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The association between angioembolization and splenic salvage for isolated splenic injuries

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ABSTRACT

Background: Recent data suggest improved splenic salvage rates when angioembolization (AE) is routinely employed for high-grade splenic injuries; however, protocols and salvage rates vary among centers.

Materials/Methods: Adult patients with isolated splenic injuries were identified using the National Trauma Data Bank, 2013-2014. Patients were excluded if they underwent immediate splenectomy or died in the emergency department. To characterize patterns of AE, trauma centers were grouped into quartiles based on frequency of AE use. Unadjusted analyses and mixed-effects logistical regression controlling for center effects were performed.

Results: Five thousand and ninety three adult patients were identified. Overall, 705 (13.8%) underwent AE and 290 (5.7%) required a splenectomy. In unadjusted comparisons, splenectomy rates were lower for patients with severe spleen injuries who underwent AE (7% *versus* 11%, $P = 0.02$). In mixed-effect logistical regression patients with severe splenic injuries undergoing AE had a lower odds ratio (OR) for splenectomy (OR = 0.67, $P = 0.04$). Patients treated at centers in the highest quartile of AE use had a lower OR for splenectomy (OR = 0.58, $P = 0.02$).

Conclusions: The use of AE in patients with isolated severe splenic injuries is associated with decreased splenectomy rates. There is an association between centers that perform AE frequently and reduced splenectomy rates.

Introduction

The spleen is a frequently injured organ. While the management for unstable patients with splenic injuries involves splenectomy, nonoperative management for hemodynamically stable patients has become common. As nonoperative management has evolved, angioembolization (AE) has been introduced as an adjunct to reduce the need for splenectomy, especially in severe splenic injuries.[1-6] Some centers have created protocols that incorporate AE into the management of

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splenic injuries. Data from these centers suggest improved splenic salvage rates when AE is employed for all high-grade injuries.[1,2]

Protocols for managing splenic injuries vary among trauma centers, and reported salvage rates are not consistent.[1-6] A meta-analysis by Requarth *et al.*[3] of 24 unique data sets comprising 14.5 y of data calculated an overall failure rate of nonoperative management of 8.3%. Failure rates were observed to be higher in grade 4 and 5 splenic injuries ranging from 43.7% to 83.1%, respectively. The addition of splenic artery embolization decreased failure rates, particularly in grade 5 injuries.[3] Miller *et al.*[1] report their institution's experience after initiation of a protocol where AE was performed for all grade 3-5 splenic injuries. Nonoperative failure rates decreased from 15% to 5% compared to preprotocol outcomes. Bhullar *et al.*[7] similarly reported on their protocol, where AE was performed for all grade 4-5 injuries or for radiographic evidence of a contrast blush on computed tomography. They observed an overall decrease in failure rates from 4% to 1%; however, the decrease in failure rates was most prominent in grade 4-5 injuries, decreasing from 19% to 3%. These recent studies point to an overall trend in increased splenic salvage with the introduction of a protocol for AE.

Despite these promising findings, it is difficult to draw conclusions about whether these protocols should be universally applied. The protocols are highly variable, including the threshold by which AE is performed, the use of contrast blush as an indication for the procedure, and what methods of embolization should be used.[3,8-11] Furthermore, there is no universal definition for "failure" of nonoperative management. It is possible that use of a protocol for AE is associated with a higher threshold and increased reluctance to perform splenectomy. Finally, the long-term consequences and failure rates for AE have not been explored.

Given this variability, there remains no consensus on when to utilize AE for splenic injuries. Given the lack of consensus, our primary goal was to evaluate the use of this technique across U.S. trauma centers to study the relationship between patterns of AE use and splenectomy rates. We hypothesized that an association between splenectomy rates with the use of AE would be present. Furthermore, we aimed to explore if the association between AE and splenectomy rates would be affected by high or low utilization of AE at trauma centers.

