Outcomes after splenic injury in geriatric trauma: Is splenic embolization helpful?

Nicholas J. Larson, BA, NREMT, Ella Chrenka, MS, David J. Dries, MD, MSE, FACS, MCCM, Benoit Blondeau, MD, MBA, FACS, *and* **Frederick B. Rogers, MD, MS, MA, FACS***, Saint Paul, Minnesota*

BACKGROUND: The spleen is one of the most frequently injured organs in abdominal trauma and is often managed nonoperatively with low rates of failure. A common adjunct to nonoperative management (NOM) is splenic artery embolization (SAE) which is controversial in some patient groups. We hypothesized that SAE would confer no benefit in elderly trauma patients undergoing NOM.

METHODS: This retrospective cohort study included patients in years 2019 to 2022 of the Trauma Quality Improvement Program database presenting after splenic trauma stratified into adult (age, 15–64 years) and elderly (age ≥65 years) cohorts. A cox proportional hazards model was used to estimate the adjusted odds of in-hospital mortality, up to 30 days, associated with age and management strategy. An interaction term between age group and management strategy allowed for evaluation of differential associations between cohorts. Secondary analysis focused on identification of predictors of NOM failure and potential differences between the age cohorts examined.

RESULTS: This study analyzed 65,421 adult and 11,813 elderly patients with splenic trauma. Age was a significant predictor of mortality with elderly patients having over triple the risk of mortality compared with adults; following age, SAE increased the mortality risk by 41%. Despite increasing overall mortality risk, in adults, SAE was protective against failure of NOM. This relationship was not seen in the elderly cohort, where SAE had no benefit for preventing failure of NOM.

CONCLUSION: Splenic artery embolization was associated with an increased risk of mortality in both adult and elderly patients and, as such, may be a marker for a decompensating patient. In the adult patient, SAE was beneficial for avoiding operative intervention. However, in the elderly patient no such benefit was seen. We recommend that in the decompensating elderly patient after splenic trauma, trauma surgeons should consider operative intervention, rather than SAE, as second-line therapy. (*J Trauma Acute Care Surg.* 2026;100: 580–587. Copyright © 2026 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Therapeutic/Care Management; Level III.

KEY WORDS: SAE; critical care; adult; mortality; nonoperative management.

Across all injury mechanisms in adult patients, the liver and the spleen are the most commonly injured solid abdominal organs requiring angioembolization, with the spleen being one of the most affected abdominal organs in polytrauma.[1–3] Nonoperative management (NOM) after splenic injury has become standard practice with around 80% of patients undergoing NOM, and upwards of 80% of those patients successfully discharging without the need for operation.[4] Recently, Bashir et al.[5] compared NOM of splenic injuries in "young" elderly patients (65–79 years) to octogenarians (80–89 years) using the Trauma Quality Improvement Program (TQIP) database (2010–2016). They found no significant difference in the rate of NOM failure between groups of elderly patients with a failure rate of 6.6% in the 'young elderly group' and 6.8% in octogenarians. In multivariable logistic regression analysis, it was found that octogenarians who failed NOM had a nearly five times greater likelihood of mortality than their "young" elderly counterparts (odds ratio [OR], 4.99; 95% confidence interval [CI], 1.11–22.49; $p = 0.04$). Warmack et al.[6] conducted a retrospective analysis of high-grade splenic injuries (Abbreviated Injury Scale [AIS] >3) included in years 2014 and 2015 of the National Trauma Databank. Patients were stratified into three cohorts, non-elderly (18–64 years), elderly (65–79 years), and advanced age (80 years and older). Failure of NOM management was associated with a 2% mortality in non-elderly patients, 22.2% in elderly, and 50% in advanced age patients. Compared with nonelderly patients, elderly patients who failed NOM had over three times greater odds of mortality (OR, 3.39; $p < 0.01$) and those of advanced age had an eight-fold increase in the odds of mortality (OR, 8.1; $p < 0.01$). However, conspicuously absent in any of these reports on elderly splenic trauma was the role of splenic embolization as a management strategy to prevent NOM failure. We hypothesized that splenic artery embolization (SAE) would confer no benefit in elderly trauma patients undergoing NOM due to decreased physiologic reserve and age-related loss of elastic fiber in the splenic capsule,[7] rendering the spleen more fragile and prone to failure to contain splenic hemorrhage. Because of this, utilizing SAE as a bridge to NOM in a decompensating patient may be inappropriate as the splenic injury may have progressed past the point where NOM is beneficial, thus delaying necessary operative intervention.

Submitted: July 24, 2025, Revised: November 11, 2025, Accepted: November 17, 2025, Published online: January 15, 2026.
From the Department of Surgery, Regions Hospital (N.J.L., D.J.D., B.B., F.B.R.), Saint Paul; and Healthpartners Institute (E.C.), Bloomington, Minnesota.
This study was presented at the 84th annual meeting of the American Association for the Surgery of Trauma, September, 12, 2025, in Boston, Massachusetts.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).
Address for correspondence: Frederick B. Rogers, MD, MS, MA, FACS, Department of Surgery, Regions Hospital, 640 Jackson Street, 11502v Saint Paul, MN 55101; email: frederick.b.rogers@healthpartners.com.

