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Angioembolization for splenic injuries: does it help? Retrospective evaluation of grade III–V splenic injuries at two level I trauma centers

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ABSTRACT

Background Splenic angioembolization (SAE) has increased in utilization for blunt splenic injuries. We hypothesized lower SAE usage would not correlate with higher rates of additional intervention or mortality when choosing initial non-operative management (NOM) or surgery.

Study design Trauma registries from two level I trauma centers from 2010 to 2020 were used to identify patients aged >18 years with grade III–V blunt splenic injuries. Results were compared with the National Trauma Data Bank (NTDB) for 2018 for level I and II centers. Additional intervention or failure was defined as any subsequent SAE or surgery. Mortality was defined as death during admission.

Results There were 266 vs 5943 patients who met inclusion/exclusion criteria at Stanford/Santa Clara Valley Medical Center (SCVMC) versus the NTDB. Initial intervention differed significantly between cohorts with the use of SAE (6% vs 17%, p=0.000). Failure differed significantly between cohorts (1.5% vs 6.5%, p=0.005). On multivariate analysis, failure in NOM was significantly associated with NTDB cohort status, age 65+ years, more than one comorbidity, mechanism of injury, grade V spleen injury, and Injury Severity Score (ISS) 25+. On multivariate analysis, failure in SAE was significantly associated with Shock Index >0.9 and 10+ units blood in 24 hours. On multivariate analysis, a higher risk of mortality was significantly associated with NTDB cohort status, age 65+ years, no private insurance, more than one comorbidity, mechanism of injury, ISS 25+, 10+ units blood in 24 hours, NOM, more than one hospital complications, anticoagulant use, other Abbreviated Injury Scale ≥3 abdominal injuries.

Conclusions Compared with national data, our cohort had less SAE, lower rates of additional intervention, and had lower risk-adjusted mortality. Shock Index >0.9, grade V splenic injuries, and increased transfusion requirements in the first 24 hours may signal a need for surgical intervention rather than SAE or NOM and may reduce mortality in appropriately selected patients.

Level of evidence Level II/III.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Splenic angioembolization (SAE) is a useful clinical treatment in appropriately selected patients with blunt splenic trauma; however, the overuse of SAE has been associated with treatment-related complications, increased resource utilization, and failure of initial treatment modality when compared with surgical intervention.

WHAT THIS STUDY ADDS

⇒ This study found that a lower rate of SAE and a higher rate of non-operative management (NOM) does not increase the failure rate of initial treatment modality or risk-adjusted mortality.

⇒ In addition, the failure of initial treatment and mortality were associated with clinical variables including spleen injury grade V, Shock Index >0.9, and 10+ units of blood in 24 hours.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study suggests that lower rates of SAE, higher rates of NOM, and early surgical intervention in appropriately selected patients may decrease the rate of initial treatment failure and mortality.

⇒ Clinical variables for early risk stratification into surgical treatment should be externally validated and used.

INTRODUCTION

Every year in the USA, >40 000 patients present to the hospital with splenic trauma, with approximately 5000 presenting with an isolated injury.[1 2] Of patients presenting with any splenic injury, approximately 30% are managed with emergency splenectomy.[1 3] Initial management strategies are often determined by hemodynamic stability and the presence of active bleeding.[3 4] Hemodynamically unstable patients may be managed with surgery or splenic angioembolization (SAE), however, patients not undergoing emergency splenectomy may be considered for non-operative management (NOM) or SAE.[3 5] Surgical management of spleen injury may include splenectomy, splenorrhaphy, or splenic auto transplant, although the latter two techniques have seen significant reductions in practice patterns over the last 40 years.[6] The use of selective SAE for stable grade III or higher injuries has become more common practice. Since its introduction in the 1980s, SAE has grown to be used in over 10%–30% of stable blunt splenic injury (BSI). Recently, the World Society on Emergency Surgery (WSES) has recommended SAE for the following definitions: (1) WSES II–III and American Association for the Surgery of Trauma

(AAST) ≥III with any contrast extravasation or vascular injuries and (2) WSES III and AAST IV–V regardless of contrast extravasation.[7] In 2018, AAST guidelines for grading splenic injuries were changed to include imaging criteria to include any injury in the presence of splenic vascular injury or active bleeding confined within the splenic capsule, which effectively makes AAST vascular injuries that were not bleeding previously as grade III into a grade IV.[8] There is some controversy as to whether SAE is underused versus overused, in particular in stable high-grade injuries with some centers advocating for prophylactic use.[9–12]

Systematic reviews have found that the 'failure' of NOM, defined as needing a procedure after an initial management strategy, ranges from 8% to 18%. Regarding the use of SAE, a meta-analysis found no significant difference in the failure rate when comparing SAE with NOM, although individual studies have found benefits to SAE.[2 13–17] Other studies have suggested that SAE may be cost-effective when compared with patients requiring additional intervention after NOM and proceeding to splenectomy.[18–20] Previously, groups have examined the causes of failure of NOM or SAE, thromboelastography (TEG)-directed resuscitation to improve outcomes, and prospective and retrospective evaluation of SAE and the need for additional intervention.[21–38] However, the prediction of failure of SAE patients remains a challenge.