Patients and methods

Data for this study were abstracted from the Committee on Trauma, American College of Surgeons, National Trauma Data Bank (Chicago, IL, 2013-2014). Patients were included in the study if they had International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) codes for splenic injury (865.0-865.2) and were 18 y or older. To avoid confounding by other injuries, we included only patients with isolated splenic injuries. Patients with an injury with an abbreviated injury score (AIS) of two or more in any other body system were therefore excluded. Patients were also excluded if they died in the emergency department. Because we were evaluating patients who were undergoing a nonoperative management plan on admission, patients undergoing emergent splenectomy were excluded from analysis. We further excluded patients from centers that did not perform any splenectomy or AE procedures. Because the ultimate splenectomy rate is dependent to some degree on splenectomy rates upon admission, a sensitivity analysis was performed analyzing rates of overall splenectomy and AE depending on centers' rates of immediate splenectomy. This was done by creating quartiles of centers based on the rate of patients who

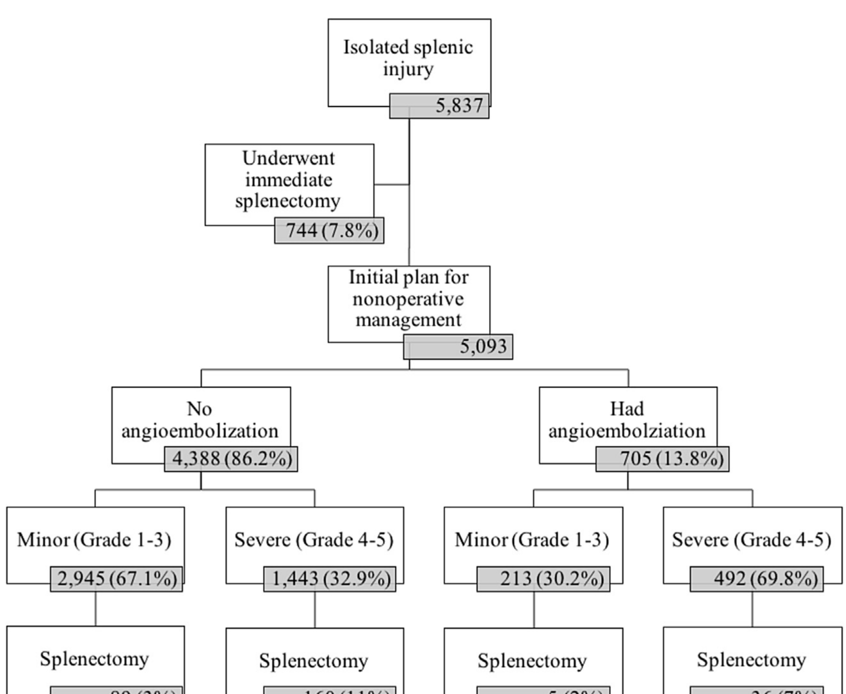

Fig. 1 – Flowchart of analytic cohorts after exclusion criteria and broken into subgroups by severity of splenic injury.

went from the emergency department to the operating room for urgent splenectomy.

Patient demographics, injury details, and center characteristics were collected for analysis. The primary outcome of interest was splenectomy. Procedures were identified using ICD-9-CM procedure codes for AE (88.4, 88.40, 88.47, and 39.79) and for splenectomy ICD-9-CM (41.5 and 41.43). Splenic injury severity was categorized as "minor" if the AIS score was ≤3 and "severe" for an AIS score of 4-5. To characterize patterns of AE, trauma centers were grouped into quartiles based on frequency of AE use in patients with splenic injuries.

We performed unadjusted analyses and mixed-effects logistical regression controlling for center effects. Variables used in regression models included demographic, hospital, and injury characteristics. The most parsimonious regression models were used. Stata does not allow for calculations of the area under the curve or Hosmer–Lemeshow statistics with the use of mixed-effects regression; therefore, the same variables were included in a logistic regression model not controlling for center. Using the logistic regression, model performance was established.

Statistical analysis was performed using Stata SE, version 14.1 (StataCorp, College Station, TX). The study was waived from formal review by the Stanford Institutional Review Board as the data were deidentified.

Results

In 2013 and 2014, there were a total of 5093 patients with isolated splenic injuries that did not undergo immediate

Table 1 – Demographic, injury, hospital, and outcome comparisons based on use of AE in isolated splenic injuries.