DOI: 10.1097/TA.0000000000004884

METHODS

Cohort Design and Inclusion and Exclusion Criteria

This retrospective cohort study included all patients ≥15 years old in the years 2019 to 2022 of the TQIP database presenting with splenic trauma stratified into adult (age 15–64 years) and elderly (age ≥65 years) cohorts. Splenic trauma was identified by the ICD-10 codes found in Supplemental Digital Content 1, http://links.lww.com/TA/F61. Fifteen years was chosen as the cutoff for pediatric patients and 65 years the cutoff for elderly patients to align with American College of Surgeons guidelines. Patients missing emergency department (ED) disposition, age, sex, procedure start time, ED discharge time (in patients discharged to the OR), or mechanism of injury were excluded from analysis. In addition, those who died in the ED, did not present to a Level I or II trauma center, were listed as "other" sex, had an AIS score of 6 in any region, and were documented as receiving SAE after splenic procedure were excluded from analysis. Patients missing these variables were excluded as they were included as covariates in the multivariable analysis or were required to calculate a covariate or outcome of interest. Those who died in the ED or had an AIS of 6 were excluded as they would confound mortality models as these injuries are assumed to be un-survivable, and those not presenting to a Level I or II trauma center were excluded as they were likely unable to obtain definitive care at the institution. Patients listed as "other" sex were excluded as this category was not available in TQIP until 2021, and those who received SAE after splenic procedure were excluded as this would confound interpretation on the effect of SAE on NOM. A STROBE checklist for cohort studies can be found in Supplemental Digital Content 2, http://links.lww.com/TA/F62.

Exposure Variables

Patients were stratified by age (adult and elderly) and also by clinical management strategies with each patient categorized as either splenectomy, NOM-success, NOM-failure, or other operative approach. Splenic artery embolization was treated as independent and not considered a procedure to allow for analysis of its effect on NOM. Splenectomy and other operative approach were identified by ICD-10 codes that can be found in Supplemental Digital Content 1, http://links.lww.com/TA/F61. Largely, other operative approaches include repositioning, release, drainage, repair, extirpation of matter and insertion of device into the spleen. Failure of NOM was defined as any patient discharged from the ED to somewhere other than the operating room who subsequently required a splenic procedure, or any patient discharged from the ED to the operating room, but the splenic operation occurred >6 hours from ED discharge.

Outcome Variables

The primary outcome was 30-day in-hospital mortality. Secondary outcomes included NOM failure and measures of acute care including length of stay and administration and volume of blood products and blood components.

Other Variables

Demographics and hospital characteristics included age, race and ethnicity, insurance status, hospital type, hospital bed size, and trauma center level. Injury characteristics including Injury Severity Score (ISS), Revised Trauma Score (RTS), American

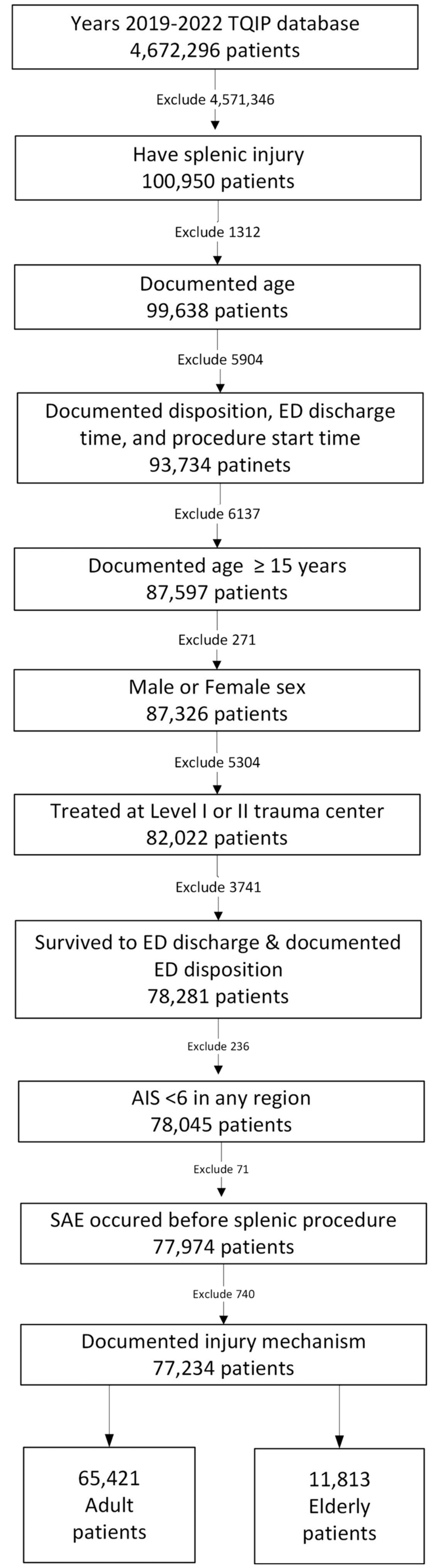

Figure 1. STROBE diagram.

