Angiography for Blunt Splenic Trauma Does Not Improve the Success Rate of Nonoperative Management

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Background: Splenic artery arteriography with possible therapeutic embolization (SAE) has been postulated to improve the success rate of nonoperative management of blunt splenic injuries and increase splenic salvage. Previous reports, however, have compared SAE with historical controls. We compared nonoperative success with SAE with a contemporaneous group treated nonoperatively without SAE.

Methods: Patients who suffered blunt splenic trauma from 2000 to 2004 were identified. Demographic and outcome data were abstracted. Data on the performance of SAE, type of vessel embolized, and success or failure of nonoperative management were collected. Analysis of variance, χ^2, and regression analysis were used to evaluate the impact of SAE on outcome.

Results: There were 570 patients who suffered blunt splenic trauma and 221 (39%) were treated operatively. There were 349 patients who were treated nonoperatively and 46 (13.2%) underwent SAE. SAE was more frequently used for patients with spleen Abbreviated Injury Score (AIS) ≥3 (31%) than AIS = 2 (6.7%). For patients with spleen AIS ≥3, there was no difference in age, gender, Injury Severity Score, or admission blood pressure between those who did or did not undergo SAE. The nonoperative success rate was similar for patients who did (79.3%) and those that did not (78.8%) undergo SAE.

Conclusions: Patients who underwent splenic arteriography did not have improved nonoperative splenic salvage rates compared with a contemporaneous control group of similarly injured patients. Subsets of patients with blunt trauma may benefit from SAE but further study will be required to define these patients.

Key Words: Spleen trauma, Wounds and injuries, Angiography, Blunt force trauma.

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The role of angiography and embolization in the nonoperative management (NOM) of blunt splenic trauma continues to be refined. Some authors report relatively selective utilization of splenic artery embolization (SAE) for the directed treatment of splenic artery pseudoaneurysms seen on computed tomography.[1] Other institutions have adopted more aggressive application of SAE, using it for high-grade splenic injuries that may be at increased risk for nonoperative failure or for injuries with active extravasation.[2–7] Proponents of SAE have emphasized the ability of SAE to improve the success rate of NOM of blunt splenic trauma in adults.[1–7]

There are several areas of controversy regarding SAE that complicate understanding precisely what the role of SAE should be in the NOM of blunt splenic trauma. SAE is not always successful in ensuring that the patient will avoid the need for an operation. Long-term failure rates have not been defined but the short-term inhospital failure rate for SAE is approximately 12% to 30%.[5–9] Furthermore, the studies that have demonstrated improved splenic salvage rates with SAE have primarily compared SAE with historical as opposed to randomized or contemporaneous nonoperatively managed controls.[1–7] Interestingly, though, several large series have demonstrated improved success rates with NOM before the widespread push for SAE.[10–12] Our own group has demonstrated that the improvement in success rates of NOM with blunt splenic injuries is caused, in part, by the substantial increase in relatively minor splenic injuries currently being seen.[13] Therefore, whether SAE improves NOM success rates above and beyond what is already occurring because of changing demographics of injured patients and improved application of NOM has not been defined. Given the enthusiastic adoption of SAE by many centers and its rapid incorporation into the armamentarium of trauma surgeons, performing a randomized trial of SAE may be quite difficult. Nevertheless, whether the overall success rate of NOM of blunt splenic injuries is improved by SAE compared with time- and injury-matched controls remains an unanswered question.

At the University of Pittsburgh Medical Center, SAE has been used more frequently in recent years for blunt splenic injuries. We therefore examined the utilization of SAE to determine its effect on the overall success rate of NOM.

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PATIENTS AND METHODS

All patients with splenic injuries because of blunt trauma admitted to University of Pittsburgh Medical Center-Presbyterian from January 1, 2000 to December 31, 2004 were identified from the trauma registry. This dataset was cross-referenced with a dataset from the hospital's computerized database for patients admitted with a traumatic injury and a splenic injury. Splenic injuries from penetrating wounds, operative misadventures, or causes not related to blunt traumatic injury were excluded. Subjects who died in the emergency department (ED) were also excluded. For all remaining subjects, demographic information, associated injuries, invasive and operative procedures, and all diagnosis codes were retrieved from the trauma registry. The University of Pittsburgh Medical Center Institutional Review Board reviewed and approved the study protocol.

