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Blunt splenic injury: Outcomes of proximal versus distal and combined splenic artery embolization

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Abstract

Purpose: To assess clinical outcomes of blunt splenic injuries (BSI) managed with proximal versus distal versus combined splenic artery embolization (SAE).

Materials and methods: All consecutive patients with BSI admitted to our trauma centre from 2005 to 2010 and managed with SAE were reviewed. Outcomes were compared between proximal (P), distal (D) or combined (C) embolization. We focused on embolization failure (splenectomy), every adverse events occurring during follow up and material used for embolization.

Results: Fifty patients were reviewed (P n=18, 36%; D n=22, 44%; C n=8, 16%). Mean injury severity score was 20. The technical success rate was 98%. Four patients required splenectomy (P n=1, D n=3, C n=0). Clinical success rate for haemostasis was 92% (4 re-bleeds: P n=2, D n=2, C n=0). Outcomes were not statistically different between the materials used. Adverse events occurred in 65% of the patients during follow up. Four percent of the patients developed major complications and 56% developed minor complications attributable to embolization. There was no significant difference between the 3 groups.

Conclusion: SAE had an excellent success rate with adverse events occurring in 65% of the patients and no significant differences found between the embolization techniques used. Proximal preventive embolization appears to protect in high-grade traumatic injuries.

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The management of hemodynamically stable splenic injuries is currently mostly medical, involving non-operative management with or without splenic artery embolization [1–10]. Debate remains about the embolization techniques and their complications. The splenic artery may be embolized in trauma, proximally or distally, and for either preventative or curative purposes. Embolization is said to be curative when it is used to treat active bleeding and preventative when it is carried out for high-grade traumatic injuries with no signs of bleeding on CT to reduce the risk of secondary bleeding. Proximal embolization is defined by introduction of the embolization material into the splenic artery trunk and distal embolization by embolizing a segmental branch in the intra-parenchymal portion of the organ. Combined embolization is defined by the combination of both techniques [11]. In active haemorrhage, some groups use both embolization techniques, choosing to prefer proximal embolization for high-grade trauma with diffuse splenic bleeding and distal embolization for isolated focal bleeds [7,9,12–16]. Others only use one embolization technique, either proximal [17] or distal [6,8,10] regardless of the splenic injury. Proximal embolization is preferred in high-grade trauma without any focal arterial abnormalities [2,11,12,17,18].

The description and prevalence of complications from embolization of the splenic artery varies between series from 23% [7] to 62% [15]. The type of complications and their severity are often defined arbitrarily [2,7,9,14,15,19–22].

The primary aim of this retrospective study is to assess the efficacy of embolization in the management of splenic injuries, comparing the different embolization technique and materials used. The secondary aim is to provide a detailed description of all of the short and medium term adverse events which occurred.

Materials and methods

Population

This was a single centre, retrospective, observational study recording all consecutive patients with splenic injury treated by embolization between 2005 and 2010 in our University Hospital. The patients were divided into three groups, depending on the embolization technique used: proximal embolization (P), distal embolization (D) and combined embolization (C).

Management algorithm

If the patient was stable, he/she was referred to the radiology department for whole body CT (Brilliance 64 or Brilliance 40, Philips Medical Systems, Eindhoven, The Netherlands or Sensation 16, Siemens AG, Medical solutions, Erlangen, Germany) with chest, abdominal and pelvic images in the arterial and venous phases. Embolization treatment was reserved for patients with:

• grade 4-5 splenic injury of the American Association for the Surgery of Trauma (AAST) classification (grade 1: hematoma < 10% or laceration < 1 cm, grade 2: hematoma 10–50% or laceration 1–3 cm, grade 3: hematoma ≥ 50% or laceration > 3 cm with de-vascularization < 25%, grade 4: major laceration with de-vascularization > 25%, grade 5: comminutive fracture or complete de-vascularisation [23]);
• a vascular injury (leak/blush, pseudo-aneurism, arterio-venous fistula) regardless of grade;
• a grade 3 injury associated with a large hemoperitoneum (injury involving the peri-splenic space, Morrison’s space, the two parieto-colonic gutters and the pelvis) or patients with pre-existing weaknesses.

Hemodynamic instability was an exclusion criterion for embolization treatment.