TABLE 1. Demographics

Characteristics	All	Adult	Elderly	*p*
N	77,234	65,421	11,813	
Age, median (IQR)	38 (26, 57)	34 (24, 48)	73 (68, 80)	<0.001
Sex				<0.001
Male	52,409 (67.9%)	45,491 (69.5%)	6,918 (58.6%)	
Female	24,825 (32.1%)	19,930 (30.5%)	4,895 (41.4%)	
Race and ethnicity				<0.001
White, non-Hispanic	50,558 (65.5%)	40,817 (62.4%)	9,741 (82.5%)	
Racial and/or ethnic minority	26,676 (34.5%)	24,604 (37.6%)	2,072 (17.5%)	
Race and ethnicity				<0.001
AI/NA	553 (0.7%)	521 (0.8%)	32 (0.3%)	
AS	1,271 (1.6%)	1,039 (1.6%)	232 (2.0%)	
BA/AA	10,684 (13.8%)	10,010 (15.3%)	674 (5.7%)	
HS/LA	10,113 (13.1%)	9,424 (14.4%)	689 (5.8%)	
OT	2,255 (2.9%)	1,991 (3.0%)	264 (2.2%)	
PI/NH	131 (0.2%)	124 (0.2%)	7 (0.1%)	
UK	1,669 (2.2%)	1,495 (2.3%)	174 (1.5%)	
WH	50,558 (65.5%)	40,817 (62.4%)	9,741 (82.5%)	
Insurance payor				<0.001
Medicaid	18,315 (23.7%)	17,858 (27.3%)	457 (3.9%)	
Medicare	10,623 (13.8%)	3,024 (4.6%)	7,599 (64.3%)	
Other	13,815 (17.9%)	13,219 (20.2%)	596 (5.0%)	
Private	34,481 (44.6%)	31,320 (47.9%)	3,161 (26.8%)	
Procedure				<0.001
Nonoperative failure	4,262 (5.5%)	3,583 (5.5%)	679 (5.7%)	
Nonoperative success	60,462 (78.3%)	50,819 (77.7%)	9,643 (81.6%)	
Other operative approach	1,334 (1.7%)	1,223 (1.9%)	111 (0.9%)	
Splenectomy	11,176 (14.5%)	9,796 (15.0%)	1,380 (11.7%)	
RTS, median (IQR)	7.84 (7.55, 7.84)	7.84 (7.55, 7.84)	7.84 (7.84, 7.84)	<0.001
Unknown	3,911	3,278	633	
Spleen embolized				<0.001
No	74,125 (96.0%)	62,856 (96.1%)	11,269 (95.4%)	
Yes	3,109 (4.0%)	2,565 (3.9%)	544 (4.6%)	
AAST splenic grade				<0.001
1	39,882 (51.6%)	32,947 (50.4%)	6,935 (58.7%)	
3	18,823 (24.4%)	16,195 (24.8%)	2,628 (22.2%)	
4	11,004 (14.2%)	9,626 (14.7%)	1,378 (11.7%)	
5	7,525 (9.7%)	6,653 (10.2%)	872 (7.4%)	
ISS, median (IQR)	21 (13, 29)	22 (14, 29)	17 (12, 26)	<0.001
Unknown	9	8	1	
AIS scores, median (IQR)				
Chest	3 (3–4)	3 (3–4)	3 (3–3)	<0.001
Abdomen pelvis	3 (2–4)	3 (2–4)	3 (2–3)	<0.001
Extremity	2 (2–3)	2 (2–3)	2 (2–3)	<0.001
External	1 (1–1)	1 (1–1)	1 (1–1)	<0.001
Head neck	3 (2–4)	3 (2–4)	3 (2–4)	0.34
Face	2 (1–2)	2 (1–2)	2 (1–2)	0.01
Mechanism				<0.001
Blunt	71,032 (92.0%)	59,470 (90.9%)	11,562 (97.9%)	
Penetrating	6,202 (8.0%)	5,951 (9.1%)	251 (2.1%)	
Hospital type				<0.001
For profit	7,629 (9.9%)	6,440 (9.8%)	1,189 (10.1%)	
Government	710 (0.9%)	653 (1.0%)	57 (0.5%)	
Nonprofit	68,895 (89.2%)	58,328 (89.2%)	10,567 (89.5%)	

Continued next page

TABLE 1. *(Continued)*

Characteristics	All	Adult	Elderly	p
Hospital bed size				0.029
≤200	20,884 (27.0%)	17,606 (26.9%)	3,278 (27.7%)	
201–400	24,796 (32.1%)	21,026 (32.1%)	3,770 (31.9%)	
401–600	13,717 (17.8%)	11,572 (17.7%)	2,145 (18.2%)	
>600	17,837 (23.1%)	15,217 (23.3%)	2,620 (22.2%)	
Classification				<0.001
Level I	50,075 (64.8%)	42,644 (65.2%)	7,431 (62.9%)	
Level II	27,159 (35.2%)	22,777 (34.8%)	4,382 (37.1%)	

All statistics n (%) or median (IQR).
AI/AN, American Indian/Alaskan Native; AS, Asian; BA/AA, Black/African American; HS/LA, Hispanic or Latino; OT, Other; PI/NH, Pacific Islander/Native Hawaiian; UK, Unknown; WH, White.

Association for the Surgery of Trauma (AAST) splenic injury grade (converted from AIS spleen score using a crosswalk published by Vanderbilt Medical Center[8]), and mechanism of injury were also collected.

Statistical Analysis

Post hoc pairwise tests with a Bonferroni correction were performed after comparison of management strategies. A cox proportional hazard model estimated the 30-day in-hospital mortality by age and management strategy adjusted for patient, injury, and hospital characteristics. Splenic artery embolization was modeled as a time-varying covariate to account for the timing of embolization during hospitalization. Inclusion of an interaction term between age group and management strategies/SAE allowed for evaluation of differential associations between management and likelihood of mortality for elderly patients as compared with the adult cohort.

Secondary analysis focused on identification of predictors of NOM failure and potential differences between the age cohorts. Logistic models stratified by age were run to estimate associations between potential predictors and odds of mortality within strata. A likelihood ratio test was used to assess whether the association between SAE and NOM failure varied between adult and elderly patients. Given the high anticipated number of eligible patients (>50,000) this study was determined to have sufficient power to detect at least a 1% difference in probability of mortality between comparisons groups. Statistical significance was assessed using a two-sided alpha of 0.05 although discussions of meaningful differences emphasized magnitude and precision of point estimates due to the large sample size. No adjustments were made for multiple outcomes. All analyses were conducted using R version 4.2. This study was deemed exempt by our institutional review board due to the publicly available nature of the TQIP database.