Patients who were evaluated in the ED and transported directly to the operating room for an abdominal operation were defined as operative management. All other patients were deemed to have undergone an attempt at NOM. Patients who subsequently required a laparotomy for management of their abdominal injuries were judged to have failed NOM.

The medical record and trauma registry were reviewed to identify patients who underwent angiography of the splenic artery during their evaluation. Splenic angiography was performed at the discretion of the patient's attending trauma surgeon. Angiographic findings, performance of embolization, type of embolization performed (selective vs. main artery), performance of other angiographic procedures (thoracic aorta, pelvis, extremity angiography), and need for subsequent angiographic or operative procedures were recorded. The performance of embolization was based on the judgment of the attending trauma surgeon in conjunction with the attending interventional radiologist.

Data are presented as the mean ± standard error of the mean (SEM). Numerical variables were analyzed by analysis of variance (ANOVA) and categorical variables were analyzed by χ^2. Logistic regression analysis was performed to evaluate the contribution of SAE to successful NOM. A value of $p < 0.05$ was considered statistically significant.

RESULTS

There were 570 patients who suffered blunt splenic injuries from 2000 to 2004. The mean age of these patients was 39.8 ± 0.8 years and 65.6% of them were men. The mean Injury Severity Score (ISS) for this group was 24.8 ± 0.6 and decreased over time from 30.3 ± 1.5 in 2000 to 21.6 ± 1.1 in 2004 ($p = 0.0001$). The mean spleen Abbreviated Injury Score (AIS) was 2.7 ± 0.0 but did not change significantly from 2000 to 2004. There was no difference in age, gender, presenting ED systolic blood pressure (SBP), lowest ED SBP, intensive care unit (ICU) length of stay (LOS), or total hospital LOS during this time period (data not shown). The mechanism of injury was motor vehicle crash in 60.6%, fall in 12.5%, motorcycle crash in 8.4%, pedestrian struck by vehicle in 4.2%, and other blunt mechanisms (assaults, all-terrain vehicle crashes, bicycle crashes, sporting injuries) in 14.3% of patients with no change in the distribution of injury mechanisms over time. The mortality rate for the group as a whole was 10.2% with no significant change from 2000 to 2004 (data not shown).

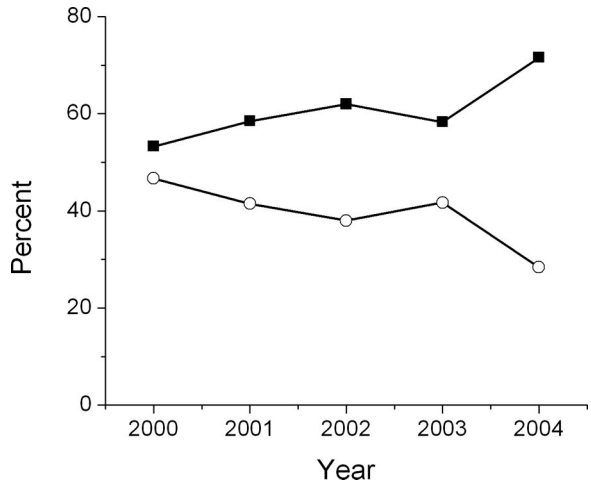

Fig. 1. *Method of initial management. Yearly percentage of initial management (○, operative; ■, nonoperative) is shown.*

There were 221 patients (38.8%) who underwent immediate operative treatment of their splenic injuries. The yearly percentage of patients undergoing operative treatment decreased and the proportion of patients undergoing nonoperative treatment increased over time (Fig. 1) and this trend approached but did not reach statistical significance ($p = 0.08$). Patients treated operatively were older (operative, 42.1 ± 1.4 years vs. nonoperative, 38.4 ± 1.0 years, $p = 0.03$), had a lower initial ED systolic BP (operative, 104 ± 3 mm Hg vs. nonoperative, 130 ± 1 mm Hg, $p < 0.0001$), had a worse lowest ED systolic BP (operative, 93 ± 3 mm Hg vs. nonoperative, 113 ± 1 mm Hg, $p < 0.0001$), were more severely injured as measured by ISS (operative, 30.7 ± 1.0 vs. nonoperative, 21.0 ± 0.6, $p < 0.0001$), and had a higher spleen AIS (operative, 3.3 ± 0.1 vs. nonoperative, 2.3 ± 0.0, $p < 0.0001$) compared with nonoperatively managed patients. Operatively managed patients also had a longer ICU stay (operative, 8.2 ± 0.8 days vs. nonoperative, 5.4 ± 0.5 days, $p = 0.001$), longer hospital LOS (operative, 13.3 ± 0.9 days vs. nonoperative, 9.7 ± 0.6 days, $p = 0.001$), and had a significantly higher mortality rate (operative mortality rate, 19.9% vs. nonoperative mortality rate, 4.0%, $p < 0.0001$). There was no significant difference in gender or mechanism of injury between patients treated operatively versus nonoperatively.