Variables	All patients, $n = 5093$	AE, $n = 705$ (13.8%)	No AE, $n = 4388$ (86.2%)	P value
Demographics, *n* (%)				
Age, years, mean (SD)	41.1 (18.6)	43.6 (18.2)	40.7 (18.7)	<0.001
Gender				
Male	3271 (64.2)	459 (65.2)	2812 (64.1)	0.285
Female	1821 (35.8)	245 (34.8)	1575 (35.9)	
Race				
White	3992 (81.0)	574 (84.2)	3417 (80.0)	<0.001
African American	381 (7.7)	38 (5.6)	343 (8.0)	
Other	557 (11.3)	70 (10.3)	512 (12.0)	
Injury characteristics, *n* (%)				
Spleen grade				
Minor (1 to 3)	3159 (62.0)	213 (30.2)	2945 (67.1)	<0.001
Severe (4 to 5)	1935 (38.0)	492 (69.8)	1443 (32.9)	
Hospital characteristics, *n* (%)				
ACS trauma designation				
Level I	2057 (65.3)	303 (71.6)	1753 (64.3)	0.025
Level II	1042 (33.1)	116 (27.4)	926 (34.0)	
Level III	51 (1.6)	4 (0.9)	47 (1.7)	
Bed size				
≤200	182 (3.6)	20 (2.8)	162 (3.7)	<0.001
201-400	1185 (23.3)	125 (17.7)	1060 (24.2)	
401-600	1481 (29.1)	188 (26.7)	1293 (29.5)	
>600	2246 (44.1)	372 (52.8)	1873 (42.7)	
Teaching				
Community	1948 (38.2)	276 (39.1)	1672 (38.1)	0.747
Nonteaching	610 (12.0)	79 (11.2)	531 (12.1)	
University	2536 (49.8)	350 (49.6)	2185 (49.9)	
Outcomes, *n* (%)				
Splenectomy	290 (5.7)	41 (5.8)	249 (5.7)	0.881
ICU LOS, days, mean (SD)	3.1 (5.7)	3.3 (4.2)	3.0 (6.0)	<0.001
Hospital LOS, days, mean (SD)	4.7 (5.5)	5.8 (5.1)	4.5 (5.6)	<0.001
Died	61 (1.9)	16 (3.5)	45 (1.6)	0.005

P <0.05 is considered significant.
SD = standard deviation; ACS = American College of Surgeons; ICU = intensive care unit; LOS = length of Stay.

splenectomy. AE was used in 705 (13.8%) of cases. Figure 1 demonstrates the analytic cohorts including pertinent subgroups. Table 1 compares patients who did and did not undergo AE with pertinent findings summarized below. Those patients who underwent AE were older (mean age 44 *versus* 41 y, $P < 0.001$), more often white (81% *versus* 78%, $P < 0.001$) and more often had a severe spleen injury (70% *versus* 33%, $P < 0.001$). Patients undergoing AE also had longer intensive care unit length of stay (3.3 *versus* 3.0 d, $P < 0.001$) and hospital length of stay (5.8 *versus* 4.5 d, $P < 0.001$). Overall mortality for all patients suffering a splenic injury was 1.2%. For patients undergoing splenectomy after initial admission, mortality was 6.6%; patients who had an AE procedure had a mortality of 2.3%.

A total of 290 (5.7%) patients initially managed nonoperatively ultimately required a splenectomy, but rates varied based on splenic injury severity. Patients with severe spleen injuries more often underwent splenectomy when compared to those with minor spleen injuries. (10.1% *versus* 3.0%, $P < 0.001$). We next evaluated whether splenectomy rates differed depending on whether a patient had AE. For the entire cohort, there was no statistical difference when evaluating rates of splenectomy in patients who had received an AE versus those who did not (5.8% *versus* 5.7%, $P = 0.576$). However, in evaluating the subgroup of patients with severe spleen injuries, splenectomy rates were significantly lower for patients who underwent AE compared to those who did not (Fig. 2; 7% *versus* 11%, $P = 0.017$). In mixed-effect logistical regression controlling for patient, injury, and center characteristics, patients with severe splenic injuries undergoing AE had a lower odds ratio (OR) for splenectomy (OR = 0.67, $P = 0.037$). These associations were not significant for patients with low-grade splenic injuries.