RESULTS

In total, 77,234 patients met the inclusion criteria for this study, 65,421 patients (84.7%) in the adult cohort and 11,813 patients (15.3%) in the elderly cohort (Fig. 1). The two cohorts differed significantly by demographics, payor, and injury severity (Table 1). Notably, the adult cohort had significantly more male patients (69.5% vs. 58.6%) and those of a racial or ethnic minority (37.6% vs. 17.5%, $p < 0.001$). Adult patients were more anatomically injured with a median ISS of 22 (IQR, 14–29) compared with 17 (IQR, 12–26) in elderly patients and had higher grades of splenic injury with 24.9% of the adult cohort having a AAST Grade IV or V compared with 19.1% of the elderly cohort. In total, 64.8% of patients were treated at a Level I trauma center while 35.2% were treated at a Level II trauma center ($p < 0.001$ for all).

The majority of the 77,234 patients evaluated (83.8%) were treated nonoperatively, with 6.6% of these patients failing NOM (Table 2). The 14.5% of patients who proceeded immediately to the operating room for splenic repair or splenectomy suffered significantly greater injuries than those who received NOM with a median AIS spleen score of 4 (IQR, 3–5), ISS of 30 (IQR, 22–41) and RTS of 7.55 (IQR, 5.97–7.84). Of the patients who underwent SAE, 97.8% trialed NOM, with 7.1% of the NOM failure group and 4.5% of the NOM success group undergoing SAE.

30-Day Mortality

In total, 13.1% of the elderly cohort died by 30 days compared with 6.4% of the adult cohort. This relationship was maintained across management strategies with elderly patients having a greater risk of death over time (Fig. 2). Risk-adjusted predictors of mortality were identified for the entire sample (Table 3). Age was strongly associated with in-hospital mortality, with elderly patients having a 3.24 times higher risk of mortality than their adult counterparts after splenic trauma (hazard ratio [HR], 3.24; 95% CI, 2.88–3.64; $p < 0.001$). Other predictors of mortality were SAE which increased risk of mortality by 41% (HR, 1.41; 95% CI, 1.20–1.66; $p < 0.001$), penetrating trauma (HR, 1.17; 95% CI, 1.06–1.30) and identifying as a racial or ethnic minority (HR, 1.10; 95% CI, 1.04–1.17; $p = 0.001$). Compared with splenectomy, other operative approach reduced the risk of mortality by 55%. In addition, NOM success lowered the risk of mortality by 47%, and NOM failure lowered the risk of death by 36%. Given that elderly patients had over three times greater risk of death compared with adults, we utilized an interaction term to determine if there were any age-related differences in mortality based on management strategy (Table 3). It was found that the risk of death related to management strategy was not more pronounced in elderly patients.

Because of the potential for severe head injury to confound mortality results, specifically within the elderly cohort, we conducted a sensitivity analysis excluding patients with an AIS head score ≥3 (Supplemental Digital Content 3, http://links.lww.com/TA/F63). Excluding these patients did not impact the direction of the effect of age or SAE on mortality but

