE in period 2 was 18%. The splenic salvage rate (SSR) after observation increased from 79% in the first to 100% in the second period. In the second period, all patients with failure after observation were successfully treated with SAE. The SSR after SAE in period 1 and 2 was respectively 100 and 86%.

Conclusion: SAE of patients with blunt splenic injuries is associated with a reduction in splenic operations. The failure and splenic salvage rates in this current study were comparable with the results from large volume studies of Level-I trauma centers. Nonoperative management is therefore also feasible in a relatively low volume Level-1 trauma center outside the US.
INTRODUCTION

Trauma is one of the leading causes of death in people below 40 years and therefore an important problem in general healthcare.1-3 The spleen is affected in 32% of patients with traumatic abdominal injuries.4 Management of splenic injuries has changed considerably during the last 20 years. Traditionally, a laparotomy and splenectomy was performed for splenic injuries. Due to its high success rate, nonoperative management (NOM) has evolved to be the standard of care in hemodynamically stable patients.

NOM can be divided in either observation or splenic artery embolization (SAE). SAE has played an increasing role in this nonoperative approach. Many reviews supported the use of SAE as an adjunct to observation. SAE can increase the success rate of NOM by stopping ongoing bleeding as well as by preventing delayed rupture of the spleen. Recent studies advocate the use of angiography and embolization in the presence of the following CT findings: contrast extravasation, pseudoaneurysm or arteriovenous fistula, large hemoperitoneum and a high grade of injury (grade III-V).5-15 Results of outcome following NOM in blunt splenic trauma are predominantly based on large volume studies from Level-I trauma centers in the United States (US).5-9,13,16,17 Trauma patients volumes in European centers are often considerably lower than in the US. Therefore, it is questionable whether these results can be translated to centers with lower volumes of patients with blunt splenic injuries.

The aim of this study was to assess the influence of SAE on the failure of NOM and the splenic salvage rate in a relatively low volume Level-1 Dutch trauma center.

METHODS

Data collection

Patients with blunt splenic injuries treated in the Academic Medical Center (AMC) between January 1997 and June 2008 were identified from the prospectively collected data in the hospital’s trauma registry. Children with an age under 17 and patients who died within 24 hours after trauma were excluded. The AMC is a designated Dutch Level-1 trauma center with 32,000 emergency department visits and 700 trauma team notifications per year. Annually, approximately 200–225 multitrauma patients are treated.

Patient demographics, which included age, gender, trauma mechanism, Injury Severity Score (ISS), Glasgow Coma Scale (GCS), and associated injuries were extracted from the computerized medical record. Furthermore, initial treatment and their indications, transfusion requirements, morbidity, mortality, ICU and overall hospital length of stay were registered.

One senior trauma-radiologist re-evaluated all admission abdominal CT scans, and classified the splenic injuries according to the American Association for the Surgery of Trauma (AAST).18
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Grade 1 and 2 were classified as low grade, grade 3–5 as high grade. Data on presence of vascular injury (contrast extravasation, pseudoaneurysm and arteriovenous fistula), hemoperitoneum and the extension of hemoperitoneum was also registered. Minimal hemoperitoneum was defined as intra-abdominal blood located only in the perisplenic recess. Significant hemoperitoneum was defined as intra-abdominal blood located in areas other than the perisplenic recess.

**Study periods**

Two time periods were defined. At the end of the first period (1997–2002) angiography and embolization for trauma patients was introduced but not used routinely. This period was compared with a second period (2003–2008) when SAE was used routinely.

**Imaging and treatment protocols**

During both periods, hemodynamically unstable patients not responding to fluid resuscitation were treated primarily operative. In period 1, the protocol dictated surgical exploration in patients with high grade injuries (grade 3–5) independent of the hemodynamic status of the patients. Operative treatment began with 4-quadrant packing before structural inspection of the abdomen. Once the spleen has been mobilized, a decision was made if a splenectomy or a splenic salvage procedure (mesh splenorrhaphy, partial resection, adhesive and/or coagulation techniques) was performed.

In period 1 NOM was performed in patients with low grade (grade 1–2) injuries who were hemodynamically stable. In period 2 NOM was performed in all hemodynamically stable patients or transient responders. NOM involves admission to a unit with monitoring of vital signs, strict bed rest, frequent monitoring of red blood cell count, and serial abdominal exams. In the second period SAE was routinely performed 24 hours/7 days a week by an experienced interventional radiologist if signs of active bleeding (contrast blush or a cut off), a pseudoaneurysm or an arteriovenous fistula were detected on CT scan. Splenic arterial catheterization was performed using the common femoral artery access. After puncture of the artery a 5 French sheath was introduced.

Diagnostic series of the splenic artery were obtained using a 4 or 5 French catheter or celiac catheter. For selective catheterization of splenic artery branches co-axial microcatheters and micro-guidewires were required.

Proximal embolization was performed if there was a diffuse bleeding of the spleen, if there were multiple focal bleeding vessels in the spleen and when there was time-pressure as a result of the hemodynamic situation of the patient or when tortuosity of the splenic artery prevented selective distal embolization. Selective distal embolization was reserved for patients who had one or only a few focal bleeding vessels in the spleen and in whom the anatomy and hemodynamic situation allowed employment of this. Follow-up ultrasounds or CT scans were not routinely performed.
Impact of splenic artery embolization on the success rate of nonoperative management for blunt splenic injury

Study endpoints

Primary outcome was the failure rate of initial treatment. Failure was defined as clinical (hemodynamically unstable or drop in Hemoglobin/hematocrit) and radiological (a blush or significant increase of hemoperitoneum on repeat CT scan) signs of a rebleeding requiring operative or radiological (re-) interventions. The failure rate and the splenic salvage rate in both periods were compared to identify the impact of SAE. Splenic salvage was considered as patient discharge with the spleen in situ.

Secondary outcome measures were length of ICU and total hospital stay, transfusion requirements in the first 24 hours and mortality rate. Mortality was either coded as due to splenic injury-related complications or due to other causes.

Statistical analysis

All statistical analysis were performed using SPSS version 17 (SPSS, Inc., Chicago, IL). Categorical variables were calculated as percentages and compared using Chi-square analyses or Fisher’s exact tests when appropriate. All continuous variables are presented as median with interquartile ranges (p25-p75) and were compared using the Mann-Whitney U test. A value of P=0.05 was considered statistically significant.

RESULTS

A total of 151 patients with blunt splenic injury were identified. Twenty-nine patients were excluded; 6 patients died within 24 hours of admission and 23 patients were children. Of the 122 included patients, the majority were young men with a mean age of 29 years (range 23–46). As demonstrated in Table 1 both periods were comparable for age, gender, ISS and AAST injury grade.

In Table 1 the initial treatment is shown for both periods. The number of patients treated with observation was similar. In period two, a significant increase of SAE’s was observed: 4 percent in the first period versus 34 percent in the second period (p < 0.001). This increase correlated with the statistically significant reduction of splenic operations (46% vs 19%, p < 0.001).

Most of the patients that underwent SAE (13/24) did so as initial treatment. In 10% of the patients injuries to other organs were also embolized during the same angiography session.

Table 2 shows the failure rate after initial treatment in both periods. The overall failure rate for observation and SAE was both 17%. In the second period the failure rate after observation was reduced from 25 to 10%. The failure rate after SAE in period 2 was 18%; SAE failed in four of the 22 patients due to rebleeding of the spleen.

Table 3 shows the injuries divided into low and high AAST grades per period and compared for primary treatment and outcomes. Most of the patients who failed initial treatment had a high grade of injury. Twenty-five percent of the patients with high grade injury failed initial SAE, while
no failure of SAE was observed in patients with low grade injury. The patient characteristics of the patients with failure of initial treatment are depicted in Table 4. In almost all these patients, the re-evaluated CT scan showed a contrast blush and/or a significant hemoperitoneum.
of the four patients who failed SAE in the second period had a grade 5 injury combined with a blush and a significant hemoperitoneum on the CT scan.

The overall splenic salvage rate (SSR) was 89%. In comparison with period 1, the splenic salvage rate after observation in period two increased from 79% to 100%. In the first period 6 of the 7 patients who failed observation underwent a splenectomy. In one patient splenic preserving therapy during laparotomy was performed. In the second period, all patients with failure
(n=3) after observation were successfully treated with SAE. The splenic salvage rate after SAE in period 1 and 2 was respectively 100 and 86%. One of the four patients with failure after initial distal selective SAE successfully underwent proximal reembolization in the second period. The other 3 patients underwent a splenectomy.

The median time from initial treatment to failure was 2 days (range 1–23). In two patients the rebleeding occurred after being discharged from hospital. One patient with a grade 5 splenic injury, initially treated with embolization had severe neurological impairment due to a rebleeding and died three months later.

The mortality rate, ICU and total length of stay were not different in both periods. The transfusion requirement was significantly (p < 0.01) lower in the second period (Table 1) in both nonoperative management as well as operative treatment.

**DISCUSSION**

The primary outcome of this study was to assess the influence of SAE on the failure and splenic salvage rate. Consistent with the literature, we showed a change from operative to nonoperative management for patients with blunt splenic injury. The first successful use of SAE for a splenic injury was described by Sclafani et al.\(^\text{19}\) In our Level-1 trauma center SAE was introduced in 1998 and since 2002 used routinely for hemodynamically stable patients considered to be at high risk of failure. In the first period we evaluated, a splenic operation was performed in almost half of the patients. In the second period, the rate of splenic operations was reduced while the use of SAE increased over time.

In this study the failure rate after observation was reduced in the second period. More frequent use of CT scan and the improvement of the quality of the CT scan could be an explanation for the clear trend of decreasing failure rate after observation in the second period. This improved CT techniques may enable a better patient selection for either observation or SAE.

We reported a failure rate of 18% after SAE in the second period. It is not fair to compare the failure rates of SAE between the two periods because only two patients in the first period were treated with SAE. This reported failure rate is comparable with the results of a large multicenter trial in which splenic embolization was used in 140 patients. This study reported an overall splenic salvage rate of 87% and 83% of grade 4 and 5 injuries were successfully managed with embolization.\(^\text{7}\)

All patients who failed initial SAE had a high grade of injury. Strikingly, in our study three of the 4 patients who failed SAE in the second period had a grade 5 injury combined with a vascular blush and a significant hemoperitoneum on the CT scan, suggesting that the optimal patient selection for SAE is still a topic for further research. Some authors recommend a low threshold to operate if there is evidence of a grade 3–5 injury combined with a significant hemoperitoneum.\(^\text{13,20}\) Furthermore, with respect to this fact one of the patient who failed SAE became
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hemodynamically unstable due to rebleeding and consequently developed severe neurological damage and died three months later.

Failure was observed after proximal as well as distal selective embolization (Table 4). The current literature provides little evidence whether proximal SAE or distal selective embolization is a better treatment. Although no prospective studies comparing the results of proximal or selective embolization are described, the use of proximal SAE seems to be faster, associated with a lower failure rate\textsuperscript{13} of NOM and a decreased incidence of splenic abscess or infarction.\textsuperscript{21,22}

A disadvantage of proximal SAE could be the fact that in case of rebleeding, more selective embolization is difficult due to the inaccessibility of the splenic artery.

The overall Splenic Savage Rate was 89%. In period two the SSR after observation was increased, due to the successful secondary treatment with SAE of patients who failed initial treatment. In the SAE group one patient with a rebleeding could successfully be treated with subsequent proximal embolization. Despite rebleeding, SAE is a valuable minimally invasive technique to control bleeding. Historically, every patient with a rebleeding was treated surgically. Currently, a second attempt of SAE can be considered, which further can increase the nonoperative splenic salvage rate.\textsuperscript{5,7,16}

Results of outcome following NOM in blunt splenic trauma are predominantly based on large volume studies from Level-1 trauma centers in the United States. Despite the lower patient volume in this study, the failure rate and SSR are comparable with the results of these large studies. In these studies the SSR of nonoperative management with the use of splenic embolization ranges from 86% to 100%, with most studies reporting success rates greater than 90%.\textsuperscript{5-9,13,16,17}

The second aim of this study was to assess the effects on clinical outcome. More frequent use of SAE and consequently lesser laparotomies have the theoretical potential of decreasing length of hospital stay and blood transfusion requirements. However, in this study the ICU and total length of stay were comparable in both periods. The transfusion requirement was significantly lower in the second period. The more frequently use of SAE could not alone explain the lower transfusion rate, while patients with operative treatment also received less transfusions in period two. Part of the explanation could possibly be found in advancements in the areas of critical care and transfusion and resuscitation policies.

As with any retrospective study, our analysis has several limitations. Selection bias might have played a role. Despite protocols for diagnostics and treatment, in practice the choice of therapy was based on the clinical judgement of the attending trauma surgeon and (interventional) radiologist. The specific indication for the chosen therapy could not always be assessed from the trauma registry or electronic medical record. Furthermore, advancements in ICU treatment, transfusion protocols, improved quality of the CT scan and SAE between the two time periods investigated could cause a bias in the results. This study did not evaluate isolated splenic trauma as in most of the published series. As a consequence the mortality, morbidity and transfusion requirement could also reflect variability in recruitment that is observed most modern countries (decrease number of severe road accidents over the last 15 years). Another limitation
is the relatively small number of patients with blunt splenic injury in our hospital. This volume however, is comparable to other Level-1 trauma centers in Europe.

In conclusion, the increased use of SAE as an adjunct to NOM was associated with a statistically significant reduction of splenic operations. The failure and splenic salvage rates in the current study were comparable with the results from large volume studies of Level-I trauma centers in the United States. Comparable with the literature, a high failure rate was observed in patients with high grade injuries combined with a contrast blush and a significant hemoperitoneum. Therefore, NOM with the adjunction of SAE in patients with low grade injuries is also feasible in a relatively low volume Level-1 trauma center outside the United States. However, the optimal treatment, especially in patients with high grade injuries is still a topic for further research.
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REFERENCES

1. Gaines BA. Intra-abdominal solid organ injury in children: diagnosis and treatment. J Trauma. 2009; 67: S135-9.

2. Gopal V, Bisno AL. Fulminant pneumococcal infections in ‘normal’ asplenic hosts. Arch Intern Med. 1977;137: 1526-30.

3. Sauaia A, Moore FA, Moore EE et al. Epidemiology of trauma deaths: a reassessment. J Trauma. 1995; 38:1 85-93.

4. Smith J, Caldwell E, D’Amours S, Jalaludin B, Sugrue M. Abdominal trauma: a disease in evolution. ANZ J Surg. 2005;75: 790-4.

5. Dent D, Alsabrook G, Erickson BA et al. Blunt splenic injuries: high nonoperative management rate can be achieved with selective embolization. J Trauma. 2004;56: 1063-7.

6. Haan J, Ilahi ON, Kramer M, Scalea TM, Myers J. Protocol-driven nonoperative management in patients with blunt trauma trauma and minimal associated injury decreases length of stay. J Trauma. 2003;55: 317-21.

7. Haan JM, Biffl W, Knudson MM et al. Splenic embolization revisited: a multicenter review. J Trauma. 2004;56: 542-7.

8. Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: a 5-year experience. J Trauma. 2005;58: 492-8.

9. Liu PP, Lee WC, Cheng YF et al. Use of splenic artery embolization as an adjunct to nonsurgical management of blunt splenic injury. J Trauma. 2004;56: 768-72.

10. Rajani RR, Claridge JA, Yowler CJ et al. Improved outcome of adult blunt splenic injury: a cohort analysis. Surgery. 2006;140: 625-631.

11. Shanmuganathan K, Mirvis SE, Sherbourne CD, Chiu WC, Rodriguez A. Hemoperitoneum as the sole indicator of abdominal visceral injuries: a potential limitation of screening abdominal US for trauma. Radiology. 1999;212: 423-30.

12. Shanmuganathan K, Mirvis SE, Boyd-Kranis T, Takada T, Scalea TM. Nonsurgical management of blunt splenic injury: use of CT criteria to select patients for splenic arteriography and potential endovascular therapy. Radiology. 2000;217: 75-82.

13. Smith HE, Biffl WL, Majercik SD, Jednacz J, Lambiase R, Cioffi WG. Splenic artery embolization: Have we gone too far? J Trauma. 2006;61: 541-4.

14. Peitzman AB, Heil B, Rivera L et al. Blunt splenic injury in adults: Multi-institutional Study of the Eastern Association for the Surgery of Trauma. J Trauma. 2000;49: 177-87.

15. Wei B, Hemmila MR, Arbabi S, Taheri PA, Wahl WL. Angioembolization reduces operative intervention for blunt splenic injury. J Trauma. 2008;64: 1472-7.

16. Haan JM. Experience with splenic main coil embolization and significance of new or persistent pseudoaneurym: reembolize, operate, or observe. J Trauma 2007 sep;63(3): 615-9.

17. Hagiwara A. Nonsurgical management of patients with blunt splenic injury: efficacy of transcatheter arterial embolization. Am J Roentgenol.1996 jul;167(1): 159-66.

18. Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni MA, Champion HR. Organ injury scaling: spleen and liver (1994 revision). J Trauma. 1995;38: 323-4.