At our training program, we use NOM without SAE and do not seem to experience the need for reintervention when compared with published rates. We hypothesized our practice pattern of patient selection, management, and low rates of SAE utilization would not result in significant increases in additional intervention or mortality. To answer this question, we compared our local experience with data from the National Trauma Data Bank (NTDB).

METHODS

Study design and patient population

A comparison cohort was generated using the NTDB from 2018, as this was the most recent audited data available. For both cohorts, we included all patients with a diagnosis of BSI by International Classification of Diseases (ICD) Clinical Modification (CM) code V.9 (2010–2015) or V.10 (2016–2020) and Abbreviated Injury Scale (AIS) code (online supplemental file 1). Exclusion criteria included patients <18 years or >89 years, spleen injury grade <III, patients who died in the emergency department, pregnant patients, prisoners, patients with penetrating injuries, and patients not treated at level I or II trauma centers. Patients with missing data related to interventions or exclusion criteria were also excluded.

Variables analyzed included gender, age, race, ethnicity, insurance, comorbidities, mechanism of injury, severity of splenic injury, complications, Injury Severity Score (ISS), other abdominal injuries with severity ≥3, systolic blood pressure (SBP) and heart rate (HR) on admission, length of stay (LOS), and blood products used in the first 24 hours. Shock Index was calculated as HR divided by SBP. Blood products were converted to binary variables for logistic regression with a cut-off of 10 units of blood for the highest category (equal to the definition of massive transfusion) and two lower thresholds with other products dichotomized in a 1:1:1 ratio. Of note, this threshold was intended to identify patients with large volume transfusion and does not represent centers' transfusion triggers. Procedure codes were obtained using ICD-9-CM and ICD-10-CM procedure codes (online supplemental file 1). The procedures identified included splenectomy, splenorrhaphy, and interventional radiology-directed angioembolization.

Patients were stratified by initial management strategy within the first 24 hours which included any splenic operation, SAE, or NOM. Additional intervention or failure was considered as the need for any SAE or surgery after 24 hours.

Statistical analysis

All data analysis was completed using Microsoft Excel and STATA/SE V.17.0 (College Station, Texas, USA). Categorical variables were summarized as frequencies or percentages while continuous variables were summarized with mean and SD or median and IQR as needed based on parametric or non-parametric status. Baseline patient characteristics were compared using univariate analysis. Univariate analysis was performed with χ^2 test, t-test, or Wilcoxon Rank Sum test with $p<0.05$ considered significant.

Multivariable regression analysis was conducted to control for confounding using after conversion to categorical variables including NTDB status, gender, age, race, ethnicity, insurance, number of comorbidities, mechanism of injury, severity of splenic injury, ISS, Shock Index on admission, other abdominal injuries, anticoagulant use on history, and blood products used in the first 24 hours when evaluating failure of initial management or selection into initial management groups. Mortality was analyzed using variables with presenting characteristics, initial management, transfusions, and hospital complications. There were missing data for some patients in transfusion characteristics and vitals, which were analyzed as non-zero missing variables and not included in univariate or multivariable analysis. The NTDB had missing values for intensive care unit LOS, which were considered as zero if there were data in the total LOS field. All data were collected from standardized databases used for reporting to the NTDB at each hospital, de-identified, and consolidated to reduce risk of bias. Loss to follow-up may have occurred with patients transferring care to another hospital after discharge resulting in additional procedures or complications. Subgroup analyses included assessing patients receiving initial NOM or SAE for predictors of failure.

Sensitivity analyses were performed using multivariate regression analyses when univariate results had differences. The rate of initial SAE or surgical intervention was assessed by multivariate regression to determine if confounding factors were related to our lower utilization rate. Confounding variables between groups were assessed using multivariate regression to determine their impact on failure of NOM, SAE, and mortality. Sensitivity analysis was not possible on the failure of initial SAE between cohorts due to limitations in incidence rate and sample size and the cohort variable was not calculable for that analysis.

RESULTS

After inclusion and exclusion criteria were applied, a total of 266 patients at Stanford/SCVMC and 5943 patients in the NTDB were identified (figure 1; table 1). On univariate analysis, several variables were significantly different between the Stanford/SCVMC cohort versus NTDB including demographics, insurance status, comorbidities, mechanism of injury, ISS, and SBP.