TABLE 2. Patient Characteristic and Distribution by Management Strategy

Characteristics	N	Overall	Splenectomy	Nonoperative Failure	Nonoperative Success	Other Operative Approach	p
N		N = 77,234	n = 11,176	n = 4,262	n = 60,462	n = 1,334	
Patient age	77,234						<0.001 *,**,†,‡,§
Adult		65,421 (84.7%)	9,796 (87.7%)	3,583 (84.1%)	50,819 (84.1%)	1,223 (91.7%)	
Elderly		11,813 (15.3%)	1,380 (12.3%)	679 (15.9%)	9,643 (15.9%)	111 (8.3%)	
Sex	77,234						<0.001 ¶,*,†,‡,§
Male		52,409 (67.9%)	8,183 (73.2%)	3,052 (71.6%)	40,150 (66.4%)	1,024 (76.8%)	
Female		24,825 (32.1%)	2,993 (26.8%)	1,210 (28.4%)	20,312 (33.6%)	310 (23.2%)	
Race and ethnicity	77,234						<0.001 *,**,†,‡,§
White, non-Hispanic		50,558 (65.5%)	6,467 (57.9%)	2,830 (66.4%)	40,708 (67.3%)	553 (41.5%)	
BIPOC		26,676 (34.5%)	4,709 (42.1%)	1,432 (33.6%)	19,754 (32.7%)	781 (58.5%)	
Embolized spleen	77,234						<0.001 ¶,*,**,†,‡
No		74,125 (96.0%)	11,114 (99.4%)	3,959 (92.9%)	57,723 (95.5%)	1,329 (99.6%)	
Yes		3,109 (4.0%)	62 (0.6%)	303 (7.1%)	2,739 (4.5%)	5 (0.4%)	
RTS	73,323	7.84 (7.55–7.84)	7.55 (5.97–7.84)	7.84 (6.82–7.84)	7.84 (7.84–7.84)	7.84 (7.11–7.84)	<0.001 ¶,*,**,†,‡,§
Unknown		3,911	732	221	2,915	43	
ISS	77,225	21 (13, 29)	30 (22, 41)	27 (18, 36)	18 (12, 27)	20 (13, 29)	
Unknown		9	1	0	8	0	
AIS spleen severity score	77,234	2.00 (2.00–3.00)	4.00 (3.00–5.00)	3.00 (2.00–4.00)	2.00 (2.00–3.00)	2.00 (2.00–3.00)	<0.001 ¶,*,**,†,‡,§
AAST splenic grade	77,234						<0.001 ¶,*,**,†,‡,§
I		39,882 (51.6%)	2,057 (18.4%)	1,186 (27.8%)	35,744 (59.1%)	895 (67.1%)	
III		18,823 (24.4%)	2,210 (19.8%)	1,107 (26.0%)	15,266 (25.2%)	240 (18.0%)	
IV		11,004 (14.2%)	3,018 (27.0%)	1,019 (23.9%)	6,854 (11.3%)	113 (8.5%)	
V		7,525 (9.7%)	3,891 (34.8%)	950 (22.3%)	2,598 (4.3%)	86 (6.4%)	
Mechanism	77,234						<0.001 ¶,*,**,†,‡,§
Blunt		71,032 (92.0%)	8,523 (76.3%)	3,733 (87.6%)	58,088 (96.1%)	688 (51.6%)	
Penetrating		6,202 (8.0%)	2,653 (23.7%)	529 (12.4%)	2,374 (3.9%)	646 (48.4%)	
Bedsize	77,234						<0.001 ¶,*,**,†,‡,§
≤200		20,884 (27.0%)	3,007 (26.9%)	1,141 (26.8%)	16,341 (27.0%)	395 (29.6%)	
>600		24,796 (32.1%)	3,537 (31.6%)	1,375 (32.3%)	19,497 (32.2%)	387 (29.0%)	
201–400		13,717 (17.8%)	1,863 (16.7%)	810 (19.0%)	10,787 (17.8%)	257 (19.3%)	
401–600		17,837 (23.1%)	2,769 (24.8%)	936 (22.0%)	13,837 (22.9%)	295 (22.1%)	
Trauma center level	77,234						<0.001 **,‡,§
Level I		50,075 (64.8%)	7,522 (67.3%)	2,740 (64.3%)	38,970 (64.5%)	843 (63.2%)	
Level II		27,159 (35.2%)	3,654 (32.7%)	1,522 (35.7%)	21,492 (35.5%)	491 (36.8%)	
Hospital LOS, median (IQR)	76,873	7 (4, 13)	10 (5, 19)	12 (7, 22)	6 (4, 11)	9 (6, 16)	<0.001 ¶,*,**,†,‡
ICU LOS, median (IQR)	53,310	4 (2, 8)	5 (3, 12)	6 (3, 13)	3 (2, 7)	5 (3, 9)	<0.001 ¶,*,**,†,‡,§
Ventilation days, median (IQR)	25,271	4 (2, 10)	3 (2, 9)	5 (2, 12)	4 (2, 10)	3 (2, 7)	<0.001 ¶,*,**,†,‡
Plasma given—yes	76,459	15,767 (20.6%)	6,698 (60.7%)	1,534 (36.4%)	7,063 (11.8%)	472 (36.1%)	<0.001 ¶,**,†,‡,§
Plasma volume, median (IQR)	15,762	880 (450–1,800)	1,198 (550–2,308)	935 (500–1,800)	600 (325–1,250)	891 (500–1,597)	<0.001 ¶,*,**,†,‡,§
Platelets given—yes	76,478	8,935 (11.7%)	4,404 (39.9%)	933 (22.2%)	3,330 (5.6%)	268 (20.5%)	<0.001 ¶,**,†,‡,§
Platelets volume, median (IQR)	8,934	300 (230–506)	300 (250–600)	300 (229–534)	278 (220–491)	272 (228–500)	<0.001 ¶,**,‡,§
Blood given—yes	76,463	22,062 (28.9%)	8,137 (73.8%)	2,067 (49.1%)	11,174 (18.7%)	684 (52.3%)	<0.001 ¶,**,†,‡,§
Blood volume, median (IQR)	22,056	975 (500–2,100)	1,400 (700–3,000)	1,050 (500–2,100)	700 (350–1,400)	1,050 (600–2,100)	<0.001 ¶,**,†,‡,§
Cryoprecipitate given—yes	76,482	2,883 (3.8%)	1,606 (14.5%)	303 (7.2%)	899 (1.5%)	75 (5.7%)	<0.001 ¶,**,†,‡,§
Cryoprecipitate volume, median (IQR)	2,883	180 (100–270)	193 (100–285)	200 (100–300)	150 (100–250)	197 (100–271)	0.001 ¶,‡

All statistics n (%) or median (IQR).
*Significant difference between NOM failure/other operative procedure.
**Significant difference between NOM failure/splenectomy.
†Significant difference between NOM success/other operative procedure.
‡Significant difference between NOM success/splenectomy.
§Significant difference between other operative procedure/splenectomy.
¶Significant difference between NOM failure/NOM success.