19. Sclafani SJ. Nonoperative salvage of computed tomography-diagnosed splenic injuries: utilization of angiography for triage and embolization for hemostasis. J Trauma 1995 nov;39(5): 818-25.

20. Duchesne JC, Simmons JD, Schmieg RE, Jr., McSwain NE, Jr., Bellows CF. Proximal splenic angioembolization does not improve outcomes in treating blunt splenic injuries compared with splenectomy: a cohort analysis. J Trauma. 2008;65: 1346-51.

21. Omert LA, Salyer D, Dunham CM, Porter J, Silva A, Protetch J. Implications of the “contrast blush” finding on computed tomographic scan of the spleen in trauma. J Trauma. 2001;51: 272-7.

22. Killeen KL, Shanmuganathan K, Boyd-Kranis R, Scalea TM, Mirvis SE. CT findings after embolization for blunt splenic trauma. J Vasc Interv Radiol. 2001;12: 209-14.
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**ABSTRACT**

**Introduction:** Currently, nonoperative management (NOM) is the standard treatment for hemodynamically patients with blunt splenic injury. Recent studies advocate the use of angiography and embolization in the presence of contrast extravasation, large hemoperitoneum and a higher grade of injury. However, the optimal patient selection for NOM is still a matter of debate. The aim of the present study was to assess the results of NOM in three Dutch Level-1 trauma centers and to investigate which patient and CT characteristics were associated with failure of NOM.

**Methods:** All consecutive adult patients admitted with blunt splenic injuries to three level-1 Trauma centers in the Netherlands between January 2001 and December 2009 were retrospectively analysed. The primary outcome measure in this study was the failure and splenic salvage rate of NOM. Secondary, potential risk factors for failure were analysed with uni- and multivariate analysis.

**Results:** 169 eligible patients were assessed. Seventy-three percent of the patients were treated with observational management and 27% underwent angiography and embolization. The overall failure rate was 17%. Seven patients who failed observational or angiography and embolization could be successfully treated with (re-)embolization, leading to a splenic salvage rate of 89%. Age >50 years and AAST grade of injury ≥ 3 were associated with failure in the multivariable logistic model. The presence of (an intraperitoneal contrast) extravasation was not significantly associated with failure of NOM.

**Conclusion:** The failure rate in this current study was low and comparable with the literature. This study showed that patients with rebleeding could be successfully treated with SAE leading to considerable SSR. The presence of a contrast extravasation is not associated with an increased failure rate.
INTRODUCTION

The management of patients with splenic injuries has changed considerably during the last 20 years. As a consequence to its high success rate, nonoperative management (NOM) has become the preferred treatment for hemodynamically stable patients.\textsuperscript{1-4} NOM can be divided in either observation (OBS) or splenic artery embolization (SAE). Many reviews support the use of splenic artery embolization as a valuable adjunct to observation.\textsuperscript{8-10} Results of NOM in blunt splenic trauma are predominantly based on studies from large volume Level-I trauma centers in the United States (US).\textsuperscript{5-7} Trauma patients volumes in European centers are often considerably lower than in the US. Therefore, it is questionable whether these results can be translated to centers with lower volumes of patients with blunt splenic injuries. In addition, the optimal patient selection for NOM is still a matter of debate and the role of CT and angio-embolization has not yet fully evolved. Several risk factors for failure of NOM have been reported in the literature: age older than 55 years, a high injury grade, hemodynamic instability, size of hemoperitoneum and the presence of contrast extravasation on CT scan.\textsuperscript{11-17} The aim of the present study was to assess the results of NOM in three Dutch Level-1 trauma centers. The second aim was to investigate which patient and CT characteristics were associated with failure of NOM in an European trauma setting.

PATIENTS AND METHODS

Study design and population

In this retrospective study, all consecutive adult patients (age >16 years) admitted with blunt splenic injuries to three level 1 Trauma centers in the Netherlands between January 2001 and December 2009 were reviewed. The patients were identified from the hospital's prospective trauma registry, the in-hospital information system and financial administrative registration. Patients who died in the trauma room and patients who were initially treated at other hospitals were excluded from this analysis. Patients primarily evaluated elsewhere (without intervention) and referred for treatment were included. The three trauma centers are designated Dutch Level-1 trauma centers, with approximately a total of 100,000 emergency department visits and 2000 trauma team notifications per year. Annually, 700 multitrauma (defined as ISS ≥ 16) patients are treated in these three centers.

Data collection

Age, gender, trauma mechanism, Injury Severity Score (ISS), Glasgow Coma Scale (GCS), and associated injuries were extracted from the hospital's trauma registry. A chart review was performed for data collection of initial diagnostics and treatment, transfusion requirements,
morbidity, mortality, ICU stay and overall hospital length of stay. Data collection was performed according to a preplanned standardized format in all 3 trauma centers.

**Imaging and Treatment protocol**

All patients were managed according to the Advanced Trauma Life Support (ATLS\textsuperscript{*}) principles. Focused Abdominal Sonography for Trauma (FAST) was part of the primary survey. Suspicion of intra-abdominal injuries in hemodynamically stable or transient responding patients was an indication for intravenous contrast-enhanced CT scanning (CECT). The admission abdominal CT scans were re-evaluated for this current study, and the splenic injuries were classified according to the Splenic Organ Injury Scale of the American Association for the Surgery of Trauma (AAST). Grade 1–2 injuries were classified as low grade, grade 3–5 as high grade injuries. Data suggestive of the presence of vascular injury (e.g. contrast extravasation, pseudoaneurysm and arteriovenous fistula), hemoperitoneum and the extent of hemoperitoneum were also scored retrospectively. Minimal hemoperitoneum was defined as intra-abdominal blood located only in the perisplenic recess. Significant hemoperitoneum was defined as intra-abdominal blood located in the perisplenic recess, one of both pericolic gutters and additional free fluid in the lesser pelvis.

Hemodynamically unstable patients not responding to fluid resuscitation (non-responders) were treated primarily with an emergency laparotomy. NOM was performed in all hemodynamically stable patients or transient responders. Observational management involved admission to a unit with constant monitoring of vital signs, bed rest, serial abdominal exams, and monitoring of red blood cell count.

Since 2003 SAE was routinely available 24 hours/7 days a week by an experienced interventional radiologist for patients with signs of active bleeding on CECT. Splenic arterial catheterization was performed using common femoral artery access. Proximal arterial embolization was performed if there was diffuse bleeding of the spleen and when there was no time to perform selective catheterization as a result of the hemodynamic instability. Selective distal embolization was reserved for patients who had one or only a few focal bleeding vessels in the spleen and in whom the anatomy and hemodynamic situation allowed employment of this. Follow-up ultrasound or CT scanning was not routinely performed.

**Outcome measures**

The primary outcome measure in this study was the failure and splenic salvage rate (SSR) of NOM. Failure was defined as clinical (hemodynamically unstable or drop in Hemoglobin/hematocrit) and radiological (a contrast extravasation or significant increase of hemoperitoneum on repeat CT-scan) signs of rebleeding requiring operative or radiological (re-) interventions. Splenic salvage was defined as a patient discharged with the spleen in situ.

Secondary, the identification of risk factors for failure of planned NOM were investigated. Potential risk factors were selected from current literature\textsuperscript{11-17} These variables consisted of:
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Patient characteristics (age, sex), mechanism of injury (traffic accident), associated injury, GCS ≤11, ISS ≥16, AAST classification (grade 1–3 or grade 4 or 5), extent of hemoperitoneum, presence and type (intraperitoneal versus intraparenchymateous) of contrast extravasation.

Statistical analysis
Continuous variables are presented as medians with interquartile ranges (IQR: p25th-p75th) and were compared using the Mann-Whitney U test. Categorical variables were calculated as frequencies with percentages and compared using Chi-square analyses and Fisher’s exact test when applicable. A test was considered significant if the p-value was smaller than 0.05 (two-sided). For all variables, the comparison between patients with successful planned NOM and patients with failed NOM was presented. Univariate logistic regression analyses were used to study the ability of variables to discriminate patients in whom planned NOM was successful with patients in whom NOM failed. The dependent variable was represented by the outcome of NOM (successful versus failed NOM); odds ratios (ORs) with the 95% confidence intervals (95% CI) were presented. The variables with a p < 0.1 of the univariate logistic analyses were imported in a multivariate logistic regression analysis with a backward selection procedure in order to evaluate their independent association with the outcome of planned NOM. Possible correlations between significant variables of univariate logistic regression analyses were also examined to check for multicollinearity before inclusion, with a p-value of 0.20. The adjusted odds ratios with 95% CIs of the final model are presented. Statistical analyses were done using SPSS for Windows, version 15.0 (SPSS Inc., Chicago, USA).

Patients
During the 9 year period, 169 patients were treated with NOM. (Figure 1) The majority (78%) were young men with a median age of 33 years. Patient characteristics are shown in Table 1. The following mechanisms of injury were recorded: traffic accident (72%), fall from height (15%), sports (1%) and various others (12%). The median length of hospital and ICU was 13 (IQR 8–25) and 2 (IQR 1–5) days, respectively. The overall mortality and splenic-related mortality was respectively 5% and 1%.

FAST was performed in 154 patients (91%); free intraperitoneal fluid was observed in 111 patients (72%). Additionally, a CT scan was performed in 144 patients (85%). The CT features which were retrospectively re-evaluated and the management strategy, are summarized in Table 2. This table showed that retrospectively eleven of the 40 patients with a blush were not treated with SAE.

One hundred twenty-four patients (73%) were treated with observational management. 45 patients (27%) underwent angiography; 13 patients were treated with proximal SAE and 22 with selective distal SAE. Combination of both techniques was used in 1 patient. In 9 patients
Consecutive adult patients with blunt splenic injury \( n = 312 \)

Exclusion: \( n = 32 \)
- Death within 24 hours after admission: \( n = 12 \)
- Initially treated at another hospital: \( n = 20 \)

Included patients \( n = 280 \)

Operative treatment \( n = 111 \)

NOM \( N = 169 \)

Angiography \( n = 45 \)

Observation \( n = 124 \)

Selective embolization \( n = 22 \)

Proximal embolization \( n = 13 \)

Both (proximal and selective) embolization \( n = 1 \)

No embolization \( n = 9 \)

Figure 1. Study design. NOM; nonoperative management

Table 1. Characteristics, treatments and outcomes of patients with blunt splenic injuries

| Characteristic                        | Value |
|--------------------------------------|-------|
| Age (years)*                         | 33 (22-47) |
| Male                                 | 131 (78%) |
| Glasgow Coma Scale*                  | 14 (14-15) |
| Injury Severity Score*               | 20 (13-29) |
| AAST grade of injury, n (%)          |       |
| - low (grade 1-2)                    | 94 (56%) |
| - high (grade 3-5)                   | 75 (44%) |
| Initial treatment, n (%)             |       |
| - observation                        | 124 (73%) |
| - angiography/ embolization          | 45 (27%) |

*Median (25th, 75th percentiles)
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no contrast extravasation was seen at angiography, therefore no embolization was performed. All these 9 patients were successfully managed non-operatively. In seventeen patients embolization of injuries to other organs were performed during the same angiography session.

RESULTS

The overall failure and splenic salvage rate was 17% and 89%, respectively (Table 3) Six patients who failed observational management could be successfully treated with SAE. Eighteen patients underwent secondary operative management: splenectomy (n=14) and spleen preserving procedure (n=4). One of the five patients with failure after initial distal SAE successfully underwent proximal re-embolization. The other 4 patients underwent a splenectomy. The information for patients with successful and failed NOM is shown in Table 4. Patients who failed NOM were significantly older and had a higher AAST grade of injury. The presence of an

Table 2. Features of the CT scan and management strategy (n=144)

| CT features                  | Management strategy | OBS  | SAE  | total |
|-----------------------------|---------------------|------|------|-------|
| **Grade of injury**         |                     |      |      |       |
| Grade 1-2                   |                     | 61   | 12   | 73    |
| Grade 3-5                   |                     | 35   | 32   | 67    |
| Unknown                     |                     |      |      | 4     |
| **Hemoperitoneum**          |                     |      |      |       |
| no                          |                     | 21   | 3    | 24    |
| minimal                     |                     | 61   | 19   | 80    |
| significant                 |                     | 16   | 23   | 39    |
| unknown                     |                     |      |      | 1     |
| **Blush**                   |                     |      |      |       |
| No                          |                     | 87   | 15   | 102   |
| Intapasplenic               |                     | 10   | 12   | 22    |
| Intraperitoneal             |                     | 1    | 17   | 18    |
| Pseudoaneurysm              |                     | 2    | 4    | 6     |
| unknown                     |                     |      |      | 2     |
| **Associated injuries**     |                     |      |      | 114   |

OBS: observation or SAE: splenic artery embolization

Table 3. Failure and splenic salvage rate

|     | n    | Failure rate% (n) | SSR  |
|-----|------|-------------------|------|
| OBS | 124  | 24 (19%)          | 89%  |
| SAE | 45   | 5 (11%)           | 91%  |
| Overall NOM | 169 | 29 (17%)          | 89%  |

OBS: observation, SAE: splenic artery embolization, NOM: nonoperative management
intraperitoneal contrast extravasation and the need for blood transfusion in the first 24 hours was associated with failure of NOM.

**Table 4.** Comparison of patients with successful versus failed NOM

|                    | Successful NOM N=140 | Failed NOM N=29 | P-value |
|--------------------|----------------------|-----------------|---------|
| Age (years)*       | 29 (21-47)           | 42 (27-58)      | 0.02    |
| Male sex           | 78%                  | 75%             | 0.71    |
| Glasgow Coma Scale*| 15 (14-15)           | 15 (9-15)       | 0.32    |
| Injury Severity Score* | 20 (13-29)        | 19 (13-33)      | 0.77    |
| Mechanism          |                      |                 |         |
| Traffic accident    | 74%                  | 81%             | 0.23    |
| Fall from height    | 17%                  | 10%             |         |
| Sports              | 2%                   | 3%              |         |
| Other               | 7%                   | 6%              |         |
| AAST grade (median)*| 2 (2-3)               | 3 (2-3)         | 0.05    |
| Associated injuries | 71%                  | 56%             | 0.10    |
| Hemoperitoneum on CT|                     |                 |         |
| - no               | 18%                  | 22%             | 0.59    |
| - minimal          | 49%                  | 41%             |         |
| - severe           | 22%                  | 28%             |         |
| Contrast blush on CT|                     |                 | 0.08    |
| Yes                | 79%                  | 65%             |         |
| Intrasplenic       | 13%                  | 13%             |         |
| Intraperitoneal     | 8%                   | 22%             |         |
| Intraperitoneal blush and severe hemoperitoneum | 7% | 16% | 0.09 |
| Red blood cell transfusion (units) < 24 hour* | 2 (0-24) | 5 (0-27) | 0.03 |
|                    | 13 (8-23)            | 13 (8-32)       | 0.49    |
| Hospital ICU*      | 2 (1-4)              | 3 (1-9)         | 0.06    |

*Median (25th, 75th percentile)

**Predictors for failure of nonoperative management**

All significant predictors of failure identified by univariable analysis are depicted in Table 5. Age >50 years, GCS <11, AAST grade of injury ≥3 and an intraperitoneal contrast extravasation were significantly associated with failure. Correlation between the significant predictors was low (p-value >0.20), implying that all factors are independent predictors of outcome. Significant factors associated with failure were included in a multivariable logistic regression model which are shown in (Table 5). Age >50 years and AAST grade of injury ≥3 were associated with failure in the multivariable logistic model.
Incidence and risk factors for failure of non operative management of blunt splenic injury

**DISCUSSION**

An overall failure rate of 17% was observed in the present study. An overall SSR of 89% was found in this study. Historically, every patient with a rebleeding has been treated surgically. Many studies have proven that SAE has increased the success rate of NOM both by stopping ongoing bleeding as well as by preventing delayed rupture of the spleen.\textsuperscript{7-10} Some studies showed that rebleeding after observational management and even after embolization could be treated with SAE, which further can increase the nonoperative SSR.\textsuperscript{10,19} In our study six patients who failed observational management and one patient with failure after initial distal SAE were successfully treated with SAE, resulting in a higher splenic salvage rate. Results of the present study are comparable with the result described in the literature which are predominantly based on large volume studies from Level-I trauma centers in the United States (US).\textsuperscript{5-7,19,20} Therefore, NOM with the adjunction of SAE in patients is also feasible in a relatively low volume Level-1 trauma center outside the US.

