Splenic injury diagnosis & splenic salvage after trauma

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Chapter 8

Time to intervention in patients with splenic injury in a Dutch level 1 trauma centre

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Abstract

Objective: Timely intervention in patients with splenic injury is essential, since delay to treatment is associated with an increased risk of mortality. Transcatheter Arterial Embolisation (TAE) is increasingly used as an adjunct to non-operative management. The aim of this study was to report time intervals between admission to the trauma room and start of intervention (TAE or splenic surgery) in patients with splenic injury.

Methods: Consecutive patients with splenic injury aged ≥16 years admitted between January 2006 and January 2012 were included. Data were reported according to haemodynamic status (stable versus unstable). In haemodynamically (HD) unstable patients, transfusion requirement, intervention-related complications and the need for a re-intervention were compared between the TAE and splenic surgery group.

Results: The cohort consisted of 96 adults of whom 16 were HD unstable on admission. In HD stable patients, median time to intervention was 105 (IQR 77-188) min: 117 (IQR 78-233) min for TAE compared to 95 (IQR 69-188) for splenic surgery (p = 0.58). In HD unstable patients, median time to intervention was 58 (IQR 41-99) min: 46 (IQR 27-107) min for TAE compared to 64 (IQR 45-80) min for splenic surgery (p=0.76). The median number of transfused packed red blood cells was 8 (3-22) in HD unstable patients treated with TAE versus 24 (9-55) in the surgery group (p = 0.09). No intervention-related complications occurred in the TAE group and one in the splenic surgery group (p = 0.88). Two spleen related re-interventions were performed in the TAE group versus 3 in the splenic surgery group (p = 0.73).

Conclusion: Time to intervention did not differ significantly between HD unstable patients treated with TAE and patients treated with splenic surgery. Although no difference was observed with regard to intervention-related complications and the need for a re-intervention, a trend towards lower transfusion requirement was observed in patients treated with TAE compared to patients treated with splenic surgery. We conclude that if 24/7 interventional radiology facilities are available, TAE is not associated with time loss compared to splenic surgery, even in HD unstable patients.
Introduction

Traumatic injuries are a worldwide problem with a particular impact on mortality and life expectancy among young people.\(^1\) A dominant cause of mortality is exsanguination from injured abdominal organs.\(^2\) The spleen is the most commonly injured organ after blunt trauma to the abdomen\(^3\) and because the spleen is highly vascular, splenic injury can be potentially life-threatening.\(^4\)

Analyses of trauma deaths revealed that most patients with severe abdominal injury who die do so between 1 to 6 h after the traumatic event.\(^5,6\) Quick intervention aimed at controlling haemorrhage is essential since a delay to treatment is associated with a greater risk of mortality.\(^7\)

Different treatment strategies are available for controlling haemorrhage in patients with splenic injury. Surgery is the classical treatment strategy. The treatment strategy that is increasingly being applied is Transcatheter Arterial Embolisation (TAE). Research has shown that TAE can be a reasonable primary alternative to surgery in selected patients with haemorrhage from abdominal injuries.\(^8\) In fully equipped centres where interventional radiology is available 24/7, TAE could even be extended to haemodynamically (HD) unstable patients with a transient response to fluid resuscitation.\(^9\) Interventional radiologists are increasingly consulted to perform interventions to stabilise acutely injured patients.\(^10\)

Non-operative management (including TAE) has a number of advantages over surgical treatment. These include preservation of splenic function,\(^11,12\) a lower lifelong risk of post splenectomy sepsis, avoidance of surgery associated morbidity and complications, shorter hospitalisation periods and a possible reduction in costs.\(^13\)

Since TAE is increasingly being applied worldwide and our level 1 trauma centre has possible TAE start up times that are comparable to surgical start up times with 24/7 availability of an interventional radiologist, we felt an analysis of times to intervention was relevant.

The aim of this study was to report time intervals between admission to the trauma room and start of intervention (TAE or splenic surgery) in patients with splenic injury treated in our center. Outcomes measures were transfusion requirements, intervention-related complications and the need for a re-intervention.
Patients and Methods

Patients and data collection
Consecutive patients with splenic injury admitted to a Dutch level 1 trauma centre, between January 2006 and January 2012 were included retrospectively. Patients under the age of 16 were excluded. In our level 1 trauma centre a prospective, comprehensive registration of all admitted trauma patients is performed according to the Major Trauma Outcome Study (MTOS+) model.14 Data were collected in the local database of the National Trauma Registry. Patient demographics were extracted from the trauma registry. Laboratory findings and treatment details were extracted from the electronic medical record. Time of start of TAE was extracted from the radiologic database. Complications, re-interventions, and mortality were manually verified per patient, in order to extract the spleen related events. Data were reported according to haemodynamic status (stable versus unstable) because of the differences in treatment options, failure rates and urgency between these two groups. In HD unstable patients, transfusion requirement, intervention-related complications and the need for a re-intervention were compared between the TAE and splenic surgery group.