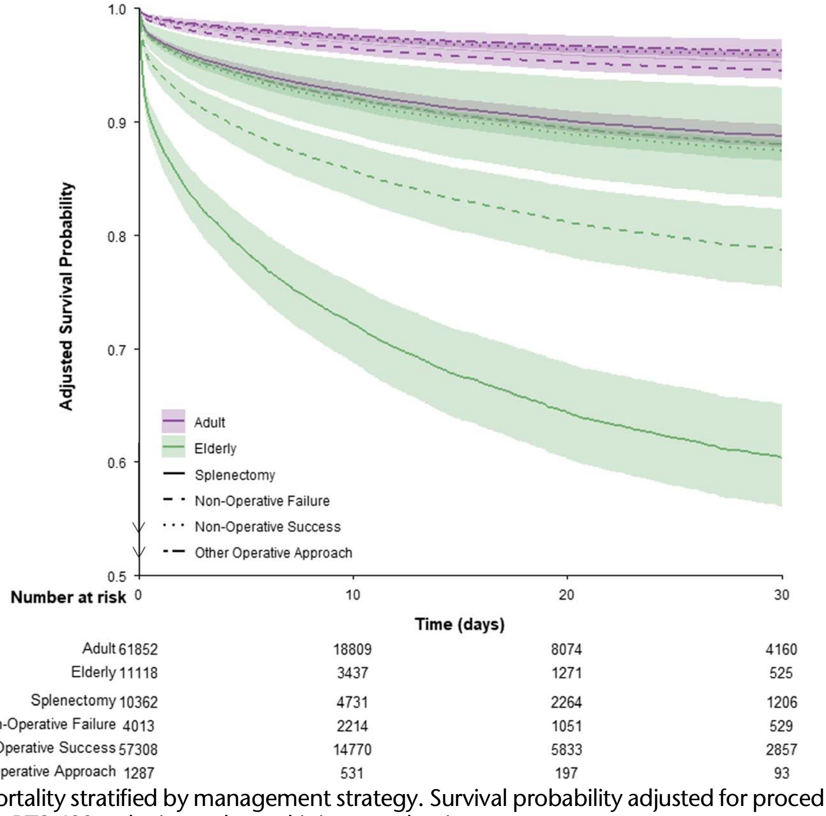

Figure 2. Adult and elderly mortality stratified by management strategy. Survival probability adjusted for procedure, time to embolized spleen, sex, race and ethnicity, RTS, ISS, splenic grade, and injury mechanism.

did result in minor changes to effect size. The effect of age and SAE on mortality became more extreme (elderly: HR, 3.82; 95% CI, 3.29–4.43; SAE: HR, 2.06; 95% CI, 1.58–2.68). In addition, the interaction terms between elderly status and NOM success and failure became significant, indicating elderly patients do worse than their adult counterparts with NOM. Given these changes did not impact the direction of the main effects, we elected to keep the original sample as the primary model.

Nonoperative Failure

Because NOM failure is a major concern when managing patients after splenic trauma, independent predictors of NOM failure in the elderly cohort were identified (Table 4). Every one-point increase in the grade of splenic injury more than doubled the odds of NOM failure (OR, 2.35; 95% CI, 2.17–2.54; $p < 0.001$). Splenic artery embolization was not protective against NOM failure in the elderly cohort and conferred no significant benefit ($p = 0.23$). However, in the adult population (Table 4) SAE was highly protective, decreasing the odds of failure by 39% (OR, 0.61; 95% CI, 0.53–0.71; $p < 0.001$). The effect of SAE on NOM failure was determined to be significantly different between adult and elderly cohorts ($p = 0.049$).

DISCUSSION

This study analyzed 77,234 patients, 65,421 adult and 11,813 elderly patients with splenic trauma found in the years 2019 to 2022 of the TQIP database. Age and SAE were identified as two major independent predictors of mortality after splenic trauma. Age was a significant predictor of mortality with elderly patients having over three times the risk of mortality compared with adults after splenic trauma; following age, SAE increased the risk of mortality by 41%. Despite increasing overall risk of mortality, in adults, SAE was protective against failure of NOM, this relationship was not seen in the elderly cohort, confirming our hypothesis that there is no benefit to SAE in elderly trauma patients for preventing failure of NOM.

The use of SAE as an adjunct to NOM after blunt splenic trauma was first described in a case series by Sclafani et al. [9] in 1981 using gelfoam particles (two patients) or steel wool coil (one patient). In 1995, these authors reported the outcomes of 150 patients undergoing NOM after splenic trauma. Sixty of these patients (40%) underwent SAE with a reported 95% salvage rate of the spleen (57 of 60 patients).[10] Since this time, the role of SAE after trauma has evolved, though not without controversy. Currently, SAE is applied in trauma centers in high-risk situations for failure of NOM such as high-grade splenic injuries (Grades IV and V), vascular abnormalities (arteriovenous fistulas or pseudoaneurysms) and large hemoperitoneum.[11] While there is much literature documenting the benefits of SAE in these situations, few studies provide age-focused analysis, leaving question to how outcomes may differ in elderly patients. There are three techniques for SAE, proximal, distal, or combined. Proximal embolization is preferred in many trauma centers for both adult and elderly patients because it is faster, technically easier, and allows the rich network of collateral circulation to reduce the risk of infarction and subsequent abscess formation.[12,13] Distal embolization, or selective embolization, is performed to devascularize only the area of injury within the spleen; this is advantageous as it allows for repeated splenic embolization as needed.[14]

TABLE 3. Adjusted Predictors of Mortality

Adjusted, N = 73,314	HR	95% CI	*p*
Patient age			
Adult	—	—	
Elderly	3.24	2.88–3.64	<0.001
Management strategy			
Splenectomy	—	—	
Nonoperative failure	0.64	0.56–0.73	<0.001
Nonoperative success	0.53	0.48–0.57	<0.001
Other operative approach	0.45	0.34–0.59	<0.001
Time to embolized spleen	1.41	1.20–1.66	<0.001
Sex			
Male	—	—	
Female	0.96	0.90–1.02	0.2
Race and ethnicity			
White, non-Hispanic	—	—	
BIPOC	1.1	1.04–1.17	0.001
RTS	0.63	0.62–0.64	<0.001
ISS	1.03	1.03–1.04	<0.001
Splenic grade			
1	—	—	
3	0.71	0.66–0.77	<0.001
4	0.64	0.59–0.70	<0.001
5	0.51	0.46–0.56	<0.001
Mechanism			
Blunt	—	—	
Penetrating	1.17	1.06–1.30	0.003
Patient age-management strategy			
Elderly-nonoperative failure	1.18	0.93–1.49	0.17
Elderly-nonoperative success	1.12	0.97–1.28	0.12
Elderly-other operative approach	1.17	0.70–1.95	0.56
Patient age-embolized spleen			
Elderly-embolized spleen	1.24	0.95–1.63	0.12
Concordance = 0.873			

BIPOC, Black/Indigenous/Person of Color.