Second aim was to assess risk factors for failure of NOM of splenic injury. Results of the literature suggest that the presence of contrast extravasation, large hemoperitoneum and especially a combination of both CT features are associated with a higher failure rate after NOM.\textsuperscript{5,12-17} The present study showed that the presence of high grade of injury, a large hemoperitoneum and a vascular blush (especially an intraperitoneal contrast extravasation) increased the failure rate of patients who were treated with NOM. However, in the multivariate analysis age > 50 years and AAST grade of injury ≥ 3 were identified as independent risk factors for failure. A large hemoperitoneum and contrast extravasation were not identified as independent risk factors for failure of NOM.

| Table 5. Univariable and multivariable logistic regression analysis of factors for failure of non operative management (n= 169) |
|---------------------------------------------------------------|
| **Univariable OR**                                             |
| **Multivariable OR**                                          |
| Gender: male                                                  | 0.8 (0.3-2.1) |
| Age >50 years                                                 | 2.7 (1.2-6.2) | 2.7 (1.1-7.5) |
| GCS <11                                                       | 2.9 (1.1-7.7) |
| ISS ≥16                                                       | 1.1 (0.5-2.5) |
| Traffic accident                                              | 1.8 (0.7-4.7) |
| Associated injury                                             | 0.6 (0.3-1.2) |
| AAST grade of injury ≥3                                        | 2.1 (1.1-4.6) | 3.8 (1.4-10.0) |
| Blush intraperitoneal                                          | 3.2 (1.1-9.0) |
| Hemoperitoneum                                                |               |
| minimal                                                       | 0.7 (0.3-1.9) |
| significant                                                   | 1.1 (0.4-3.3) |

OR = odds ratio
Currently, our protocol dictates that each patient with a vascular blush at CT scan would be treated with angiography (and embolization). Based on our results the question arises if this strategy is currently advisable, especially in hemodynamically stable patients despite having intrasplenic contrast extravasation at CT scan. Omert et al. have questioned the importance of a contrast extravasation and suggested that this is not an absolute indication for any intervention.\textsuperscript{16} Factors such as patient’s age, grade of injury, and hemodynamic status should be considered in the management of these patients.\textsuperscript{16} In the current study advanced age >50 years was an independent factor associated with a higher failure rate which is supported by several other studies.

This study has several limitations, which are mainly related to the retrospective analysis of data. Despite protocols for diagnostics and treatment, in practice the considerations for a specific treatment was also based on the clinical judgment of the attending trauma surgeon. The continuous evolution and improvement of imaging techniques during the period studied could also cause a bias in the results. The better imaging quality could influence and increase the injury gradations because of more specific injury details. However, by re-evaluation of all available CT scans we tried to prevent this bias.

In conclusion, the failure rate of patients with blunt splenic injuries is low and comparable with the literature. This study showed that patients with rebleeding could be successfully treated with SAE leading to considerable SSR. The presence of a contrast extravasation is not independently associated with an increased failure rate. Factors such as patient age, grade of injury need to be considered in the treatment management of these patients.
REFERENCES

1. Frumiento C, Vane DW. Changing patterns of treatment for blunt splenic injuries: an 11-year experience in a rural state. J Pediatr Surg. 2000;35:985-988.
2. Savage SA, Zarzaur BL, Magnotti LJ, Weinberg JA, Maish GO, Bee TK, Minard G, Schroeppl T, Croce MA, Fabian TC. The evolution of blunt splenic injury: resolution and progression. J Trauma. 2008 Apr; 64(4):1085-91
3. Pachter HL, Guth AA, Hofstetter SR, Spencer FC. Changing patterns in the management of splenic trauma: the impact of nonoperative management. Ann Surg. 1998;227:708-717.
4. Leenen LP. Abdominal trauma: from operative to nonoperative management. Injury. 2009 Nov;40 Suppl 4:S62-8.
5. Haan JM, Biffl W, Knudson MM et al. Splenic embolization revisited: a multicenter review. J Trauma. 2004;56:542-547.
6. Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: a 5-year experience. J Trauma. 2005;58:492-498.
7. Liu PP, Lee WC, Cheng YF et al. Use of splenic artery embolization as an adjunct to nonsurgical management of blunt splenic injury. J Trauma. 2004;56:768-772.
8. Davis KA, Fabian TC, Croce MA et al. Improved success in nonoperative management of blunt splenic injuries: embolization of splenic artery pseudoaneurysms. J Trauma. 1998;44:1008-1013.
9. Wei B, Hemmila MR, Arbabi S, Taheri PA, Wahl WL. Angioembolization reduces operative intervention for blunt splenic injury. J Trauma. 2008;64:1472-1477.
10. Sabe AA, Claridge JA, Rosenblum DI, Lie K, Malangoni MA. J Trauma. The effects of splenic artery embolization on nonoperative management of blunt splenic injury: a 16-year experience. 2009 Sep; 67(3):565-72
11. Ochsner MG. Factors of failure for nonoperative management of blunt liver and splenic injuries. World J Surg. 2001 Nov;25(11):1393-6.
12. Shanmuganathan K, Mirvis SE, Boyd-Kranis R, Takada T, Scalea TM. Nonsurgical management of blunt splenic injury: use of CT criteria to select patients for splenic arteriography and potential endovascular therapy. Radiology. 2000;217:75-82.
13. Federle MP, Courcoulas AP, Powell M, Ferris JV, Peitzman AB. Blunt splenic injury in adults: clinical and CT criteria for management, with emphasis on active extravasation. Radiology. 1998;206:137-142.
14. Schurr MJ, Fabian TC, Gavant M et al. Management of blunt splenic trauma: computed tomographic contrast blush predicts failure of nonoperative management. J Trauma. 1995;39:507-512.
15. Shanmuganathan K, Mirvis SE, Sherbourne CD, Chiu WC, Rodriguez A. Hemoperitoneum as the sole indicator of abdominal visceral injuries: a potential limitation of screening abdominal US for trauma. Radiology. 1999;212:423-430.
16. Omert LA, Salyer D, Dunham CM, Porter J, Silva A, Protetch J. Implications of the «contrast blush» finding on computed tomographic scan of the spleen in trauma. J Trauma. 2001;51:272-277.
17. Peitzman AB, Heil B, Rivera L et al. Blunt splenic injury in adults: Multi-institutional Study of the Eastern Association for the Surgery of Trauma. J Trauma. 2000;49:177-187.
18. Haan JM. Experience with splenic main coil embolization and significance of new or persistent pseudoaneurysm: reembolize, operate, or observe. J Trauma. 2007;63:615-619.
19. Dent D, Alsabrook G, Erickson BA et al. Blunt splenic injuries: high nonoperative management rate can be achieved with selective embolization. J Trauma. 2004;56:1063-1067.
20. Smith HE, Biffl WL, Majercik SD, Jednacz J, Lambiase R, Cioffi WG. Splenic artery embolization: Have we gone too far? J Trauma. 2006;61:541-544.
Improved outcome in nonoperative management of liver injuries

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ABSTRACT

Introduction: Nonoperative management has become the treatment of choice for the majority of liver injuries. The aim of this study was to assess the changes in primary treatment and outcomes in a single Dutch Level-1 trauma center with wide experience in angio-embolization.

Methods: The prospective trauma registry was retrospectively analyzed for a 6-year period before (period 1) and after the introduction of angio-embolization (period 2). Primary outcome was the failure rate of primary treatment defined as liver injury-related death or re-bleeding requiring radiological or operative (re)interventions. Secondary outcomes were liver injury-related intraabdominal complications.

Results: Despite an increase in high grade liver injuries, primary nonoperative management had more than doubled from 20/61 (33%) to 84/116 (72%) (p<0.001). In comparison with period 1, failure rate of primary treatment in period 2, was 11/61 (18%) compared to 13/116 (11%) (p=0.21), complication rate was 14/61 (23%) compared to 18/116 (16%) (p=0.22) and liver-related mortality was 6/61 (9.8%) compared to 4/116 (3.4%) (p=0.095). The increase in nonoperative management was even higher in high grade injuries. In high grade injuries outcomes were improved with more nonoperative management, respectively a decreased in failure rate of 9/20 (45%) to 11/55 (20%) (p=0.041), liver-related mortality of 6/20 (30%) to 4/55 (7%) (p=0.019) and complication rate of 12/20 (60%) to 15/55 (27%) (p=0.014). Liver infarction or necrosis and abscess formation seemed to occur more frequently with angio-embolization.

Conclusion: Overall, liver-related mortality, treatment failure and complication rates remained equal despite the increase in nonoperative management. However, in high grade injuries the outcomes improved after the introduction of angio-embolization.
INTRODUCTION

The liver is the most frequently injured organ after abdominal trauma. During the last two decades management of traumatic liver injuries has changed considerably. Traditionally, surgery was the treatment of choice for most liver injuries. However, with the increasing fast availability of Computed Tomography scanning (CT) and modern minimally invasive, percutaneous interventional techniques such as angio-embolization, nonoperative management has evolved as the treatment of choice for both minor and major liver injuries.\textsuperscript{1-3} With nonoperative management strategies, approximately 70% of all liver injuries can be treated without increased risk of mortality.\textsuperscript{4} Many studies have described decreasing mortality rates using this strategy.\textsuperscript{2,4,9-11} However, at the same time, several studies report an increase in major complications such as hepatic necrosis, abscesses or bile leakage.\textsuperscript{5-7}

In 1999, angio-embolization was introduced in the Academic Medical Center (AMC), which is a designated Dutch Level-1 trauma center. Since 2002, angiography with or without embolization has become an accepted method for the evaluation and treatment of liver injuries. The aim of this study was to compare the failure rate of primary treatment before and after the introduction of angiography in patients with liver injury in the AMC. Furthermore, the effects on clinical outcomes and complication rates were assessed.

METHODS

Data collection

All patients with liver injuries admitted between January 1995 and December 2008 to the Academic Medical Center (AMC) were identified for review from the hospital’s prospective trauma registry, the in-hospital information system or financial administrative registration. For verification the prospective interventional radiology registry was checked for potentially missed patients. Patients who were initially treated at other hospitals were excluded from this analysis. Patients primarily evaluated elsewhere (without intervention) and referred to the AMC for initial treatment were however, included. A chart review was performed for data collection of demographic data including age, gender, trauma mechanism, and Injury Severity Score (ISS). Data collection was performed according to a preplanned, standardized format. Primary treatment was assessed as nonoperative (observation and/or angio-embolization) or surgical exploration. Potential liver injury related complications with subsequent interventions were also recorded. One radiologist (KPvL) with trauma and vascular interventional experience re-evaluated all available admission CT scans and classified the liver injury grades according to the AAST classification.\textsuperscript{8} Grade 1 and 2 were classified as low grade, grade 3–5 as moderate to high grade. Data on presence of contrast blushes, hemoperitoneum and the extension of hemoperitoneum was also registered. If no
CT scan was available injuries were graded according to intra-operative findings or ultrasonographic outcome.

**Study periods**

Two periods were compared, before and after the introduction of angio-embolization in the treatment of liver injuries in the AMC, i.e. 1995–2001 (period 1) and 2002–2008 (period 2), respectively. A total of 186 patients were eligible for inclusion during the study period. Nine patients were excluded because initial evaluation and stabilizing interventions were performed in other hospitals.

**Treatment and imaging protocols**

In period 1, the protocol dictated surgical exploration in patients with a suspicion of moderate to severe liver injury independent of the hemodynamic status. In period 2, according to the changed protocol, hemodynamically unstable patients not responding to fluid resuscitation (non-responders) were treated primarily operatively. Operative treatment began with 4 quadrant packing before structural exploration of the abdomen. If necessary the Pringle maneuver was performed to stop extensive hemorrhage and gain overview. Grade 1 to 3 injuries were treated with local tamponade, electro-coagulation, local haemostatic materials (i.e. TachoSil®) or several sutures (monofilament). Operative treatment of grade 4 and 5 injuries was dependent of stability of the abovementioned local hemorrhage control measures but most frequently these injuries were packed with several gauzes for 24–48 hours. Resections were preferably not performed in the acute phase. In hemodynamically stable patients or transient responders management was primarily nonoperative. Nonoperative management was observation in the intensive care unit (ICU) with regular (6-hour) blood tests on the first day. Length of ICU observation was depending on the clinical and laboratory findings and varied from 24 till 72 hours. Depending on CT findings (liver injury combined with contrast blush) an angiography was subsequently performed.

In the period 1995–2001 a dual slice helical CT-scanner was used for scanning trauma patients. Five mm slices (increment of 5mm) were acquired in arterial (using bolus tracking) and portal phase (70 seconds time delay) to detect liver laceration and contrast extravasation. Between 2002–2008 16-slice and 64-slice CT scanners were available. The scanning protocol was adapted with acquisition of 3 mm slices (increment of 2 mm) in the arterial and portal phase.

The angiography procedure was performed under local anesthesia. Subsequently, the common femoral artery was punctured, followed by introduction of a 5 Fr. Sheath. For selective catheterization of the celiac trunk a 5 Fr. cobra catheter or celiac catheter (Cordis, Johnson &Johnson, Miami, Florida) was used. Identification of the lacerated branches of the hepatic artery was performed with Digital Subtraction Angiography. Superselective catheterisation and embolization was done using a 3 Fr. microcatheter (Renegade, Boston Scientific) and 0.018 inch microcoils (Boston Scientific, USA). Occasionally a combination of coils and 300–500 µ
Polyvinyl Alcohol particles (Cook, Bloomington USA) was used. Contrast blush was defined as contrast extravasation or pseudoaneurysms.

**Study endpoints**

Primary outcome was the failure rate of primary treatment. Failure was defined as death due to uncontrollable liver hemorrhage or rebleeding after primary intervention requiring radiological or operative (re-)interventions. Preplanned second-look operations to inspect or remove the packing were not considered a failure. Secondary operations, which were performed within 24 hours because of increased hemodynamic instability were considered a failure. Complications were defined as liver injury-related or intra-abdominal complications, such as abscess formation, bile leakage, jaundice, liver infarction and liver necrosis, cholecystitis and fistula formation. Wound infections or general complications such as pneumonia were not assessed. Secondary clinical outcome parameters were length of ICU and total hospital stay, transfusion requirements in the first 48 hours and overall mortality rate. Mortality was defined as either due to liver-related complications or due to other causes, be it traumatic or non-traumatic.

**Statistics**

All continuous variables are presented as medians with interquartile ranges (p25-p75) and were compared using the Mann-Whitney U test for two variables or when more than two variables using the Kruskal-Wallis test. Categorical variables were calculated as percentages and compared using Chi-square analyses and Fisher’s exact test when applicable. Statistical significance was declared at the 0.05 level. All data were collected and analyzed using SPSS® for Windows, version 15.0.1 (SPSS, Inc., Chicago, IL).

**RESULTS**

Of the included 177 patients, 122 (69%) were male with a median age of 29 years (19–38). 43 (24%) sustained penetrating trauma. Median ISS was 22 (10–34) and median liver AAST grade was 2 (2–3). The demographic data, severity of trauma and initial investigations and treatment for period 1 and 2 are shown in Table 1.

In Table 2 the clinical outcomes are presented for both periods. In period 2, the failure and complication rates and liver-related mortality did not significantly differ from period 1. The only patient in period 2 that died of liver failure was not eligible for liver transplantation because of abdominal sepsis.

Table 3 shows the liver injury-related, intraabdominal complications occurring during the two periods. Abscess formation seemed to occur more frequently after angio-embolization. In period 1 more bile leakage was found after operative interventions. Four operative interventions in 4 patients and 9 radiographical interventions in 5 patients were necessary to
resolve the complications in period 1. In period 2, it took 8 operations in 6 patients and 22 percutaneous interventions in 14 patients to treat the complications. Two patients required a complication-related operation after nonoperative management in period 2. Just one patient required a cholecystectomy due to liver and gallbladder necrosis after embolization. The two other patients after nonoperative management in period 2 had temporary liver infarction and

| Table 1. Demographic data, severity of trauma and initial investigations and treatment |
|--------------------------------------|------------------|------------------|------------------|
|                                      | Period 1 | Period 2 | P-value |
| n                                     | 61       | 116      |         |
| Age (years)                           | 29 (19-36) | 29 (20-41) | 0.617 |
| Male                                  | 44 (72%) | 78 (67%) | 0.609 |
| Blunt trauma                          | 43 (71%) | 91 (78%) | 0.241 |
| ISS                                   | 20 (9-34) | 22 (11-34) | 0.866 |
| Multitrauma                           | 38 (62%) | 79 (68%) | 0.438 |
| Initial CT scan                       | 21 (36%) | 89 (77%) | <0.001 |
| Injury grade                          |          |          |         |
| - low (grade 1-2)                     | 41 (67%) | 61 (53%) | 0.061 |
| - high (grade 3-5)                    | 20 (33%) | 55 (47%) |         |
| Initial treatment                     |          |          |         |
| - observation                         | 20 (33%) | 61 (52%) | <0.001 |
| - operative                           | 41 (67%) | 32 (28%) |         |
| - angio-embolization                  | 0 (0%)   | 23 (20%) |         |

ISS: Injury Severity Score

| Table 2. Clinical outcomes |
|---------------------------|-----------------|-----------------|-----------------|
|                          | Period 1 (n=61) | Period 2 (n=116) | P-value |
| Length of hospital stay (days) | 11 (7-20) | 10 (4-26) | 0.83 |
| ICU stay                  | 1 (0-6) | 2 (0-5) | 0.47 |
| PRBC units                | 4 (0-14) | 2 (0-8) | 0.183 |
| FFP units                 | 2 (0-12) | 0 (0-4) | 0.029 |
| Failure rate              | 11 (18%) | 13 (11%) | 0.207 |
| Overall mortality         | 16 (26%) | 17 (15%) | 0.060 |
| liver-related:            |          |          |         |
| - uncontrollable hemorhage | 6 (9.8%) | 4 (3.4%) | 0.095 |
| - liver failure           | 0 (0.0%) | 1 (0.9%) |         |
| Complication              | 14 (23%) | 18 (16%) | 0.222 |
| - ≥ 2 complications       | 4 (6.6%) | 9 (7.8%) |         |

ICU: Intensive Care Unit
PRBC: Packet Red Blood Cells
FFP: Fresh Frozen Plasma

In period 2, it took 8 operations in 6 patients and 22 percutaneous interventions in 14 patients to treat the complications. Two patients required a complication-related operation after nonoperative management in period 2. Just one patient required a cholecystectomy due to liver and gallbladder necrosis after embolization. The two other patients after nonoperative management in period 2 had temporary liver infarction and...
resolved completely without further intervention. Six planned re-operations were performed for depacking in period 1 versus eight in period 2.

