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Non-surgical Management of Blunt Splenic Trauma: A Comparative Analysis of Non-operative Management and Splenic Artery Embolization—Experience from a European Trauma Center

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Abstract

Purpose The objective of our study was to retrospectively compare the outcomes of non-operative management (NOM) and splenic artery embolization (SAE) in the management of hemodynamically stable patients with splenic injuries.

Materials and Methods In a 5-year period, 109 patients were recorded; 60/109 were treated with NOM and 49/109 with SAE. For each patient, the following parameters were assessed: Glasgow coma scale, injury severity score, American Association for the Surgery of Trauma splenic injury grade, transfusion requirements, hemoglobin level, presence of a splenic vascular lesion (SVL) and amount of hemoperitoneum (Bessoud scale). Different SAE techniques (proximal, distal, combined) with different materials were employed. Clinical success was defined as spleen conservation at 30 days; failure was defined as spleen re-bleeding within 30 days, requiring splenectomy. Student's *t* test or Chi-square analysis and the Kaplan–Mayer curve were used to analyse each group's results and compare them with those of the other group.

Results In the SAE group, AAST splenic injury grade was higher and serum hemoglobin levels were lower. The SAE group had significantly more SVL and hemoperitoneum compared to the NOM group. The clinical success rate was not significantly different between groups (NOM = 95%, SAE = 87.8%; $p = 0.16$). Sixty-six percent of NOM failures were related to inadequate patient selection, while 67% of SAE failures were due to technical/procedural issues.

Conclusion Our study observed a high splenic salvage rate with the use of SAE as an adjunct to NOM, and suggests that it may be further improved with appropriate patient selection and an improved embolization technique.

Keywords Non-operative management · Splenic artery embolization · Blunt trauma · Angiography · Spleen

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Introduction

Abdominal trauma injuries are frequent and carry significant mortality and morbidity [1]. The spleen is involved in about 32% of abdominal injuries [2]. Over the last 40 years, management of splenic injuries has evolved from a mainly surgical approach, to what was called "non-operative management" (NOM), aimed at spleen conservation in hemodynamically stable patients, on account of the long-term risks of splenectomy [3–5]. The term NOM is employed in this study as synonymous with observation.

Splenic artery embolization (SAE), first proposed by Sclafani [6], was employed to reduce the incidence of recurrent bleeding leading to hemodynamic instability. We will therefore use these terms separately, in this retrospective analysis, differently from other authors who include SAE in the NOM policy [7–14].

The role of SAE in the management of blunt splenic injury is debated, as studies of similar patient populations have reported opposite results. Three main issues are a matter of debate: selection criteria for SAE and NOM, embolization technique and material used [3].

Selection criteria for SAE are controversial [15–17]. Although most authors agree in considering splenic vascular lesions (SVL) as an indication for SAE, there is still no consensus on the inclusion of Grade III lesions in the embolization protocol [18]. What embolization technique (proximal versus distal) should be employed and what materials should be used are debated, as will be further discussed below [12, 19, 20].

Outcome data on NOM in blunt splenic trauma are predominantly from studies from large trauma centers in the United States and it is not known if these results can be translated to European centers with lower activity volumes [13]. In Europe, NOM and SAE are probably underutilized, with high variability between centers, but epidemiologic data are lacking.

This retrospective study aims to review the experience of non-surgical management in blunt splenic traumas in a European trauma center by comparing two groups of patients: one treated with NOM and one with SAE.

The objectives of the study are as follows: (1) to assess the overall success rate of non-surgical management of splenic injuries following blunt abdominal trauma; (2) to evaluate the success rates of SAE and NOM; (3) to compare the two populations of patients (NOM and SAE); (4) to identify and describe risk factors associated with clinical and/or radiological failure of NOM and SAE.

Some management suggestions are proposed based upon the results.

Materials and Methods

The study included patients with blunt splenic trauma treated by non-surgical management at an Italian trauma center, between December 2008 and December 2013.

In the setting of the study, patients with trauma and suspected splenic injury underwent clinical examination and focused abdominal sonography for trauma (FAST) and were managed according to a clinical algorithm, published in 2014 by Tugnoli et al. [21].

Hemodynamically stable patients underwent a total-body CT scan: a 4-slice scanner was used from December 2008 until June 2013, and a 64-slice scanner until the end of the study. The CT protocol consisted of a pre-contrast scan followed by post-contrast acquisitions obtained in the arterial phase (using a bolus tracking system) and venous phase at 65 s, using a contrast volume of 2 mL/kg and injection speed of 3–4 mL/s.

The following splenic lesions, in the absence of other associated injuries requiring laparotomy, were selected for non-surgical treatment: Grade I-II lesions without associated SVL were selected for NOM; lesions Grade IV and V underwent SAE; patients with Grade III lesions were evaluated case by case and the final decision was made by the trauma surgeon. SVL was diagnosed in the presence of pseudoaneurysm, arteriovenous fistula or active bleeding [22] and considered an indication for SAE.

NOM consisted in bed rest for the first 48–72 h with clinical and laboratory surveillance, including serial blood tests (complete blood count) and clinical observation (GCS, Sp02, heart rate, respiratory rate, blood pressure) every 6 h during the first 72 h.