As use of AE varies between centers and may be a marker for differing thresholds to perform splenectomy, we divided centers into quartiles based on AE rates. The mean rates of AE at centers in the lowest *versus* highest quartiles were 0% and 37%, respectively. In unadjusted analyses, the rates of splenectomy ranged from 4.4% to 8.3% but were not significantly different ($P = 0.13$). We then included the quartile in a mixed-effects logistical regression model that controlled for center effects, age, gender, race, spleen AIS, mechanism of injury, and type of center (Table 2). Patients treated at centers in the highest quartile of AE use had a lower OR for splenectomy (OR = 0.58, $P = 0.02$). Furthermore, having AE at a high-quartile center was independently associated with a lower OR for splenectomy (OR = 0.46, P = 0.02).

We next conducted a sensitivity analysis around centers that perform a large number of immediate splenectomies, as a high immediate splenectomy rates may affect delayed splenectomy rates resulting in the introduction of bias. We stratified centers based on the proportion of patients who underwent immediate splenectomy. We found that the rate of immediate splenectomy ranges from 6% to 35% across centers. When these strata were included in the regression model, mentioned previously, AE remained significantly associated with lower rates of splenectomy (OR = 0.67, P = 0.04).

Discussion

This study evaluated national patterns of AE utilization for isolated splenic injuries and associated outcomes related to splenic preservation. We found that 14% of patients presenting with an isolated splenic injury not initially undergoing an immediate splenectomy had AE performed. For the group of patients with severe splenic injuries, splenectomy rates were 40% lower when AE was used (7% *versus* 11%). Furthermore, we demonstrated that patients treated at centers that frequently performed AE had lower splenectomy rates. Although the ability to draw a causative association between AE and splenic salvage is limited because of the retrospective nature of the data, these findings do support the single-center studies that show decreased splenectomy rates after initiation of protocols that utilize AE.

We also explored the possibility that centers that perform AE frequently may have a treatment bias toward spleen preservation, which would confound the ability to comment specifically about the effect of AE on splenic salvage. However,

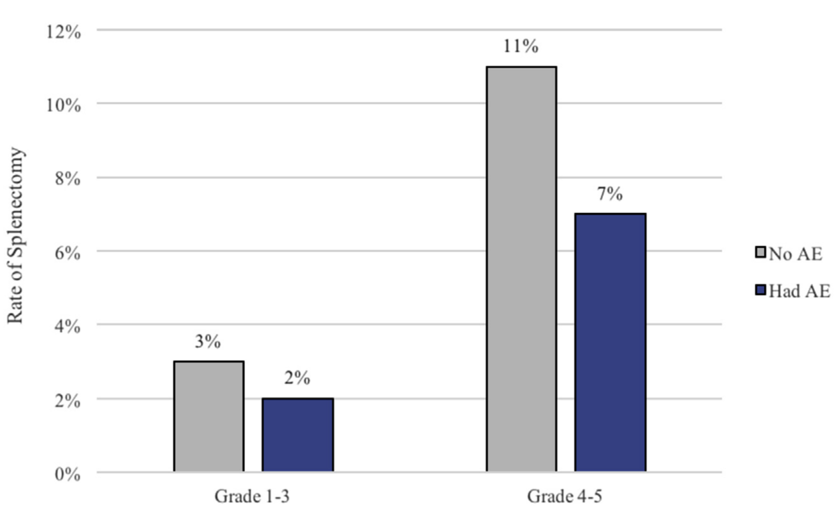

Fig. 2 – The rate of splenectomy in isolated splenic injuries initially managed nonoperatively depending on use of AE stratified by grade of splenic injury. (Color version of figure is available online).

Table 2 – Mixed-effect logistical regression analyzing adjusted risk of splenectomy while controlling for center effect based on quartiles for rate of AE use.

