KANSAS JOURNAL *of* MEDICINE

Outcomes Following Blunt Traumatic Splenic Injury Treated with Conservative or Operative Management

Sarah Corn, M.D.[1], Jared Reyes, Ph.D.[1],
Stephen D. Helmer, Ph.D.[1,2], James M. Haan, M.D.[1,3]
[1]University of Kansas School of Medicine-Wichita,
Department of Surgery, Wichita, KS
Via Christi Hospital Saint Francis, Wichita, KS
[2]Department of Medical Education
[3]Department of Trauma Services

Received Oct. 17, 2018; Accepted for publication June 4, 2019; Published online Aug. 21, 2019

ABSTRACT

Introduction. Laparotomy, embolization, and observation are described for blunt splenic injury management. This study evaluated outcomes of blunt splenic injury management based on baseline factors, splenic injury severity, and associated injuries.

Methods. A nine-year retrospective review was conducted of adult patients with blunt splenic injury. Collected data included demographics, injury characteristics, treatment modality, complications, and outcomes (mechanical ventilation, days on mechanical ventilation, intensive care unit [ICU] admission and length of stay, hospital length of stay, and in-hospital mortality). Categorical and continuous variables were analyzed using χ^2 analysis and one-way analysis of variance for normally distributed variables and a non-parametric test of medians for variables that did not meet the assumption of normality, respectively.

Results. Splenic injury grade was similar between operative and embolization groups, but severe hemoperitoneum was more common in the operative group. Complications and mortality were highest in the operative group (50.7% and 26.3%, respectively) and lowest in the embolization group (5.3% and 2.6%, respectively). Operative patients required more advanced interventions (ICU admission, mechanical ventilation). There were no differences between those treated with proximal versus distal embolization. Observation carried a failure rate of 11.2%, with no failures of embolization.

Conclusions. Embolization patients had the lowest rates of complications and mortality, with comparable splenic injury grades to those treated operatively. Further prospective research is warranted to identify patients that may benefit from early embolization and avoidance of major abdominal surgery.

Kans J Med 2019;12(3):83-88.

INTRODUCTION

Splenic injury is common affecting up to 32% of patients with blunt abdominal trauma.[1-5] Laparotomy is accepted as the recommended management strategy for blunt splenic injury in hemodynamically unstable patients.[2-14] In contrast, the efficacy of nonoperative management in hemodynamically stable patients may consist of observation (with or without angiography) or angiography with proximal or selective splenic embolization.[1-5] The failure rate of observation alone is high for patients with contrast blush on computed tomography (CT), grade IV injuries (lacerations involving segmental or hilar vessels producing major devascularization greater than 25% of the spleen) or grade V injuries (completely shattered spleens or spleens with hilar vascular injury which devascularizes the spleen),[15] higher injury severity score (ISS), decreasing hemoglobin, and presence of vascular injury or large volume hemoperitoneum.[2-6,8-10,12,14] Age as a risk factor for failure of nonoperative management has been evaluated with some evidence showing increased failure rates in older age groups,[3,16-18] but other studies have shown no such association.[19-26]

Angiography with the option of performing splenic artery embolization has emerged as a viable option to decrease the rate of nonoperative management failure.[2-4,6-14] Embolization is completed either by occluding the main splenic artery, referred to as proximal embolization, or by selectively targeting splenic artery branches with visualized injuries on angiography, referred to as distal embolization. Proposed benefits to proximal embolization include speed and ease of procedure, lower cost, and fewer splenic abscesses and infarctions.[27-29] A significant disadvantage includes rendering the splenic artery inaccessible for future angiographic interventions.[5] It is controversial if either site is associated with a lower failure rate. The literature is clear that splenic artery embolization is associated with preserved immune function compared to splenectomy.[30-33] Studies evaluating the effects of proximal versus distal splenic artery embolization on immune function have not shown a difference between these methodologies, although these studies have included only small data sets and may not have sufficient power to detect any variability.[30-32]

The aim of this study was to evaluate modes of treatment of blunt splenic injury based on patient factors, physiology, splenic injury severity, and associated injuries based on radiographic findings. A secondary aim was to assess if there were any differences in failure rate and complications between those treated with proximal versus distal splenic artery embolization.

METHODS

A retrospective review was conducted of all patients 18 years of age or older with a splenic injury following blunt trauma. A total of 405 patients were identified initially through a search of our trauma registry, of which 62 were excluded. The remaining 343 patients were the focus of this investigation. All patients were evaluated at an American College of Surgeons-verified level I Trauma Center from January 1, 2008 to February 1, 2017. Data collection included demographics (age, gender, and race), imaging results at admission, injury characteristics, treatment modality (observation, embolization, and surgery), complications, and hospital outcomes (mechanical ventilation, days on mechanical ventilation, intensive care unit [ICU] admission and length of stay, hospital length of stay, and in-hospital mortality). The amount of hemoperitoneum was quantified on CT into mild, moderate, and severe. Hemoperitoneum was defined as mild if blood was confined to the peri-splenic area, moderate if blood was found throughout the left abdomen, and severe if it extended

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License. (CC-BY-NC-ND 4.0: https://creativecommons.org/licenses/by-nc-nd/4.0/)

to the right hemi-abdomen. Data regarding embolization was identified by reviewing procedure reports and imaging.