SAE procedures were performed by a team of eight interventional radiologists, with between 1 and 22 years of experience. An anteroposterior selective arteriogram of the splenic artery was obtained using a 4Fr or 5Fr catheter (Simmons or Cobra). Super-selective catheterization of distal splenic artery branches, when required, was performed using coaxial microcatheters. Different SAE techniques (proximal, distal, combined) and different embolic materials were used, on the basis of the type of lesion found at diagnostic angiography and on operator experience (see Table 1).

CT scan was usually repeated when hemoglobin levels declined (indications on a case by case basis, according to the whole clinical picture) when complications were suspected and in routine follow-up for high-grade lesions (IV–V), usually on the 5th day.

The following patient demographics were retrospectively collected: sex, age, trauma mechanism, clinical parameters at presentation (sp O2, heart rate, blood systolic pressure, hemoglobin), Glasgow Coma1 Scale (GCS), Injury Severity Score (ISS) [23], transfusion requirements, mortality, complications, intensive care unit and length of hospital stay.

CT and angiographic images were re-evaluated jointly by a senior interventional radiologist and a radiology resident in their last year. Any discordance that arose was resolved by a second expert. Splenic lesions were classified according to the American Association for the Study of

Table 1 Embolic materials

Material	Diameter × length mm	Indication
Platinum coils, 0,038 inches Spi®—*Balt Extrusion*, Montmorency, France	12 × 300, 10 × 120, 8 × 300, 6 × 300, 8 × 120, 6 × 120	Proximal embolization
Platinum coils, fibered, 0.018 inches Vortex®—*Boston Scientific Corporation*, Natick, USA	3 × 22, 4 × 42, 5 × 58	Distal embolization
Platinum coils, fibered, 0.035 inches 2D Helical®—*Boston Scientific Corporation*, Natick, USA	6 × 40, 7 × 40, 9 × 60	Proximal embolization
Inconel coils, fibered, 0,035 inches MReye®—*COOK Incorporated Group*, Bloomington, Indiana, USA	6 × 50, 7 × 50, 8 × 50, 10 × 50	Proximal embolization
Gelatin sponge Spongostan®—*Johnson and Johnson*, USA		Distal embolization
Sintethic glue (N-2-butil-cianoacrylate) Glubran®, *GEM*, Italy		Distal embolization

Trauma grading system [24]. The presence and the type of SVL were recorded.

Hemoperitoneum was classified in four grades, according to the scale proposed by Bessoud et al. [25]: 0, absence of hemoperitoneum; 1, hemoperitoneum in the perisplenic and/or perihepatic region and/or Morrison's pouch; 2, Grade 1 plus hemoperitoneum in one or both paracolic gutters; and 3, Grade 1 or 2 plus hemoperitoneum in the pelvis.

The clinical success of both NOM and SAE was defined as spleen conservation at a clinical re-evaluation at 30 days; failure was defined as spleen re-bleeding within 30 days, requiring splenectomy.

In the case of proximal embolization, the technical success of SAE was defined as complete interruption of direct blood flow in the middle third of the splenic artery [7]. In case of distal embolization, success was defined as the occlusion of the injured intrasplenic arterial branch with resolution of bleeding.

Unplanned increases in the level of care, prolonged hospitalization, permanent adverse sequelae or death were defined as major complications, according to the Quality Improvement Guidelines for Percutaneous Transcatheter Embolization of the Society of Interventional Radiology.

Statistical analysis was performed using Medcalc software (© 2017 MedCalc Software bvba—Belgium). Patient demographics of the two study groups were compared using Student's t test and Chi-square analysis. A value of $p < 0.05$ was considered statistically significant.

The sensitivity, specificity, predictive values, and accuracy of the pre-intervention CT in detecting SVL in the SAE group were calculated based on the results of arteriography, according to Marmery et al. [26].

The retrospective study was authorized by the hospital's ethics committee.

Results

Study Population: Baseline Data

One hundred and sixty-eight patients with blunt splenic trauma treated during the study period were identified; 59 patients underwent laparotomy and splenectomy in the first 24 h of hospitalization and were not included in the present analysis; in 57 cases, the reasons for surgery were linked to the severity of the picture, in two cases to morphological peculiarities (extreme tortuosity of the splenic artery; stenosis of the celiac trunk).

The remaining 109 patients, treated non-surgically with NOM (n = 60, 55%) or SAE (n = 49, 45%), were included in our study.

There were 68 males and 41 females, with a mean age of 47 ± 21 years. The mean AAST grade of splenic injuries was 2.2 ± 0.9. The average hospital stay was 12.5 ± 7.9 days.

Differences Between NOM and SAE

The baseline characteristics of the two groups are shown in Table 2.

There were 60 patients in the NOM group, of which 21 (35%) were AAST Grade I, 28 (47%) Grade II, and 11 (18%) Grade III. In five patients, the retrospective CT analysis identified signs of SVL (one case of intrasplenic bleeding and four pseudoaneurysms).