Definitions
Splenic injury was graded according to the American Association for the Surgery of Trauma (AAST) splenic injury grading scale.15 Haemodynamic instability was defined as a SBP ≤100 mmHg and/or a heart rate ≥120 beats per minute on admission. Patients with an increased heart rate only were only categorized as HD unstable if one of the following terms or its synonyms were cited in the medical chart: haemodynamic instability, rapid clinical deterioration or decreasing haemoglobin levels despite transfusion. If SBP and heart rate were unknown, haemodynamic status was assessed from the trauma room report or medical chart according to the before mentioned terms. Patients that met the criteria for HD instability but were unstable due to injuries other than splenic injury were analysed in the stable group. There had to be a strong assumption that splenic injury significantly contributed to HD instability. Although TAE is often regarded as non-operative management (NOM) strategy, in this study NOM for splenic injury was defined as observational management,
i.e. the absence of an intervention. In our centre NOM involves admission to the intensive care unit (ICU) or medium care unit (MCU). The patient is kept at strict bed rest, vital signs are monitored, frequent haemoglobin checks and serial abdominal examinations are performed.

Figure 1 Flowchart of the evaluation and management (decisions) in patients with a suspicion of abdominal trauma during daytime and night-time hours

Abbreviations: FAST: Focused Assessment with Sonography for Trauma; CT: Computed Tomography
— defined as systolic blood pressure <100 mmHg and/or heart rate >120 mmHg
— patients with compromised vital parameters but responsive to resuscitation (transient responders) or when trauma team decides (Total Body)CT scanning is possible despite compromised vital parameters
— minimal or non-responsive to fluid administration
* patients included in the REACT-2 trial were either randomised to the conventional diagnostic work-up or to an immediate total-body CT scan.
Protocol holds during daytime and night-time. During the night the surgeon and interventional radiologist on call are in hospital within 30 minutes
In our level 1 trauma centre the (64-slice) CT scanner is located on a sliding gantry in the trauma room.\textsuperscript{16,17} This enables start of imaging as part of the secondary survey according to the Advanced Trauma Life Support (ATLS) directly after complementing the primary survey. Previous research showed an almost 25% reduction in total evaluation time with this setting in comparison to the conventional setting in which the scanner was located in the Radiology Department.\textsuperscript{17} An emergency trolley is available on the trauma room which is fully equipped for performing emergency procedures if necessary. Angiographic intervention is provided by an interventional radiologist team, which is available immediately during office hours (8 am - 6 pm) and within less than 30 min outside office hours. Two types of TAE were applied during the study period: proximal and (super) selective embolisation; this decision was at the discretion of the interventional radiologist.

Complications were defined as intervention-related complications or death due to failure of initial treatment strategy. Re-interventions were described as all failures of initial treatment strategy requiring a re-intervention. The process by which a patient proceeded to TAE versus surgery depended on several factors. First, HD stability was determined. Stable patients underwent chest and pelvic X-rays and Focussed Assessment for Sonography of Trauma (FAST). Stable patients with an indication for additional imaging as well as patients with compromised vital parameters but responsive to fluid administration underwent selective CT scanning. Furthermore, patients in which the trauma team decided that CT scanning was possible despite compromised vital parameters underwent selective CT scanning. Patients randomised to total-body CT scanning in the REACT-2 trial received an immediate total-body CT scan without preceding conventional imaging. HD unstable patients in whom there was no time for imaging (as assessed by the trauma team) were directly brought to the operation room for splenic surgery. Indications for TAE in HD stable and unstable patients with a suspicion of blunt abdominal trauma in our hospital are depicted in Figure 1. This protocol applies during daytime and night-time hours and deviations were at the trauma teams' discretion.
Statistical analysis
Statistical analysis was performed with PASW Statistics version 19 (2012). Data were expressed as number (percentage) or median with interquartile ranges (p25–p75). The Mann-Whitney U test was used to compare non-normally distributed variables. The Fisher's exact test was used to compare proportions for qualitative variables with a small sample size. In order to attach equal importance to differences in each direction, the doubled one-tailed probability was reported instead of the two-tailed probability for the Fisher's exact test. Data were reported with rounding to two decimal places. A p value <0.05 was considered statistically significant. Median times to intervention were presented in a Boxplot.