Table 4 shows the injuries divided into low and high AAST grades per period and compared for primary treatment and outcomes. In period 2, more high grade injuries were treated nonoperatively with equal outcomes with respect to liver-related mortality rate, failure and complication rates. An increase in nonoperative treatment was also seen for the low-grade injuries. Although the complication rates were comparable, the failure rate seemed to decrease but also without reaching statistical significance.

Table 5 shows the specific CT findings of all patients evaluated with CT in both periods, classified according to primary treatment and outcomes. Although patients primarily treated with angio-embolization had sustained more severe liver injuries with more contrast bluses and

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**Table 3. Liver injury-related or intra-abdominal complications**

|                     | Period 1 (n=20) | Operation (n=41) | Period 2 (n=61) | Operation (n=32) | Angio-embolization (n=23) |
|---------------------|-----------------|-----------------|-----------------|-----------------|--------------------------|
| Bile leakage        | 6               | 1               | 2               |                 |                          |
| Jaundice/ liver failure | 1               | 1               | 1               |                 |                          |
| Necrosis/ infarction | 1               | 1               | 1               | 3               |                          |
| Abscess             | 1               | 1               | 1               | 1               | 5                        |
| Cholecystitis       |                 |                 |                 |                 | 1                        |
| ACS                 |                 |                 |                 |                 | 1                        |
| Fistula             |                 | 1               |                 |                 |                          |
| (re-)Bleeding       | 2               | 3               | 3               | 8               | 2                        |
| Total               | 4               | 12              | 6               | 12              | 13                       |

ACS: abdominal compartment syndrome
fistula: biliary pleural fistula

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**Table 4. Outcomes per period for low and high grade injuries.**

|                     | Low grade injuries | High grade injuries |
|---------------------|--------------------|--------------------|
|                     | Period 1 (n=41) | Period 2 (n=61) | P-value | Period 1 (n=20) | Period 2 (n=55) | P-value |
| AAST grade          | 1 (1-2) | 2 (2-2) | 0.003 | 3 (3-4) | 3 (3-4) | 0.363 |
| Observation         | 16/41 | 40/61 | 0.008 | 4/20 | 21/55 | 0.173 |
| Operation           | 25/41 | 14/61 | <0.001 | 16/20 | 18/55 | <0.001 |
| Angio-embolization  | 0/41 | 7/61 | 0.040 | 0/20 | 16/55 | 0.040 |
| Liver related mortality | 0/41 | 0/61 | n.a. | 6/20 | 4/55 | 0.019 |
| Complication        | 2/41 | 3/61 | 1.000 | 12/20 | 15/55 | 0.014 |
| Failure rate        | 2/41 | 2/61 | 1.000 | 9/20 | 11/55 | 0.041 |

AAST: American Association for the Surgery of Trauma
n.a. = not available
hemoperitoneum detected on CT, equal failure rates were detected. However, the patient treated nonoperatively did receive less transfusion within the 1st 24 hours compared to the primarily operated group. There were 13 patients observed although a contrast blush was visible on the CT scan. Two of these patients (15%) had a rebleeding which could eventually be treated successfully with angio-embolization.

In Table 6 the outcomes of primary treatment are presented per injury grade for both periods. In one of the nine patients with a grade 3 injury, who underwent angio-embolization primary treatment failed whereas this was one of the six patients who underwent AE with a grade 4 injury in period 2. The one patient with a grade 5 injury who was treated nonoperatively underwent angio-embolization. The patients’ course was complicated by temporary hepatic ischemia and abscess formation but finally recovered completely with nonoperative management.

| Grade | Period 1 | | | Period 2 | | |
|-------|----------|----------|----------|----------|----------|
|       | Nonoperative | Failure | Operative | Failure | Nonoperative | Failure | Operative | Failure |
| 1     | 9          | 0        | 12        | 1        | 11          | 0        | 3          | 1        |
| 2     | 7          | 1        | 13        | 0        | 36          | 0        | 11         | 1        |
| 3     | 2          | 0        | 11        | 6        | 28          | 4        | 13         | 3        |
| 4     | 2          | 1        | 3         | 0        | 8           | 1        | 4          | 3        |
| 5     | 0          | 0        | 2         | 2        | 1           | 0        | 1          | 0        |
DISCUSSION

In concordance with recent literature, the present study shows an important shift in the treatment of choice during the two studied periods. In the first period (1995–2001), primary surgical exploration was performed in more than two thirds of the patients. After the introduction of angio-embolization and endovascular intervention in the second period (2002–2008) primary operative management was reduced to one third of the patients whereas nonoperative management was successful in the majority of patients. Despite this increase in the nonoperative management rate and notwithstanding an increase in the severity of injuries the clinical outcomes did not differ significantly between the two periods. In addition, the outcomes showed improved outcomes with respect to failure rate of nonoperative management and liver-injury related mortality and complication rate in high grade injuries after the introduction of angio-embolization. This shift to nonoperative management, especially in higher grade injuries with better outcomes, reflects the outcomes described in literature in which in recent years, the majority of all liver injuries are managed successfully with nonoperative management.\textsuperscript{2,4,9,11}

One explanation for the increased success in nonoperative management is the continuous evolution and improvement of imaging and endovascular techniques. With modern imaging techniques such as a thin-slice multidetector CT, a detailed overview of the extent of liver injury and the presence of active hemorrhage is provided. Based on this information a more specific treatment can be devised. Secondly, with the introduction of angio-embolization, patients with specific CT findings can potentially be treated minimally invasive. With the availability of angio-embolization, trauma surgeons are more likely to initiate nonoperative treatment even in higher grade injuries because in case of failure they still have access to intervention by angio-embolization, and in case of failure, can still decide on surgical intervention.

Recent literature reveals that with the increased use of angio-embolization and decreased mortality, an increase of severe complications such as liver necrosis, bile leakage and intra-abdominal abscesses is found.\textsuperscript{6,10,12} The present study showed that abscess formation and liver infarction or necrosis was more common in the period after the introduction of angio-embolization. However, there was no increase in radiographically confirmed bile leakage.

In general in period 2, there were few complications after nonoperative management. After angiography, 2 surgical interventions were required in 2 patients and 16 radiological (re-)interventions in 8 patients. The observed re-operation rate of 2% was acceptable, as compared to the complication-related, re-operation rates of 21–34% described in the literature.\textsuperscript{5,13}

This study has several limitations, which are mainly related to the retrospective analysis of data. Firstly, two periods were compared in which not only angio-embolization was introduced but in which also other improvements in trauma care occurred. After period 1 the AMC became a dedicated Level-1 trauma center to which injured patients were referred requiring specialized trauma care. Simultaneously, advancements in ICU treatment, transfusion and fluid resuscitation protocols and radiological and surgical techniques during period 2 could also have contributed
to a better outcome. The continuous evolution and improvement of imaging techniques could also cause a bias in the results. The better imaging quality could influence and increase the injury gradations because of more specific injury details. However, by re-evaluation of all available CT scans we tried to prevent this bias. Second, injury characteristics such as blushes and/or large hemoperitoneum, which are suggestive of more severe injuries and can be diagnosed with all types of CT scanners, were diagnosed more frequently in the second period.

Secondly, due to the study design the considerations that had led to nonoperative management could not be assessed. Based on these results, the grade of liver injury or other specific CT findings did not seem to predict the primary choice of treatment. Within the population that was initially observed, 22% of patients had a contrast blush on CT and 21% had signs of severe hemoperitoneum. In contrast, patients who were treated with angio-embolization had more CT findings of severe injuries than the patients who were primarily operated. In addition, 23% of the low grade injuries still received operative treatment in period 2. Although several studies described flowcharts based on CT findings to facilitate decision making, the present data on CT findings and primary treatment showed that other, clinical signs or injuries must have played an important role in treatment planning. A final limitation of the present study is that the inclusion numbers were relatively small. Although there was an overall increase in nonoperative management we also found a slight but statistically non-significant improvement in clinical outcomes in the period after the introduction of angio-embolization. The relatively low number of inclusions provides an explanation for not reaching statistical significance.

CONCLUSION

Nonoperative management of liver injuries is currently undertaken more frequently, with low failure rates despite an increase in severity. After the introduction of angio-embolization in the nonoperative management protocols in the AMC, liver-related mortality, treatment failure and complication rates remained equal despite the increase in nonoperative management. In high grade injuries outcomes with respect to liver injury related mortality, complication rate and failure of primary treatment, improved after the introduction of angio-embolization. Abscess formation and liver infarction were more common after angio-embolization than after laparotomy.
REFERENCES

1. Richardson JD. Changes in the management of injuries to the liver and spleen. J Am Coll Surg. 2005; 200(5): 648-69.
2. Croce MA, Fabian TC, Menke PG, Waddle-Smith L, Minard G, Kudsk KA et al. Nonoperative management of blunt hepatic trauma is the treatment of choice for hemodynamically stable patients. Results of a prospective trial. Ann Surg. 1995; 221(6): 744-53.
3. Omoshoro-Jones JA, Nicol AJ, Navsaria PH, Zellweger R, Krije JE, Kahn DH. Selective non-operative management of liver gunshot injuries. Br J Surg. 2005; 92(7): 890-5.
4. Velmahos GC, Toutouzas K, Radin R, Chan L, Rhee P, Tillou A et al. High success with nonoperative management of blunt hepatic trauma: the liver is a sturdy organ. Arch Surg. 2003; 138(5): 475-80.
5. Mohr AM, Lavery RF, Barone A, Bahramipour P, Magnotti LJ, Osband AJ et al. Angiographic embolization for liver injuries: low mortality, high morbidity. J Trauma. 2003; 55(6): 1077-81.
6. Dabbs DN, Stein DM, Scalea TM. Major hepatic necrosis: a common complication after angioembolization for treatment of high grade liver injuries. J Trauma. 2009; 66(3): 621-7.
7. Kozar RA, Moore JB, Niles SE, Holcomb JB, Moore EE, Cothren CC et al. Complications of nonoperative management of high grade blunt hepatic injuries. J Trauma. 2005; 59(5): 1066-71.
8. Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni MA, Champion HR. Organ injury scaling: spleen and liver (1994 revision). J Trauma. 1995; 38(3): 323-4.
9. Christmas AB, Wilson AK, Manning B, Franklin GA, Miller FB, Richardson JD et al. Selective management of blunt hepatic injuries including nonoperative management is a safe and effective strategy. Surgery. 2005; 138(4): 606-10.
10. Gaarder C, Naess PA, Eken T, Skaga NO, Pillgram-Larsen J, Klow NE et al. Liver injuries—improved results with a formal protocol including angiography. Injury. 2007; 38(9): 1075-83.
11. Malhotra AK, Fabian TC, Croce MA, Gavin TJ, Kudsk KA, Minard G et al. Blunt hepatic injury: a paradigm shift from operative to nonoperative management in the 1990s. Ann Surg. 2000; 231(6): 804-13.
12. Misselbeck TS, Teicher EJ, Cipolle MD, Pasquale MD, Shah KT, Dangleben DA et al. Hepatic angioembolization in trauma patients: indications and complications. J Trauma. 2009; 67(4): 769-73.
13. Kozar RA, Moore FA, Cothren CC, Moore EE, Sena M, Bulger EM et al. Risk factors for hepatic morbidity following nonoperative management: multicenter study. Arch Surg. 2006; 141(5): 451-8.
Management of blunt renal injury in a level-1 trauma center in view of the European guidelines

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ABSTRACT

Introduction: Debate continues about the optimal management strategy for patients with renal injury. Aim of this study was to compare the diagnostics and treatment applied in a Level-1 trauma center and to compare it to the recommendations of the European Association of Urology guidelines concerning blunt renal injury.

Methods: The management of all patients with blunt renal injury, admitted to the Level-1 trauma center of the Academic Medical Center, between January 2005 and December 2009 was reviewed retrospectively.

Results: Median age and ISS of the 186 included patients were 40 and 17 years respectively. All but one hemodynamically stable patients with microscopic hematuria received nonoperative management. Sixty percent of the hemodynamically stable patients with gross hematuria underwent CT scanning. Patients with Grade 1-4 renal injury were treated conservatively. Additionally, two patients with Grade 3-4 renal injury received angiography and embolization (AE). One patient with grade 5 injury underwent renal exploration and two AE. Seven of the 8 hemodynamically unstable patients underwent emergency laparotomy and in 2 patients, hemodynamically unstable because of renal injury, AE was performed as an adjunct to surgical intervention.

Conclusions: In the present study, violation of the guidelines increased with injury severity. AE can provide both a useful adjunct to nonoperative management and alternative to surgical intervention in specialised centers with appropriate equipment and expertise, even in patients with high grade renal injury. We advocate an update of the guidelines with a more prominent role of AE.
INTRODUCTION

Renal injury occurs in approximately 1–5% of all trauma patients.\textsuperscript{1,2} Blunt trauma, mainly caused by traffic accidents, falls and sports, accounts for 90–95% of the renal injuries.\textsuperscript{3} The majority of blunt renal injuries are low-grade injuries, not requiring any intervention.\textsuperscript{3,4} Evidence based (trauma) guidelines help physicians to select the best treatment for patients. Furthermore, the use of guidelines is considered to be an important method to standardize and optimize medical care.\textsuperscript{5} In 2004, Santucci et al. published a consensus document on renal injury.\textsuperscript{6} One year later, Lynch et al. published the European Association of Urology (EAU) guidelines on urological trauma (update 2009).\textsuperscript{7,8} These guidelines are a summary of available literature on the diagnostic strategies and treatment of genitourinary trauma. In daily practice, however, guidelines are often not followed. Earlier research showed that only half of the urologists in the United Kingdom utilize the guidelines in the management of renal trauma and that there was variable adherence to the recommendations.\textsuperscript{5} The aim of the present study was to compare the diagnostics and treatment of patients with blunt renal injury applied in a Level-1 trauma center to the recommendations of the EAU guidelines. Furthermore, the outcome (success or failure) of the treatment was reported.

METHODS

Data collection

All consecutive patients with blunt renal injury who were admitted to the Level-1 trauma center of the Academic Medical Center (AMC), the Netherlands, between January 2005 and December 2009 were retrospectively reviewed. Patients under the age of 16 years, patients with penetrating injuries and patients who were initially treated at other hospitals were excluded from this analysis. Patients primarily evaluated elsewhere (without intervention) and referred to the AMC for treatment were however, included. Details of all these patients were prospectively recorded in the trauma registry by the trauma surgeons. The hospital information system was checked for potentially missed patients. Data collection of demographic information including age, gender, trauma mechanism and Injury Severity Score (ISS) were extracted from the trauma registry. Associated injuries were extracted from the electronic medical record. The hemodynamic status, presence and grade of renal injury, diagnostic strategies, initial treatment, morbidity, mortality, intensive care unit (ICU) and overall length of stay in the hospital were collected. Renal lacerations were graded according to the Organ Injury Scale as described by the American Association for the Surgery of Trauma (AAST).\textsuperscript{9} Failure of nonoperative management (NOM) was defined as clinical signs of a rebleeding requiring operative or radiological (re-) interven-
Renal salvage assessed if renal flow was present during contrast-enhanced Computed Tomography (CT) scanning.

**Diagnostic and treatment AMC**

There was no dedicated protocol for renal injury in the AMC during the study period. All patients were managed according to the Advanced Trauma Life Support (ATLS®) principles. Hemodynamically unstable patients not responding to fluid resuscitation (non-responders) were treated primarily with an emergency laparotomy. In hemodynamically stable patients, the CT scan played a crucial role in initial triage; suspicion of intra-abdominal injuries in these patients was an indication for contrast enhanced CT scanning in the trauma resuscitation room.\(^{10}\) NOM was performed in all haemodynamically stable patients or patients responding to initial fluid administration (transient responders). NOM involves admission to a unit with monitoring of vital signs, strict bed rest, frequent monitoring of red blood cell count, and serial abdominal exams. Selective arterial embolization was routinely performed by an experienced interventional radiologist if signs of active bleeding (contrast extravasation), a pseudoaneurysm or an arteriovenous fistula were detected on CT scan. This illustrates that, in our hospital, the results of CT scanning were of overriding importance in the management decisions and the decision to proceed to angiography. The trauma-surgeon and radiologist determined further diagnostic and treatment strategies for each individual patient, if necessary in consultation with an urologist.