Variable	OR (95% CI)	*P* value
Age		
Mean	1.02 (1.01-1.03)	<0.01
Gender		
Male	Reference	~
Female	1.08 (0.82-1.43)	0.59
Ethnicity		
White	Reference	~
African American	0.55 (0.30-0.99)	0.05
Other	0.50 (0.20-1.27)	0.14
Mechanism of injury		
Motor vehicle trauma	Reference	~
Fall	1.84 (1.31-2.60)	<0.01
Struck	2.05 (1.34-3.12)	0.001
Cut	2.93 (1.47-5.84)	0.002
Pedal cyclist	0.49 (0.15-1.65)	0.25
Other	2.05 (1.37-3.05)	<0.01
Spleen grade		
1-3	Reference	~
4-5	4.54 (3.40-6.06)	<0.01
Quartile of immediate splenectomy		
1	Reference	~
2	1.36 (0.66-2.81)	0.40
3	0.84 (0.56-1.27)	0.42
4	0.58 (0.37-0.93)	0.02
Bed size		
≤200	Reference	~
201-400	1.22 (0.47-3.13)	0.68
401-600	1.25 (0.48-3.27)	0.64
>600	1.36 (0.48-3.27)	0.53
Teaching status		
Community	Reference	~
Nonteaching	1.30 (0.76-2.21)	0.34
University	0.59 (0.39-0.91)	0.02
ACS trauma designation		
Level I	Reference	~
Level II	0.65 (0.40-1.03)	0.07
Level III	0.41 (0.14-1.20)	0.10

$P < 0.05$ is considered significant.
CI = confidence interval; ACS = American College of Surgeons.

when we stratified centers based on rates of AE use, we found that in the highest tier quartile of centers performing AE, AE remained independently associated with reduced splenectomy rates. This suggests that while such a bias may exist, the relationship between AE and reduced splenectomy rates appears to hold true. Additional center-related factors may influence splenectomy rates at centers that perform AE frequently. For example, interventional radiologists at centers frequently performing the procedure may demonstrate improved expertise at controlling bleeding. Furthermore, experience of intensive care unit teams and 24-h resident coverage may influence the decision to continue nonoperative management.

We also considered the effect of immediate splenectomy rates on ultimate splenectomy rates. We found that the likelihood of ultimately having a splenectomy is higher at centers in the highest quartile for frequency of immediate splenectomy. This observation argues that there are differences either in patient characteristics or in the threshold to perform splenectomies at centers with high *versus* low rates of immediate splenectomies. Despite these differences, we found that the association between AE and splenectomy did not change when stratified based on these immediate splenectomy rates.

This study was not able to address some important questions regarding the use of AE in splenic injuries. For example, do the costs and complications associated with AE outweigh the benefits of improved splenic salvage? AE is not without risks including contrast nephropathy, splenic infarct, splenic abscess, and groin percutaneous access hematoma or infection.[1,12,13] On the contrary, splenectomies also carry risks including intraabdominal abscess, pancreatic injury, iatrogenic injuries, bleeding, and later complications such as adhesive small bowel obstruction and abdominal wall hernias.[13] Further evaluation of treatment-related outcomes would need to take into consideration these complications to fully inform the development of future protocols. Our findings also suggest that accurate identification of specific patient populations who may benefit the most from AE would be important.

This study has several limitations. First, it is a retrospective observational review subject to the limitations inherent to retrospective studies. In addition, we were limited by ICD-9-CM procedure codes, specifically for details regarding AE. The analysis and conclusions are based only on isolated splenic injuries. It may be that associations are different when applied to the polytrauma patient with a splenic injury. Conducting the same analysis in the future may be facilitated by the fact that procedural data will be coded in ICD-10 Procedure Coding System (ICD-10-PCS). The ICD-10-PCS codes for body parts and would allow for more specific identification of AE location and for analysis of all patients with splenic injuries. Inclusion of a cohort of isolated splenic injuries likely underestimates the rate of splenectomy when patients are managed nonoperatively because consideration of other injured structures affects decisions related to the management of the spleen. Other studies that included polytrauma spleen injuries report rates of failure of nonoperative management as high as 20%.[1,3,4,14] Although results of studies from the National Trauma Data Bank provide important insights into management trends, any causal relationships cannot be specifically determined. However, this study approaches the question of AE and its role in spleen-injured patients in a novel way. The observed variation in the use of AE for isolated splenic injuries provides a natural experiment by which we were able to observe associated splenectomy rates depending on use of AE.

Conclusions

These findings suggest that AE is associated with improved splenic salvage in patients with isolated injures, specifically grade 4-5 splenic injuries. Furthermore, patients at centers who frequently use AE experience the greatest benefit. Further research is required to identify the ideal patient population where risks of splenectomy are balanced with cost, possible complications, and patient satisfaction.

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Disclosure

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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