Table 2 Patient characteristics of the two study groups (NOM and SAE) are compared

	NOM group (n = 60)	SAE group (n = 49)	*p* value
Age (years ± sd)	45 ± 21	49 ± 20	0.2596
Sex (males/females)	37/23	32/17	0.6949
GCS (mean ± SD)	14 ± 2.4	14.1 ± 2.6	0.881
Serum hemoglobin (mean ± SD)	12.7 ± 0.9	11.7 ± 2	**0.0091**
AAST[a] (mean ± SD)	1.8 ± 0.7	2.8 ± 0.8	**< 0.0001**
Hemoperitoneum grade[b] (mean ± SD)	1.1 ± 1.1	1.8 ± 1.1	**0.0037**
Contrast extravasation on CT	1	13	**0.0001**
Pseudoaneurysm on CT	4	21	**< 0.0001**
Transfusions (yes/no)	4/56	7/42	0.1890
ISS (mean ± SD)	16.6 ± 10	17.3 ± 8	0.7096
Clinical success (rate and no of patients)	95% (57)	87.8 (43)	0.1696

Causes of injury included 58 motor vehicle crashes, 19 accidental falls, 11 pedestrian injuries, 9 falls from heights, 6 bicycle accidents, 4 sports-related injuries and 2 assaults. Associated traumatic lesions were present in 78% ($n = 85$) of the study population, and included: rib fractures (62%), pulmonary contusions (35%), spine fractures (30%), pelvic fractures (21%), facial fractures (15%), lower-limb fractures (13%), brain injuries (12%), upper-limb fractures (11%), kidney injuries (8%), and liver injuries (5.5%)

Significant *p* values in boldface

[a]According to the American Association for the Surgery of Trauma grading system

[b]According to the classification proposed by Bessoud et al.

There were 49 patients treated with SAE. Four (8%) patients had AAST Grade I injuries, 10 (20%) Grade II, 26 (53%) Grade III, and 8 (16%) Grade IV. One patient was impossible to classify due to CT artifacts. Ten of the 26 patients with Grade III injury displayed no SVL.

Most of the patients (35/49, 71%) underwent angiography within 24 h of hospitalization because of SVL on CT scan at admission. The remaining patients (14/49, 29%) were treated between 2 and 21 days later, following subsequent imaging conducted when bleeding was suspected, which showed an SVL not previously present or detected.

As for the technical approach used, 13 patients were treated with distal embolization; coils were used in five; synthetic glue in three: gelatin sponge in four; coils and synthetic glue in one patient.

There were 28 patients treated with proximal coil embolization.

The remaining eight patients were treated with a combined technique of distal and proximal coil embolization ($n = 7$) and distal synthetic glue with proximal coils ($n = 1$).

In the SAE group, AAST and hemoperitoneum grades contrast extravasation and pseudoaneurysms were significantly higher, while serum hemoglobin levels lower (Table 2).

The pre-intervention CT in the SAE group yielded the following diagnostic values for detecting vascular injuries: sensitivity 89%; specificity 71%; PPV 89%; NPV 71%; and diagnostic accuracy 84%.

Success Rate

The overall clinical success rate of non-surgical treatment (NOM and SAE) was 91%.

There was no significant difference in the clinical success rates of the two groups (NOM = 95%, SAE = 87.8%; $p = 0.16$). The technical success of SAE was 90% ($n = 44$).

Analysis of failures and complications

NOM failed in three patients, whose characteristics are shown in Table 3. In two of these patients, the retrospective analysis of CT scans revealed a small pseudoaneurysm (< 3 mm). In the third patient, CT scan artifacts did not allow excluding small vascular lesions.

Clinical failure of SAE was observed in six patients (Table 4).

Technical failure of SAE was observed in five cases of proximal embolization, all characterized by lack of interruption of blood flow in the angiogram at the end of the procedure. Two technical failures were associated with clinical failures.

No major complication was observed. Minor complications included 13 splenic infarctions from distal embolization techniques, which involved < 50% of the spleen (symptomatic in two cases). There were five splenic infarctions from proximal embolization, two of which involved more than 50% of the organ. In two cases distal coil migration occurred, without complications.

Table 3 Characteristics of NOM failures

Patient	Age and Sex	Hemoperitoneum (0–3)	AAST (I–V)	CE	PSA	Outcome
1	58 F	0	I	No	Yes	Splenectomy, death
2	27 M	3	II	No	No	Splenectomy
3	73 F	3	III	No	Yes	Splenectomy

CE contrast extravasation on CT, *PSA* pseudoaneurysm on CT, *AAST* American Association for the Surgery of Trauma splenic injury grade

Table 4 Characteristics of SAE clinical failures

Patient	AAST	PSA on CT	CE on CT	PSA on angiography	CE on angiography	Embolization Technique	Material	Technical failure	Outcome
1	3	No	Yes	No	Yes	Distal	Gelatin sponge	No	Splenectomy
2	2	Yes	No	Yes	No	Distal	Gelatin sponge	No	Splenectomy
3	3	No	Yes	No	Yes	Prox	Coils	Yes	Splenectomy
4	3	No	Yes	Yes	Yes	Prox	Coils	Yes	Splenectomy
5	3	Yes	No	Yes	No	Prox	Coils	No	Splenectomy
6	*	Yes	No	No	Yes	Prox	Coil	No	Death

The patient six had synchronous bleeding from spleen and clavicle fracture that were embolized at the same time. She died 2 days after the procedure of multiorgan failure, caused by hemorrhagic shock

CE contrast extravasation, *PSA* pseudoaneurysm, *AAST* American Association for the Surgery of Trauma splenic injury grade

*AAST grade at admission not assessable (artifacts)

Discussion

In the context of a shift toward conservative treatment of spleen injuries, which ranged in our hospital from about 27% in 1989–2001 to 65% at the time of the present study, the overall success rate with non-surgical management (NOM and SAE) was high and in line with the 90% rates published in the literature [27].