A urine sample of all patients was collected during the secondary survey (entire examination (including imaging) of the patient from top to toe) on the shock room or early after admission. In the week following admission, renal injury was scored for the trauma registry and calculation of the ISS. Patients with microscopic hematuria admitted after a blunt trauma mechanism were classified as sustaining Grade 1 renal injury although some studies state that there is no absolute relationship between the presence, absence or degree of hematuria and the severity of renal injury.\(^{11,12}\)

**Diagnostic and treatment protocol EAU guidelines\(^7\)**

Renal trauma may be expected based on the reported mechanism of injury and physical examination. The first step in the evaluation of trauma patients is to determine hemodynamic stability. Hemodynamically unstable patients should immediately undergo emergency laparotomy according to the EAU guidelines (Figure 1). A one-shot IntraVenous Pyelogram (IVP) during operation can be useful in these patients to determine if renal exploration is necessary. Hemodynamically stable patients are divided into two groups: patients with microscopic hematuria and patients with gross hematuria. The presence of gross hematuria is an absolute indication for renal imaging. Renal imaging should also be performed in patients with microscopic hematuria with major associated injuries or rapid deceleration injury. Contrast enhanced CT is the
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Radiological gold standard method for evaluating renal injuries in stable patients. The grade and extent of renal injury can be determined, as well as the presence of vascular injuries. The EAU Guidelines distinguish operative and nonoperative management of blunt renal injury. Absolute indications for emergency laparotomy include hemodynamic instability or the presence of associated injuries requiring laparotomy. Absolute indications for renal exploration are: a pulsatile or expanding retroperitoneal haematoma identified at exploratory laparotomy and/or a grade 5 renal injury identified with the CT scan in a patient with gross hematuria. Persistent bleeding and suspected renal pelvis or an ureteral injury is a relative indications for renal exploration.

NOM consists of close observation, bed rest, frequent monitoring of haemoglobin concentration and the administration of antibiotics. NOM is adopted in renal injury grade 1, 2 and often grade 3. Essential in this management strategy is quick evaluation and intervention in case of deteriorating condition of the patient. There still is controversy about the optimal treatment for grade 4 renal injury. This group of patients often requires laparotomy because of associated injuries, but the EAU Guidelines recommend to start with NOM. It is of great importance to exclude coexisting injuries before initiating NOM. Diagnostic angiography and simultaneous selective renal embolization is briefly mentioned in the guidelines as an alternative for laparotomy in selected patients.

**Figure 1.** Flowchart of management of patients with suspected blunt renal trauma according to EAU guidelines
RESULTS

Demographic data
A total of 253 patients were eligible during the study period. Sixty-seven patients were excluded because of their age (n=38) or penetrating trauma mechanism (n=29). Of the included 186 patients the majority were male (70%) with a median age of 40 years (range 16–93 years). Median ISS was 17 (range 1–75) and median renal injury grade was 2 (1–4). Eight patients died, all of injuries other than the kidney injury. The demographic data and characteristics are depicted in Table 1.

Table 1. Demographics and characteristics of patients with blunt renal injury

| n (%) | n |
|-------|---|
| Age * | 40 (16-93) |
| Male | 132 (70) |
| ISS* | 17 (1-75) |
| High Energy Trauma | 157 (84) |
| Haemodynamics | |
| Stable | 178 (96) |
| Unstable | 8 (4) |
| Length of stay * | 11 (0-310) |
| ICU stay * | 2 (0-38) |
| Mortality rate | 9 (5) |

*: median (range)
ISS: Injury Severity Score
ICU: Intensive Care Unit

Table 2. Diagnostic strategies and treatment of haemodynamically stable patients with microscopic haematuria (n=148)

| n (%) | n |
|-------|---|
| CT scan | 33 (22) |
| Grade 1-2 | 142 (96) |
| Observation | 142 |
| Grade 3-4 | 6 (4) |
| Observation | 5 |
| AE | 1 |
| Outcome of treatment | |
| Failure of NOM | 0 |

AE: angiography and embolization
**Hemodynamically stable patients with microscopic hematuria**

The results will be discussed in view of the flowchart depicted in the EAU guidelines (Figure 1).7 Of the hemodynamically stable patients 148 (83%) had microscopic hematuria. The majority of the patients with microscopic hematuria had grade 1–2 renal injury (Table 2). Thirty-three (22%) of the 148 patients with microscopic hematuria underwent a CT scan of the abdomen from which 32 because of rapid deceleration injury or major associated injuries. Almost all patients were treated with observation (Table 2). One patient with a grade 4 injury and a bleeding (blush of contrast extravasation) from the renal artery successfully underwent AE. No failure of the initial treatment was observed.

**Hemodynamically stable patients with gross hematuria**

Sixty percent of the hemodynamically stable patients with gross hematuria underwent a CT scan of the abdomen. The treatment of these patients is shown in Table 3. One patient (3%) with a grade 1 renal injury underwent laparotomy because of associated injuries. Two patients (22%) with grade 3–4 renal injury and a blush of contrast extravasation on contrast enhanced CT scanning successfully underwent AE in addition to NOM. In one of the latter patients NOM failed and surgical intervention was necessary. One of the 3 patients with renal injury grade 5 initially underwent renal exploration with a nephrectomy.

| Table 3. Diagnostic strategies and treatment of haemodynamically stable patients with gross haematuria (n= 30) |
|-----------------|-----------------|
| n (%)           |                 |
| CT scan         | 18 (60)         |
| Grade 1-2       | 18 (60)         |
| Observation     | 17              |
| Associated injuries requiring laparotomy | 1 |
| Grade 3-4       | 9 (30)          |
| Observation     | 7               |
| AE              | 2               |
| Grade 5         | 3 (10)          |
| Observation     | 0               |
| AE              | 2               |
| Renal exploration (nephrectomy) | 1 |
| Outcome of treatment |     |
| Failure of NOM  | 1               |

AE: angiography and embolization
Hemodynamically unstable patients

7 of the 8 (87.5%) hemodynamically unstable patients underwent an emergency laparotomy. In half of the hemodynamically unstable patients, the renal injury was the (possible) cause of instability. Two of the former patients, positive for bleeding sites, were embolized: one as single treatment and one to correct the hemodynamic status before going to the operating room for associated injury (pelvic). In the other two patients the kidney could be salvaged with packing and stitching. No nephrectomy was performed. No IVP was performed during laparotomy. The imaging techniques and treatment strategies are depicted in Table 4.

### Table 4. Diagnostic strategies and treatment of haemodynamically unstable patients (n=8)

| Imaging          | n (%) |
|------------------|-------|
| IVP              | 0     |
| CT scan          | 6 (75)|

| Treatment HD unstable patients          | n (%) |
|-----------------------------------------|-------|
| Emergency Laparotomy                    | 7 (87.5)|

| Treatment of patients with renal injury as cause of instability | n (%) |
|-----------------------------------------------------------------|-------|
| Renal injury as cause of haemodynamic instability              | 4     |
| - Emergency Laparotomy                                        | 3 (75)|
| - AE in addition                                              | 2 (50)|
| Only AE                                                       | 1 (25)|

| Conservative treatment                                      | 0     |

| Outcome of treatment                                        | n (%) |
|--------------------------------------------------------------|-------|
| Failure                                                      | 0     |

IVP: Intravenous Pyelogram
AE: angiography and embolization

DISCUSSION

In the present study the management of patients with blunt renal injury admitted to a Level-1 trauma center was compared to the recommendations of the EAU guidelines, published in 2005. In addition, the outcome (success or failure) of the treatment was reported. Considerable differences and some similar strategies between the management in the AMC and the recommendations of the EAU guidelines were observed.

The diagnostics and treatment of patients with microscopic hematuria was consistent with the EAU guidelines. In 1 out of 148 (0.7%) patients a deviation of the guidelines was observed. Despite hemodynamic stability, this patient, with a grade 4 renal injury, was embolized. The reason was the presence of a contrast extravasation.

In patients with gross hematuria the following aspects were not in accordance with the guidelines. A high number of patients (40%) did not receive imaging for the evaluation of renal injury...
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despite the presence of a CT scanner on the shock room. An explanation could be that the CT scanner was installed in 2007 on the shock room and that not all patients admitted before that time, were scanned. Another explanation could be that in our trauma center CT scanning is partially being replaced by AE, which can serve both as diagnostic modality and intervention. Twenty-two percent of the patients with grade 3–4 renal injury, qualifying for NOM according to the guidelines, received AE as an adjunct to NOM. Again, because of the presence of a contrast extravasation. Of the 3 patients with renal injury grade 5 two patients (66%) successfully underwent AE instead of renal exploration, the recommended treatment in the EAU guidelines. Renal salvage was achieved.

Fifty percent of the hemodynamically unstable patients, with renal injury being the reason of instability, positive for bleeding sites on contrast enhanced CT scanning, and responding to fluid therapy, were treated successfully with AE. In the guidelines, surgical intervention is advised for this patient group. Instead of an IVP during laparotomy, the majority (75%) of the hemodynamically unstable patients underwent CT scanning pre-operatively in the trauma resuscitation room. The presence of a moveable CT scanner in the trauma resuscitation room of our trauma center allows rapid imaging during initial trauma screening in patients who respond to fluid therapy. Contrast enhanced CT scanning provides, just like IVP, information for decision-making in the critical time of urgent laparotomy. In the AMC IVP imaging has been entirely replaced by CT scanning. CT scanning is faster, associated intraperitoneal and retroperitoneal injuries can be assessed and the presence and location of active arterial arterial haemorrhage, a pseudoaneurysm or an arteriovenous fistula in the kidney can be detected. However, intra-operative IVP remains critical to decision making, especially when CT scanning was not possible pre-operatively and in penetrating trauma. Therefore, this diagnostic modality should not be lost.

The findings of the current study are consistent with those of Sharma et al. who found that only a part of the physicians in the UK utilize the guidelines in the management of renal trauma, and that adherence to the guidelines is variable. Compared with the guidelines, AE is an important step in our treatment plan of patients with blunt renal injury. AE is a minimally invasive, renal sparing intervention with high success rates, even in patients with high grade renal injury. Since 2002 angiography, with or without embolization, is an accepted method in our trauma center for the evaluation and treatment of patients with renal, splenic or hepatic vascular injuries. In this study AE failed in only one patient. For these reasons, in our opinion AE is a good alternative for renal exploration in specialised centers with appropriate equipment and expertise. Since AE is only briefly mentioned in the EAU guidelines but not integrated in the flowchart, we advocate an update of the guidelines with a more prominent role of AE.

This study has several limitations. First of all, the retrospective design. Moreover, because a protocol for the management of renal injury was lacking, the choice of therapy was based on the clinical judgment of the attending trauma-surgeon and (interventional) radiologist. The decisions on which the therapy choices were made could not always be retrieved from the
trauma registry or electronical medical record. Another limitation of this study is the relative small number of patients with high grade renal injury just as patients undergoing AE. In addition, the volume of renal loss from embolization was not assessed. Although it is believed that embolization has a higher renal parenchymal salvage rate compared to operative management, this conclusion cannot be drawn from the present study. Lastly, urological trauma rarely occurs in isolation.$^{16}$ The results may be confounded by the presence of other injuries and therefore possibly more difficult to interpret.

CONCLUSION

In the present study, violation of the guidelines increased with injury severity. Angiography and embolization can provide both a useful adjunct to nonoperative management and alternative to surgical intervention in specialised centers with appropriate equipment and expertise, even in patients with high grade renal injury. We advocate an update of the guidelines with a more prominent role of angiography and embolization.
REFERENCES

1. Zwingmann J, Schmal H, Sudkamp NP, Strohm PC. Injury severity and localisations seen in polytraumatized children compared to adults and the relevance for emergency room management. Zentralbl Chir. 2008 Feb; 133(1): 68-75

2. Buse S, Lynch TH, Martinez-Piñeiro L, Plas E, Serafetinides E, Turkeri L, Santucci RA, Sauerland S, Hohenfellner M; German Society for Trauma Surgery. Urinary tract injuries in polytraumatized patients. Unfallchirurg. 2005 Oct; 108(10): 821-8

3. Chow SJ, Thompson KJ, Hartman JF, Wright ML. A 10-year review of blunt artery injuries at an urban level 1 trauma centre. Injury. 2009; 40(8): 844-50

4. Santucci RA, Fisher MB. The literature increasingly supports expectant (conservative) management of renal trauma—a systematic review. J Trauma. 2005; 59: 493-503.

5. Sharma D, Butt N, Barrass B, Dawson C, Examining the impact of renal trauma guidelines on urologists in UK. Eur J Trauma Emerg Surg. 2008;34: 54-8

6. Santucci RA, Wessells H, Bartsch G, Descotes J, Heyns CF, McAninch JW, Nash P, Schmidlin F, Consensus on Genitourinary Trauma Evaluation and management of renal injuries: consensus statement of the renal trauma subcommittee. BJU Int. 2004; 93(7): 937-54

7. Lynch TH, Martínez-Piñeiro L, Plas E, Serafetinides E, Türkeri L, Santucci RA, Hohenfellner M; European Association of Urology. EAU guidelines on urological trauma. Eur Urol. 2005 Jan; 47(1): 1-15

8. European Association of Urology Guidelines on Urological Trauma (online), http://www.uroweb.org (2009)

9. Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni MA, Champion HR. Organ injury scaling: spleen and liver (1994 revision). J. Trauma. 1995; 38: 323-4.

10. Fung Kon Jin PH, Goslings JC, Ponsen KJ, van Kuijk C, Hoogerwerf N, Luitse JS. Assessment of a new trauma workflow concept implementing a sliding CT scanner in the trauma room: the effects on workup times. J Trauma. 2008 May; 64(5): 1320-6.

11. Brandes SB, McAninch JW. Urban free falls and patterns of renal injury: a 20-year experience with 396 cases. J Trauma. 1999 Oct; 47(4): 643-50

12. Gourgiotis S, Germanos S, Dimopoulos N et al. Renal injury: 5-year experience and literature review. Urol Int. 2006; 77(2): 97-103

13. Stawicki SP. Trends in nonoperative management of traumatic injuries: A synopsis. OPUS 12 Scientist. 2007;1(1): 19-35.

14. Mansi MK, Alkhudair WK. Conservative management with percutaneous intervention of major blunt renal injuries. AM J Emerg Med 1997; 15(7): 633-7

15. Miller LA, Shanmuganathan K. Multidetector CT evaluation of abdominal trauma. Radiol Clin North Am. 2005 Nov;43(6): 1079-95

16. Bent C, lyngkaran T, Urological Injuries following trauma, Clinical Radiology. 2008;63: 1361-71
Failure rate and complications of angiography and embolization for abdominal and pelvic trauma

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ABSTRACT

Introduction: Angiography and embolization has become the treatment of choice after abdominal trauma or pelvic injury in hemodynamically stable patients with suspicion of internal hemorrhage (contrast extravasation, pseudo-aneurysm or a vessel ‘cut-off’ diagnosed on CT scan). Some studies, however report a high incidence of rebleeding (failure) or complications. The aim of this study was to evaluate the failure rate and the complications in trauma patients undergoing such procedures.

Methods: All consecutive patients (n=97) admitted to our level-I trauma center between January 2002 and December 2008 in whom angiography with or without embolization was performed were analysed. Complications were classified as organ-specific, puncture-site related and systemic. Additional interventions, required to treat complications were documented.

Results: The overall failure rate was 12%. Overall, 48 complications were documented in 28 patients. Organ-specific complications were observed in 18 patients (19%), especially abscess formation and infarction of the liver. Puncture-site related complications occurred in 3 patients. The incidence of Contrast Induced Nephropathy (CIN) was 24%. Three patients developed renal failure. Nine of the 15 patients with rebleeding could be managed with reembolization or operative packing resulting in an organ salvage rate of 93%. Most (83%) of the organ-specific complications and all of the puncture-site related complications could be managed conservatively or with percutaneous treatment.

Conclusions: In the present study the failure rate and incidence of organ-specific and procedure-related complications were low and often could be managed with nonoperative minimally invasive interventions. Trauma patients undergoing angiography have a high chance (24%) to develop CIN and should therefore receive optimal prophylactic measures to avoid this complication.
INTRODUCTION

Angiography and embolization (AE) has become an accepted therapeutic modality for trauma patients with suspicion of internal hemorrhage. After identification of injuries or bleeding sites on Computed Tomography (CT), an interventional radiologist performs AE and vascular injuries to pelvic vessels as well as solid abdominal organs can be treated in a minimally invasive and nonoperative way.

Since 2002 angiography has become a routine procedure in our trauma center for the evaluation and treatment of selected trauma patients. The interventional radiology department provides 24/7 service for treating patients with suspicion for injuries amenable to angiographic embolization and the angiography suite is equipped to deal with patients undergoing continuous resuscitation.

In our academic Level-1 trauma center, general indications to perform angiography of abdominal vessels include the presence of a contrast extravasation ("contrast extravasation"), a pseudoaneurysm or a vessel ‘cut-off’ diagnosed on contrast enhanced CT. A large hemoperitoneum in combination with clinical signs of ongoing bleeding is also an indication for angiography. In hemodynamically stable and even unstable patients with high suspicion of the main focus of bleeding in the pelvis, angiography is also considered.

