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Quantity of hemoperitoneum is associated with need for intervention in patients with stable blunt splenic injury

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ABSTRACT

Background In patients with hemodynamically stable blunt splenic injury (BSI), there is no consensus on whether quantity of hemoperitoneum (HP) is a predictor for intervention with splenic artery embolization (SAE) or failing nonoperative management (fNOM). We sought to analyze whether the quantity of HP was associated with need for intervention.

Methods This retrospective cohort study included adult trauma patients with hemodynamically stable BSI admitted to six trauma centers between 2014 and 2016. Quantity of HP was defined as small (perisplenic blood or blood in Morrison's pouch), moderate (blood in one or both pericolic gutters), or large (additional finding of free blood in the pelvis). Multivariate logistic regression was performed to identify predictors of intervention with SAE or fNOM versus successful observation.

Results There were 360 patients: hemoperitoneum was noted in 214 (59%) patients, of which the quantity was small in 92 (43%), moderate in 76 (35.5%), and large in 46 (21.5%). Definitive management was as follows: 272 (76%) were observed and 88 (24%) had intervention (83 SAE, 5 fNOM). The rate of intervention was univariately associated with quantity of HP, even after stratification by American Association for the Surgery of Trauma (AAST) grade. After adjustment, larger quantities of HP significantly increased odds of intervention (p=0.01). Compared with no HP, the odds of intervention were significantly increased for moderate HP (OR=3.51 (1.49 to 8.26)) and large HP (OR=2.89 (1.03 to 8.06)), with similar odds for small HP (OR=1.21 (0.46 to 2.76)). Other independent predictors of intervention were higher AAST grade, older age, and presence of splenic vascular injury.

Conclusion Greater quantity of HP was associated with increased odds of intervention, with no difference in risk for moderate versus large HP. These findings suggest quantity of HP should be incorporated in the management algorithm of BSI as a consideration for angiography and/or embolization to maximize splenic preservation and reduce the risk of splenic rupture.

Level of evidence III, retrospective epidemiological study.

INTRODUCTION

Nonoperative management (NOM) is the standard treatment strategy for patients with hemodynamically stable blunt splenic injury (BSI). NOM consists of observation for lower injured spleens and splenic artery embolization (SAE) for higher injured spleens.[1–3] Studies to date have reported disparate findings on whether quantity of hemoperitoneum (HP) reflects a more injured spleen with subsequent higher risk of rupture. Some studies report quantity of HP to be associated with failed embolization,[4] need for massive transfusion,[5] and failed NOM,[6] whereas other studies reported quantity of HP had no independent association with the studied outcome.[7–9]

Thus, there is no consensus on whether quantity of HP should be incorporated into NOM algorithms for patients with hemodynamically stable BSI. Only the Eastern Association for the Surgery of Trauma (EAST) guidelines state that, in patients with moderate hemoperitoneum, angiography should be considered. Guidelines by the Western Trauma Association (WTA, 2016 update)[10] and the World Society of Emergency Surgery (WSES) do not suggest angiography and/or embolization should be considered based on presence or quantity of HP. In contrast, all of the above guidelines specify consideration for SAE based on American Association for the Surgery of Trauma (AAST) grade and presence of contrast blush.

This study sought to analyze whether the quantity of HP was associated with need for intervention in a large cohort of patients with hemodynamically stable BSI from six level I and II trauma centers in the USA.

METHODS

This was a retrospective, multi-institutional cohort study of trauma patients admitted between January 1, 2014 and December 31, 2016 with BSI defined by ICD-9 or ICD-10 diagnosis code. Exclusion criteria included: age <18, dead on arrival or died in the ED (emergency department), transfers to the level I trauma center more than 24 hours after the injury, transfers with inadequate documentation of the initial assessment or CT findings, hemodynamic instability (based on blood pressure <90 mm Hg), and patients who went directly to the operating room for splenectomy or another abdominal surgical indication. Of note, there were 62 patients excluded due to missing or inadequate documentation of presence of hemoperitoneum.