There were 349 patients who were initially managed nonoperatively. For patients treated nonoperatively, there was a decrease over time in ISS (27.1 ± 1.8 in 2000 vs. 18.1 ± 1.2 in 2004, $p = 0.0003$) but no change in age, gender, ED systolic BP, ICU or total LOS, spleen AIS, or overall mor-

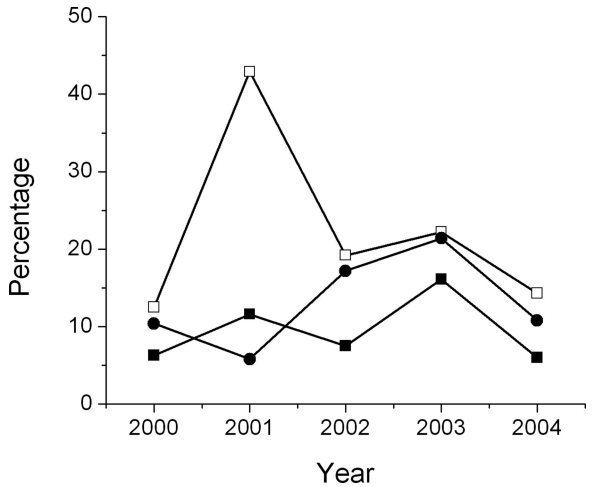

Fig. 2. *Impact of angiography on failure of nonoperative management. Yearly percentage of all patients undergoing angiography (●) is plotted along with the percentage of nonoperative failures for all patients with injuries (■) and for patients with spleen AIS = 3–5 (□).*

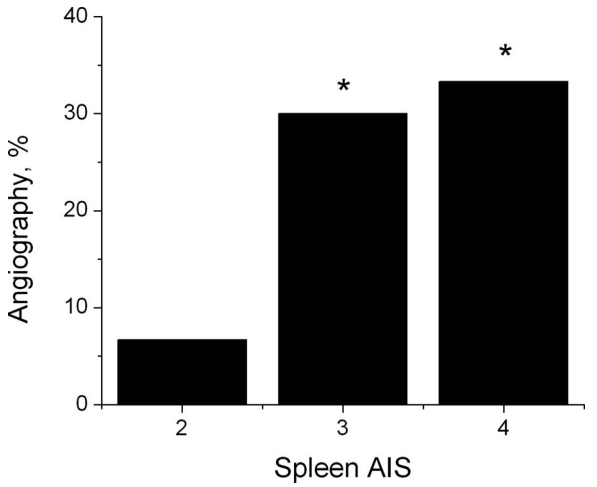

Fig. 3. *Frequency of splenic artery angiography per magnitude of splenic injury.*

Table 1 Angiographic Findings

	All Patients	Spleen AIS ≥3
Total patients	46	29
No abnormalities	27	18
Abnormal findings	19	11
Extravasation	4	1
Pseudoaneurysm	13	7
Blush	4	3

Table 2 Performance of Embolization

	All Patients	Spleen AIS ≥3
No embolization	18	9
Embolization	28	20
Main	21	15
Selective	5	3
Both	2	2

tality rate (data not shown). A total of 32 patients failed NOM (9.2%) and there was no significant difference in failure rate over time (Fig. 2). Patients who failed NOM were older (45.7 ± 3.9 years vs. 37.6 ± 1.1 years), had a higher ISS (26.4 ± 2.1 vs. 20.4 ± 0.7), and more frequently had associated abdominal injuries (53.1% vs. 24.6%). Patients who failed NOM also had a longer ICU LOS (8.9 ± 1.8 vs. 5.0 ± 0.5 days), had a worse lowest systolic BP (103 ± 4 vs. 114 ± 1 mm Hg), and had a higher spleen AIS (2.9 ± 0.2 vs. 2.3 ± 0.0) (failed vs. successful NOM, respectively) compared with patients who were successfully managed nonoperatively. In addition, the mortality rate associated with failure of NOM (12.5%) was significantly greater than that of patients successfully managed nonoperatively (3.2%, $p = 0.01$).