Results

Inclusion
One hundred nine patients were eligible for inclusion during the study period. Patients with age under 16 years (n=11) or patients with incomplete data (n=2) were excluded. The study cohort consisted of 96 patients.

Haemodynamic stability
The majority of patients was HD stable (n=80; 83%). Sixteen patients (17%) were HD unstable: eight because of a lowered SBP, one because of an increased heart rate and two because of both a low SBP and increased heart rate. In seven patients, vital parameters on admission on the trauma room were not registered. Four of the seven patients directly underwent an emergency laparotomy without preceding CT-scanning due to HD instability (reported in medical chart) and were analysed in the unstable group. One patient, who did not fulfil the criteria for HD instability (SBP slightly above 100 mmHg) was analysed in the unstable group because the trauma team judged this patient to be unstable.
Table 1. Demographics and baseline characteristics of included patients (n=96) with splenic injury

<table>
<thead>
<tr>
<th></th>
<th>HD stable n=80</th>
<th>HD unstable § n=16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>32 (22 - 54)</td>
<td>38 (23 - 54)</td>
</tr>
<tr>
<td>Male gender</td>
<td>60 (75%)</td>
<td>16 (100%)</td>
</tr>
<tr>
<td>Blunt trauma mechanism</td>
<td>71 (89%)</td>
<td>14 (88%)</td>
</tr>
<tr>
<td>Referral from another hospital</td>
<td>16 (20%)</td>
<td>3 (19%)</td>
</tr>
<tr>
<td>GCS on admission</td>
<td>15 (13 - 15)</td>
<td>15 (3-15)</td>
</tr>
<tr>
<td>Hemoglobin level (g/dl) on admission</td>
<td>11.6 (10-12.9)</td>
<td>8.9 (6.4-9.7)</td>
</tr>
<tr>
<td>Grade of splenic injury</td>
<td>3 (2-4)</td>
<td>4 (3-5)</td>
</tr>
<tr>
<td>ISS (points)</td>
<td>25 (17 - 34)</td>
<td>40 (17-50)</td>
</tr>
<tr>
<td>Hospital length of stay – total group (days)</td>
<td>9 (6 - 21)</td>
<td>5 (2 - 40) ¶</td>
</tr>
<tr>
<td>- intensive care – total group (days)</td>
<td>2 (0 - 4)</td>
<td>2 (1 - 16)</td>
</tr>
<tr>
<td>Hospital length of stay – survivors (days)</td>
<td>9 (7 - 23)</td>
<td>32 (6 - 59) ¶</td>
</tr>
<tr>
<td>- intensive care – survivors (days)</td>
<td>2 (0 - 4.5)</td>
<td>11 (2 - 39) ¶</td>
</tr>
<tr>
<td>In hospital mortality</td>
<td>3 (4%)</td>
<td>6 (38%)</td>
</tr>
</tbody>
</table>

Data are expressed as number (percentage) or median (interquartile range). Abbreviations: ISS, Injury Severity Score; GCS, Glasgow Coma Score; SBP, systolic blood pressure; HR, heart rate; bpm, beats per minute; NOM, non-operative management; TAE, transcatheter arterial embolization; OM, operative management.

§: Defined as SBP ≤ 100mmHg and / or HR > 120 bpm or considered hemodynamically unstable by the attending surgeon. ¶: 3 patients died 1 or 2 days after admission lowering the total length of hospital stay.

Haemodynamically stable patients

Baseline characteristics of the 80 HD stable patients are depicted in Table 1. In 38 (48%) patients an intervention was performed. In 25 out of 31 patients who received angiography, TAE was performed. In the remaining 6 patients the bleeding focus could not be detected during the procedure and angiography was only diagnostic. Seven (9%) patients were treated with primary splenic surgery (see Fig. 2).

Median time from admission to intervention was 105 (IQR 77-188) min: 117 (IQR 78-233) min for TAE compared to 95 (IQR 69-188) min for splenic surgery (p = 0.58) (depicted in Fig. 3A). Median number of transfused packed red blood cells was 0 (IQR 0 - 4).

No intervention-related complications occurred. A re-intervention was performed in 10 (13%) patients: in 5 out of 48 patients initially treated with NOM, in 3 out of the 25 patients treated with TAE and in 2 out of 8 patients initially treated with surgery. The re-interventions in the surgically treated patient group were non-planned (real failures of initial management).
Haemodynamically unstable patients

Baseline characteristics of the 16 HD unstable patients are depicted in Table 1. In all 16 patients an intervention was performed: 9 (56%) patients underwent TAE and 7 (44%) patients underwent primary splenic surgery. Patients treated with TAE did not differ from patients in the surgery group with regard to demographics, baseline characteristics, grade of splenic injury and associated injuries (ISS) (data not presented; available upon request).