The study was performed by the Injury Outcomes Network, a collaborative research network of six

community based, level I trauma centers: Swedish Medical Center, Englewood, CO; St. Anthony Hospital, Lakewood, CO; Penrose Hospital, Colorado Springs, CO; Medical City Plano, Plano TX; Research Medical Center, Kansas City, MO; Wesley Medical Center, Wichita, KS. This study received Institutional Review Board approval at all participating centers and was granted a waiver of consent and HIPAA authorization.

Study variables

The following demographic and clinical characteristics and outcomes were obtained from the trauma registries: admission date; transfer status; age, years; gender; cause of injury (motor vehicle crash (MVC), fall, other cause); injury severity score (ISS); admission vital signs including Glasgow coma score (3–8 or 9–15), systolic blood pressure (<90 mm Hg or ≥90 mm Hg), pulse (<120 or 120 beats/minute), and respiratory rate (<12 or >20 vs. 12–20 breaths/minute); in-hospital mortality; ICU LOS (length of stay), days; Hospital LOS, days.

The following radiographic findings were abstracted from the electronic medical record: hemoperitoneum and quantity (small, moderate, large); AAST grade (the 1994 scale was in use during the study period[11]); presence of contrast blush; presence of splenic vascular injury (defined as a pseudoaneurysm or arteriovenous fistula[12]); presence of a nonsurgical abdominal injury.

The quantity of hemoperitoneum was defined semiquantitatively as small (perisplenic blood or blood in Morrison's pouch), moderate (presence of blood in one or both pericolic gutters), and large (additional finding of free blood in the pelvis).[13 14] This definition uses the Federle score, which quantifies hemoperitoneum based on the count of compartments in the peritoneal cavity affected by the effusion.[15]

The primary outcome was definitive intervention strategy. Intervention techniques were abstracted as both the initial intended intervention (NOM in all cases) and definitive intervention technique (observation, SAE, and failed NOM).

Hospital protocols

Consideration for angiography and/or embolization included a combination of high grade IV/V injuries, contrast blush, and pseudoaneurysm, but varied slightly by hospital guideline. None of the hospital protocols incorporate quantity of HP in guidelines for considering SAE. The standard CT protocol for trauma patients is a combination of Chest/Abdomen/Pelvis with IV contrast on a 64-slice or greater CT in venous phase.

Statistical analyses

All statistical analyses were two-tailed with a $p<0.05$ defined as significant and were conducted using SAS 9.4 (SAS Institute, Cary, NC). Univariate statistics (Pearson χ^2 tests, Fisher's exact tests, and Wilcoxon rank-sum tests) were performed to analyze the association between study covariates and intervention strategy and between study covariates and quantity of HP. Multivariate logistic regression was performed to identify independent predictors of intervention (SAE, fNOM) versus observation. The Firth method was used to reduce small sample size bias in maximum likelihood estimates. The final model adjusted for covariates with $p<0.15$ in univariate analyses.

RESULTS

There were 360 patients with stable BSI. The median age of the population was 36 years, patients were predominantly male (68%), and the most common injury mechanism was MVC (75%). The median ISS was 17 and the median hospital LOS was 6 days.

Hemoperitoneum was noted in 214 (59%) patients. In these patients, the quantity was small in 92 (43%), moderate in 76 (35.5%), and large in 46 (21.5%). Contrast blush was present in 51 (15%) patients and 14 (4%) had a splenic vascular injury (all were pseudoaneurysm).

There were no differences by quantity of HP in age, gender, cause of injury, presence of abnormal vital signs, or a nonsurgical abdominal finding (table 1). There were differences in the ISS, where patients with small HP had the highest ISS compared with the other groups. There were also significant increases by quantity of HP in patients presenting with low initial hemoglobin value and O blood type (table 1).