Embolization techniques

Arteriography was performed in an interventional radiology suite (Allura Integris, Philips Medical Systems, Eindhoven, The Netherlands).

The interventional radiology team was made up of 5 radiologists with 3 to 20 years’ experience.

The most common approach was through the right femoral artery. Diagnostic arteriography of the coeliac axis and splenic artery was performed using a 4 or 5 French catheter and possibly a 3 French micro-catheter.

Depending on the splenic artery, three embolization techniques were available, the choice of which was left to the discretion of the interventional radiologist:

• proximal embolization: the embolization materials were positioned as a compact unit in the trunk of the splenic artery, proximal to its dividing branches but distal to the dorsal pancreatic artery. These were either 0.035 inch coils or Amplatzer plugs (St Jude Medical, St. Paul, MN, USA) when the anatomy was favourable. Proximal embolization was used in preference for high-grade injuries without vascular abnormalities, in which case the embolization was preventative. The same technique was used when multiple inaccessible or excessive numbers of vascular abnormalities were present. Technically successful embolization was defined as complete obstruction of the artery treated at the point of the “packing” with distal flow provided from collaterals (Fig. 1);
• distal embolization: the embolization materials were positioned in the segmental branches of the splenic artery, within the parenchyma. 0.018 inch micro-coils, resorbable gelatine material or surgical glue was used. The ischemia-producing embolization [24] was intended to cover a limited vascular territory and was selected for patients with an isolated vascular abnormality. Technical success was defined as complete obstruction of the distal arterial branch without returned collateral supply (Fig. 2);
• combined embolization: this technique combines proximal with distal embolization and was reserved for vascular lesions combining AAST high-trade trauma (grade 4 and 5) or a large hemoperitoneum.

Data collection

All imaging investigations were archived in a PACS and were reviewed. Medical details were recorded from the electronic patient medical records by one of the authors who independently reviewed all of the medical and imaging records
on two occasions. Thirty records selected at random were checked by a senior radiologist.

The following population characteristics were recorded: age, gender, circumstances of injury, hemodynamic stability, simplified severity index (IGSZ), injury severity score (ISS), AAST grade of splenic injury, intra-splenic arterial abnormality, a large hemoperitoneum, concomitant traumatic injuries, embolization materials used, length of hospitalization and length of follow up by imaging.

Failure of embolization treatment was defined as failure to salvage the spleen, requiring splenectomy, regardless of cause, or failure to achieve haemostasis with a secondary fall in haemoglobin (requiring secondary embolization, partial splenectomy or splenorraphy, or secondary total splenectomy). Short and medium term adverse events were separated into major and minor complications attributable to the embolization, and other complications attributable to the multiple injuries or care. The major complications involved events possibly resulting in serious consequences to the patient and the minor complications were those which were not life-threatening. Isolated fever or pain were not deemed to be complications, given the background of multiple injuries.

Figure 1. Proximal embolization: a: diagnostic arteriography with the catheter (7) positioned at the origin of the splenic artery (1) showing a superior pole contusion (5) and an intra-splenic pseudo-aneurism (6); b: repeat arteriography after proximal embolization of the splenic artery with a plug (8). Complete obstruction of the artery distal to the plug with contralateral supply returning to the distal end (2, 3, 4). 1: splenic artery pancreatic arcade, 2: pancreatic arcade, 3: left gastroepiploic artery, 4: short gastric arteries, 5: enhancement defect in the superior pole of the spleen indicating splenic contusion, 6: intra-splenic pseudo-aneurism, 7: cobra 5 French catheters, 8: plug embolization material.

Statistical analysis

Data were processed on Stata/IC 12.1 software on a Mac OS X. Qualitative variables are expressed as numbers and percentages and quantitative variables as mean, plus or minus the standard deviation. The statistical tests used were the Chi² test or Fisher’s case for low numbers and the Mann-Whitney test. The significance threshold was set at $P \leq 0.05$.