The clinical success rate was 95% for NOM and 87:5% for SAE and the salvage rate was not significantly different ($p = 0.16$) despite the fact that patients in the SAE group had significantly higher AAST, hemoperitoneum grade and SVL (Table 2).

The success rate of NOM, in the high range in the current literature (85–94%) is likely to be related to the relatively low SAE threshold: in fact 70% of patients with Grade III lesions were treated with embolization. Management of Grade III lesions is very controversial: some studies support embolization [14, 28] while other authors report no significant benefits [3, 29]. Our finding is in agreement with the analysis of Banerjee, suggesting SAE in grade III lesions [28].

Rajani [9], Davis [30] and Dent [31] suggested that SAE associated with NOM can improve the clinical success rate, while Harbrecht [32], Duchesne [33], and Smith [17] saw no improvement in splenic salvage rate. In our study, patients in the SAE group had significantly higher severity compared to patients in the NOM group, while success rates were similar. This indirectly suggests that embolization allowed us to achieve a high rate of success, in agreement with other reports [9, 30, 31].

In this study, all cases of Grade IV AAST injuries (8 patients) were treated with SAE (Fig. 1), 4/8 with proximal embolization and 4/8 with a combined technique, with a 100% clinical success rate.

There were no patients with Grade V injuries in our study. This may be due to a potential underestimation of high-grade injuries, as the definition of a "shattered spleen" is quite subjective.

There are some papers comparing the efficacy of proximal versus distal splenic embolization [25, 34, 35], however, in our opinion, this comparison is misleading because the two techniques are indicated in different situations, according to the type and setting of the lesions.

If technically feasible, distal embolization usually provides safer hemostasis (no collateral flow) and should be preferred when there are only one or two target lesions on angiography.

Proximal embolization is usually chosen when there are no targetable or defined lesions, in high-grade spleen trauma, in the presence of multiple vascular injuries in different segments of the spleen, and when distal

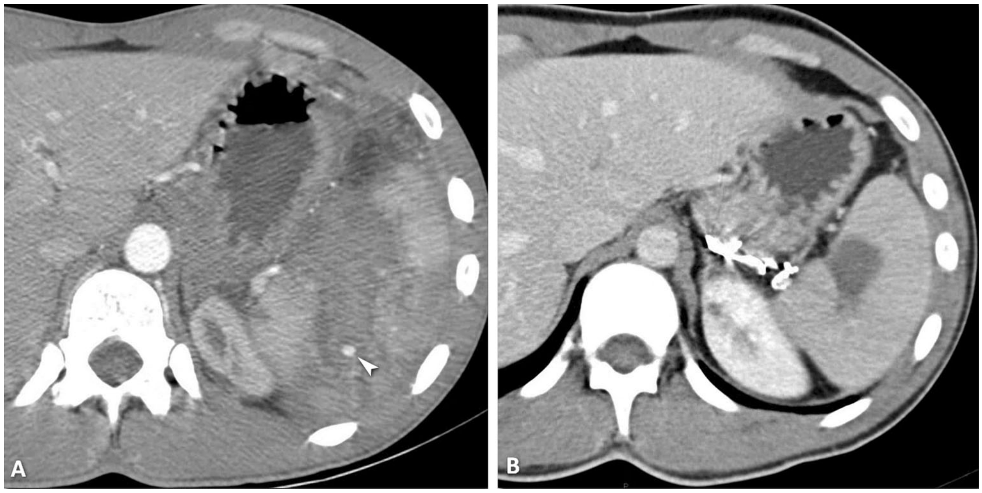

Fig. 1 A post-traumatic splenic lesion grade IV treated with SAE. **A** CT at the admission show a laceration extended to hilar region with a major devascularization and a contrast blush (arrowhead). The patient was treated by distal and proximal embolization. **B** The control CT at one month show a significant resorption of the hematoma

embolization is not possible because of technical or anatomical issues.

Reports on combined embolization are scant [18]. In our experience, combined embolization can be considered where a dominant distal lesion, such as a large pseudoaneurysm or a focus of contrast extravasation, is associated with a diffusely damaged spleen that angiographically corresponds to a coarse and irregular mottled pattern in the arteriogram [36]. In these cases, we treated the lesion with the highest bleeding risk using distal embolization, then added proximal embolization to minimize the risk of a delayed spleen rupture (Fig. 2).

Synthetic glue was safely and successfully used to treat four patients (three distal embolizations and one with combined technique). We were not able to find other references to the use of synthetic glue in traumatic spleen lesions, although this material is reported to have been successfully used in hypersplenism [37].