As the quantity of HP increased so did the presence of other "high risk" radiographic findings, including presence of blush ($p<0.001$), splenic vascular injury ($p=0.01$), and high grade IV/V BSI ($p<0.001$) (figure 1). Still, even in patients with large HP, the majority did not have another high risk finding; the rate of blush was 30%, splenic vascular injury was 14%, and grade IV/V BSI was 50%.

Overall, 272 (76%) patients were observed, 83 (23%) had SAE, and 5 (1%) failed NOM, resulting in an overall rate of intervention of 24%. The rate of intervention significantly increased with HP quantity: 11% without HP, 17% with small HP, 43% with moderate HP, and 50% with large HP ($p<0.001$, table 1). The rate of intervention remained significantly associated with quantity of HP after stratification by AAST grade (figure 2). Other predictors of intervention include greater age, higher ISS, abnormal respiratory rate, blood type O, and other "high risk" radiographic characteristics (table 2).

Multivariate logistic regression was used to identify the independent association of quantity of HP on need for intervention and included all covariates with $p<0.15$ in univariate analyses: age, sex, ISS, abnormal respiratory rate, blood type O, low initial hemoglobin, BSI grade, and presence of blush and splenic vascular injury. After adjustment, larger quantity of HP significantly increased odds of intervention ($p=0.01$). Compared with no HP, the odds of intervention were significantly increased for moderate HP (OR=3.51 (1.49 to 8.26)) and large HP (OR=2.89 (1.03 to 8.06)), whereas the odds were similar for minimal HP (OR=1.21 (0.46 to 2.76)). Other independent predictors of intervention were higher AAST grade, older age, and presence of splenic vascular injury (table 3).

Even in a subgroup analysis of patients who would not be considered for SAE based on hospital protocols (excluding 102 patients with high grade IV-V injuries, contrast blush, or splenic vascular injury), the rate of intervention increased with quantity of HP: 8% without HP, 8% with small HP, 33% with moderate HP, and 24% with large HP. After adjustment, moderate and large quantity of HP remained significantly associated with need for intervention (table 4).

Study outcomes were not significantly different by quantity of HP (table 1). As expected, there were differences by definitive management (table 2), with patients requiring intervention having longer hospital and ICU LOS and higher rate of ICU admission.

DISCUSSION

In patients with hemodynamically stable BSI, there is still uncertainty as to which patient and clinical factors may prompt the need for intervention with angiography and embolization or result in a failed trial of NOM. The results of this study demonstrate that

Table 1 Demographics and clinical characteristics by quantity of HP

Covariate	No HP (n=146)	Minimal HP (n=92)	Moderate HP (n=76)	Large HP (n=46)	P value
General characteristics					
Age, years*	38 (25–55)	36 (25–54)	35.5 (25–55)	30.5 (24–52)	0.51
Age≥65 years	11.0% (16)	6.5% (6)	13.2% (10)	13.0% (6)	0.48
Female sex	37.7% (55)	25.0% (23)	27.6% (21)	37.0% (17)	0.15
Cause of injury					0.24
Vehicular cause	78.1% (114)	78.3% (72)	69.7% (53)	65.2% (30)	
Fall cause	14.4% (21)	13.0% (12)	13.2% (10)	21.7% (10)	
Other cause	7.5% (11)	8.7% (8)	17.1% (13)	13.0% (6)	
ISS*	17 (10–24)	21 (14–29)	17 (10–26)	17 (14–27)	**0.04**
ED GCS 3–8	13.0% (19)	18.5% (17)	11.8% (9)	6.5% (3)	0.25
ED RR<12 or >20	25.4% (33)	22.7% (20)	27.4% (20)	25.6% (11)	0.92
ED HR>120	10.4% (15)	12.4% (11)	9.2% (7)	10.9% (5)	0.93
Blood type O	30.8% (45)	34.8% (32)	50.0% (38)	39.1% (18)	**0.04**
First Hb<10ˆ	9.6% (14)	5.4% (5)	10.5% (8)	21.7% (10)	**0.03**
Radiographic characteristics					
High AAST grade (IV/V)	5.48% (8)	16.30% (15)	28.95% (22)	50.00 (23)	**<0.001**
Non-surgical abdominal finding	4.1% (6)	6.5% (6)	9.2% (7)	6.5% (3)	0.51
Blush (any)	8.4% (12)	9.1% (8)	24.3% (18)	29.6% (13)	**<0.001**
Splenic vascular injury	2.1% (3)	2.4% (2)	4.2% (3)	13.6% (6)	**0.01**
Definitive management					**<0.001**
Observation	89.0% (130)	82.6% (76)	56.6% (43)	50% (23)	
SAE	8.9% (13)	17.4% (16)	42.1% (32)	47.8% (22)	
fNOM	2.1% (3)	0%	1.3% (1)	2.2% (1)	
Outcomes					
Mortality	1.4% (2)	4.4% (4)	5.3% (4)	2.2% (1)	0.35
ICU admission	79.5% (116)	87.0% (80)	92.1% (70)	87.0% (40)	0.07
# blood products*	5 (2–12)	5 (2–8)	3 (2–5)	4 (2–7)	0.56
Hospital LOS*	6 (3–12)	7 (4–14)	6 (4–11)	6 (3–8)	0.33
ICU LOS*	2 (1–5)	3 (2–6)	3 (2–5)	3 (2–4)	0.10