Forty-six patients (13.2%) who were nonoperatively managed underwent splenic angiography or embolization as an adjunct to nonoperative treatment. There was no difference in age, gender, mechanism of injury, ISS, mortality, ICU LOS, hospital LOS, ED SBP, or presence of associated abdominal injuries between patients treated nonoperatively who did or did not undergo angiography (data not shown). The overall mortality rate for nonoperatively managed patients was no different whether the patients underwent angiography (4.3% mortality vs. 4.0% mortality, with angiography vs. without angiography, $p = 0.9$) although the cause of death was not identified. We did find a statistically significant increase in mean spleen AIS between those who did (spleen AIS 2.8 ± 0.1) and did not (spleen AIS 2.3 ± 0.0) undergo angiography ($p < 0.0001$). The use of angiography tended to increase over time in a manner that approached but did not reach statistical significance (Fig. 2) ($p = 0.07$). Angiography use was significantly greater for splenic injuries with an AIS of 3 or 4 than for injuries with an AIS of 2 (Fig. 3). In this dataset, only one patient with an AIS of 5 was treated nonoperatively and that individual did not undergo angiography. The angiographic findings for the 46 patients are listed in Table 1. Nineteen patients (41%) were found to have abnormalities on angiography and two patients had two discreet abnormalities noted. The performance of embolization in this group is shown in Table 2. Twenty-eight (61%) patients undergoing angiography had embolization performed with most of those procedures occluding the proximal portion of the splenic artery. Despite the trend toward increased use of angiography over time, however, the absolute rate of failure of NOM for the group as a whole did not change (Fig. 2).

One explanation for the difference in mean spleen AISs between the patients that did and did not undergo angiography is that the majority of patients undergoing angiography had spleen AISs of 3 and 4, whereas angiography was infrequently performed in patients with a spleen AIS of 2 (Fig. 3).

We therefore analyzed the impact of SAE according to the magnitude of splenic injury. There were 236 patients with a spleen AIS of 2 treated nonoperatively who did not undergo angiography and they had a nonoperative failure rate of 4.7%. There were 17 patients with a spleen AIS of 2 (6.7%) who underwent angiography as an adjunct to nonoperative treatment and they had a nonoperative failure rate of 5.9% ($p = 0.82$).

There were 95 patients from 2000 to 2004 who were managed nonoperatively with a spleen AIS ≥3 after blunt trauma and 29 (30.5%) underwent angiography. Angiographic findings for this subset of patients are presented in Table 1. For patients with an AIS ≥3, there was no statistically significant difference in age, gender, ISS, initial ED SBP, lowest ED SBP, ICU LOS, total hospital LOS, or mechanism of injury between patients who did or did not undergo angiography (data not shown). Twenty patients who underwent angiography (69%) had embolization performed (Table 2). Fourteen of 21 patients with a spleen AIS of 3 (67%) who had angiography underwent embolization, whereas six of eight patients with an AIS of 4 (75%) underwent embolization. There was no significant difference in age, ISS, or ED systolic BP between patients who underwent angiography but did or did not undergo embolization (data not shown).

For patients with a spleen AIS ≥3, the overall success rate of NOM was similar whether patients did or did not undergo splenic artery angiography (Fig. 4) and did not change over time (Fig. 2). Furthermore, the success rate of NOM was similar whether patients did or did not undergo embolization at the time of angiography (successful nonoperative treatment with embolization: 80%, 16 of 20 patients; successful nonoperative treatment with no embolization: 77.8%, 5 of 7 patients). When individual splenic injury grades were examined, the nonoperative success rate was similar for patients with a splenic injury AIS of 3 (85.7% vs. 76.2%, $p = 0.33$) and an AIS of 4 (62.5% vs. 87.5%, $p = 0.20$) (no angiography vs. angiography, respectively) irrespective of whether they underwent angiography.