Combined embolization involves the concurrent use of both proximal and distal SAE. The optimal technique for SAE has yet to be determined and there appears to be no difference in the rate of NOM success between proximal and distal embolization.[15]

Splenic artery embolization is an important adjunct to the NOM of splenic trauma in adult patients and improves outcomes. In a well-done trial of 133 patients presenting with Grade III splenic injury and ISS >15, large hemoperitoneum, or Grade IV/V splenic injury, Arvieux et al.[16] randomized patients to either receive SAE or observation. The authors found that the SAE group had a significantly shorter hospital length of stay and significantly fewer splenic pseudoaneurysms identified 5 days after discharge on follow-up CT (1 of 65 patients in the SAE group vs. 8 of 65 in the observation group). Notably, 19 of the 65 observation patients subsequently required SAE. There was no significant difference in splenic salvage rates between cohorts. It should be noted that the median age in this study was 30 years, limiting the generalizability of the findings across age groups. Requarth et al.[17] in a meta-analysis studying more than 10,000 patients with splenic injury found that in patients with Grades IV or V splenic injury, NOM was significantly more likely to fail if SAE was not used (mean age <40 years in all studies). The protective effect of SAE described by Requarth and colleagues is consistent with the results described in this article for adult patients. It should be noted that the long-term effects of SAE does not appear to be associated with alternation in splenic volume, platelet count, or the ability to prevent infection.[18–20]

There are several reported complications of SAE including splenic infarction, abscess, hyperthermia, and hyperalgesia without associated infarction which may occur in up to 47% of cases.[21] Wu et al. (2011)[22] reported that elderly patients (≥65 years) had a nearly six-fold greater odds of complication after SAE compared with their younger counterparts, with half of the elderly patients (4 of 8 patients) reporting a major complication. In the 53 patients who underwent SAE, there were 12 major complications in 11 patients, including 8 cases of postprocedural bleeding, 2 cases of total splenic infarction, 1 case of splenic abscess and 1 case of splenic atrophy.

Given the results of this study, and the reported increase in complications in elderly patients undergoing SAE, we recommend trauma centers incorporate age into their clinical decision making for patients with splenic trauma. As the splenic capsule ages, there is a loss of elastic fiber[7] rendering the spleen more fragile, limiting its ability to contain hemorrhage. In the elderly patient with splenic

TABLE 4. Adult and Elderly Adjusted Predictors of Nonoperative Failure

	Adults: N = 51,822		Elderly: N = 9,766	
	aOR	**95% CI**	**OR**	**95% CI**
Sex				
Male	—	—	—	—
Female	**0.84**	**0.77–0.91**	0.88	0.74–1.05
Race and ethnicity				
White, non-Hispanic	—	—	—	—
BIPOC	**1.15**	**1.06–1.24**	0.98	0.78–1.22
Embolized spleen				
No	—	—	—	—
Yes	**0.61**	**0.53–0.71**	0.83	0.61–1.12
RTS	**0.82**	**0.80–0.84**	**0.83**	**0.78–0.88**
AIS Spleen Severity Score	**2.29**	**2.21–2.37**	**2.35**	**2.17–2.54**
AUC, 95% CI	0.73 (0.72–0.74)		0.73 (0.71–0.75)	

*Bold values are statistically significant.
AUC, area under the receiver operating characteristic curve.

trauma, we recommend decision-making with a low threshold for operative intervention when there is evidence of ongoing bleeding. Splenic artery embolization as a method to prevent operative intervention has limited utility in these patients and may increase mortality. That said, SAE should be utilized in all patients, regardless of age, for the treatment of splenic pseudoaneurysm.

There are several limitations of this study. The retrospective nature of the data carries its own inherent limitations. The TQIP database does not document SAE technique, preventing analysis of outcomes based on technique. Further, NOM failure was not stratified by those who required spleen sparing procedures vs. total splenectomy, though it is unlikely this stratification would have changed the results. We were unable to separate out patients who received SAE as an intervention to prevent operation from those who received it as treatment for splenic pseudoaneurysm, however, all patients undergoing SAE in this study were embolized within 24 hours of arrival with 86% embolized within 6 hours. Given how rapidly SAE was performed, we can assume the majority of patients underwent SAE to prevent operation, not treatment of a pseudoaneurysm. While we controlled for ISS and RTS, there are implicit differences in the level of injury seen between those patients who require immediate splenectomy compared with those who are able to trial NOM. The decreased risk of mortality seen with NOM failure is likely a reflection of these differences and should be interpreted with caution. Finally, the results of this study may be confounded by the clinical indication for SAE. By nature, SAE is more common in critically ill patients (e.g., those with high-grade splenic injuries or those in physiologic decline). Despite controlling for admission RTS, patients receiving SAE may have had a higher likelihood of death at baseline accounting for some of the 41% increased risk of death after SAE described in this report. Due to these limitations, the conclusions of this study should not be generalized beyond patients with splenic trauma who survive long enough to potentially undergo SAE. Future research should focus on why elderly patients do not appear to benefit from SAE and if this is true across all SAE techniques, as well as focus on the disparity seen with the increased risk of mortality for racial/ethnic minorities after splenic trauma.

CONCLUSION

The benefits of SAE described in the literature have historically lacked age-specific analysis, leaving question to the utility of SAE across age groups. This study found that there to be no benefit to SAE in elderly patients. In the elderly patient with splenic trauma surviving long enough to potentially undergo SAE, we recommend decision-making with a low threshold for taking a patient to the operating room with evidence of ongoing bleeding as SAE has limited utility in these patients and may increase mortality.