Bold values denote significance <0.05.
*Results presented as median (IQR).
AAST, American Association for the Surgery of Trauma; fNOM, failing nonoperative management; GCS, Glasgow Coma Score; HP, hemoperitoneum; HR, heart rate; ICU, intensive care unit; ISS, injury severity score; SAE, splenic artery embolization.

quantity of HP is independently associated with intervention, which suggests that quantity of HP should be used to optimize NOM. We also identified additional variables that were associated with intervention, including AAST grade, splenic vascular injury, and older age; these variables have previously been shown to be associated with higher fNOM rates.[16] Our study confirms the association of these variables as a marker of worse splenic injury and identifies that volume of HP is an additional factor that may guide placement of these patients in the ICU and earlier intervention to maximize splenic preservation.

These results suggest that hospital and national guidelines would benefit from incorporating quantity of HP into their algorithms. Currently, only the EAST guidelines use moderate or large HP in the guidelines; none of our institution's guidelines consider quantity of HP in their algorithms. In general, there is little consensus on the importance of presence and quantity of HP on splenic management. In a survey of 30 expert trauma surgeons and interventional radiologists from around the world, the survey results were as follows: with low grade I-II injuries, small HP are managed with observation. If the HP is large, then 50% say to perform SAE and 42% say to do operation. For grade III-IV injuries, small HP are managed with observation, unless there is contrast extravasation, then they are managed with SAE more than 50% of the time. If the HP is large, then there is no consensus on optimal splenic management.[17]

The Memphis group published a large study of 430 patients with hemodynamically stable BSI in 2001 and reported that the quantity of HP did not independently predict fNOM.[7] At the time the authors stated that "hemoperitoneum alone is again an indication for increased awareness but not a contraindication to splenic NOM." However, their study was published at a time prior to the widespread adoption of SAE as an adjunct for high-risk patients, when NOM was defined as conservative management with observation only. We agree that HP is not a contraindication for splenic NOM, but our study findings suggest that quantity of HP is significantly associated with intervention and thus moderate or large quantity HP should be a consideration for angiography and/or embolization to maximize splenic preservation and reduce the risk of splenic rupture.