Initial management of BSI with NOM, surgery, or SAE was significantly different than the NTDB patients and those at our institutions (table 2). Differences in SAE utilization was assessed through multivariate analysis with similar significant findings (online supplemental file 1). Furthermore, there appeared to be a trend in increased utilization of SAE in the NTDB cohort when

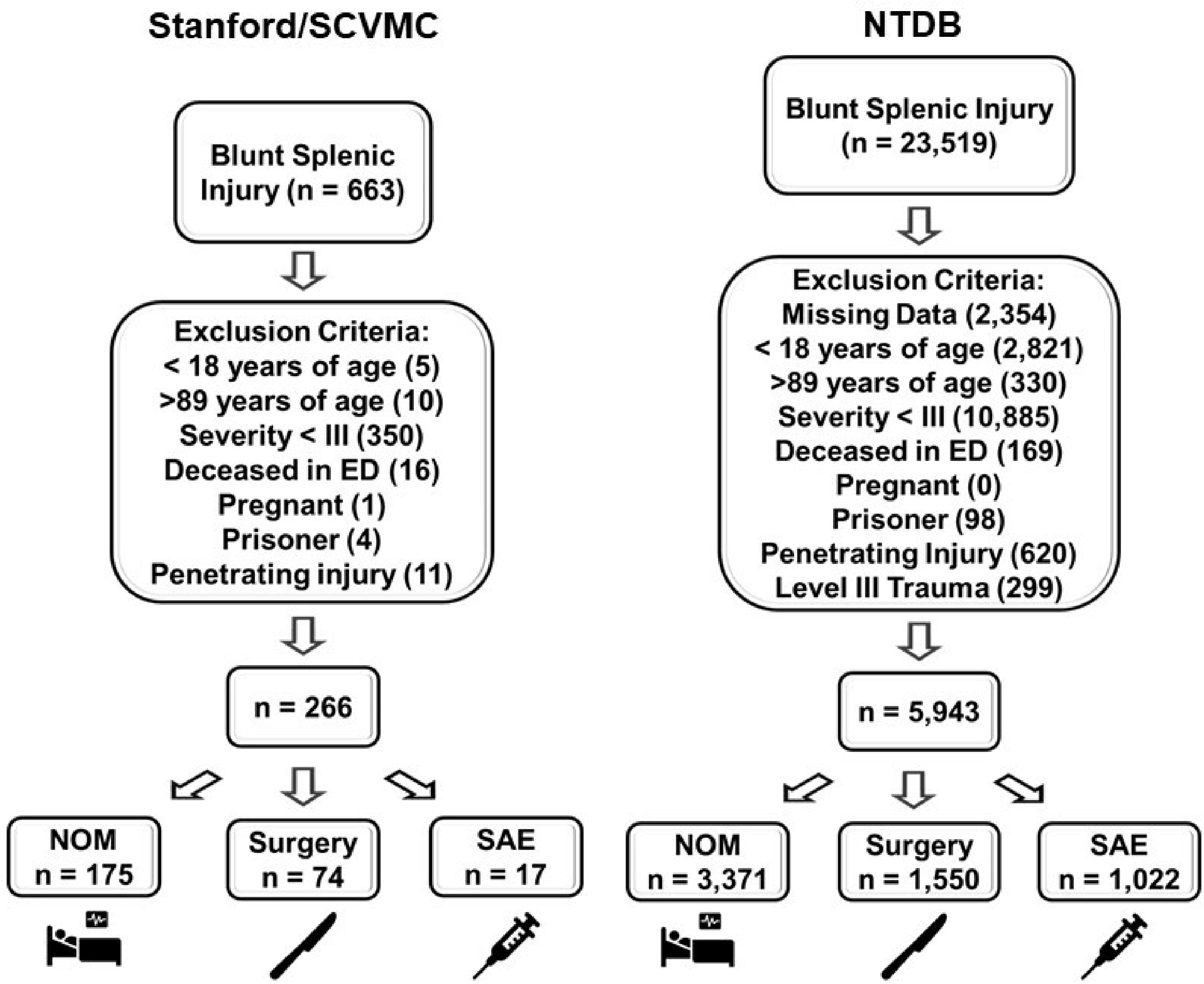

Figure 1 Stanford/SCVMC versus NTDB BSI patient inclusion and exclusion. 663 patients were initially found over 10 years during retrospective review. Patients were excluded based on age, early mortality, instability, or other factors which preclude them from study. 23 519 patients were initially found in the NTDB for 2018. Patients were similarly excluded. BSI, blunt splenic injury; ED, emergency department; NOM, non-operative management; NTDB, National Trauma Data Bank; SAE, splenic angioembolization; SCVMC, Santa Clara Valley Medical Center.

stratified by severity of injury or splenic grade (figure 2A,B). Similar stratification appeared to show a trend in increased need for re-intervention in the NOM and SAE groups for the NTDB (figure 2C,D).