Results

Population

Fifty consecutive patients were included. This was a young population of average age (standard deviation; range) of 32-years-old (16-years-old; 8–76-years-old), who suffered a sports accident (53%) or road traffic accident (30%). The average time between the injury and embolization was 3 days (5 days; 0–21 days). The patients were hospitalized for an average of 16 days (7 days; 8–43 days): 4 days in intensive care (5 days; 0–22 days) and 12 days in the clinical

Figure 2. Distal embolization: a: diagnostic arteriography with catheter (1) advanced into the splenic artery which shows a massive active leak of contrast medium (3) into the parenchyma and peritoneum; b: repeat angiography post-selective embolization of the active leak with gelatine fragments deposited distally using a micro-catheter. Complete obstruction of the segmental branch responsible for the leakage with no return contralateral supply and stagnation of contrast medium (4). 1: cobra 5 French catheter, 2: heterogeneous enhancement of the spleen suggestive of contusions, 3: active leak of contrast medium, 4: stagnation of contrast medium at the former active leakage site.
The injuries were high-grade: mean AAST grade (standard deviation) 3 (1), mean IG52 grade IG52 20 (12), and mean ISS grade 20 (11). The patients had suffered multiple injuries with at least one concomitant injury in 70% of cases, including a chest injury in half of the cases (rib fracture, lung contusion or hemo-pneumothorax). A vascular abnormality was present in 84% of cases, a blush or active leak in 52%, pseudo-aneurism in 24% and an arterio-venous fistula in 8%.

Eighteen patients (36%) were treated by proximal embolization, 22 (44%) by distal embolization, and 8 (16%) by combined embolization. Two patients underwent angiography only: one failure of catheterization and one spontaneous haemostasis without leakage found on angiography and not treated by embolization. Two CTs could not be consulted as they were performed in another centre and were not archived in the PACS. The AAST grade was higher in groups P and C (P = 0.035) suggesting more severe injury. Patients in group P were treated more quickly, with an average time between injury and the initial CT of 1.3 days, compared to 3.7 and 4.7 for groups D and C respectively (P = 0.05). The average management time between CT and angiography, however, was the same in all 3 groups (5 hours) (Table 1).

**Efficacy**

Technical success was achieved in 98% of cases, with a single catheterization failure in a patient who did not subsequently undergo splenectomy. We found failed haemostasis with recurrent bleeding in 4 patients: 1 secondary splenectomy on D0 (D), one splenoraphy on D3 (P), a partial splenectomy on D0 (P), a further ineffective embolization followed by splenectomy on D4 for an AAST grade 4 splenic injury with active leakage (D). In terms of haemostasis, embolization was therefore clinically successful in 92% with only 2 splenectomies. There were no significant differences between the groups. In terms of splenic salvage, we found one splenectomy because of a painful pseudocyst on D240 (D) and one splenectomy to facilitate the approach to an oesophagectomy on D0 in a patient who had swallowed a potent corrosive (P). There were therefore a total of 4 splenectomies, including patients who failed haemostasis. There were no statistically significant differences between the groups.

All of the embolizations carried out in groups D and C were performed for curative purposes (100% vascular abnormalities). In group P, eight patients (44%) underwent preventative embolization for a high-grade AAST injury and large hemoperitoneum.

**Embolization materials used**

We used coils in 62% of the patients: 14 proximal embolizations, 13 distal embolizations and 4 combined embolizations. Two patients who had a distal coil embolization underwent splenectomy for secondary haemostasis. Temporary gelatine material was used in 6 patients (12%): 5 distal embolizations using small fragments, 1 proximal embolization with large fragments introduced into the splenic artery trunk. Two patients underwent subsequent splenectomy, including one for a persistent fall in haemoglobin. Plugs were used in preference in 9 patients. These were used alone in proximal embolization (44%) and combined with another material in combined embolization (56%). Distal coil embolization was required to treat arterio-venous fistulae in 3 patients and for a severe active leak in another patient.

**Short and mid-term adverse effects**

None of the population died. Sixty-five percent of patients developed an event during their hospitalization (Table 2).