This study is intended to aid in the clinician's initial NOM choice of observation or angiography with consideration for embolization. Our study suggests that splenic injury management

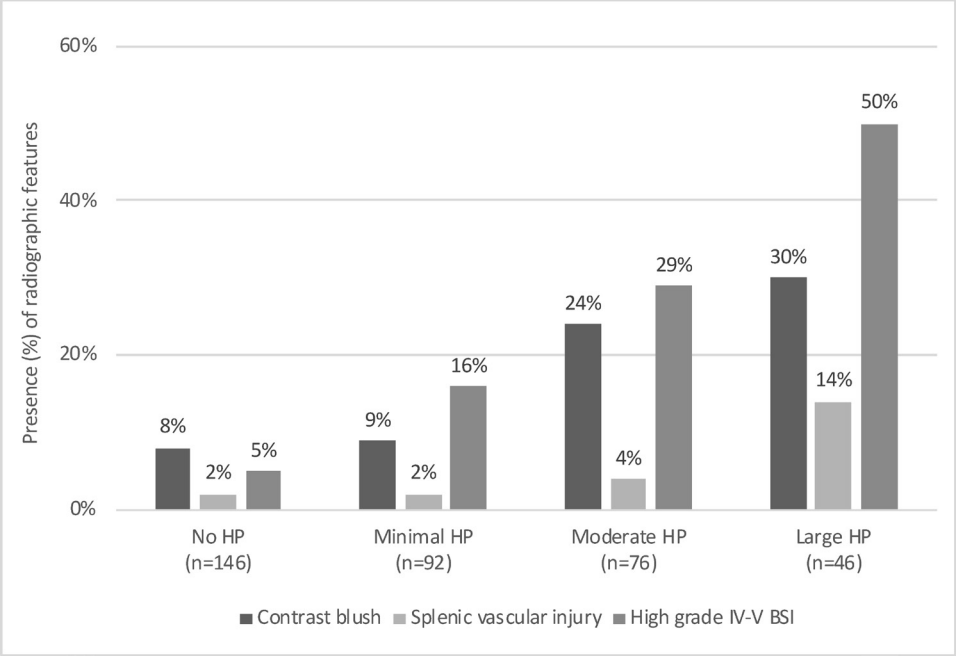

Figure 1 Presence of radiographic features by quantity of HP. BSI, blunt splenic injury; HP, hemoperitoneum.

guidelines should incorporate hemoperitoneum as follows: in patients who have a hemodynamically stable BSI as identified by contrast enhanced CT, angiography with embolization should be considered for any of the following: AAST grade IV or V, active contrast extravasation, splenic vascular injury, or moderate/large HP. Angiography is not indicated for AAST grade I-III, no evidence of contrast extravasation or splenic vascular injury, or no/small HP. These findings have widespread implications considering the prevalence of moderate or large HP was 34% of all patients with hemodynamically stable BSI in our study, and in 24% of patients who did not have another characteristic that is already incorporated in most guidelines, such as grade IV/V injury, vascular blush and/or splenic vascular injury. In this latter subset of patients that only had moderate/large HP, nearly one-third of patients had SAE, and the quantity of HP remained significantly associated with need for intervention.

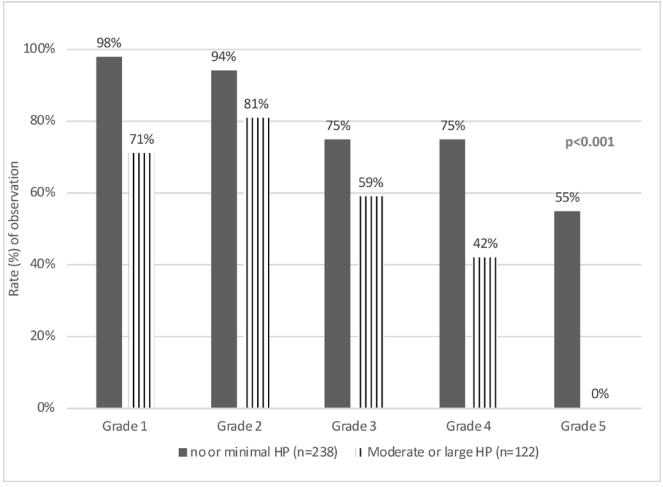

Figure 2 Rate (%) of observation by quantity of HP and AAST grade. AAST, American Association for the Surgery of Trauma; HP, hemoperitoneum.

