Splenic injury diagnosis & splenic salvage after trauma
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This thesis discussed diagnostics - and treatment strategies of trauma patients with blunt abdominal (mainly splenic) injury.

In the narrative review in Chapter 1 we state that non-operative management (NOM) has replaced surgery as the treatment of choice for hemodynamically stable patients. The growing use of NOM for blunt abdominal organ injury has been made possible by the progress in the quality and availability of the multidetector CT scan and the development of minimally invasive intervention options such as splenic artery embolization (SAE). SAE can be used as an adjunct to observation and has increased the success rates. However, controversies exist about the optimal patient selection for NOM, the proper role of SAE in NOM, the best material and technique to use in SAE, and the follow-up strategy of patients with splenic, kidney or liver injury after trauma.

PART 1 - Diagnostics of blunt abdominal injuries

In Chapter 2 inter- and intraobserver reliability of the grading system of the American Association for Surgery of Trauma was compared to the reliability of the ‘Baltimore CT grading system’. We retrospectively reviewed CT scans of 83 patients with blunt splenic injury. Overall the inter- and intraobserver reliability for the two systems were equally high with overall weighted interobserver Kappa coefficients of 0.80 for the AAST and 0.85 for the ‘Baltimore CT grading system’. Average weighted intraobserver Kappa values were 0.91 and 0.81, respectively. 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.

The Academic Medical Center applies a step-up imaging guided strategy for paediatric patients with a blunt abdominal trauma presentation. In this step-up strategy the decision to observe the patient or to perform an intervention depends on the vital parameters of the patient, in combination with the presence or absence of free fluid at Focused Assessment with Sonography for Trauma (FAST) and the findings on CT (performed selectively). Chapter 3 tested the hypothesis that with the step-up imaging guided strategy, a low rate of clinically relevant injuries is missed without doing unnecessary harm, e.g. radiation or an intervention. Sensitivity and negative predictive value (NPV) of the imaging strategy were calculated in 122 children. Clinical course was used as reference. 66 (54%) patients were discharged home after primary survey, 51
(41%) patients were admitted and observed, 3 (2%) patients underwent SAE and 2 (2%) patients underwent surgery. Observational management failed in 1 patient. The sensitivity of the imaging strategy was 0.83 (0.45 - 0.99) and the NPV was 0.99 (0.96 - 1.00). We concluded that the step-up imaging strategy that is applied in our academic level 1 trauma centre has a high sensitivity and a high negative predictive value. No clinically relevant injuries were missed.

PART 2 - Management of splenic injuries

The second part considers the treatment, follow-up and immunocompetence of patients with blunt splenic injury.

Chapter 4 examined whether differences exist between five Dutch level 1 trauma centres with respect to the treatment of blunt splenic injuries, and if variation in treatment is related to outcome. A total of 253 patients were included: 149 (59%) were observed, 57 (23%) were treated with SAE and 47 (19%) were operated. The observation rate was comparable in all hospitals. SAE and surgery rates varied from 9% to 32% and 8% to 28%, respectively. After adjusting for hemodynamic instability, high grade splenic injury and Injury Severity Score, the odds of operative management were significantly higher in one hospital compared to the reference hospital (adjusted OR 4.98 (1.02 - 24.44). The odds of splenic salvage were significantly lower in another hospital compared to the reference hospital (adjusted OR 0.20 (0.03-1.32). We concluded that variation in treatment and outcome exists. The development of a national guideline is advised to minimalize splenectomy after trauma.

In Chapter 5 the results of a systematic review are described on prognostic factors for failure of NOM. A qualitative synthesis of the available evidence (best-evidence synthesis1) was performed owing to heterogeneity of study characteristics and methodological quality of the studies. Of the 31 included studies, 10 were qualified as high quality. Twenty-five prognostic factors were investigated, and 14 were found to significantly affect outcome of NOM. Strong evidence exists that age above 40 years, an ISS of 25 or higher, and splenic injury grade 3 or greater are prognostic factors for failure of NOM. Moderate evidence was available for abdominal Abbreviated Injury Scale score 3 or greater, Trauma and Injury Severity Score of less than 0.80, the presence of an intraparenchymal contrast extravasation, and transfusion of more than 1 Unit of blood. Limited
or no evidence was found for the remaining identified prognostic factors (e.g. lower admission systolic blood pressure, large hemoperitoneum). The factors for failure of NOM that were identified in Chapter 5, were used in Chapter 6. Using propensity score analysis, we set out to investigate whether SAE improves success rate compared to observation alone. 206 patients were included in the study. Treatment was successful in 180 patients: 132 (89%) patients treated with observation and 48 (84%) patients treated with SAE. The weighted RR for success with SAE was 1.23 (0.97 to 1.54); for complications the weighted RR was 0.71 (0.41 to 1.22). The mean number of transfused blood products was 4.4 (SD 9.9) in the observation group versus 9.1 (SD 17.2) in the SAE group. In conclusion, there was a small, but consistent advantage of SAE over observation alone with regard to successful treatment and all-cause complications in patients with blunt splenic injury after trauma. This difference was, however, not statistically significant.