Encouraged by good results of the literature and by its minimally invasive nature indications for performing angiography in trauma patients are expanding and in experienced centers there is a low threshold for performing angiography. However, at the same time, several studies report the high occurrence of rebleeding (failure) or of major complications such as or organ-specific, systemic and puncture-site related complications in comparison with patients who underwent an operative treatment.1-5 Patients in whom no bleeding is found during the angiogram (negative angiogram) do not benefit from AE, while being exposed to the potential dangers and adverse effects of the procedure.

The aim of this study was to evaluate the failure rate and the frequency and type of AE-related complications in trauma patients undergoing such procedures. Furthermore, the characteristics in patients with a negative angiography are described.

METHODS

All consecutive trauma patients admitted to our level-I trauma center between January 2002 and December 2008 in whom angiography with or without embolization was performed after abdominal trauma or pelvic injuries were identified for review. For data collection we used the trauma registry, the in-hospital financial administrative registration and the prospective interventional radiology registry. Complications were identified from the prospectively collected complication database of the department of Surgery. Additionally, a chart review of electronic
and paper hospital registration systems and discharge letters was performed. Patients who were transferred to other hospitals directly after angiography were excluded from the study. Demographic data included age, gender, trauma mechanism, the Injury Severity Score (ISS) and the presence of a multitrauma (ISS >16). All organ systems for which angiographic evaluation was performed were registered.

Primary outcome was the failure rate (rebleeding) and the frequency and type of complications after angiography with or without subsequent embolization. Failure was defined as clinical and radiological (a contrast extravasation or significant increase of hemoperitoneum on repeat CT-scan) signs of rebleeding requiring operative or radiological (re-) interventions. The definition of a complication as used in our hospital was any unintended and unwanted event or state occurring or following medical care, that is so harmful to the patients' health that it requires (adjustment of) treatment or leads to permanent damage. Complications were classified as organ-specific, puncture-site related and systemic complications and occurring within 30 days after the last angiography.

Organ-specific complications included ischemia or necrosis of target or non-target organs or tissues and abscess formation. Systemic complications were defined as contrast induced nephropathy (CIN) and renal failure. CIN was defined as an increase in serum Creatinine (Cr) levels of >25% compared to baseline creatinine at 48–72 h after exposure to an iodinated contrast agent compared to baseline serum creatinine levels. Renal failure was defined as loss of renal function requiring (temporary) dialysis. Puncture-site related complications were hematoma of the groin and a false aneurysm.

Additional interventions, required to treat the complications were also documented and included both nonoperative interventions (AE, Percutaneous transhepatic Cholangiography and Drainage (PTCD), Endoscopic Retrograde CholangioPancreatography (ERCP), percutaneous drainage of abscess or infected fluid collections and dialysis) or operative treatment. Furthermore, the follow-up and frequency and type of complications after negative angiography were described. A negative angiography was defined as an angiography without a subsequent embolization in the same procedure. All continuous variables are presented as medians (with interquartile ranges) and were compared using the Mann-Whitney U test. Categorical variables were calculated as percentages and compared using Chi-square analyses. Statistical significance was declared at the 0.05 level. All statistical analyses were performed using SPSS for Windows, version 15.0.1 (SPSS, Inc., Chicago, IL).

RESULTS

During the study period 97 hemodynamically stable patients underwent angiography procedures for the evaluation of 129 potentially injured organs or pelvic fractures. Table 1 describes
Table 1. Patient characteristics for the total population and the patients in whom a negative angiography was performed

|                              | Total population | Patients with negative angiography |
|------------------------------|------------------|------------------------------------|
| n                            | 97               | 19                                 |
| Age *                        | 35 (22-45)       | 31 (20-59)                         |
| Male                         | 71 (73%)         | 12 (63%)                           |
| ISS *                        | 29 (20-36)       | 27 (23-34)                         |
| Potentially injured organs   | 129              | 25                                 |
| Pelvic                       | 47 (36%)         | 9 (36%)                            |
| Liver                        | 31 (24%)         | 10 (40%)                           |
| Spleen                       | 30 (23%)         | 3 (12%)                            |
| Kidney                       | 21 (16%)         | 3 (12%)                            |
| Multitrauma (ISS >16)        | 84 (87%)         | 16 (84%)                           |
| Trauma mechanism             |                  |                                    |
| Blunt                        | 89 (92%)         | 18 (95%)                           |
| Sharp                        | 8 (8%)           | 1 (5%)                             |
| Admission CT scan            | 90 (93%)         | 18 (95%)                           |
| Angiography                  |                  |                                    |
| Initial                      | 100 (78%)        | 13 (68%)                           |
| Secondary                    | 29 (22%)         | 6 (32%)                            |
| Length of hospital stay *     | 25 (12-45)       | 25 (15-45)                         |
| ICU stay *                   | 4 (2-12)         | 7 (2-14)                           |
| PRBC < 48 hr *               | 4 (1-10)         | 4 (2-6)                            |
| FFP < 48 hr *                | 2 (0-8)          | 4 (2-6)                            |

* Median (p25-75)
ISS: Injury Severity Score
ICU: intensive Care Unit
PRBC: Packed Red blood Cell transfusion
FFP: Fresh Frozen Plasma

The patient characteristics for the total population and for the patients in whom angiography was negative. The overall 30-day mortality rate was 8%. None of the patients with a negative angiography died. In addition, no complication-related mortality occurred. Rebleeding was observed in 15 patients (liver n=5, pelvis n=4, spleen n=3, kidney n=3) for an overall failure rate of 12% (15 of the 120 potentially injured organs) (table 2). The failure rate after AE of the liver, kidney, spleen and pelvis was 16, 14, 10 and 9% respectively. (Re)bleeding occurred in three patients after negative angiography for suspected injury of the kidney, pelvis and liver (failure rate 12%). Overall, 48 complications were documented in 28 patients after angiography (table 2). The majority of these patients had one complication. In 11 patients more than one complication was observed.
Organ-specific complications were observed in 18 patients, especially abscess formation and infarction of the liver. Puncture-site related complications occurred in 3 patients (two groin hematomas and one false aneurysm of the common femoral artery).

In patients with a negative angiography (n=19), 4 complications occurred in 3 patients. The most frequent complication was Contrast Induced Nephropathy (n=4). No organ-specific, puncture-site related or other systemic complications were encountered. The number and type of complications in trauma patients with (negative) angiographies are described in Table 2.

**Table 2.** Failure rate and frequency and type of complications in trauma patients with (negative) angiographies

|                        | Total population | Patients with negative angiography |
|------------------------|------------------|------------------------------------|
| n                      | 97               | 19                                 |
| Potentially injured organs | 129             | 25                                 |
| Failure rate (rebleeding) in follow-up | 15 (12%) | 3 (12%)                            |
| Patients with complications | 28 (29%) | 3 (16%)                            |
| 1 complication         | 17               | 2                                  |
| 2 complications        | 6                | 1                                  |
| 3 complications        | 2                | 1                                  |
| 4 complications        | 2                | 1                                  |
| 5 complications        | 1                |                                    |
| Overall                | 48               | 4                                  |

**Organ-specific**

- abscess: 8
- false aneurysm splenic artery: 1
- liver infarction/ necrosis: 4
- gluteal muscle necrosis: 1
- urinoma: 1
- bile leakage / biloma: 3
- other: 5
- Overall: 23 (24%)

**Puncture-site related**

- false aneurysm femoral artery: 1
- groin hematoma: 2
- Overall: 3 (3%)

**Systemic**

- contrast induced nephropathy: 19
- renal failure: 3
- Overall: 22 (23%) 4 (21%)

**Contrast Induced Nephropathy (CIN)**

In 4 patients the serum creatinin level after angiography or embolization was not measured. CIN occurred in a total of 22 patients (24%). Four of these patients (21%) developed CIN after a negative angiography: two of these patients had no contrast extravasation on CT scan; the indication for angiography was the presence of large hemoperitoneum. Three patients developed
renal failure. In 2 patients temporary dialysis was necessary and one of these patients was hemodialysis dependent at the time of hospital discharge. All these 3 patients underwent an angiography and embolization for suspected hemorrhage from pelvic injury. None of the patients with a negative angiography underwent temporary dialysis or developed renal failure. There were no statistically significant relations (table 3) between the CIN and non-CIN patients in terms of sex (p=0.58), the presence of multitrauma (p 0.49), age (p 0.45) or performing a CT scan (p 0.44). The pre-existing Creatinine was significantly higher in patients with CIN. The incidence of CIN was also increased in patients with AE of multiple organs in comparison with patients with AE of one organ (p 0.08). Although all patients were hemodynamically stable patients with CIN received more PRBC (p 0.02) and FFP (p 0.01) transfusions. The incidence of Diabetes Mellitus, time from injury to AE and amount of contrast medium administered could not be extracted from the retrospective data.

Table 3. Characteristics of patients with CIN and non-CIN

|                | CIN n= 22 | Non-CIN n= 71 | P-value |
|----------------|----------|---------------|---------|
| Male female ratio | 16:6     | 52:19         | 0.58    |
| Multitrauma (ISS>16) | 20       | 62            | 0.49    |
| Age *           | 35 (25-55) | 35 (20-49)    | 0.45    |
| Age > 55 year   | 16       | 59            | 0.36    |
| Performing CT scan | 20     | 67            | 0.44    |
| AE multiple organs | 9       | 16            | 0.08    |
| Number of PRBC * | 7 (2-26) | 4 (0-6)       | 0.02    |
| Number of FFP * | 7 (0-21) | 2 (0-5)       | 0.01    |
| Pre-existing Creatinine * | 87 (85-98) | 77 (60-95) | 0.04    |

* Median (p25-75)
PRBC: Packed Red blood Cell transfusion
FFP: Fresh Frozen Plasma

Treatment of rebleeding and complications

All 9 patients with failure of AE or negative angiography after liver and pelvic injury could be managed with reembolization or surgery without resection leading to salvage of the target organ. All patients with renal and splenic injuries who failed AE or negative angiography (n=1) underwent splenectomy or nephrectomy. The overall organ salvage rate was 93%. Most (83%) of the organ-specific complications could be managed with minimal invasive interventions such as embolization, PTC, ERCP or percutaneous drainage. All abscesses were treated by percutaneous drainage. Four patients (17%) underwent operative treatment to solve the complication (Table 3). The two patients with a local hematoma in the groin were treated conservatively. The patient who developed a false aneurysm was treated with percutaneous thrombin injection. Table 4 shows the results of the treatment of rebleeding and complications after (negative) angiography.
The primary aim of this study was to describe the failure rate and frequency, type and consequences of complications in trauma patients after AE for internal haemorrhage. In the present study 97 patients underwent an angiography for the evaluation of 129 potentially injured organs.

The most frequent complication in this study was CIN with an incidence of 23%. The literature reveals that the incidence of CIN in patients with normal renal function has been calculated to be less than 2%. However, it can be considerably higher (50–90%) in those with risk factors (elderly >55 year, severe renal insufficiency at baseline and Diabetes Mellitus). Recent literature describes an incidence of 5.1% of CIN in trauma patients who received a contrast enhanced CT scan. There was no significant difference in gender, the presence of multitrauma and age >55 year between CIN and non-CIN patients. Diabetes Mellitus and the time from injury to AE could possibly contribute to the incidence of CIN among patients. However, these parameters could not be extracted due to the retrospective design of the study.

**Table 4. Treatment of rebleeding and complications in patients treated with angiography**

| Rebleeding       | N | Treatment                                      |
|------------------|---|-----------------------------------------------|
|                  | 15| AE n= 5                                        |
|                  |   | splenectomy n= 3                              |
|                  |   | nefrectomy n= 3                               |
|                  |   | packing n= 4                                  |

| Organ-specific complications | N | Treatment                                      |
|------------------------------|---|-----------------------------------------------|
| abscess organ/ (retro)-peritoneal | 8 | percutaneous drainage                         |
| false aneurysm splenic artery | 1 | angiography and embolization                  |
| liver infarction/ necrosis   | 4 | hemihepatectomy n=1                           |
|                             |   | cholecystectomy n= 1                          |
| gluteal muscle necrosis      | 1 | necrotectomy                                  |
| urinoma                      | 1 | percutaneous drainage                         |
| bile leakage / biloma        | 3 | PTC n= 1, ERCP n=1, percutaneous drainage n=1  |
| other                        | 5 | conservative n=4                              |
|                             |   | operative n=1                                 |

| Puncture-site related | N | Treatment                                      |
|-----------------------|---|-----------------------------------------------|
| false aneurysm femoral artery | 1 | percutaneous trombin injection                |
| groin hematoma         | 2 | conservative                                  |

| Systemic               | N | Treatment                                      |
|------------------------|---|-----------------------------------------------|
| contrast induced nefropathy | 19| CVVH n=2                                       |
| renal failure          | 3 | dialysis n=1                                  |

PTC: Percutaneous Transluminal Cholangiography  
ERCP: Endoscopic retrograde cholangiopancreatography  
CVVH: continuous veno-venous hemofiltration

**DISCUSSION**

The primary aim of this study was to describe the failure rate and frequency, type and consequences of complications in trauma patients after AE for internal haemorrhage. In the present study 97 patients underwent an angiography for the evaluation of 129 potentially injured organs.

The most frequent complication in this study was CIN with an incidence of 23%. The literature reveals that the incidence of CIN in patients with normal renal function has been calculated to be less than 2%. However, it can be considerably higher (50–90%) in those with risk factors (elderly >55 year, severe renal insufficiency at baseline and Diabetes Mellitus). Recent literature describes an incidence of 5.1% of CIN in trauma patients who received a contrast enhanced CT scan. There was no significant difference in gender, the presence of multitrauma and age >55 year between CIN and non-CIN patients. Diabetes Mellitus and the time from injury to AE could possibly contribute to the incidence of CIN among patients. However, these parameters could not be extracted due to the retrospective design of the study.
An explanation for the difference in incidence between this study and our results could be the total administered dose of contrast agent, i.v for CT and i.a for subsequent AE. A recent meta-analysis showed a close relationship between the dose of iodine per ml of GFR, and the occurrence of CIN.\textsuperscript{11} Almost all our patients underwent both a contrast enhanced CT scan and AE. Furthermore, the incidence of CIN was more likely increased in patients in whom AE of more than one organ was performed, which is probably also related to the increase in contrast agent in these procedures. However, the exact amount of contrast medium administered to patients during AE was not registered.

In trauma patients the presence of hypotension due to shock and multi-organ damage as well as volume depletion in trauma patients are also risk factors for CIN. Therefore it is not certain that the renal impairment could be attributed to CIN, but in this complex group of patients, there may be many factors contributing to renal impairment.

The acute indications of CT scanning and performing an AE in trauma patients make implementation of preventive protocols before imaging difficult. Despite numerous clinical trials and meta-analyses, the utility of the often-used antioxidant N-acetylcysteine and/or sodium bicarbonate infusion in CIN prophylaxis remains unclear, not least because the statistical design of many of the relevant studies has been criticized.\textsuperscript{12-15} Current best practice calls for intravenous periprocedural volume expansion with normal saline at 1 ml/kg body weight for at least 6 hours before and after the procedure, but this is often not practical in trauma patients.\textsuperscript{16} Although bolus volume expansion during the procedure has been reported to be inferior to intravenous volume expansion, this method should be strongly considered for all trauma patients who underwent CT scanning and AE, especially in patients with other risk factors for CIN.

Furthermore, whole body CT and AE protocols that incorporate the lowest contrast medium volume and iodine dose to achieve a diagnostic and therapeutic result in combination with the use of iso-osmolar contrast agents should be used to prevent CIN.

The present study showed rebleeding in 15 patients (failure rate 12%). This failure rate is comparable with the literature.\textsuperscript{17-22} Delayed rupture of organs/vessels could explain rebleeding and is of major concern because this type of complication remains difficult to predict. Historically, most patients with rebleeding were treated surgically. Currently, a second attempt of AE can be considered, which further can increase the nonoperative target organ salvage rate. In the present study 5 patients were treated with a second AE.

Most of the organ specific complications could be managed with minimal invasive interventions such as embolization, PTC, ERCP or percutaneous drainage to solve the complications. This study showed a low incidence (3%) of puncture-site related complications. In addition, these complications could be managed nonoperatively.

Recent literature suggests that with the increased use of AE, an increase of major complications such as rebleeding, organ-specific, systemic and puncture-site related complications occurs.\textsuperscript{1-5} However, these results must be interpreted with some caution, because they are based on
cohort studies, which were compared with results of historical studies. Prospective randomized controlled trials comparing operative treatment and AE have never been published. Furthermore, the question is whether the complications, especially biliary complications have arisen from the accident itself or were secondary to the treatment with AE.\textsuperscript{23} Four of the 19 patients (21\%) with a negative angiography developed a total of 4 complications. The incidence of CIN in this particular patient group was 21\%. Contrast-enhanced CT scanning can help to select both hemodynamically stable patients or fluid responders for angiography and embolization but the optimal patient selection still remain to be established. In this retrospective study the specific indication for angiography could not always be extracted. Further prospective studies should therefore focus on proper patient selection and the prevention of procedure related complications.\textsuperscript{24} In our hospital the indication for AE has altered after the results of this study. Hemodynamically patients without contrast extravasation on CT scan are initially treated with observation. In case of failure AE can still be performed.