Multivariate logistic regression was conducted to ascertain factors associated with failure of NOM or SAE by controlling for confounding variables including cohort status (table 3). Independent variables included NTDB status, age, gender, race, ethnicity, insurance, comorbidities, mechanism of injury, spleen AIS score, ISS score, Shock Index, other abdominal injuries, anticoagulant history, and transfusion parameters. Failure of NOM was significantly associated with NTDB cohort status, age 65+ years, more than one comorbidity, grade V spleen injury, and ISS 25+. Failure in SAE was significantly associated with Shock Index >0.9 and 10+ units of blood in 24 hours.

Multivariate logistic regression was conducted to ascertain factors associated with mortality (table 4). Independent variables included NTDB status, age, gender, race, ethnicity, insurance, comorbidities, mechanism of injury, spleen AIS score, ISS score, Shock Index, and transfusion parameters. Mortality was significantly associated with NTDB cohort status, age 65 years or older, race—not available, non-private insurance, more than one comorbidity, mechanism of injury, ISS 25+, grade V injury, Shock Index >0.9, 10 or more units blood transfused in 24 hours, NOM, hospital complications, anticoagulant history, and the presence of any other severe abdominal injury as defined by abdominal AIS of 3 or more (table 4). Although abdominal injuries AIS ≥3 were associated with mortality, this particular variable was not associated with NOM failure, SAE failure, and surgery utilization. However, patients with SAE were less likely to have AIS of 3 or more injuries (0.69, p=0.000). This suggests that other significant abdominal injuries were not overall associated with splenic treatment plans. However, it is likely that there were cases where other significant injuries in the abdomen did drive a decision to perform a splenectomy or not.

DISCUSSION

Compared with national data, our cohort has less SAE and lower rates of additional intervention, and had lower risk-adjusted

Table 1 Characteristics of the study populations

Characteristic	Sample size (n/n)	Stanford/ SCVMC	NTDB	Univariate (p value)
Age, years, median (IQR)	266/5943	41 (28–56)	39 (27–56)	0.869
Sex, n (%)	266/5943			0.023*
Female		68 (26)	1913 (32)	_
Male		198 (74)	4030 (68)	_
Race, n (%)	266/5943			0.000*
White		189 (71)	4678 (79)	_
Asian		22 (8)	97 (2)	_
Other†		55 (21)	1168 (19)	_
Ethnicity, n (%)†	266/5943			0.000*
Hispanic		64 (24)	681 (11)	_
Non-Hispanic		199 (75)	5017 (84)	_
Spleen AIS, n (%)	266/5943			0.371
III		148 (56)	3558 (60)	_
IV		74 (28)	1527 (26)	_
V		44 (16)	858 (14)	_
Mechanism, n (%)	266/5943			0.000*
MVC		84 (32)	2893 (49)	_
MCC		65 (24.4)	816 (14)	_
Fall		49 (18)	1173 (20)	_
Pedestrian		24 (9.0)	391 (7)	_
Bicycle		22 (8.3)	112 (2)	_
Other blunt		22 (8.3)	558 (9)	_
ISS, n (%)†	266/5943			0.002*
9–15		38 (14)	1299 (22)	_
16–24		77 (29)	1853 (31)	_
≥25		151 (57)	2791 (47)	_
SBP mm Hg, mean (SD)	244/5829	126 (28)	121 (27)	0.006*
HR, bpm, mean (SD)	264/5850	95 (24)	97 (24)	0.186
Blood, first 4 hours, median (IQR)	266/5710	0 (0–2)	0 (0–2)	0.694
Blood, first 24 hours, median (IQR)	260/5710	0 (0–2)	0 (0–2)	0.637
Outcomes				
Mortality, n (%)	266/5943	16 (6.0)	492 (8.3)	0.188
LOS, days, median (IQR)	266/5872	6.5 (4–14)	7 (4–12.5)	0.118
ICU LOS, days, median (IQR)	266/5922	3 (1–5)	3 (1–6)	0.716

*Statistically significant.
†Some numbers too small to report <10.
AIS, Abbreviated Injury Scale; HR, heart rate; ICU, intensive care unit; ISS, Injury Severity Score; LOS, length of study; MCC, motorcycle collision; MVC, motor vehicle collision; NTDB, National Trauma Data Bank; SBP, systolic blood pressure; SCVMC, Santa Clara Valley Medical Center.

mortality. This is consistent with our hypothesis that performing SAE less frequently does not result in increased failure or mortality. This is in contrast to suggestions that SAE reduces the need for later interventions.[23–25 32 36–38] The differences in initial SAE strategy may reflect a difference in patient populations as reflected in table 1. Although grading changes by the AAST may have changed the distribution of III–V injuries, we did not find a difference in our cohort when compared with the NTDB. Our grading criteria has stayed consistent with the guidelines as required. However, multivariate analysis verified increased utilization of SAE in the NTDB cohort (2.79 OR, 95% CI 1.68 to 4.66, p=0.000, online supplemental file 1) despite higher rates of ISS 25+ on univariate analysis in our cohort (table 1). Unmeasured variables may also contribute to this finding.