We previously reported findings in a similar patient population that demonstrated moderate/large HP had greater odds of intervention compared with small HP.[18] The present study was able to tease out the individual effects of quantity of HP as absent, small, moderate, and large. The present results were similar, demonstrating moderate and large HP have similar risk for intervention while also showing small HP does not have increased risk for intervention compared with patients without HP. Our primary outcome, definitive intervention strategy, was examined as observation versus intervention (SAE or failed NOM). We did not exclude five patients who failed NOM because we wanted to include all patients eligible for a trial of NOM; still, the "intervention group" is a majority (94%) SAE, leaving the comparison in our final models to be, in essence, an analysis of whether quantity of HP is associated with SAE as an adjunct to conservative management to improve the NOM failure rate. Past studies chose to examine whether HP is a predictor of fNOM. However, since adopting SAE as part of the NOM strategy the rates of fNOM have significantly decreased and was only 1% in our population.

There are limitations of the study. First, this was a retrospective study, which resulted in missing or incomplete documentation of important covariates such as presence of blush (n=11) or pseudoaneurysm (n=18). Second, the 1994 Organ Injury Scale (OIS) grading scale version was in use during the study period and was used for analysis rather than the more recent 2018 OIS revision which incorporates CT diagnosed splenic vascular injury. Also, owing to the time frame of this study (2014–2016), hospital CT protocols used venous phase scanning rather than biphasic scanning with additional delayed postcontrast images that are currently suggested. Finally, we used a semiquantitative definition of quantity of HP. The definition we utilized has been used in prior studies as well.[13 14] This definition is adapted from the seminal article by Federle *et al*.[15] Other definitions for large HP include blood in both upper quadrants and pelvis,[19] free pelvic fliud,[7] and presence of blood in the small pelvic cavity.[20] We attempted to identify a more quantitative method but none existed.

Table 2 Demographics and clinical characteristics by definitive management

Covariate	Observation (n=272)	Intervention* (n=88)	P value
General characteristics			
Age, years†	34 (25–53)	42.5 (26–57)	**0.03**
Age≥65 years	9.2% (25)	14.8% (13)	0.14
Female sex	33.1% (90)	29.6% (26)	0.54
Cause of injury			0.64
Vehicular cause	72.3% (202)	76.1% (67)	
Fall cause	14.3% (39)	15.9% (14)	
Other cause	11.4% (31)	8.0% (7)	
ISS†	17 (10–24)	22 (16–29)	**<0.001**
ED GCS 3–8	13.6% (37)	12.5% (11)	0.79
ED RR<12 or>20	22.3% (56)	33.7% (28)	**0.04**
ED HR>120	10.1% (27)	12.6% (11)	0.50
Blood type O	33.5% (91)	47.7% (42)	**0.02**
First Hb<10ˆ	10.3% (28)	10.2% (9)	0.99
Radiographic characteristics			
High AAST grade (IV/V)	10.29% (28)	45.45% (40)	**<0.001**
Non-surgical abdominal finding	5.2% (14)	9.1% (8)	0.18
Blush	10.3% (27)	27.9% (24)	**<0.001**
HP	52.2% (142)	81.8% (72)	**<0.001**
Splenic vascular injury	1.2% (3)	13.3% (11)	**<0.001**
Outcomes			
Mortality	2.94 (8)	3.41 (3)	0.82
ICU admission	80.5% (219)	98.9% (87)	**<0.001**
# blood products†	3.5 (2–10)	3 (2–6)	0.45
Hospital LOS†	5 (3–10)	8.5 (5–14)	**<0.001**
ICU LOS†	2 (1–5)	4 (2–8)	**<0.001**

Bold values denote <0.05.
*Intervention: SAE (n=83) or failed NOM (n=5).
†Median (IQR).
AAST, American Association for the Surgery of Trauma; GCS, Glasgow Coma Score; HP, hemoperitoneum; ICU, intensive care unit; ISS, injury severity score; NOM, nonoperative management; SAE, splenic artery embolization.