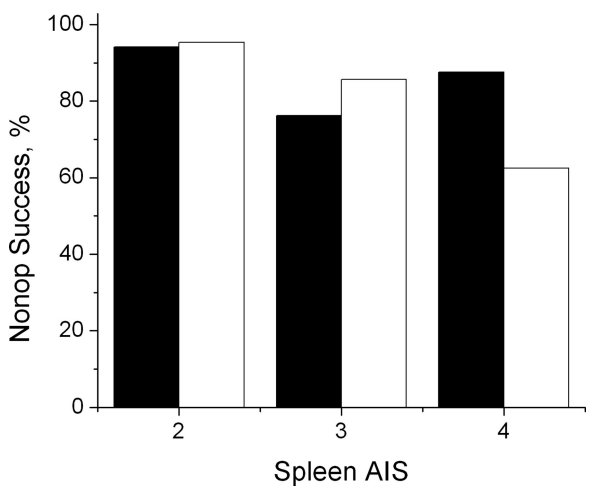

Fig. 4. *Impact of angiography on overall success rate of nonoperative management. The success rate of nonoperative management of patients who did (filled columns) and did not (open columns) undergo angiography is demonstrated for each grade of splenic injury.*

We performed regression analysis to evaluate factors associated with successful NOM. For patients managed nonoperatively, successful NOM was associated with age (odds ratio [OR] 0.98, 95% confidence interval [CI] 0.95–1.00, $p = 0.02$), spleen AIS (OR 0.27, 95% CI 0.15–0.50, $p < 0.0001$), and the presence of associated abdominal injuries (OR 0.24, 95% CI 0.10–0.58, $p = 0.002$), whereas gender, ISS, ED systolic BP, ED pulse, and the performance of splenic artery angiography or embolization were not (data not shown). If we restricted the regression analysis to splenic injuries with an AIS ≥3, associated abdominal injuries remained significantly associated with management outcome (OR 0.26, 95% CI 0.08–0.91, $p = 0.04$), whereas spleen AIS (OR 0.31, 95% CI 0.09–1.05, $p = 0.06$) and ED systolic BP (OR 1.02, 95% CI 1.00–1.05, $p = 0.07$) approached statistical significance. Age, gender, ISS, ED pulse, and the performance of splenic artery angiography were not significantly associated with NOM outcome for injuries with an AIS ≥3 (data not shown).

DISCUSSION

Angiography of the spleen for diagnosis of traumatic injuries was described several decades ago as an adjunct to physical examination before the development of diagnostic peritoneal lavage.[14] Once diagnostic peritoneal lavage became widely adopted, most splenic injuries were identified at laparotomy. Occlusion of the splenic artery to decrease bleeding and as an alternative to splenectomy was developed when the immunologic consequences of splenectomy were identified.[15–18] Initially, this was performed by operative ligation[15–19] but as interventional radiologic techniques improved over time, angiographic splenic artery occlusion became feasible.[20,21] More widespread use of angiography and embolization in the management of splenic trauma has been reported during the last several years.[1–7,21,22] Several authors have suggested that angiography and embolization have increased the success rate of NOM of blunt splenic injuries.[1,3,4,6,7,22] Unfortunately, the studies suggesting that angiography improves nonoperative outcome primarily use historical controls as the comparison group, often with many years difference between the treatment groups.[1,3,4,6,22] Using data from both a state trauma registry and the National Trauma Data Bank, we have demonstrated, though, that there has been a dramatic increase over time in the number of relatively minor blunt splenic injuries compared with that of more severe injuries.[13,23] The reasons for this are likely multifactoral but appear to be caused, in large part, by the more widespread use of computed tomography scanning detecting previously unidentified minor injuries.[13,24] As proportionately more injuries seen in trauma centers are low-grade injuries that have a low risk for bleeding, it is not surprising that improved nonoperative success occurs over time.

Whether angiography and SAE improve NOM above and beyond what is occurring because of changing patterns of injury remains to be demonstrated and studies using historical controls will be unable to clarify this issue. We therefore examined our institutional experience with splenic artery angiography and embolization to evaluate outcome using contemporaneous controls.

Our data demonstrate that angiography was used proportionately more frequently in patients with higher grade injuries (Fig. 3). We could detect no difference in demographic characteristics, magnitude of overall injury, or risk factors for nonoperative failure in patients who did or did not undergo angiography. Notably, the success rate of NOM of patients who underwent angiography was statistically similar to that of patients who were managed nonoperatively without angiography regardless of the grade of splenic injury. Embolization at the time of angiography was not associated with a higher success rate of NOM. The overall rate of successful NOM in our series was 91%, which is similar to other published series in which the rate of successful NOM ranges from 86% to 98%.[1,4,6,8,9] A limitation in trying to compare studies from different institutions is that not all series of blunt splenic injuries stratify their rate of successful NOM by grade of splenic injury. It is clear that NOM will more frequently be successful in lower grade injuries. It is worth noting that the success rate for NOM in our series for grades 2 (95%) and grades 3 to 5 (80%) compares favorably to published success rates in series that stratify outcome according to the grade of splenic injury.[1,6,8] In these prior studies, NOM was successful in 71% to 88% of cases with splenic injury grades ≥3 using angiography more frequently than in our series in which the success rate was 80%.[1,6,8] The failure of angiography and embolization to increase the success rate of NOM in our series, as well as its documented incidence of complications,[8,9,25] tempers enthusiasm for the routine use of angiography for blunt splenic injuries.