For comparisons, patients were categorized based on treatment modality: observation alone, embolization, or operative intervention. Operative intervention included splenectomy and splenorrhaphy. Patients who underwent angiography without embolization were included in the observation group. Failure was defined as additional procedures (embolization, splenectomy, or splenorrhaphy) occurring in a patient who initially had been managed non-operatively.

Comparisons of categorical data were conducted using χ^2 analysis with Fisher's exact correction for comparisons with expected counts less than five in any cell. Comparisons of continuous data were done using one-way analysis of variance for normally distributed variables and a non-parametric test of medians for variables that did not meet the assumption of normality. When a test of medians could not be accomplished, a Kruskal-Wallis test was used to assess differences in distributions between groups on the variable of interest. All statistical tests were two-sided and analyses were considered significant when the resultant p value was ≤ 0.05.

Pairwise comparisons were conducted when a significant p value indicated differences between the three study groups (Tables 2 - 6). Paired values within a row in each table with different superscripts were different with a $p < 0.05$. Bonferroni or Games-Howell corrections were used to correct for multiple comparisons for cases in which homogeneity of variance could and could not be assumed, respectively. For Bonferroni corrections, the resultant p value was multiplied by the number of comparisons to calculate an adjusted p value. All analyses, except where noted, were conducted using SPSS release 24.0 (IBM Corp., Somers, New York). This study was approved for implementation by the institutional review board of Via Christi Hospitals Wichita Inc.

RESULTS

Patient Demographics, Injury Severity, Initial Vital Signs, and Injury Details. Patient demographics were similar between the three groups with no differences in age, gender, or race between treatment modalities (Table 1). Admission parameters are listed in Table 2. Patients that were treated operatively had a higher overall ISS than those managed with either observation or embolization (31 vs 17 and 20, respectively, $p < 0.001$). Those treated by observation alone had a lower splenic injury grade (2) than those treated with embolization or surgically (3 and 3, respectively, $p < 0.001$), the latter treatment modalities having similar splenic injury grades. There was no significant difference in overall ISS in those treated with observation alone or with embolization. More patients in the operative group were described as hemodynamically unstable on admission with lower systolic and diastolic blood pressure, and higher heart rate than were seen in the observation and embolization groups. More patients undergoing operative intervention required blood transfusions than the embolization or observation groups. Concomitant injuries such as traumatic brain injury, spinal injury, pneumothorax, hemothorax, rib fractures, liver injury, renal injury, and extremity fractures were varied, but overall were common, and were generally more prevalent in the operative group (Table 3).

Table 1. Comparison of demographics for patients undergoing observation, embolization, or operative management of splenic trauma.

Parameter	Treatment Group			p value
	Observation Number (%)	**Embolization** Number (%)	**Operative** Number (%)	
Number of observations	169 (49.3)	78 (22.7)	96 (28.0)	---
Age (years; Mean ± SD)	41.0 ± 18.5	39.6 ± 17.1	42.0 ± 17.8	0.676
Male	117 (69.2)	60 (62.5)	70 (72.9)	0.264
Race				0.956
White	155 (91.7)	71 (91.0)	90 (93.8)	
Black	3 (1.8)	2 (2.6)	2 (2.1)	
Asian	1 (0.6)	0 (0.0)	1 (1.0)	
Native Hawaiian or other Pacific Islander	1 (0.6)	0 (0.0)	0 (0.0)	
Other	9 (5.3)	5 (6.4)	3 (3.1)	

Table 2. Comparison of injury severity for patients undergoing observation, embolization, or operative management of splenic trauma.

Parameter	Treatment Group*			p value
	Observation	**Embolization**	**Operative**	
Number of observations	169 (49.3)	78 (22.7)	96 (28.0)	---
Injury severity score	17 (9,27)[a]	20 (10,27)[a]	31 (22,41)[b]	< 0.001
Glasgow Coma Scale score	15 (14,15)[a]	15 (15,15)[a]	14 (3,15)[b]	< 0.001
Systolic blood pressure (mmHg)	127.7 ± 29.3[a]	122.5 ± 20.3[a]	103.5 ± 27.4[b]	< 0.001
Diastolic blood pressure (mmHg)†	81.4 ± 22.9[a]	81.8 ± 17.9[a]	68.4 ± 22.8[b]	< 0.001
Heart rate (bpm)	95.1 ± 22.5[a]	100.6 ± 21.7[a]	111.5 ± 28.5[b]	< 0.001
Hemoglobin (g/dL)†	13.4 ± 3.4[a]	12.2 ± 2.3[b]	11.5 ± 3.4[b]	< 0.001
Hemodynamically stable†	141 (89.2)[a]	75 (96.2)[a]	18 (18.9)[b]	< 0.001
Transfusion required	45 (26.6)[a]	19 (24.4)[a]	83 (86.5)[b]	< 0.001

*Data are presented as Number (%), Median (interquartile range), or Mean ± SD.
†Missing values are present in the dataset.
[a,b]Values within a row with different superscript letters are significant at the 0.05 level.