This study has several limitations, which are mainly related to the retrospective analysis of data. Although the complications were prospectively registered, there may be missing data. Furthermore, a Type 2 error could be present, due to the low patient numbers for complications. As stated before, the specific considerations that have led to angiography could not always be assessed. The definition of CIN used in this study is the same that is used in the general literature to define CIN after percutaneous vascular interventions. However, in the literature there are multiple definitions for CIN making it difficult to compare these results to other studies. Another limitation is the relatively small number of patients with (negative) angiography in our series making it difficult to draw strong conclusions. The rate of negative angiographies however is comparable to other Level 1 trauma centers.\textsuperscript{1}

**CONCLUSION**

In this present study the failure rate and incidence of organ-specific and procedure-related complications after AE were low and comparable with the literature. In the vast majority, complications often (83\%) could be managed with nonoperative minimal invasive interventions. However, a high incidence (23\%) of CIN in trauma patients both after AE as well as after (negative) angiography was observed. Trauma patients undergoing angiographic treatment have shown to have a high chance for developing CIN and should therefore receive optimal prophylactic measures to avoid this complication. Further strategies to prevent CIN should focus on further optimization of patient selection avoiding negative angiograms and the use of whole-body CT protocols with the use of low iodine dose and volume of intravenous contrast medium.
REFERENCES

1. Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: a 5-year experience. J Trauma 2005;58: 492-498.
2. Haan J, Scott J, Boyd-Kranis RL, Ho S, Kramer M, Scalea TM. Admission angiography for blunt splenic injury: advantages and pitfalls. J Trauma 2001;51: 1161-1165.
3. Ekeh AP, McCarthy MC, Woods RJ, Haley E. Complications arising from splenic embolization after blunt splenic trauma. Am J Surg 2005;189:335-339.
4. Kozar RA, Moore JB, Niles SE, Holcomb JB, Moore EE, Cothren CC et al. Complications of nonoperative management of high grade blunt hepatic injuries. J Trauma 2005; 59: 1066-1071.
5. Hipp A, Desai S, Lopez C, Sinert R. The incidence of contrast-induced nephropathy in trauma patients. Eur J Emerg Med 2008 Jun;15: 134-9.
6. Goslings JC, Gouma DJ. What is a surgical complication? Word J Surg 2008 Jun;32: 952.
7. Mehran R, Nikolsky E. Contrast-induced nephropathy: definition, epidemiology, and patients at risk. Kidney Int Suppl 2006: S11–15.
8. Berg KJ. Nephrotoxicity related to contrast media. Scand J Urol Nephrol 2000 Oct; 34: 317-322.
9. Laville M, Juillard L. Contrast-induced acute kidney injury: how should at-risk patients be identified and managed? J Nephrol 2010;23: 387-98.
10. McGillicuddy EA, Schuster KM, Kaplan LJ, Maung AA, Lui FY, Maerz LL, Johnson DC, Davis KA. Contrast-induced nephropathy in elderly trauma patients. J Trauma 2010;68: 294-7.
11. Nyman U, Almen T, Aspelin P, Hellstrom M, Kristiansson M, Sterner G. Contrast-medium-induced nephropathy correlated to the ratio between dose in gram iodine and estimated GFR in mL/min. Acta Radiol 2005;46: 830-842.
12. Pannu N, Wiebe N, Tonelli M. Prophylaxis strategies for contrast-induced nephropathy. JAMA 2006:21: 2765-79.
13. Massicotte A. Contrast medium-induced nephropathy: strategies for prevention. Pharmacotherapy 2008;28: 1140-50.
14. Stenstrom DA, Muldoon LL, Armijo-Medina H, Watnick S, Doolittle ND, Kaufman JA, Peterson DR, Bubalo J, Neuwelt EA. N-acetylcysteine use to prevent contrast medium-induced nephropathy: premature phase III trials. J Vasc Interv Radiol 2008;19: 309-18.
15. Brown JR, Block CA, Malenka DJ, O'Connor GT, Schoolwerth AC, Thompson CA. Sodium bicarbonate plus N-acetylcysteine prophylaxis: a meta-analysis. JACC Cardiovasc Interv 2009;2: 1116-24.
16. Thomsen HS. ESUR guidelines on contrast media, version 7.0. Heidelberg, Germany: European Society of Urogenital Radiology; 2008.
17. Raikhlin A, Baerlocher MO, Asch MR, Myers A. Imaging and transcatheter arterial embolization for traumatic splenic injuries: review of the literature. Can J Surg 2008 Dec;51: 464-72.
18. Dent D, Alsabrook G, Erickson BA et al. Blunt splenic injuries: high nonoperative management rate can be achieved with selective embolization. J Trauma 2004;56: 1063-1067.
19. Velmahos GC, Toutouzas K, Radin R, Chan L, Rhee P, Tillou A et al. High success with nonoperative management of blunt hepatic trauma: the liver is a sturdy organ. Arch Surg 2003;138: 475-480.
20. Gaarder C, Naess PA, Eken T, Skaga NO, Pillgram-Larsen J, Klow NE et al. Liver injuries--improved results with a formal protocol including angiography. Injury 2007;38: 1075-1083.
21. Stewart AF, Brewer ME Jr, Daley BJ, Klein FA, Kim ED. Intermediate-term follow-up of patients treated with percutaneous embolization for grade 5 blunt renal trauma. J Trauma 2010;69: 468-70.
22. Fu CY, Wang YC, Wu SC, Chen RJ, Hsieh CH, Huang HC, Huang JC, Lu CW, Huang YC. Angioembolization provides benefits in patients with concomitant unstable pelvic fracture and unstable hemodynamics. Am J Emerg Med 2010;13.
23. Cogbill TH, Moore EE, Jurkovich GJ, Feliciano DV, Morris JM, Mucha P. Severe hepatic trauma: a multicenter experience with 1335 liver injuries. J Trauma 1988;28: 1433-1438.
24. Omert LA, Salyer D, Dunham CM, Porter J, Silva A, Protech J. Implications of the "contrast blush" finding on computed tomographic scan of the spleen in trauma. J Trauma 2001;51: 272-277.
Summary and general discussion
INTRODUCTION

This thesis has focused on the diagnostics and treatment of patients with blunt abdominal injuries. Over the past 40 years, several changes have occurred in the management of patients with blunt abdominal trauma. Traditionally, open surgery was considered the standard of care. Currently, due to its low failure rate, nonoperative management (NOM) has evolved into the treatment of choice in hemodynamic stable patients. Failure is defined as clinical and radiological signs of a rebleeding requiring operative or radiological (re-) interventions. Chapter 1 describes the outlines of this present thesis.

Chapter 2 consists of a literature review, describing the advances in computed tomography (CT) scan and interventional radiology, which have contributed to an improved patient selection for the optimal treatment. Especially, the prominent place of multi-detector computed tomography scanning and the use of angiography and embolization (AE) are highlighted.

Part 1: Diagnostic strategies in blunt abdominal injury

The first part of this thesis describes the various aspects and findings of different diagnostic strategies and its implications for patients.

Other than hemodynamic instability, no reliable indicators, that predict the failure of NOM in pediatric trauma patients, are found in the current literature. Several recent studies in adults suggest that the presence of a contrast blush on CT scan is associated with an increased failure rate of NOM of blunt splenic and/or liver injury. However, the clinical implication of a contrast blush on CT scan with liver and/or splenic injury in the pediatric population has not yet been assessed. Chapter 3 presents a systematic review, which assessed all available literature on failure of NOM in children with splenic and liver injury in whom contrast extravasation is observed on CT scanning. Nine studies, published between 1985 and 2009, were included, describing 117 paediatric patients. Seven studies (including 71 patients) reported a total of 16 patients with failure after NOM without AE. The pooled failure rate was 28.2%. Two studies (including 46 patients) reported a total of 3 patients with failure after NOM with primary AE: a crude failure rate of 6.5%. Despite the current low level of evidence on failure rates of NOM when a contrast blush is present on CT scan, we emphasize that there is a significant number of patients in whom NOM fails. Therefore, the management of splenic and hepatic injury in children should not only be based on the hemodynamic situation, but should include consideration of the presence of contrast extravasation on CT scanning.

In Chapter 4 the history of three patients with a seatbelt sign following a car accident is described. All 3 patients exhibited various injuries that may occur in the case of blunt trauma, including rib fractures. In one patient, symptoms of internal abdominal injury only occurred several days after the accident. Typically, the presence of a seatbelt sign is associated with an increased risk of internal abdominal injury. Therefore, we advise that a CT scan of the abdomen
Chapter 12

needs to be considered in every patient, who presents with a seatbelt sign, even if abdominal ultrasound does not reveal signs of injury.

In Chapter 5 we investigate the inter- and intraobserver reliability between radiologists in classifying splenic injury on CT scanning. This study was performed according to the most widely used AAST grading system and the ‘Baltimore CT grading system’, of which the latter integrates vascular injuries into the score. Prior studies have shown that this system was superior to the AAST system in predicting the need for AE or surgery. CT scans of 83 patients with blunt splenic injury, admitted between 1998 and 2008, were retrospectively reviewed. The inter- and intrainobserver reliability of both grading systems were equally high. Due to the integration of vascular injury into the system, the ‘Baltimore CT grading system’ supports clinical decision-making and therefore the use of this system in the classification of splenic injury is recommended.

Chapter 6 is a review of the literature assessing the role of ultrasonography and CT features, such as contrast extravasation, pseudoaneurysms, arteriovenous fistulas or hemoperitoneum, in the selection of patients for AE. The efficiency, technical considerations (proximal versus selective embolization), logistics and complication rates of AE in patients with blunt splenic injury are also discussed.

Part 2: Treatment strategies in blunt abdominal trauma

In the second part of this thesis, the results of NOM in patients with blunt splenic, liver and/or renal injuries, treated in Dutch level-1 trauma centers, are analysed and discussed.

In Chapter 7 the single center results of NOM in patients with blunt splenic injury, treated at the Academic Medical Center Amsterdam (1997–2008), are demonstrated. An analysis of a prospective trauma registry was performed for a 6-year period, both before (period 1) and after (period 2), the introduction of splenic artery embolization. An increased use of splenic artery embolization and a reduction of splenic operations in the second period were observed. The failure and splenic salvage rate were 17% and 89%, respectively, which is similar to the results of large volume studies from other Level I trauma centers. A high failure rate was observed in patients with a high grade injury combined with a contrast extravasation and a significant hemoperitoneum. In the second period, all patients with failure after observation could be successfully treated with splenic artery embolization.

To analyze risk factors for failure after NOM of patients with blunt splenic injury, we performed a multicenter cohort study, which is described in Chapter 8. In this retrospective analysis of 169 patients the overall failure rate was 17%. Seven patients who failed observation or AE could successfully be treated with (re-)embolization, leading to a splenic salvage rate of 91%.

Increased age (>50 years) and AAST grade of injury ≥3 were associated with failure in the multivariable logistic model. Although contrast extravasation is mentioned as a risk factor for failure and as an indication for AE, in this current study the presence of (intraperitoneal) contrast extravasation was not significantly associated with failure of NOM.
In Chapter 9 the results of NOM of liver injuries, before (period 1) and after (period 2) the introduction and implementation of AE, are described. Despite an increase in high grade liver injuries, NOM increased significantly in period 2 (72% versus 33% in period 1). Overall, liver-related mortality, treatment failure and complication rates remained equal in both periods. In patients with high grade injuries, the outcome improved significantly after the introduction of AE. However, liver infarction and abscess formation were more common after AE than after laparotomy.

Chapter 10 presents the results of a study comparing the diagnostics and treatment of blunt renal injury applied in a Level-1 trauma center with the recommendations of the European Association of Urology guidelines. Non-compliance with the guidelines increased with the severity of renal injury. The general conclusion was that high grade renal injuries were often successfully treated with AE instead of surgery (resulting in preservation of the kidney), which is recommended in the guidelines. In the next update of the guidelines AE deserves a more prominent role.

Complication registration is an important part of monitoring the quality of health care. Therefore, Chapter 11 describes the outcome of an analysis of complications occurring in hemodynamically stable patients, who underwent AE for internal hemorrhage after abdominal trauma or pelvic injury. The failure rate (12%) and incidence of organ-specific (19%) and procedure-related complications (3%) were low and could be managed conservatively or with minimally invasive interventions. In the present study trauma patients undergoing angiography had a high chance (24%) to develop Contrast Induced Nephropathy and future patients should therefore receive optimal prophylactic measures to avoid this complication.

**GENERAL DISCUSSION**

In the present thesis different aspects of the diagnostics and treatment of patients with blunt splenic, liver and renal injury are reported. In the first part various aspects and changing patterns of the diagnostic workup are analyzed and described.

Currently, the role of the CT scanner is very important, because of its high sensitivity (90–100%) to detect injuries to the spleen, liver, kidney and associated (intra-abdominal) injuries. Furthermore, the presence and exact localisation of contrast extravasation can be detected. Advances in CT technology have improved the physician’s ability to determine more details of the parenchymatous injury and minor vascular lesions. Since vascular injuries are associated with failure of NOM, improvements in CT technology seem advantageous for the patient selection for the best treatment and thus to prevent failure of NOM. We found a tendency towards increased failure in children with splenic injury with a contrast extravasation on CT scan. However, the question arises if all hemodynamically stable patients with intraparenchymal contrast extravasation on CT scan should be treated with AE. In the multivariate regression analysis,
contrast extravasation was not identified as an independent risk factor for failure of NOM in patients with splenic injury.

Until now, CT scanning has not been able to differentiate exactly between patients who can be treated conservatively, patients who would benefit from AE and patients that would respond best to an operation. This decision should always be based on the clinical situation, the physiological response of the patient to initial resuscitation, the CT findings, the availability of an angio-room and expertise of performing AE.

In the second part of this thesis different studies have shown that patients treated with NOM in Level 1 trauma centers in the Netherlands was successful with success rates around 90%. These results are in accordance with the literature. The results showed that AE was a valuable adjunct to observational management and has increased the success rate of NOM. Most of the patients who failed treatment with observation and AE had high grade injuries combined with a contrast extravasation and a significant hemoperitoneum on the CT scan. Furthermore, these studies showed that the mortality and morbidity have improved after the introduction of AE, resulting in saved patients’ lives, with blunt abdominal injury and immune function after splenic trauma.

Although the use of AE is generally reported to increase success rates of NOM, the optimal use of AE, especially in patients with high grade injury and a contrast extravasation, is still a subject of discussion. Future studies will need to focus on the prevention of failure of NOM and optimizing the patient selection for observational management, AE or operation. A well-designed randomised clinical trial is preferable, but is difficult to conduct because of the nature of the trauma population. Therefore, we are currently conducting a Delphi study to obtain experience-based agreement from a panel of independent international experts.
Summary in Dutch / Nederlandse samenvatting
INLEIDING

Dit proefschrift beschrijft enkele aspecten van de diagnostiek en behandeling van patiënten met een stomp trauma van de buik. In de afgelopen 40 jaar is er veel veranderd in de diagnostiek en behandeling van deze patiënten. In het verleden werd vrijwel iedere patiënt met een traumatisch letsel van de milt, lever of nier direct geopereerd. Door de lage kans op falen is tegenwoordig niet-operatieve behandeling de eerste keuze bij hemodynamisch stabiele patiënten. Indien er klinisch en radiologisch tekenen van een recidiefbloeding zijn, waarbij operatieve of radiologische (re-) interventies noodzakelijk zijn is er sprake van falen van de niet-operatieve behandeling. Hoofdstuk 1 geeft het doel van dit proefschrift en een overzicht van de hoofdstukken weer.

Door de verbeterde kwaliteit en beschikbaarheid van de Computer Tomografie (CT) scan en de ontwikkelingen van de interventieradiologie kan tegenwoordig een betere keuze gemaakt worden voor de juiste behandeling.

In hoofdstuk 2 wordt een overzicht gegeven van de literatuur over de ontwikkelingen van de diagnostiek en behandelopties voor patiënten met een stomp buikletsel. De nadruk ligt op de prominente rol van de CT scan en de toepassing van angiografie en embolisatie (AE) in de behandeling van deze patiënten.

Deel 1: diagnostiek bij stomp buikletsel

Het eerste deel van dit proefschrift belicht verschillende aspecten van de diagnostische mogelijkheden en beschrijft bevindingen van de diagnostiek en de gevolgen voor de patiënt.

Hoofdstuk 3 beschrijft de resultaten van een systematische review van de literatuur over de waarde van contrast extravasatie op een CT scan bij kinderen met een lever en/of miltletsel na stomp trauma van de buik. Negen studies (n=117) gepubliceerd tussen 1985 en 2009, werden geïncludeerd en geanalyseerd. Zeven studies (n=71) rapporteerden falen van niet-operatieve behandeling zonder AE bij 16 kinderen. De gepoolde kans op falen was 28,2%. Twee studies (n=46) beschreven falen van niet-operatieve behandeling met AE bij 3 kinderen: de kans op falen was 6,5%. Hoewel de studie te weinig statische power had om een definitieve uitspraak te kunnen doen, lijkt er een grotere kans op falen van niet-operatieve behandeling bij kinderen met contrast extravasatie op de CT scan. De aan- of afwezigheid van contrast extravasatie moet worden meegenomen in de beslissing voor de juiste behandeling.