Table 2 Management in first 24 hours and need for additional intervention

Characteristic	Sample size (n/n)	Stanford/ SCVMC	NTDB	Univariate (p value)
Intervention in first 24 hours, n (%)	266/5943			0.000*
NOM		175 (66)	3371 (57)	_
Surgery		74 (28)	1550 (26)	_
SAE		17 (6)	1022 (17)	_
Need for intervention after 24 hours based on initial treatment, n (%)	266/5943			0.008*
NOM		3 (1.1)	286 (4.8)	_
Surgery		1 (0.4)	16 (0.3)	_
SAE		0 (0)	82 (1.4)	

*Statistically significant.
NOM, non-operative management; NTDB, National Trauma Data Bank; SAE, splenic angioembolization; SCVMC, Santa Clara Valley Medical Center.

The failure of NOM and/or SAE may contribute to improving practice management in our clinical practices and nationally. Other than NTDB status, failure of NOM was associated with age 65+ years, more than one comorbidity, mechanism of injury, grade V spleen injury, and ISS 25+ while plasma transfusion was not significant (p=0.063) (table 3). Thus, patients with grade V spleen injury, increased comorbidities, age 65+ years, and complex injuries may be candidates for SAE and/or surgery. Many of these variables are non-modifiable factors related to older patients with comorbidities and complex injuries and thus may constitute a population of patients that may have poorer response to bleeding injuries or coagulopathy and require earlier risk stratification. In addition, older patients have an altered hemodynamic response that may underestimate the extent of their injuries and may reflect other institutional or cultural factors such as permissive hypotension, threshold for intervention (surgery or SAE), and other unmeasured confounders. Defining failure can be challenging, because in this case the definition of 'failure' is based the decision to make another intervention. The threshold to perform a procedure may vary center-by-center or surgeon-by-surgeon. Furthermore, there are likely interactions and associations within a center around decisions to perform SAE versus splenectomy. For example, a center that more frequently uses SAE may also have a lower threshold to operate. Therefore, interpreting any splenic injury data that uses failure should be interpreted with this nuance in mind. Compared with the Splenic Arterial Embolization to Avoid Splenectomy (SPLASH) trial where 35% of III–IV injuries require SAE after observation, we have rates of 8.9% in our cohort vs 23% in the NTDB.[37] Given the structure of the trial when compared with our analytic methods which include some potentially unstable patients that may have received surgery and/or SAE and unclear end points determined for failure, our results are not directly comparable. However, we did find that in a real-world cohort a higher rate of NOM did not consequently result in a need for additional SAE, although our cohort patients do appear to be older than the SPLASH trial, for example, 41 (28–56) vs 30 (22–42).[37] Thus, our results support the conclusion that delayed SAE does not necessarily result in increased failure rates of SAE.

Failure of SAE was associated with Shock Index >0.9 and 10+ units of blood in 24 hours (table 3). Thus, these two clinical variables may pose a viable stratification for early surgical intervention, especially for patients that may not meet the massive