Median time from admission to intervention was 58 (IQR 41-99) min: 46 (IQR 27-107) min for TAE compared to 64 (IQR 45-80) min for splenic surgery ($p = 0.76$) (depicted in Fig. 3B). The median number of transfused packed red blood cells was 14 (IQR 6-31). Transfusion requirement did not differ statistically significantly between patients treated with TAE or splenic surgery ($p = 0.09$) (see Table 2).
Figure 3A. Median times to intervention in HD stable (n=80) patients with splenic injury

Abbreviations: HD, haemodynamically; TAE, transcatheter arterial embolisation. The whiskers show the minimum and maximum. The bottom of the boxplot represents the 25th percentile and the top the 75th percentile. The black line in the boxplot represents the median.

Figure 3B. Median times to intervention in HD unstable (n=16) patients with splenic injury

Abbreviations: HD, haemodynamically; TAE, transcatheter arterial embolization. The whiskers show the minimum and maximum. The bottom of the boxplot represents the 25th percentile and the top the 75th percentile. The black line in the boxplot represents the median.
No intervention-related complications occurred in the TAE group. In the splenic surgery group one complication occurred. The patient died from haemorrhagic shock due to severe abdominal injury (lacerations of liver, kidney and spleen). Operative intervention could not resolve HD instability in this patient. An unsuccessful attempt to stop the bleeding of the hepatic artery with TAE followed. A second surgical attempt could not prevent excessive blood loss, which eventually caused death. The difference in intervention-related complications was not statistically significant with the Fisher exact test ($p = 0.88$, Table 2).

A spleen related re-intervention was performed in 5 (31%) of the unstable patients. In Table 2 the number of re-interventions per initial treatment strategy is depicted. Two versus three spleen related re-interventions were performed in patients treated with proximal TAE and splenic surgery ($p = 0.73$), respectively. The two re-interventions in the patients initially treated with proximal TAE were performed because of persistent HD instability with abdominal tenderness and distension due to haemorrhage. In both patients a decompression laparotomy with splenectomy was performed. One of the three re-interventions in the splenic surgery group was performed in the patient that eventually died (described above) and two re-interventions (second surgical attempt) were performed because of persistent HD instability due to associated (intra-abdominal) injuries. The patients intentionally treated with damage control procedure were taken back to theatre for non-planned procedures (real failure).

Table 2 Embolisation versus splenic surgery in HD unstable patients (n=16) with splenic injury

<table>
<thead>
<tr>
<th></th>
<th>TAE n=9</th>
<th>Splenic surgery n=7</th>
<th>P-value</th>
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<tbody>
<tr>
<td>Transfusion requirement</td>
<td>8 (IQR 3-22)</td>
<td>24 (IQR 9-55)</td>
<td>0.09</td>
</tr>
<tr>
<td>Intervention related complications</td>
<td>0 (0%)</td>
<td>1 (11%)</td>
<td>0.88</td>
</tr>
<tr>
<td>Need for re-intervention</td>
<td>2 (22%)</td>
<td>3 (43%)</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Data are expressed as number (percentage) or median (interquartile range). Transfusion requirement is expressed as number of packed red blood cells. Abbreviations: HD, haemodynamically; TAE, transcatheter arterial embolisation. §: one-tailed probability with the Fisher’s exact test

Eleven patients underwent CT scanning before initiation of treatment: nine out of nine (100%) patients in the TAE group compared to 2 out of 7 (29%) in the surgery group (Fisher exact test: $p = 0.005$).
Discussion

Median time from admission to intervention was 105 (IQR 77-188) min in HD stable patients and 58 (IQR 41-99) min in HD unstable patients with splenic injury. Time to intervention did not differ significantly between HD unstable patients treated with TAE and patients treated with splenic surgery. Although no difference was observed with regard to intervention-related complications and the need for a re-intervention, a trend towards lower transfusion requirement was observed in patients treated with TAE compared to patients treated with splenic surgery.

To our knowledge, this is the first report comparing time to embolisation with time to splenic surgery. Median time to splenic surgery in HD unstable patients in our study (58 (IQR 41-99)) was shorter than in a previous study (median of 2.3 h)\(^{18}\). Nance et al. only adjusted for AIS code, while we took into account haemodynamic status on admission. Median time to TAE in HD unstable patients in our study (46 (IQR 27-107)) was also shorter than reported in a previous study of Franco et al. with a median of 171 min (120-130) in patients with grade IV injury or contrast extravasation \(^{19}\). The cohort of Franco et al. was comparable to ours where all but one embolized patient suffered from grade IV splenic injury or a contrast extravasation.