In hoofdstuk 4 worden 3 patiënten met een stomp buiktrauma en een zogenaamd “seatbelt sign” (zichtbare striemen van de autogordel) bij lichamelijk onderzoek beschreven. Alle drie patiënten vertoonden diverse letsels die zich kunnen voordoen in het geval van een stomp trauma van de buik. Bij één patiënt ontstonden de symptomen van intra-abdominaal letsel enkele dagen na het ongeval. Indien er een “seatbelt sign” aanwezig is, is er een verhoogde kans op intra-abdominaal letsel. Derhalve adviseren wij, op basis van de literatuur en onze eigen
bevindingen, om bij patiënten met een ‘seatbelt sign’ een CT scan met intraveneus contrast van de buik te verrichten, zelfs als de echografie geen afwijkingen laat zien.

In hoofdstuk 5 onderzochten wij de inter- en intrawaarnemer betrouwbaarheid onder radiologen bij de classificatie van miltletsel volgens twee CT-graderingsystemen: het AAST en ‘Baltimore’ graderingsysteem. In tegenstelling tot het AAST systeem wordt de aanwezigheid van vasculair letsel meegewogen in de score van het ‘Baltimore’ graderingsysteem. Eerdere studies toonden aan dat het ‘Baltimore’ systeem beter voorspelt of AE dan wel een operatie noodzakelijk is. CT scans van 83 patiënten die tussen 1998 en 2008 werden behandeld met stomp miltletsel werden retrospectief beoordeeld. De inter- en intrawaarnemer betrouwbaarheid van beide graderingsystemen was hoog. Door de integratie van vasculair letsel in de score ondersteunt het ‘Baltimore’ systeem in grotere mate de klinische besluitvorming en zou daarom in de praktijk vaker gebruikt moeten worden bij de classificatie van het miltletsel.

Hoofdstuk 6 beschrijft een overzicht van de literatuur over de rol van echografie en CT scan in het diagnostische traject bij patiënten met stomp miltletsel. De waarde van de aanwezigheid van CT kenmerken, zoals contrast extravasatie, een pseudoaneurysma, een arterioveneuse fistel of een hemoperitoneum voor de keuze om AE te verrichten, werd besproken. De techniek, keuze voor de exacte plaats van de embolisatie (proximale versus selectieve embolisatie), de logistiek rondom deze ingreep en complicaties van AE werden besproken.

Deel 2: behandeling van patiënten met stomp buikletsel

In het tweede deel van dit proefschrift worden de resultaten besproken van het niet operatief behandelen van patiënten vanwege stomp milt-, lever- en nierletsel in level-1 traumacentra in Nederland.

De resultaten van de niet-operatieve behandeling van patiënten met een stomp miltletsel, die gedurende de periode 1997–2008 werden opgenomen in het Academisch Medisch Centrum worden beschreven in hoofdstuk 7. De gegevens uit de prospectieve trauma registratie werden gebruikt voor analyse. De studiegroep werd opgedeeld in twee periodes: voor (periode 1) en na (periode 2) de introductie van routinematig gebruik van AE. In de tweede periode werd een toename van AE en een afname van het aantal operaties gevonden. Het percentage falen en behoud van de milt na niet-operatieve behandeling, respectievelijk 17 en 89%, was vergelijkbaar met resultaten van andere studies uit level-1 trauma centra met grotere patiënten aantallen. Het percentage falen was hoog bij patiënten met een hooggradig letsel (graad 3–5 letsels volgens de AAST classificatie) gecombineerd met contrast extravasatie en een hemoperitoneum. In de tweede periode konden alle patiënten met falen na observatie met succes behandeld worden met AE.

Hoofdstuk 8 beschrijft de resultaten van een multicenter cohort studie. Het doel van deze studie was het analyseren van risicofactoren voor het falen van niet-operatieve behandeling van stomp miltletsel. Honderd negenenzestig patiënten werden retrospectief geanalyseerd. Het percentage falen was 17%. Zeven patiënten, bij wie observatie of AE faalden, konden succesvol
worden behandeld met (re-) embolisatie, hetgeen resulteerde in een percentage behoud van milt van 91%. In de multivariate analyse waren leeftijd >50 jaar en AAST gradering van ≥ 3 onafhankelijke risicofactoren voor falen van niet operatieve behandeling. Hoewel de aanwezigheid van contrastextravasatie in de literatuur wordt genoemd als een risicofactor voor falen was een (intraperitoneale) contrast extravasatie niet significant aantoonbaar geassocieerd met falen van niet operatieve behandeling.

In hoofdstuk 9 worden de resultaten van niet-operatieve behandeling van patiënten met traumatisch leverletsel voor (periode 1) en na (periode 2) het de introductie van AE beschreven. In de tweede periode werden meer patiënten niet operatief behandeld (72 t.o.v. 33% in periode 1), ondanks de toename van het aantal hooggradige leverletsels in deze periode. Het percentage falen van behandeling, levergerelateerde sterfte en het aantal complicaties waren gelijk in beide perioden. De resultaten van behandeling van hooggradige letsels waren aanzienlijk verbeterd door het gebruik van AE in periode 2. Leverinfarcten en abcesvorming kwamen echter wel vaker voor bij AE dan na een laparotomie.

In hoofdstuk 10 worden de resultaten van een onderzoek gepresenteerd, waarin geanalyseerd wordt of de diagnostiek en behandeling van patiënten met stomp nierletsel in een Nederlands level-1 trauma centrum plaatsvindt volgens de Europese richtlijnen voor urologisch trauma. Bij hooggradige letsels werd vaak afgeweken van de richtlijnen. De belangrijkste bevinding was dat patiënten met hooggradig nierletsel in het Nederlandse level-1 trauma centrum vaak succesvol, dat wil zeggen resulterend in het behoud van de nier, embolisatie ondergaan in plaats van een operatieve behandeling, zoals die wordt aanbevolen in de Europese richtlijn. In de volgende revisie van de richtlijn zal er daarom meer aandacht moeten zijn voor de rol van AE.

Complicatieregistratie is een belangrijk onderdeel binnen de kwaliteitsbewaking van de geleverde zorg. In hoofdstuk 11 beschrijven wij de uitkomsten van een studie naar het voorkomen van complicaties na AE van hemodynamisch stabiele patiënten na stomp buik of bekkenletsel. Het percentage falen (12%), de incidentie van orgaanspecifieke (19%) en proceduregerelateerde complicaties (3%) waren laag. Al deze complicaties konden conservatief dan wel met minimaal invasieve ingrepen behandeld worden. Verder bleek dat trauma patiënten die AE ondergaan een relatief grote kans (24%) hebben om contrast nefropathie te ontwikkelen. Bij deze patiënten moeten adequate preventieve maatregelen worden genomen om deze complicatie te voorkomen.

**ALGEMENE DISCUSSIE**

In dit proefschrift worden verschillende aspecten van de diagnostiek en behandeling van patiënten met traumatisch letsel van milt, lever en nieren beschreven. In het eerste deel worden diverse aspecten en de verandering van de diagnostische mogelijkheden besproken.
De CT scan heeft een hoge sensitiviteit (90–100%) om letsels van de milt, lever, nieren en andere geassocieerde (intra-abdominale) letsels te detecteren evenals de aanwezigheid en de exacte lokalisatie van contrastextravasatie. Door de verbetering van de CT scan is het mogelijk om parenchymateus letsel en vasculaire letsels, welke geassocieerd zijn met verhoogde kans op falen, beter en met meer detail vast te stellen. Dit lijkt een voordeel voor de patiënt, omdat hierdoor een betere keuze voor behandeling gemaakt kan worden. Met andere woorden: om falen van niet operatief management te voorkomen. Bij kinderen met miltletsel en contrastextravasatie op CT-scan werd een tendens gezien naar meer falen van niet operatieve behandeling.

De vraag is of elke hemodynamisch stabiele patiënt met een intraparenchymateuse contrastextravasatie op de CT-scan moet worden behandeld met AE. Contrastextravasatie werd in de multivariate regressie analyse niet geïdentificeerd als onafhankelijke risicofactor voor het falen van niet-operatieve behandeling bij patiënten met miltletsel. De CT-scan is tot op heden niet in staat om onderscheid te maken welke patiënt bij voorkeur conservatief, met AE dan wel operatief behandeld moet worden. Deze beslissing moet altijd gebaseerd zijn op de combinatie van de volgende factoren: de klinische situatie en fysiologische respons van de patiënt na resuscitatie, de bevindingen van CT scan en de aanwezigheid van faciliteiten en expertise in het ziekenhuis.

In het tweede deel van dit proefschrift bleek dat het slagingspercentage van niet-operatieve behandeling in level-1 trauma centra in Nederland hoog is met percentages rond de 90%. Deze resultaten zijn in overeenstemming met de literatuur. De resultaten tonen aan dat AE een waardevolle aanvulling is op de conservatieve behandeling met observatie en dat door deze toevoeging de kans op succesvolle niet-operatieve behandeling de laatste jaren sterk is toegenomen. Het merendeel van de patiënten bij wie niet-operatieve behandeling en/ of AE faalde hadden hooggradige letsels in combinatie met een contrastextravasaat en een hemoperitoneum. Uit deze studies bleek eveneens dat na de invoering van AE de mortaliteit en morbiditeit verminderd was. Niet-operatieve behandeling heeft zodoende geleid tot het sparen van mensenlevens en behoud van de (immuunfunctie van de) milt.

Hoewel het gebruik van AE heeft geleid tot een beter slagingspercentage van niet-operatieve behandeling, is er nog steeds discussie over de exacte plaats van AE, met name bij patiënten met een hooggradig letsel.

Toekomstige studies zullen zich vooral moeten richten op het voorkomen van falen van niet-operatieve behandeling en optimalisatie van de criteria voor selectie welke patiënten in aanmerking komen voor observatieve behandeling, angiografie en embolisatie dan wel operatieve behandeling. Een goed opgezet gerandomiseerd klinisch onderzoek heeft de voorkeur, maar is lastig uitvoerbaar vanwege de aard van de traumapopulatie. Op dit moment wordt er door onze onderzoeks groep onder meer een Delphi-studie uitgevoerd onder een panel van onafhankelijke internationale experts met als doel overeenstemming te verkrijgen over deze vragen.
Curriculum Vitae

CURRICULUM VITAE

Cornelis Hendrik van der Vlies werd geboren op 3 juli 1975 te Rijssen. Na enkele jaren verhuisde hij naar Dordrecht. In 1993 behaalde hij zijn VWO diploma aan de Guido de Brès scholenge- meenschap te Rotterdam. Aansluitend ging hij geneeskunde studeren aan de Erasmus Universiteit Rotterdam.

Eind 1999 behaalde hij zijn artsdiploma, waarna hij in 2000 begon als ANIOS gynaecologie en verloskunde in het Zuiderziekenhuis te Rotterdam. In 2001 werd hij ANIOS chirurgie in het Albert Schweitzer Ziekenhuis Dordrecht, waar hij in 2003 begon met zijn opleiding tot chirurg (opleiders dr. K.G. Tan en dr. R.J. Oostenbroek). Het tweede deel van de opleiding werd gevolgd in het Academisch Medisch Centrum Amsterdam (opleider prof. dr. J.L. van Lanschot). Een stage in het St Joseph’s Hospital te Ghana in 2008 bevestigde zijn keuze om traumachirurg te worden. In 2008, tijdens het laatste jaar van zijn opleiding tot chirurg, kreeg hij van de Nederlandse Vereniging voor Traumachirurgie (NVT) een beurs toegewezen om de postdoctorale opleiding tot Klinisch Epidemioloog aan de VUMC te volgen. Sinds mei 2010 is hij klinisch epidemioloog.

Op 1 januari 2009 werd hij geregistreerd als chirurg en startte hij met de vervolgopleiding tot traumachirurg in het Academisch Medisch Centrum onder leiding van prof. dr. J.C. Goslings. In deze periode startte hij met onderzoek naar de niet-operatieve behandeling van patiënten met stomp buikletsel na een trauma, hetgeen geresulteerd heeft in dit proefschrift. Sinds 2010 is hij werkzaam als traumachirurg in het Maasstadziekenhuis te Rotterdam en is hij medisch manager van het Brandwondencentrum Rotterdam.

Op 14 september 2000 is hij getrouwd met Esther Wijzenbroek, met wie hij vier prachtige kinderen heeft: Sjuul, Thijs, Roos en Just.
DANKWOORD

“All good things comes to an end”. Na enkele jaren hard werken het resultaat: het boekje! Dankzij de inzet en steun van vele vrienden en betrokkenen is dit proefschrift tot stand gekomen. Graag wil ik een aantal personen in het bijzonder bedanken.

**Prof. dr. J.C. Goslings**, promotor en opleider, beste Carel. Waar een opmerking tijdens een boottocht op de Vinkeveense plassen al niet toe kan leiden! Het probleem ‘in de huidige tijd geen doctor zijn’ werd door ons beiden gezien als een kans en uitdaging. Ook hierin kwam jouw levensmotto ‘tijd en tempo zijn van levensbelang’ (in de traumachirurgie) duidelijk van pas. Zowel een plek als CHIVO als een opleiding tot klinisch epidemioloog werden geregeld. Daarnaast werd de mogelijkheid om onderzoek te doen geboden. Jouw voortdurende enthousiasme, onuitputtelijke energie en vermogen om de puntjes op de i te zetten zijn van grote invloed geweest op dit proefschrift. Veel dank voor het vertrouwen en alle mogelijkheden die jij mij hebt gegeven.

**Prof. dr. J.A. Reekers**, promotor, beste Jim. Hoewel jij niet betrokken was bij het begin van dit traject ben je door de scherpe, soms prikkelende opmerkingen erg waardevol geweest om de vaart erin te houden en dit proefschrift met succes af te ronden.

**Dr. K.J. Ponsen**, copromotor, beste Kees Jan. Jouw enthousiasme en positieve instelling zijn ongekend. Het is mij een groot genoegen (geweest) om samen met jou, in de kliniek te werken, alwaar jij mij de ‘kneepjes’ van het vak geleerd hebt, congressen te bezoeken en te discussiëren over nieuwe ideeën voor onderzoek. ‘Last but not least’ is het een genoegen om met jou te filosoferen over het leven en over de toekomst van de traumachirurgie.

**Dr. O.M. van Delden**, copromotor, beste Otto. Jouw scherpe analyses, grote kennis en kwaliteiten als interventieradioloog zijn zeer waardevol geweest. Dank dat jij, ondanks het hectische bestaan als interventieradioloog, altijd de tijd wist te creëren voor overleg en adviezen over het onderzoek en het beoordelen van talloze CT scans.

**Dr. F.W. Bloemers, prof. dr. T.M. van Gulik, prof. dr. R.J. de Haan, prof. dr. M.W. de Haan, prof. dr. J.S. Lameris, prof. dr. P. Patka**, leden van de promotiecommissie. Dank dat u de tijd en moeite heeft genomen om mijn proefschrift te beoordelen. Het is voor mij een eer dat u zitting wilt nemen in deze commissie.

**Prof. dr. R.J. de Haan**, begeleider tijdens mijn opleiding tot klinisch epidemioloog, beste Rob. Als geen ander heb jij de gave om lastige vraagstukken te reduceren tot relatief eenvoudige
Dankwoord

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**Joost Hoekstra**, onderzoeksstudent. Omdat ik mijn promotietraject naast mijn dagelijkse werk als chirurg deed, zou zonder jouw enorme inzet (een week data scoren in Groningen: ‘geen probleem’) en enthousiasme dit proefschrift er niet zijn geweest. Hartelijk dank voor al het werk en wie weet mag ik je ooit opleiden tot chirurg.

**Dominique Olthof**, onderzoeksstudent. Het feit dat je slechts twee jaar geleden als onderzoeksstudent binnen kwam op de Trauma Unit en heden ten dage al heel ver bent met promotieonderzoek spreekt voor zich. Heel veel dank voor jouw hulp bij het verzamelen en analyseren van data, schrijven en corrigeren van de artikelen en voor de gezellige discussies! Het lijkt mij mooi om betrokken te blijven bij jouw promotieonderzoek.

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“*But the best things …*”. Lieve Esther, ik heb veel bewondering voor de manier waarop jij alle balletjes (de organisatie van ons gezin, (vrijwilligers)werk, ons drukke sociale leven) in de lucht houdt. Heel veel dank voor jouw liefde, interesse in mijn werk en de ruimte die jij mij geeft om mijn ambities na te streven. Gelukkig komt er nu meer rust en tijd voor de mooie uitdagingen die er zijn in de komende jaren. Lieve Essie, ik hou van je!

Lieve Sjuul, Thijs, Roos en Just, jullie zijn prachtige, lieve, soms ondeugende schatjes. Ik ben blij dat er nu meer tijd komt om van elkaar te genieten.
