Blunt abdominal trauma: changing patterns in diagnostic and treatment strategies
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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 postsplenectomy 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 hemo-peritoneum, 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%.\(^{16,21-23}\)

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.\(^{24,25}\) 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.\(^{20,26-28}\) 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

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**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)
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location of active arterial haemorrhage as well as the presence of a pseudoaneurysms or arteriovenous fistulas in the spleen. 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). 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.

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. 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. This grading system (table 1) is based on the anatomic extent 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.

Previous studies have shown that the CT injury grade alone is a poor predictor for the success of NOM. 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.
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.

### Table 1. Splenic Trauma Grading Systems

<table>
<thead>
<tr>
<th>Grading System</th>
<th>Criteria</th>
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<tbody>
<tr>
<td><strong>Baltimore</strong></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td>1 2 3 4a 4b</td>
</tr>
<tr>
<td>Subcapsular hematoma</td>
<td>&lt; 1 cm 1-3 cm &gt;3 cm</td>
</tr>
<tr>
<td>Parenchymal hematoma</td>
<td>&lt; 1 cm 1-3 cm &gt; 3 cm</td>
</tr>
<tr>
<td>Laceration</td>
<td>&lt;1 cm 1-3 cm &gt; 3 cm Shattered spleen</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Splenic capsular disruption Active intraparenchymal and subcapsular bleeding Splenic vascular injury Active intraperitoneal bleeding</td>
</tr>
<tr>
<td><strong>AAST</strong></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td>I II III IV V</td>
</tr>
<tr>
<td>Hematoma</td>
<td>&lt; 10 % 10-50 % &gt; 50 %</td>
</tr>
<tr>
<td>Laceration</td>
<td>&lt; 1 cm 1-3 cm &gt; 3 cm &gt; 25 % devascularization Completely shattered spleen</td>
</tr>
<tr>
<td>Vascular Injury</td>
<td>Hilar vascular injury with devascularized spleen</td>
</tr>
</tbody>
</table>

**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 1990s 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 (66%) 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.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{flowchart}
\caption{Flowchart for the diagnostic and therapeutic management of blunt splenic injury.}
\end{figure}

**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

* 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}
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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.  

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%).  

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. The surgical equivalent of PSAE

**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.** 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 abscess or infarction as compared to selective distal embolization.\textsuperscript{65, 77} However, it has to be noted, that splenic infarcts after selective distal embolization rarely lead to clinical sequelae and splenic abscess 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.\textsuperscript{42, 78,79}

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.\textsuperscript{80} 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.\textsuperscript{42, 78,79} 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.\textsuperscript{81} 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.\textsuperscript{82,83} 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.\textsuperscript{84} 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%. In a small study of Ekeh and colleagues major complications such as bleeding, abscess and contrast nephropathy occurred in 27%. Minor complications, fever, pleural effusions and coil migration occurred in 53%. Other studies have demonstrated lower complication rates. In the Western Trauma Association multi-institutional trial 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. In one study, the infarction rate was 100% following distal embolization and 63% following proximal embolization. Most of patients with splenic infarcts are asymptomatic and could be managed conservatively. 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.

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

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