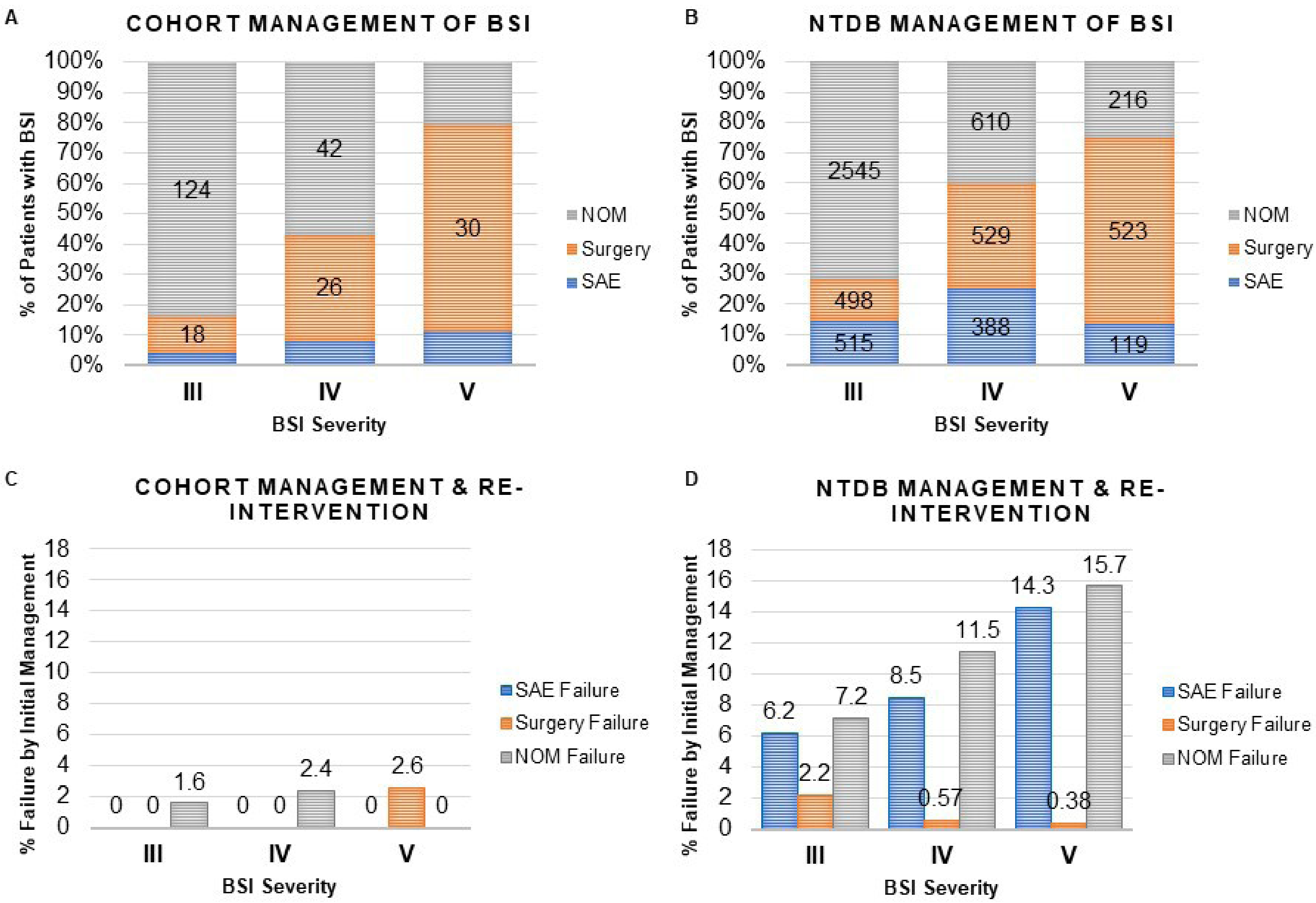

Figure 2 Management of BSI and treatment failure. (A, B) Management of BSI in the Stanford/Santa Clara Valley Medical Center and NTDB cohorts are stratified by severity of injury and type of initial intervention. (C, D) The number of patients undergoing initial management by strategy were compared with patients failing by severity of injury revealing a trend of increasing failure in the NTDB cohort. BSI, blunt splenic injury; NOM, non-operative management; NTDB, National Trauma Data Bank; SAE, splenic angioembolization.

transfusion protocol early and continue to bleed at a slower rate in the first 24 hours. Although Shock Index has previously been validated as predictive for SAE failure, these two clinical variables have not been validated in combination.[21] Further evaluation with a coagulopathy-based measurement such as TEG may allow for additional information on bleeding and failure risk.

Compared with national data, our cohort had lower risk-adjusted mortality (table 4). Although there was a higher rate of SAE in the NTDB, there was no difference in the utilization of surgery in multivariable analysis between cohorts (online supplemental file 2). Thus, our cohort had a higher rate of NOM and still had risk-adjusted lower mortality. Mortality was significantly associated with NTDB cohort (vs Stanford/SCVMC), age 65 years or older, non-private insurance, more than one comorbidity, mechanism of injury, ISS 25+, grade V injury, Shock Index >0.9, 10 or more units blood transfused in 24 hours, NOM, hospital complications, anticoagulant history, and the presence of any other severe abdominal injury as defined by abdominal AIS of 3 or more (table 4). Although abdominal injuries AIS ≥3 were associated with mortality, this variable was not associated with NOM failure, SAE failure, surgery utilization, or NOM utilization. However, patients with SAE were less likely to have AIS of 3 or more injuries (0.69, p=0.000) (online supplemental file 1). Although the effect of this variable on surgical intervention was not significant (online supplemental file 2), it is our opinion that other significant injuries in the abdomen may play a role in the choice of splenectomy. The association between mortality and the decision to forgo operative management for splenic injury is likely complicated by unmeasured confounders. For example, it may have been that those with severe traumatic brain injury (TBI) or those with Do not resuscitate/do not intubate (DNR/DNI) status were in the process of discussing goals of care. This would be difficult to discern from the data. Other confounding variables may have included other relevant factors such as perceived futility from other injuries. SAE and surgery appear to decrease the rate of mortality on multivariate analysis (table 4). However, we do not believe that intervention alone is the cause for this effect. For example, in our sensitivity analyses we found that our cohort has higher rates of NOM, lower rates of SAE, and no difference in surgery when accounting for confounding clinical variables (online supplemental file 1). However, our cohort still does appear to have lower mortality when compared with the NTDB, again accounting for confounding clinical variables (table 4). Thus, it appears there may be unmeasured confounders in NOM that may result in improved outcomes in addition to using intervention on appropriate risk stratified patients. Due to the limitations of the study, we are unable to recommend or state that more conservative approach may be warranted in certain cases and should be considered alongside clinical and patient factors. One of the three risk factors for mortality are shared with the risk of SAE failure, thus, these patients may be early candidates