Three failures occurred in the NOM group: the retrospective review of the CT images found a small pseudoaneurysm in two cases; their proportion is similar to the rate reported by Davis [30]. In one of our patients, a second CT on day 4 demonstrated a large pseudoaneurysm and a subcapsular hematoma that prompted an emergency splenectomy. The second patient developed delayed splenic rupture on day 6, with hemorrhagic shock and death, despite emergency splenectomy (Fig. 3).

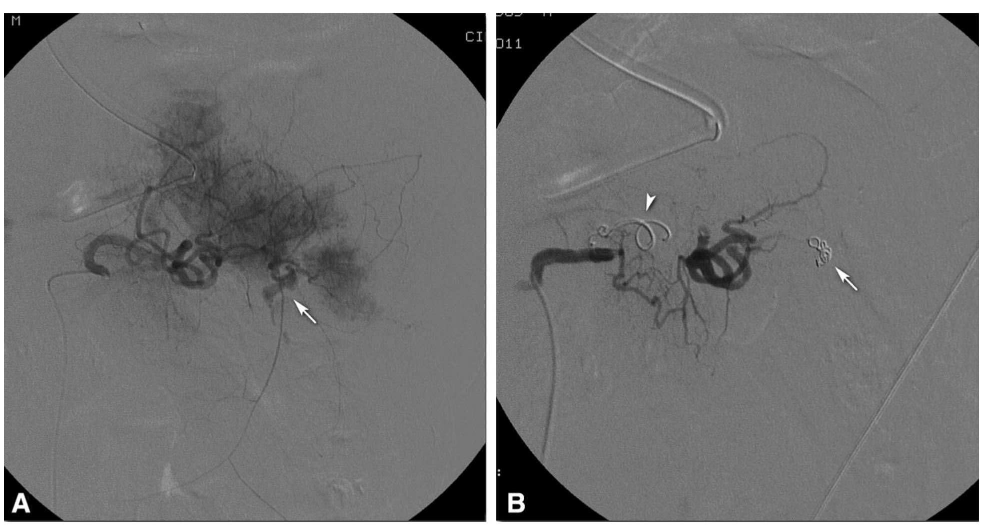

Fig. 2 Selective splenic angiography **A** heterogeneous enhancement of the spleen suggestive of multiples contusions and a vascular injury with active leak of contrast medium (arrow). **B** Post-procedural splenic arteriogram shows successful combined embolization with coils in the proximal splenic artery (arrowhead) and in the distal branch (arrow)

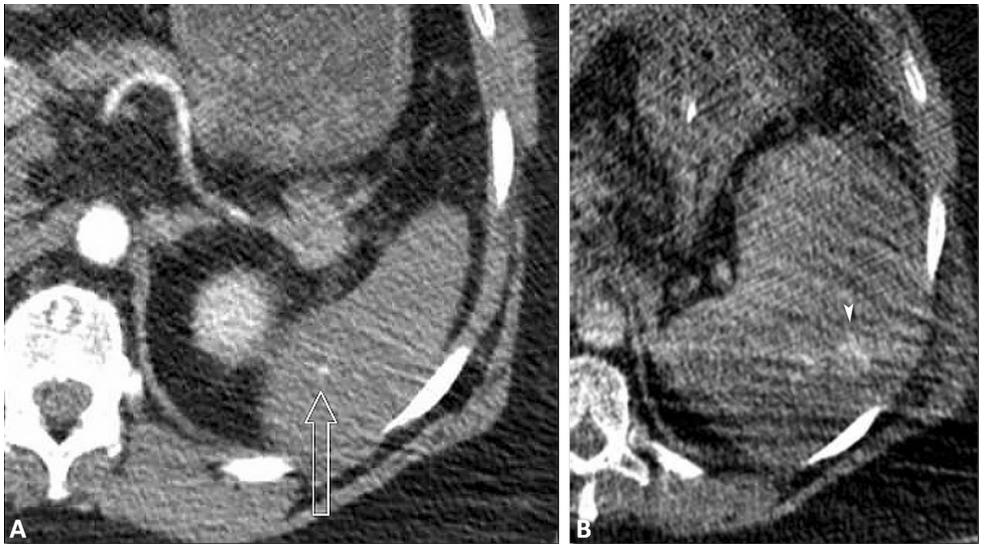

Fig. 3 Failure of NOM. **A** Female, 58 years, accidental fall. CT at admission shows a grade II splenic injury with a millimetric pseudoaneurysm (open arrow). **B** 6 days after admission CT shows the evolution to a laceration with signs of active bleeding. The patient died after emergency splenectomy for multiple organ failure due to hemorrhagic shock