Table 3 Logistic regression modeling the need for SAE or failing nonoperative management, vs. successful observation

Covariate	OR (95% CI)	P value
No HP	1.0 (Ref)	Ref
Small HP	1.21 (0.46 to 2.76)	0.80
Moderate HP	3.51 (1.49 to 8.26)	**0.004**
Large HP	2.89 (1.03 to 8.06)	**0.03**
Age (10-unit increase)	1.25 (1.06 to 1.49)	**0.01**
Male sex vs. females	1.55 (0.76 to 3.17)	0.23
ISS (10-unit increase)	1.39 (0.96 to 2.00)	0.08
Blood type O vs. other	1.60 (0.83 to 3.07)	0.16
Abnormal RR vs. RR 12–20	1.82 (0.90 to 3.71)	0.10
Blush vs. not	1.39 (0.62 to 3.14)	0.43
Splenic vascular injury vs. not	5.88 (1.12 to 30.99)	**0.04**
Initial hemoglobin <10	0.52 (0.16 to 1.75)	0.29
BSI grade (continuous)	2.41 (1.68 to 3.47)	**<0.001**

Variables marginally associated in the univariate analysis (p<0.15) were included in the final multivariate logistic regression model. Model fit: AUROC: 0.87; r^2=0.47. Bold values denote p<0.05.
AUROC, area under the receiver operating characteristic curve; BSI, blunt splenic injury; HP, hemoperitoneum; ISS, injury severity score; RR, respiratory rate; SAE, splenic artery embolization.

Table 4 Logistic regression modeling the need for SAE or failing nonoperative management, vs. successful observation: subset of patients with low grade I–III injury and absence of blush and splenic vascular injury (n=258)

Covariate	OR (95% CI)	P value
No HP	1.0 (Ref)	Ref
Small HP	0.68 (0.22 to 2.06)	0.49
Moderate HP	5.55 (2.07 to 14.82)	**<0.001**
Large HP	4.88 (1.23 to 19.40)	**0.03**
Age (10-unit increase)	1.40 (1.12 to 1.74)	**0.003**
Male sex vs. females	2.77 (1.03 to 7.40)	**0.04**
ISS (10-unit increase)	1.60 (1.04 to 2.46)	**0.03**
Blood type O vs. other	1.93 (0.85 to 4.36)	0.12
Abnormal RR vs. RR 12–20	1.28 (0.53 to 3.10)	0.59
Initial hemoglobin <10	0.47 (0.11 to 2.08)	0.32

Variables marginally associated in the univariate analysis (p<0.15) were included in the final multivariate logistic regression model. Model fit: AUROC: 0.80; r^2=0.28. Bold values denote p<0.05.
AUROC, area under the receiver operating characteristic curve; HP, hemoperitoneum; ISS, injury severity score; SAE, splenic artery embolization.

CONCLUSION

Greater quantity of hemoperitoneum was associated with increased odds of intervention with SAE or failing a trial of NOM, with no difference in risk for moderate versus large HP. These findings support inclusion of HP into the algorithm for management of BSI by EAST. Furthermore, WTA and WSES guidelines could be altered to include moderate and large hemoperitoneum into their indications for SAE. Knowledge that moderate and large HP increased the odds for SAE and fNOM will assist the trauma surgeon in their decision-making process at the bedside. Thus, moderate or large quantity HP should incorporated as a consideration for angiography and/or embolization to maximize splenic preservation and reduce the risk of splenic rupture.

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Contributors All authors made substantial contributions to the article as follows: KS is responsible for data analysis, interpretation of data, and drafting the article. MO is responsible for literature search, data acquisition, and revising the article. RMM is responsible for study conception, interpretation of the data, and critical revisions. DB-O, JY, AT, AT, ML, MMC, and CWM are responsible for interpretation of the data and critical revisions. All authors provided final approval of the submitted article.

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