Table 3 Logistic regression on factors associated with additional intervention (surgery or SAE) after NOM or SAE

Initial strategy (n=3308/831)	Initial NOM strategy that required later intervention			Initial SAE strategy that required later intervention		
Characteristic	**OR**	**95% CI**	**P value**	**OR**	**95% CI**	**P value**
NTDB cohort (vs Stanford/SCVMC)	4.58	1.42 to 14.6	0.010*	1	Omitted	_
Age 18–25 years	0.49	0.29 to 0.83	0.008*	_	_	_
Age 26–35 years	0.69	0.43 to 1.09	0.118	_	_	_
Age 36–49 years	0.77	0.49 to 1.22	0.267	_	_	_
Age 50–64 years	0.95	0.62 to 1.45	0.805	_	_	_
Age 65+ years	1	Reference	_	_	_	_
Race—N/A	1.09	0.41 to 2.94	0.857	_	_	_
Race—other	0.74	0.41 to 1.35	0.324	_	_	_
Race—Asian	1.65	0.68 to 4.04	0.272	_	_	_
Race—black	1.11	0.71 to 1.73	0.646	_	_	_
Race—white	1	Reference	_	_	_	_
Comorbidity (one)	2.15	1.52 to 3.04	0.000*	_	_	_
Comorbidity (two+)	2.27	1.57 to 3.28	0.000*	_	_	_
Comorbidity (none)	1	Reference	_	_	_	_
Mechanism—motor vehicle	0.56	0.36 to 0.85	0.007*	_	_	_
Mechanism—motorcycle	0.57	0.34 to 0.97	0.040*	_	_	_
Mechanism—fall	0.67	0.42 to 1.04	0.077	_	_	_
Mechanism—pedestrian	0.73	0.39 to 1.38	0.329	_	_	_
Mechanism—bicycle	0.23	0.05 to 0.98	0.047*	_	_	_
Mechanism—blunt other	1	Reference	_	_	_	_
Spleen AIS III	0.41	0.25 to 0.65	0.000*	0.42	0.16 to 1.07	0.068
Spleen AIS IV	0.63	0.39 to 1.03	0.066	0.70	0.33 to 1.49	0.355
Spleen AIS V	1	Reference	_	1	Reference	_
ISS—9–15	0.64	0.41 to 0.98	0.040*	_	_	_
ISS—16–24	0.93	0.66 to 1.29	0.661	_	_	_
ISS ≥25	1	Reference	_	_	_	_
Shock Index (<0.5)	0.88	0.49 to 1.58	0.693	1	Omitted	_
Shock Index (0.5–0.9)	0.97	0.71 to 1.33	0.860	0.44	0.26 to 0.74	0.002*
Shock Index (>0.9)	1	Reference	_	1	Reference	_
Blood 24 hours (0–2 units)	12.1	0.33 to 449	0.177	0.01	0.00 to 0.31	0.007*
Blood 24 hours (3–9 units)	13.9	0.39 to 502	0.149	0.06	0.03 to 1.04	0.053
Blood 24 hours (10+ units)	1	Reference	_	1	Reference	_
Plasma 24 hours (0–2 units)	0.03	0.00 to 1.21	0.063	_	_	_
Plasma 24 hours (3–9 units)	0.04	0.00 to 1.64	0.089	_	_	_
Plasma 24 hours (10+ units)	1	Reference	_	_	_	_
Anticoagulant history	1.06	0.54 to 2.08	0.855	0.57	0.16 to 2.04	0.391
Any abdominal injury AIS ≥3	1.22	0.83 to 1.79	0.315	1.71	0.83 to 3.52	0.144

*Statistically significant, only selected variables shown.
AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; N/A, not available; NOM, non-operative management; NTDB, National Trauma Data Bank; SAE, splenic angioembolization; SCVMC, Santa Clara Valley Medical Center.

for surgical intervention rather than SAE. Further validation of a coagulopathy or bleeding risk-related early surgical intervention model may provide further evidence on preventing early mortality after non-penetrating injury in trauma with BSI.