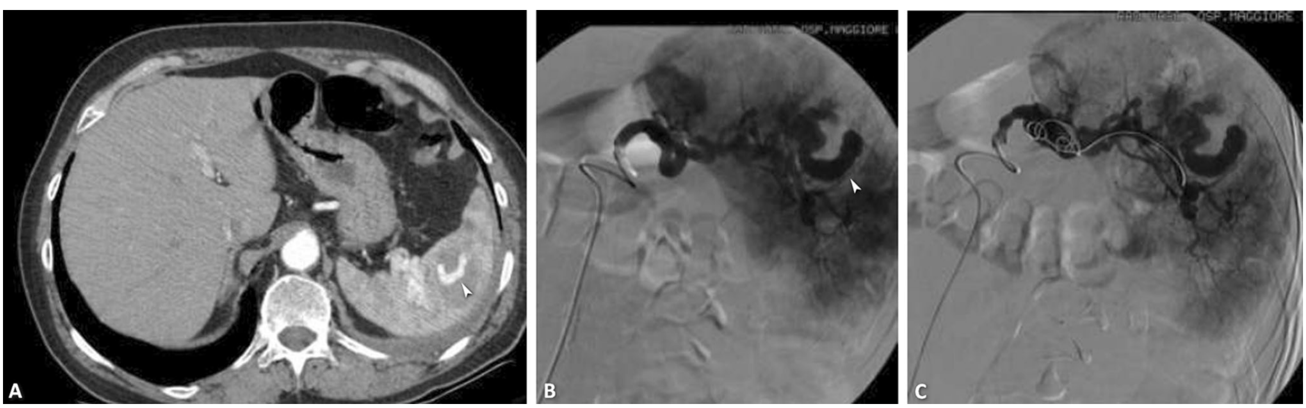

Fig. 4 Technical failure of SAE. **A** Female, 65 years, accidental fall with rib fractures. CT at admission shows a Grade 3 splenic lesion with signs of active bleeding (arrowhead). **B** Diagnostic angiography confirms the presence of active contrast extravasation (arrowhead). **C** angiographic control after proximal SAE shows distal dislocation of the coils with insufficient reduction of blood flow. Ultrasound follow-up at 2 days showed an increase of the splenic vascular injury; splenectomy was performed

In both cases, identification of the pseudoaneurysm would have been an indication for embolization. Our observation suggests that a small pseudoaneurysm should not be underestimated, in contrast with Thompson and Michailidou who suggest a cutoff of 1 and 1.5 cm for embolization [38, 39].

An accurate CT study is therefore essential to exclude even small vascular lesions; in cases of artifacts, as we observed in the third NOM failure, we suggest repeating the exam after 48 h.

There were six clinical failures in the SAE group. In two cases, gelatin sponge was used as the sole embolizing agent. While some recent studies reported a higher rate of complications associated with the use of resorbable embolization agents, with a success rate not lower than the one obtained using coils [35, 40], our data are in agreement with other authors who suggested a high risk of re-bleeding associated with resorbable agents [41–43].

In two cases, proximal embolization failed to achieve complete obstruction of blood flow (Fig. 4). Proximal embolization can be a challenging technique, especially for less experienced operators, due to frequent migration toward the hilum of the first coil deployed. The ideal arterial segment to embolize is between the dorsal pancreatic artery and the great pancreatic artery [7]. The choice of coils is critical: a high radial force and the right size are needed because the splenic artery is a high-flow vessel [44]. The first coil deployed should be oversized so that it does not completely expand but instead forms a scaffold that blocks the next coil.

Of the six cases of SAE failure described, there were four Grade III injuries, one Grade II injury and one which could not be evaluated on CT (artifacts). In contrast to van der Vlies, the failure rate was not related to AAST grade [13].

In two recent studies, major complications associated with SAE ranged from 14 to 28.5% [45, 46].

We did not observe any major complications such as splenic abscess or pancreatitis. Minor splenic infarctions, which were almost always asymptomatic, were observed in all patients treated with distal embolization and did not require treatment.

CT imaging was essential in selecting patients and deciding how they should be treated. In this study, the specificity of CT imaging in the detection of vascular injury was 71%, which is slightly lower than the figures published by Marmery [26]. The use of an older generation scanner (4 slices) during the early period of our study may explain this difference.

Our study has several limits: It is a retrospective observational study and the number of cases is limited (although one of its interesting feature is that it reports on results obtained in a relatively small center, similar in size to those in European countries rather than the large units found in North America). The two groups were non-randomized and baseline differences are significant; however, the aim of the study was to evaluate a personalized approach to blunt splenic injury, and to identify ways that results could be improved.

Our study can therefore add to current knowledge on non-surgical management of blunt splenic trauma, first of all providing data from an European trauma center, secondly providing more details on the debated topic on how to perform SAE and what materials to use; the analysis of failures underlines the importance of an accurate interpretation of CT, without neglecting small initial lesions, and of a rigorous technique for SAE.

Conclusions

Our study confirms a high splenic salvage rate obtained by combining SAE and NOM.

In the setting of an overall success rate in line with the best results reported in the literature, our study suggests that focusing on patient selection for NOM, and careful implementation of embolization techniques will further improve the outcome of treatment for blunt splenic trauma.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval Statement All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent For this type of study, formal consent is not required.