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**Table 1** Description of the population included in our study.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Groups</th>
<th>P</th>
<th>D</th>
<th>C</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td></td>
<td>18</td>
<td>22</td>
<td>8</td>
<td>NS</td>
</tr>
<tr>
<td>Mean age (SD)</td>
<td></td>
<td>28 (14)</td>
<td>33 (18)</td>
<td>36 (19)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean AAST grade (SD)</td>
<td></td>
<td>3.6 (0.5)</td>
<td>3.1 (0.9)</td>
<td>3.5 (0.5)</td>
<td>P = 0.035</td>
</tr>
<tr>
<td>Mean IG52 grade (SD)</td>
<td></td>
<td>22.1 (14.7)</td>
<td>20 (10)</td>
<td>14 (4.4)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean ISS2 grade (SD)</td>
<td></td>
<td>26.1 (11.5)</td>
<td>20 (10)</td>
<td>19 (14)</td>
<td>NS</td>
</tr>
<tr>
<td>Coexistant injuries (%)</td>
<td></td>
<td>65</td>
<td>77</td>
<td>67</td>
<td>NS</td>
</tr>
<tr>
<td>Vascular abnormality (%)</td>
<td></td>
<td>59</td>
<td>100</td>
<td>100</td>
<td>NS</td>
</tr>
<tr>
<td>Large hemoperitoneum</td>
<td></td>
<td>12</td>
<td>9</td>
<td>2</td>
<td>NS</td>
</tr>
<tr>
<td>Mean time from injury to embolization (SD), days</td>
<td></td>
<td>1.3 (2.3)</td>
<td>4.7 (6.2)</td>
<td>4.1 (4.9)</td>
<td>P = 0.05</td>
</tr>
<tr>
<td>Mean time from initial CT to embolization (SD), hours</td>
<td></td>
<td>3.8 (5.7)</td>
<td>5.4 (11.7)</td>
<td>9.1 (11.7)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean admission in the intensive care department (SD), days</td>
<td></td>
<td>5 (6.3)</td>
<td>3.2 (4.8)</td>
<td>1.75 (1.4)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean total hospital stay (SD), days</td>
<td></td>
<td>16.1 (8.6)</td>
<td>16.3 (6.6)</td>
<td>15.4 (3.5)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean follow up by imaging (SD), days</td>
<td></td>
<td>43.1 (92)</td>
<td>95.6 (174.8)</td>
<td>106.3 (255.8)</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS: not significant; SD: standard deviation; P: proximal embolization group; D: distal embolization group; C: combined embolization group.
Four percent of patients suffered major complications, including 2 extensive splenic infarctions, one of which was associated with an abscess (D).

Minor complications occurred in 56% of patients. Ten of the 11 pseudocysts were found incidentally and one was treated symptomatically by a splenectomy. These involved distal embolization (groups D and C) in 82% of cases.

In the other complications, infection included a sepsis requiring laparoscopy with peritoneum lavage to investigate for small bowel perforation (P), an abdominal collection following splenectomy, which was treated with antibiotic therapy (P), 6 cases of pneumonia (3 in P and 3 in D). Three patients developed a deep vein thrombosis, including one pulmonary embolism which was then complicated by acute respiratory distress syndrome (P). One patient developed acute respiratory distress syndrome due to decompensation of chronic obstructive pulmonary disease on a background of a chest injury (D).

Group C developed fewer complications, with 0.6 per patient compared to 1.9 in group P. The difference was not statistically significant.

**Discussion**

The technical success rate in our series was 98% with only one failed catheterization. Embolization treatment was extremely effective in terms of spleen salvage (92% salvage rate). These results are the same as those published in the literature [22] and support the concept that embolization is an independent factor for salvaging the spleen [27]. Unlike the literature [22], we chose to study the clinical effectiveness of embolization in terms of haemostasis and defined re-bleeding as failed embolization and not as a complication of treatment. Our clinical success rate for embolization in terms of sustained haemostasis was 92%. These results are consistent with re-bleeding rates published previously between 4.5% and 15% [2,7,14,15,19,21].

No haemostasis splenectomies were performed in groups C and P and one splenectomy was performed for a high-grade injury with a vascular abnormality which was treated with distal embolization alone. Although not statistically valid, this case confirms the concept that proximal embolization could protect AAST high-grade splenic injuries. The 84% vascular abnormality rate shows that we carried out far fewer preventive embolizations than haemostatic embolization.

Embolization with gelatine alone was only complicated by one haemostatic splenectomy out of the 6 patients concerned, compared to one out of 13 patients treated with distal coil embolizations. This difference in effectiveness has also been reported in the literature [11,28,29]. Although the result was not significant, we cannot draw any conclusion that distal gelatine embolization was less effective.