In Chapter 7 we have sought to reach consensus among 30 international expert trauma surgeons and intervention radiologists concerning optimal treatment and follow-up strategies, using the Delphi method. An online survey was used in the two study rounds. Consensus was defined as an agreement of 80% or greater. Response rates of the first and second rounds were 90% and 80%, respectively. Consensus was reached for 43% of the (sub)questions. The American Association for the Surgery of Trauma organ injury scale for grading splenic injury is used by 93% of the experts. In hemodynamically stable patients, observation or SAE can be applied in the presence of a small or no hemoperitoneum combined with an intraparenchymal contrast extravasation or no contrast extravasation, regardless of the presence of an arteriovenous (AV) fistula/pseudoaneurysm. HD instability is an indication for operative management, irrespective of CT characteristics and grade of splenic injury (82% of the experts). Operative management is also indicated in the presence of associated intra-abdominal injuries and/or the need for five or more packed red blood cell transfusions (22 of 27 experts, 82%). Patients should be admitted 1 to 3 days to a monitored setting (27 of 27 experts, 100%). Serial hemoglobin checks are performed by all experts, every 4 to 6 hours in the first 24 hours and once or twice a day after that (21 of 24 experts, 88%), in observation as well as after SAE. Routine postdischarge imaging is not indicated (21 of 24 experts, 88%). Although treatment should always be
adjusted to the specific patient, the results of this study may serve as general guidelines.

As SAE is increasingly being applied, Chapter 8 presents the results of a retrospective study in which time to surgery was compared with time to SAE. 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 SAE 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 SAE 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 SAE versus 24 (9 - 55) in the surgery group (p = 0.09). In conclusion, time to intervention did not differ significantly between patients treated with SAE 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 HD unstable patients treated with SAE compared to patients treated with splenic surgery. If 24/7 interventional radiology facilities are available, SAE is not associated with time loss compared to splenic surgery, even in patients who are HD unstable upon presentation.

In the final chapter, Chapter 9, the results of a clinical, prospective study are presented in which splenic function of patients treated with SAE was assessed. Splenic function was assessed by examining the antibody response to polysaccharide antigens, by evaluating B-cell subsets and assessing the presence of Howell-Jolly Bodies (HJB). The data were compared to those obtained in splenectomised patients and healthy controls (HC) who had been included in a previously conducted study. A total of 30 patients were studied: 5 with proximal SAE, 7 patients treated with distal SAE, 8 splenectomised patients and 10 HC. The median response following vaccination of the SAE patients (fold increase 3.97) did not differ significantly from the HC (5.29; p value 0.90), the response of the splenectomised patients, however, did (2.30; p value 0.003). In 2 of the proximally embolised patients and none of the distally embolised patients the ratio was <2. There were no significant differences in lymphocytes or B-cell subsets between the SAE patients and the HC. HJB were not observed.
in the SAE patients. We concluded that splenic function of embolised patients is preserved and routine vaccination appears not to be indicated. Although the median antibody response did not differ between proximally and distally embolised patients, 2 of the 5 proximally embolised patients had an insufficient response to vaccination, as opposed to none of the distally embolised patients. Further research should be done to confirm this finding.

**Future perspectives**

The current trend toward non-operative management (NOM) continues to evolve and the further refining of patient selection remains an ongoing subject of interest within contemporary research. NOM clearly has advantages over surgical treatment, the most important being the avoidance of surgery-related complications and the negative life-long consequences of removal of the spleen. There is, however, the risk of a delayed splenic rupture, a re-bleed, and visual inspection of the abdominal contents remains impossible. There continues to be a group of patients who needs immediate surgical treatment, i.e. those with a splenic injury who are haemodynamically unstable and do not respond to fluid resuscitation. The clinical acumen needs to be supported by evidence-based guidelines in order to define the optimal treatment strategy for each individual patient.

The fact that patient selection is continually being refined is most clearly visible in splenic artery embolization (SAE). Although the presence of a contrast extravasation is an accepted indication for SAE, more evidence is accumulating that not all patients with a contrast extravasation benefit from SAE. Besides the location of the blush, size matters. Recently, cut-off values of > 1cm and 1.5 cm or greater diameter have been proposed in the literature because these correlate with the need for intervention. More extensive, preferably prospective research needs to be done before implementing these criteria in clinical practice.

At the same time, huge advancements are being made in the field of technology. Hospitals with a hybrid operating room are now in place allowing angiography to be performed, and therapeutic intervention, being endovascular, open or a combination of both, in the same room. In this setting, SAE can be used at the same time as surgery or both treatments can done immediately after one
another, according to the principles of trauma surgery, to stop the bleeding as quickly as possible: ‘Time is life’. For vascular injuries, especially in areas that are difficult to assess surgically (i.e. the pelvis), or in severely injured patients who are injured to several body areas, both therapies complete each other very well. As a result, the differences between minimally invasive radiological techniques and traditional surgical sciences fade away.

With these advancements in the field of technology, cooperation between the different specialists involved (e.g. the trauma surgeon, interventional radiologist, and the anaesthesiologist) is indispensable. In research, this applies as well. Combined efforts and data sharing (individual patient data) will be needed for useful conclusions to be drawn.

In summary, the challenge in the future will be to ensure that the least invasive techniques are used to control life threatening haemorrhage as quickly as possible (‘Time is life’) which would in turn reduce the number of unnecessary splenectomies. This would maximise patient benefit while maintaining high standards of safety.
References