References

1. Søreide K. Epidemiology of major trauma. Br J Surg. 2009;96:697–8. https://doi.org/10.1002/bjs.6643.
2. Smith J, Caldwell E, D'Amours S, et al. Abdominal trauma: a disease in evolution. ANZ J Surg. 2005;75:790–4. https://doi.org/10.1111/j.1445-2197.2005.03524.x.
3. Stassen NA, Bhullar I, Cheng JD, et al. Selective nonoperative management of blunt splenic injury: an Eastern Association for the Surgery of Trauma practice management guideline. J Trauma Acute Care Surg. 2012;73:S294–300. https://doi.org/10.1097/TA.0b013e3182702afc.
4. Singer DB. Postsplenectomy sepsis. Perspect Pediatr Pathol. 1973;1:285–311.
5. Hansen K, Singer DB. Asplenic-hyposplenic overwhelming sepsis: postsplenectomy sepsis revisited. Pediatr Dev Pathol. 2001;4:105–21.
6. Sclafani SJ. The role of angiographic hemostasis in salvage of the injured spleen. Radiology. 1981;141:645–50. https://doi.org/10.1148/radiology.141.3.7029619.
7. Sclafani SJ, Shaftan GW, Scalea TM, et al. Nonoperative salvage of computed tomography-diagnosed splenic injuries: utilization of angiography for triage and embolization for hemostasis. J Trauma. 1995;39:818–25 **(discussion 826-827)**.
8. Peitzman AB, Heil B, Rivera L, et al. Blunt splenic injury in adults: multi-institutional Study of the Eastern Association for the Surgery of Trauma. J Trauma. 2000;49:177–87 **(discussion 187-189)**.
9. Rajani RR, Claridge JA, Yowler CJ, et al. Improved outcome of adult blunt splenic injury: a cohort analysis. Surgery. 2006;140:625–31. https://doi.org/10.1016/j.surg.2006.07.005 **(discussion 631-632)**.
10. Haan JM, Biffl W, Knudson MM, et al. Splenic embolization revisited: a multicenter review. J Trauma. 2004;56:542–7.
11. Ekeh AP, Izu B, Ryan M, McCarthy MC. The impact of splenic artery embolization on the management of splenic trauma: an 8-year review. Am J Surg. 2009;197:337–41. https://doi.org/10.1016/j.amjsurg.2008.11.017.
12. Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: a 5-year experience. J Trauma. 2005;58:492–8.
13. van der Vlies CH, Hoekstra J, Ponsen KJ, et al. Impact of splenic artery embolization on the success rate of nonoperative management for blunt splenic injury. Cardiovasc Intervent Radiol. 2012;35:76–81. https://doi.org/10.1007/s00270-011-0132-z.
14. Miller PR, Chang MC, Hoth JJ, et al. Prospective trial of angiography and embolization for all grade III to V blunt splenic injuries: nonoperative management success rate is significantly improved. J Am Coll Surg. 2014;218:644–8. https://doi.org/10.1016/j.jamcollsurg.2014.01.040.