The complications of treatment of splenic injuries vary depending on the studies from 23 [7] to 62% [15]. The choice and definition of the complications are not clearly stated and no causal relationship with the treatment has ever been proven. We therefore decided to list all events which occurred during the patient’s treatment and we also had a higher comorbidity rate with secondary events occurring in 65% of cases, as our record was more complete.

We separated major from minor complications using the criteria described in previous studies [14,15,22,30].

Splenic infarctions occurred in 5.1% of cases in Clancy’s study [21] and 13% in Ekeh’s study [14]. Schnüriger et al reported a complication rate of 0 to 8.4% infarctions with proximal embolizations and 14.3 to 19.8% with distal embolizations in their meta-analysis and even found a

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**Table 2** Short and medium term adverse events.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Groups</th>
<th>P(n = 18)</th>
<th>D(n = 22)</th>
<th>C(n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients with at least one event (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major complications</td>
<td></td>
<td>72</td>
<td>64</td>
<td>50</td>
</tr>
<tr>
<td>Extensive splenic infarction</td>
<td></td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Splenic abscess</td>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Minor complications</td>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pseudocyst</td>
<td></td>
<td>18</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Acute abdominal compartment syndrome</td>
<td></td>
<td>2</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Migration of embolization material</td>
<td></td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Secondary vascular abnormality</td>
<td></td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Left drainage</td>
<td></td>
<td>8</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Pancreatitis</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Renal impairment</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other complications</td>
<td></td>
<td>12</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Acute respiratory distress syndrome</td>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Right pleural drainage</td>
<td></td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Vascular thrombosis</td>
<td></td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Infectious complications</td>
<td></td>
<td>5</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

P: proximal embolization group; D: distal embolization group; C: combined embolization group.
significant difference between the two groups [22]. However, the extent of the infarction was not described in any of these studies. Considering only total or subtotal (70% of the splenic parenchyma infarcted) infarctions, we found a 4% infarction rate, which is low compared to the study reported by Wu et al. [15] that described a rate of 13% using the same criteria.

Only one study lists episodes of acute respiratory failure and reported a rate of 22% in 76 patients undergoing embolizations [31]. We found a rate of 4% in our patients.

As embolization increases in practice, some complications would logically be expected to increase. Acute ischemic pancreatitis as a complication of splenic embolization is well known [32] although the risk of this has not been assessed. We found a significant rise in serum lipase suggesting pancreatic distress in 6% of our cases although no pancreatitis was seen on CT. Pseudocysts are well known in children [33], and are very rarely described in adults [34,35]. When we read the CTs carefully, we found 11 pseudocysts, one of which was symptomatic, similar to the results of pediatric studies: 5 pseudocysts, including 2 symmetric cysts in 65 patients [33]. Eighty-two percent of these pseudocysts were associated with distal embolization and resulted in splenectomy in one patient, which could encourage us to use proximal embolization in preference. The acute abdominal compartment syndrome has never been described, despite non-operative management of patients with a large hemoperitoneum. We found 4 patients (8%) with raised abdominal pressure requiring peritoneal lavage [36].

In his meta-analysis, Schnüriger [22] compared proximal and distal embolizations in terms of efficacy and complications. Out of the 479 patients reported, 60.3% were treated by proximal embolization, 33.2% by distal embolization and 6.5% by combined embolization. This meta-analysis describes more minor complications in distal embolization. We did not find a significant difference between our groups and there was actually a trend towards more complications in the P group. This may be due to the fact that the patients in this group had more serious splenic injury. We found a larger proportion of combined embolizations (16%) which had a trend to fewer complications in this group, suggesting that this technique is effective with no added morbidity.

The weak statistical power of the study and lack of a written protocol defining the embolization technique limit the interpretation of our results and may explain why no significant differences were found between the different techniques.

Conclusion

Our study shows that for trauma, embolization of the spleen is effective in terms of organ salvaging, and in terms of haemostasis, with a 92% splenic salvage rate and 92% haemostasis sustained over time. This effectiveness could be improved using a routine embolization strategy for high-grade injury as is proposed in the literature. The complications of these embolizations are, however, poorly defined as they are interlinked with events due to the injury itself. Only a comparative study of the different methods of care (surgery, embolization and medical treatment only) would better define the complications specific to the different treatments.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

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