AUTHORSHIP

Conception and study design: NL, FR; Literature review: NL, FR, DD; Data acquisition: NL, BB; Analysis and interpretation: EC; Drafting of manuscript: NL, EC, DD, BB, FR; Critical revision: NL, EC, DD, BB, FR.

DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/F60).
Funding Sources: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Choi Y, Kim S, Ko J, Kim M, Shim H, Han J, et al. A study on trauma mechanisms and injury sites in patients with blunt abdominal trauma. *Emerg Med Int*. 2022;2022:2160766.
2. Coccolini F, Montori G, Catena F, Kluger Y, Biffl W, Moore EE, et al. Splenic trauma: WSES classification and guidelines for adult and pediatric patients. *World J Emerg Surg*. 2017;12:40.
3. Meira Júnior JD, Menegozzo CAM, Rocha MC, Utiyama EM. Non-operative management of blunt splenic trauma: evolution, results and controversies. *Rev Col Bras Cir*. 2021;48:e20202777.
4. Werner NL, Zarzaur BL. Contemporary management of adult splenic injuries: what you need to know. *J Trauma Acute Care Surg*. 2025;98(6):840–849.
5. Bashir R, Grigorian A, Lekawa M, Joe V, Schubl SD, Chin TL, et al. Octogenarians with blunt splenic injury: not all geriatrics are the same. *Updates Surg*. 2021;73(4):1533–1539.
6. Warnack E, Bukur M, Frangos S, DiMaggio C, Kozar R, Klein M, et al. Age is a predictor for mortality after blunt splenic injury. *Am J Surg*. 2020;220(3):778–782.
7. Rodrigues CJ, Sacchetti JC, Rodrigues AJ Jr. Age-related changes in the elastic fiber network of the human splenic capsule. *Lymphology.* 1999;32(2):64–69.
8. *Spleen Injury Grading Scale [Internet]*. Vanderbilt University Medical Center: [cited 2025 Sep 4]. Available from: https://www.vumc.org/trauma-and-scc/sites/default/files/public_files/Protocols/SPLEEN_INJURY_SCALE_051420.pdf.
9. Sclafani SJ. The role of angiographic hemostasis in salvage of the injured spleen. *Radiology.* 1981;141(3):645–650.
10. Sclafani SJ, Shaftan GW, Scalea TM, Patterson LA, Kohl L, Kantor A, et al. Nonoperative salvage of computed tomography-diagnosed splenic injuries: utilization of angiography for triage and embolization for hemostasis. *J Trauma*. 1995;39(5):818–825 discussion 826–827.
11. Raza M, Abbas Y, Devi V, Prasad KV, Rizk KN, Nair PP. Non operative management of abdominal trauma - a 10 years review. *World J Emerg Surg*. 2013;8:14.
12. Lin BC, Wu CH, Wong YC, Chen HW, Fu CJ, Huang CC, et al. Comparison of outcomes of proximal versus distal and combined splenic artery embolization in the management of blunt splenic injury: a report of 202 cases from a single trauma center. *Surg Endosc*. 2023;37(6):4689–4697.
13. Bessoud B, Denys A, Calmes JM, Madoff D, Qanadli S, Schnyder P, et al. Nonoperative Management of Traumatic Splenic Injuries: is there a role for proximal splenic artery embolization? *AJR Am J Roentgenol*. 2006;186(3):779–785.
14. Imbrogno BF, Ray CE. Splenic artery embolization in blunt trauma. *Semin Intervent Radiol*. 2012;29(2):147–149.
15. Lin BC, Wu CH, Wong YC, Chen HW, Fu CJ, Huang CC, et al. Comparison of outcomes of proximal versus distal and combined splenic artery embolization in the management of blunt splenic injury: a report of 202 cases from a single trauma center. *Surg Endosc*. 2023;37(6):4689–4697.
16. Arvieux C, Frandon J, Tidadini F, Monnin-Bares V, Foote A, Dubuisson V, et al. Effect of prophylactic embolization on patients with blunt trauma at high risk of splenectomy: a randomized clinical trial. *JAMA Surg*. 2020;155(12):1102–1111.
17. Requarth JA, D'Agostino RB Jr., Miller PR. Nonoperative management of adult blunt splenic injury with and without splenic artery embolotherapy: a meta-analysis. *J Trauma*. 2011;71(4):898–903 discussion 903.
18. Bhatia A, Bryant EH, Fox B, Richardson A, Leichter J, Mohan P. Long-term effects of proximal splenic artery embolization on splenic volume and platelet count. *Ann Vasc Surg*. 2023;89:166–173.
19. Olthof DC, Lammers AJ, van Leeuwen EM, Hoekstra JB, ten Berge IJ, Goslings JC. Antibody response to a T-cell-independent antigen is preserved after splenic artery embolization for trauma. *Clin Vaccine Immunol*. 2014;21(11):1500–1504.
20. Pirasteh A, Snyder LL, Lin R, Rosenblum D, Reed S, Sattar A, et al. Temporal assessment of splenic function in patients who have undergone percutaneous image-guided splenic artery embolization in the setting of trauma. *J Vasc Interv Radiol*. 2012;23(1):80–82.
21. Chastang L, Bège T, Prudhomme M, Simonnet AC, Herrero A, Guillon F, 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(2):85–91.
22. Wu SC, Fu CY, Chen RJ, Chen YF, Wang YC, Chung PK, et al. Higher incidence of major complications after splenic embolization for blunt splenic injuries in elderly patients. *Am J Emerg Med*. 2011;29(2):135–140.