The higher transfusion requirements for patients treated with surgery was also reported by Bruce et al. in a study about cost-effectiveness of surgical versus angiographic management of patients with blunt splenic injury\(^{20}\). A median of 6.7 units of packed red blood cells was transfused in the splenic surgery group (\(n = 15\)) versus 2.7 units in the TAE group (\(n = 31\)). The reason for lower overall transfusion requirements compared to our study was because they analysed all patients that received TAE with splenic surgery, regardless of haemodynamic stability.

A relatively high percentage (63\%) of the unstable patients underwent CT scanning before treatment. This high percentage is partly being explained by the REACT-2 trial, an international, multicentre randomised clinical trial to direct total body CT scanning versus conventional radiology in trauma patients\(^{21}\). Moreover, this involves patients who are unstable on admission but who respond to fluid administration (responders). In all cases the trauma team, led by a senior trauma surgeon and anaesthesiologist, decided if the additional value of a CT scan matched the additional risks of time sacrifice. Our fully equipped trauma resuscitation room with all types of immediate care needs and the CT scanner located on a sliding gantry allows this hazardous strategy.
An optimal diagnostic workflow is essential to perform TAE in patients considered unstable. In our opinion the immediate availability of i.v. contrast enhanced CT scanning (e.g. in the trauma room) is important just as the availability of an angiography suite or hybrid OR with optimal equipment for performing TAE (wires, catheters, and haemostatic implants) as well as support and intervention of vital parameters (e.g. ventilatory support, chest tubes, blood products). A skilled interventional radiologist is an indispensable adjunct to the trauma team in these patients. Lastly, local experience and service availability are essential in order to perform an angio-intervention in a trauma patient.

Limitations
The results of this study suggest that TAE is feasible in patients with splenic injury, even in HD unstable patients. However, the sample size of this retrospective study, and especially the HD unstable group, was relatively small. Furthermore, the exact reasons for selecting patients for either NOM or an intervention (TAE or splenic surgery) could not be retrieved. The protocol in our hospital dictates that besides clinical signs (e.g. vital parameters), injury mechanism and index of suspicion, treatment strategy is based on the specific injuries diagnosed by radiologic imaging (described in Fig. 1) in HD stable as well as HD unstable patients. Patients requiring an emergency laparotomy, are directly brought to the operation theatre without preceding imaging. However, in two HD unstable patients who underwent CT scanning in this retrospective study, the considerations to perform CT scanning prior to surgery were unclear. We experienced difficulties in defining HD instability. Although often defined as a SBP below 90 mmHg, research has shown that mortality starts to drop below 110 mmHg. Some patients may not have fulfilled the criteria for instability at admission but deteriorated rapidly to an unstable situation. Others may have had a low blood pressure at admission entrance but may have been responsive to fluid administration. Additionally, time to haemostasis could not be retrieved. This would have been an even more effective endpoint for successful treatment. Although time to intervention did not differ significantly between patients treated with TAE and splenic surgery (both in the HD stable as in the HD unstable group), time to haemostasis might have been different. The fifth limitation, also related to the retrospective design, is that timing of transfusion could not be retrieved. The trend towards lower transfusion requirement in HD unstable patients treated with TAE could be associated
with successful treatment but could also be explained by a ‘less unstable’ haemodynamic condition compared to patients who were immediately operated. Although not significant, additional analysis showed that HD unstable patients treated with TAE had slightly higher systolic blood pressures on admission and a lower median Injury Severity Score than patients treated with splenic surgery (data not shown).

**Future research**
Since TAE does not allow a visual inspection of the abdominal contents, the possibility of hollow organ injury should of course always be kept in mind when selecting patients for TAE. Since patient selection is critical, in future prospective studies it will be valuable to report the indications for performing TAE or splenic surgery in HD unstable patients and record the timing of blood transfusions. Future studies could also investigate whether a further refining of criteria is possible for stable patients who do not benefit of embolisation and provide knowledge about the cost-effectiveness of this policy.

**Conclusion**
Median time from admission to intervention was less than 2 h in both haemodynamically stable and unstable patients and shorter than reported in previous studies. Time to intervention did not differ significantly between HD unstable patients treated with TAE and splenic surgery. Although no difference was observed with regard to intervention-related complications and the need for a re-intervention, a trend towards lower transfusion requirement was observed in patients treated with TAE compared to patients treated with splenic surgery. We conclude that if 24/7 interventional radiology facilities are available, TAE is not associated with time loss compared to splenic surgery, even in HD unstable patients.
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