Limitations of this study include inability to measure coagulopathy directly, between-cohort differences, differing time period of patient management, for example, 2010–2020 (Stanford/SCVMC) vs 2018 (NTDB), and inability to account for management after index discharge. Stevens *et al* did find that TEG-directed management of blunt organ injury in pediatric patients may improve outcomes.[34] However, this finding has not been replicated in adult patients and we lacked the data to validate this finding. The differences between cohorts were accounted for by using multivariate analyses conducted in this study to validate our findings on initial management, failure, and mortality. However, unmeasured confounders such as differences in medical management could not be accounted for based on the design of this study. In addition, our study was not designed with the intent of understanding the causes of mortality in BSI and this finding requires further study in an appropriately designed cohort. For example, unmeasured confounders include TBI, DNR/DNI status, futility, and other factors that may have resulted in low rates of surgery in the non-operative cohort. Finally, the time period of data collection was different and may reflect a difference in practice. Although this may influence the overall rates of utilization of practices such as SAE, it would not explain differences in mortality or failure of initial management strategy. Furthermore, the predictors of failure of SAE primarily used data from the NTDB cohort due to the requirements of multivariable logistic regression and sample size. Although additional interventions or treatments may have occurred after initial discharge, the data analyzed from both cohorts are similarly

Table 4 Logistic regression on factors associated with mortality

Characteristic (n=5704)	OR	95% CI	P value
NTDB cohort (vs Stanford/SCVMC)	2.62	1.22 to 5.64	0.013*
Age 18–25 years	0.22	0.14 to 0.33	0.000*
Age 26–35 years	0.16	0.10 to 0.24	0.000*
Age 36–49 years	0.20	0.13 to 0.31	0.000*
Age 50–64 years	0.33	0.23 to 0.48	0.000*
Age 65+ years	1	Reference	–
Race—N/A	2.59	1.35 to 4.99	0.004*
Race—other	0.88	0.52 to 1.47	0.616
Race—Asian	1.31	0.58 to 2.95	0.510
Race—black	1.40	0.97 to 2.03	0.071
Race—white	1	Reference	–
Public insurance	1.39	1.04 to 1.87	0.024*
No insurance	2.30	1.62 to 3.27	0.000*
Other insurance	3.12	1.69 to 5.75	0.000*
Private insurance	1	Reference	–
Comorbidity (one)	0.42	0.29 to 0.58	0.000*
Comorbidity (two+)	0.66	0.48 to 0.90	0.010*
Comorbidity (none)	1	Reference	–
Mechanism—motor vehicle	2.27	1.11 to 4.62	0.024*
Mechanism—motorcycle	1.90	0.89 to 4.04	0.095*
Mechanism—fall	1.38	0.64 to 2.95	0.413
Mechanism—pedestrian	4.02	1.86 to 8.68	0.000*
Mechanism—bicycle	0.48	0.06 to 4.09	0.501
Mechanism—blunt other	1	Reference	–
ISS—9–15	0.13	0.07 to 0.24	0.000*
ISS—16–24	0.29	0.19 to 0.42	0.000*
ISS ≥25	1	Reference	–
Spleen AIS III	1.02	0.73 to 1.43	0.892
Spleen AIS IV	0.63	0.45 to 0.91	0.013*
Spleen AIS V	1	Reference	–
Shock Index (<0.5)	1.60	0.96 to 2.67	0.068
Shock Index (0.5–0.9)	0.91	0.69 to 1.19	0.497
Shock Index (>0.9)	1	Reference	–
Blood 24 hours (0–2 units)	0.59	0.19 to 1.83	0.367
Blood 24 hours (3–9 units)	0.45	0.22 to 0.90	0.024*
Blood 24 hours (10+ units)	1	Reference	–
Splenic angioembolization	0.43	0.27 to 0.68	0.000*
Spleen surgery	0.66	0.48 to 0.92	0.012*
Hospital complication (one)	2.09	1.57 to 2.78	0.000*
Hospital complication (two+)	1.94	1.37 to 2.73	0.000*
Hospital complication (none)	1	Reference	–
Anticoagulant history	2.11	1.25 to 3.57	0.005*
Any abdominal injury AIS ≥3	1.06	0.79 to 1.42	0.012*

*Statistically significant, only selected variables shown.
AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; N/A, not available; NTDB, National Trauma Data Bank; SAE, splenic angioembolization; SCVMC, Santa Clara Valley Medical Center.

reported and neither included data for follow-up in our analysis. However, this clinical question was assessed with the clinical trial conducted by Arvieux *et al* with 1-month follow-up of treatment and injury.[37]

CONCLUSIONS

This study found that a lower rate of SAE and higher rate of NOM in our cohort does not increase the failure rate of initial treatment modality or risk-adjusted mortality. In addition, the failure of initial treatment and mortality were associated with clinical variables including spleen injury grade V, Shock Index >0.9, and 10+ units of blood in 24 hours. This may be used to stratify patients to select for early surgical treatment.

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