As with any retrospective study, there are limitations with our analysis that can be identified. For the time frame covered by this analysis, a guideline for the management of splenic trauma was in use but there was no formal protocol for the performance of angiography for blunt splenic injuries. The decision on whether to proceed to angiography, as well as whether to perform embolization, was based on the clinical judgment of the attending trauma surgeon and radiologist. We cannot therefore eliminate selection bias as a role player in the results of this analysis, although we could detect no difference in demographic variables, presence of shock, or magnitude of injury between patients who did or did not undergo angiography. Interestingly, this study was undertaken in part because we were updating our institution's guideline for the management of blunt splenic trauma and were unsure if or how to incorporate angiography and embolization. Our data suggest that the incorporation of routine splenic artery angiography into management guidelines of blunt splenic injuries will not increase the overall success rate of NOM.

As we have discussed previously, another limitation in any study of splenic trauma is the trend for trauma centers to see significantly more minor splenic injuries than higher grade injuries. This temporal trend limits the number of high-grade injuries any one center or trauma surgeon will see on a yearly basis. It is in this group of patients that the risks and benefits of angiography might be the most important to define but might be the most difficult to assess. We cannot exclude the possibility of a type 2 statistical error because of the proportionately small number of severe injuries any single institution will see. There may be subsets of patients with blunt splenic injuries for whom angiography and embolization may be beneficial. Given the limited number of major splenic injuries seen at any single institution, and the defined success rate of NOM for higher grade injuries without angiography, a well-constructed multi-institutional trial will likely be required to generate an adequate number of high-grade injuries to address this problem.

Proper selection of patients for SAE remains a problematic issue. Intuitively, the benefit of SAE will be greatest for patients who are actively bleeding and who can have embolization serve as their primary mode of hemorrhage control. Patients who are not actively bleeding but are at high risk for delayed hemorrhage, such as those with splenic artery pseudoaneurysms,[1,8] may also benefit from SAE. Unfortunately, identifying patients with multiple injuries who are actively bleeding from their splenic injury is imprecise. Hemodynamic status, grade of splenic injury, quantity of hemoperitoneum, and presence of associated injuries may help stratify patients at risk for active bleeding from their spleen injury but none of these factors are absolute. These selection issues contribute to the fact that the percentage of patients who undergo splenic angiography that is negative or who do not undergo embolization is reported to be 31% to 68%.[5,6,22] The benefit of SAE will need to be balanced against the potential for hemodynamic deterioration during angiography, delayed hemorrhage control, associated missed intra-abdominal injuries, and the failure rate of SAE. These issues may only be effectively addressed by a prospective randomized trial with well-designed selection criteria.

An additional consideration that must be kept in mind is whether angiography and embolization improve salvage of an immunologically competent and normally functioning mass of splenic tissue or simply avoids an operation. Splenic infarction is a documented complication of embolization of the splenic artery[3,8,9,25] and maintenance of a critical mass of functioning splenic tissue with good blood supply is vital to preserving splenic function.[26–28] Some authors have demonstrated preservation of splenic function after operative splenic artery ligation.[17,18,29,30] Others, however, have demonstrated temporary or permanent defects in splenic function after operative or angiographic splenic artery occlusion.[31–34] The reason for the differences in these studies is unclear but may be

related to the specific test used to assess splenic function and the technique used to occlude the splenic artery. The method of splenic artery occlusion (operative vs. angiographic, main artery vs. hilar vs. selective branch, coil vs. gelfoam) may significantly impact the liklihood of significant splenic infarction and subsequent depressed splenic function.[33,34] Whether SAE as practiced today in trauma centers using this technique for splenic salvage actually preserves splenic function has not been established.

In conclusion, in our institutional experience splenic artery angiography and embolization did not improve the success rate of NOM for patients with blunt splenic trauma. Carefully selected patients may benefit from angiography and embolization but additional studies will be required to define how these patients can be appropriately identified.

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