15. Van der Cruyssen F, Manzelli A. Splenic artery embolization: technically feasible but not necessarily advantageous. World J Emerg Surg WJES. 2016;11:47. https://doi.org/10.1186/s13017-016-0100-7.
16. Olthof DC, van der Vlies CH, Goslings JC. Evidence-based management and controversies in blunt splenic trauma. Curr Trauma Rep. 2017;3:32–7. https://doi.org/10.1007/s40719-017-0074-2.
17. Smith HE, Biffl WL, Majercik SD, et al. Splenic artery embolization: have we gone too far? J Trauma. 2006;61:541–4. https://doi.org/10.1097/01.ta.0000235920.92385.2b **(discussion 545-546)**.
18. Rong J-J, Liu D, Liang M, et al. The impacts of different embolization techniques on splenic artery embolization for blunt splenic injury: a systematic review and meta-analysis. Mil Med Res. 2017;4:17. https://doi.org/10.1186/s40779-017-0125-6.
19. Bessoud B, Duchosal MA, Siegrist C-A, et al. Proximal splenic artery embolization for blunt splenic injury: clinical, immunologic, and ultrasound-Doppler follow-up. J Trauma. 2007;62:1481–6. https://doi.org/10.1097/TA.0b013e318047dfb8.
20. Rasuli P, Moosavi B, French GJ, et al. Splenic artery embolization in blunt trauma: a single-center retrospective comparison of the use of gelatin sponge versus coils. AJR Am J Roentgenol. 2017;209:W382–7. https://doi.org/10.2214/AJR.17.18005.
21. Tugnoli G, Bianchi E, Biscardi A, et al. Nonoperative management of blunt splenic injury in adults: there is (still) a long way to go: the results of the Bologna-Maggiore Hospital trauma center experience and development of a clinical algorithm. Surg Today. 2015;45:1210–7. https://doi.org/10.1007/s00595-014-1084-0.
22. Uyeda JW, LeBedis CA, Penn DR, et al. Active hemorrhage and vascular injuries in splenic trauma: utility of the arterial phase in multidetector CT. Radiology. 2014;270:99–106. https://doi.org/10.1148/radiol.13121242.
23. Baker SP, O'neill B, Haddon WJ, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma Acute Care Surg. 1974;14:187.
24. Moore EE, Cogbill TH, Jurkovich GJ, et al. Organ injury scaling: spleen and liver (1994 revision). J Trauma. 1995;38:323–4.
25. Bessoud B, Denys A, Calmes J-M, et al. Nonoperative management of traumatic splenic injuries: is there a role for proximal splenic artery embolization? AJR Am J Roentgenol. 2006;186:779–85. https://doi.org/10.2214/AJR.04.1800.
26. Marmery H, Shanmuganathan K, Mirvis SE, et al. Correlation of multidetector CT findings with splenic arteriography and surgery: prospective study in 392 patients. J Am Coll Surg. 2008;206:685–93. https://doi.org/10.1016/j.jamcollsurg.2007.11.024.
27. Requarth JA, D'Agostino RB, Miller PR. Nonoperative management of adult blunt splenic injury with and without splenic artery embolotherapy: a meta-analysis. J Trauma. 2011;71:898–903. https://doi.org/10.1097/TA.0b013e318227ea50 **(discussion 903)**.
28. Banerjee A, Duane TM, Wilson SP, et al. Trauma center variation in splenic artery embolization and spleen salvage: a multicenter analysis. J Trauma Acute Care Surg. 2013;75:69–74. https://doi.org/10.1097/TA.0b013e3182988b3b **(discussion 74-75)**.
29. Crichton JCI, Naidoo K, Yet B, et al. The role of splenic angioembolization as an adjunct to nonoperative management of blunt splenic injuries: a systematic review and meta-analysis. J Trauma Acute Care Surg. 2017;83:934–43. https://doi.org/10.1097/TA.0000000000001649.
30. Davis KA, Fabian TC, Croce MA, et al. Improved success in nonoperative management of blunt splenic injuries: embolization of splenic artery pseudoaneurysms. 1998;.
31. Dent D, Alsabrook G, Erickson BA, et al. Blunt splenic injuries: high nonoperative management rate can be achieved with selective embolization. J Trauma. 2004;56:1063–7.
32. Harbrecht BG, Ko SH, Watson GA, et al. Angiography for blunt splenic trauma does not improve the success rate of nonoperative management. J Trauma. 2007;63:44–9. https://doi.org/10.1097/TA.0b013e3180686531.
33. Duchesne JC, Simmons JD, Schmieg RE, et al. Proximal splenic angioembolization does not improve outcomes in treating blunt splenic injuries compared with splenectomy: a cohort analysis. J Trauma. 2008;65:1346–51. https://doi.org/10.1097/TA.0b013e31818c29ea **(discussion 1351-1353)**.
34. Schnüriger B, Inaba K, Konstantinidis A, et al. Outcomes of proximal versus distal splenic artery embolization after trauma: a systematic review and meta-analysis. J Trauma. 2011;70:252–60. https://doi.org/10.1097/TA.0b013e3181f2a92e.
35. Frandon J, Rodière M, Arvieux C, et al. Blunt splenic injury: outcomes of proximal versus distal and combined splenic artery embolization. Diagn Interv Imaging. 2014;95:825–31. https://doi.org/10.1016/j.diii.2014.03.009.
36. Lepasoon J, Olin T. Angiographic diagnosis of splenic lesions following blunt abdominal trauma. Acta Radiol Diagn (Stockh). 1971;11(3):257–73.
37. Koizumi J, Itou C, Wray R, et al. Partial splenic embolisation using n-butyl cyanoacrylate: intraprocedural evaluation by magnetic resonance imaging. Eur Radiol. 2013;23:1429–42. https://doi.org/10.1007/s00330-012-2711-z.
38. Thompson BE, Thompson BT, Munera F, et al. Novel computed tomography scan scoring system predicts the need for intervention after splenic injury. J Trauma. 2006;60:1083–6. https://doi.org/10.1097/01.ta.0000218251.67141.ef.
39. Michailidou M, Velmahos GC, van der Wilden GM, et al. "Blush" on trauma computed tomography: not as bad as we think! J Trauma Acute Care Surg. 2012;73:580–4. https://doi.org/10.1097/TA.0b013e318265cbd4 **(discussion 584-586)**.
40. Dasgupta N, Matsumoto AH, Arslan B, et al. Embolization therapy for traumatic splenic lacerations. Cardiovasc Intervent Radiol. 2012;35:795–806. https://doi.org/10.1007/s00270-011-0186-y.
41. Franco F, Monaco D, Volpi A, et al. The role of arterial embolization in blunt splenic injury. Radiol Med (Torino). 2011;116:454–65. https://doi.org/10.1007/s11547-011-0624-y.
42. Liu PP, Lee WC, Cheng YF, et al. Use of splenic artery embolization as an adjunct to nonsurgical management of blunt splenic injury. J Trauma. 2004;56:768–72 **(discussion 773)**.
43. Chastang L, Bège T, Prudhomme M, et al. Is non-operative management of severe blunt splenic injury safer than embolization or surgery? Results from a French prospective multicenter study. J Visc Surg. 2015;152:85–91. https://doi.org/10.1016/j.jviscsurg.2015.01.003.
44. White RI, Pollak JS. Controlled delivery of pushable fibered coils for large vessel embolotherapy. Vascular embolotherapy. Berlin: Springer; 2006. p. 35–42.
45. Ekeh AP, Khalaf S, Ilyas S, et al. Complications arising from splenic artery embolization: a review of an 11-year experience. Am J Surg. 2013;205:250–4. https://doi.org/10.1016/j.amjsurg.2013.01.003 **(discussion 254)**.
46. Wu S-C, Chen R-J, Yang AD, et al. Complications associated with embolization in the treatment of blunt splenic injury. World J Surg. 2008;32:476–82. https://doi.org/10.1007/s00268-007-9322-x.