Table 3. Injury details for patients undergoing non-operative, operative, and embolization management of splenic trauma.

Parameter	Treatment Group*			p value
	Observation	Embolization	Operative	
Number of observations	169 (49.3)	78 (22.7)	96 (28.0)	---
Traumatic brain injury	61 (36.1)[a,b]	23 (29.5)[b]	48 (50.0)[a]	0.015
Spine injury	47 (27.8)[a,b]	13 (16.7)[b]	36 (37.5)[a]	0.010
Pneumothorax	47 (27.8)[a,b]	17 (22.1)[b]	39 (40.6)[a]	0.018
Hemothorax	26 (15.4)	5 (6.4)	18 (18.8)	0.058
Rib fractures	85 (50.3)	33 (42.3)	58 (60.4)	0.055
Grade of spleen injury†	2 (1,3)[a]	3 (3,4)[b]	3 (2,4)[b]	< 0.001
Liver injury	27 (16.0)[a,b]	4 (5.1)[b]	26 (27.1)[a]	0.001
Grade of liver injury†	2 (1,3)	2 (1,n/a)	3 (1,4)	0.323
Kidney injury	23 (13.6)[a,b]	3 (3.8)[b]	20 (20.8)[a]	< 0.005
Bladder injury	2 (1.2)	2 (2.6)	1 (1.0)	0.715
Extremity injury	61 (35.7)[a]	27 (34.6)[a]	56 (58.3)[b]	0.001
Vascular injury†	14 (8.8)	4 (5.3)	3 (3.2)	0.204

*Data are presented as Number (%) or Median (interquartile range).
†Missing values are present in the dataset.
[a,b]Values within a row with different superscript letters are significant at the 0.05 level.

Radiographic Findings. Radiographic parameters were evaluated as a possible modality to predict appropriate management (Table 4). Contrast blush on CT was seen significantly more often in the embolization and operative groups compared to the observation group, yet blush was seen in less than half of each group. Mild hemoperitoneum was seen relatively frequently in all three groups, with severe hemoperitoneum occurring more commonly in the operative group than the non-operative groups.

Treatment Failures. There were no treatment failures in the embolization group. In the observation group, there were 19 treatment failures for an overall failure rate of 11.2%. Splenectomy and splenorrhaphy were each performed once, while the remaining 17 failures underwent embolization. Of note, the patient that underwent splenorrhaphy had undergone exploratory laparotomy for another reason, and splenorrhaphy was performed incidentally due to that procedure. Each of these patients showed severe hemoperitoneum on CT imaging.

Complications and Hospital Outcomes. Complications are listed in Table 5. The fewest complications were seen in the embolization group. The incidence of wound infections (11.5% vs 1.3% vs 0%, $p < 0.001$), pneumonia (12.3% vs 7.9% vs 1.3%, $p = 0.033$), and other complications, such as urinary tract infection, deep vein thrombosis, and pressure sores (46.6% vs 17.6% vs 5.3%, $p < 0.001$) were significantly higher in the operative group than in the observation and embolization groups, respectively. Operative patients also had a greater need for mechanical ventilation (75.0% vs 24.9% vs 11.5%, $p < 0.001$), although total ventilator days were not significantly different than the observation group or the embolization group (Table 6). Intensive care unit admission was common among all three groups, with operative patients requiring a longer length of stay in both the ICU setting and hospital. Operative patients also succumbed to their injuries and experienced in-hospital mortality more frequently than their counterparts managed non-operatively (26.3% vs 4.1% and 2.6%, $p < 0.001$).

Table 4. Comparison of radiology findings for patients undergoing observation, embolization, or operative management of splenic trauma.

Parameter	Treatment Group			p value
	Observation Number (%)	Embolization Number (%)	Operative Number (%)	
Number of observations	169 (49.3)	78 (22.7)	96 (28.0)	---
Contrast blush*	13 (9.0)[a]	30 (46.9)[b]	28 (47.5)[b]	< 0.001
Hemoperitoneum (mild)*	58 (40.3)	30 (46.9)	22 (37.3)	0.529
Hemoperitoneum (moderate)*	20 (13.9)[a]	21 (31.8)[b]	14 (23.7)[a,b]	0.006
Hemoperitoneum (severe)*	3 (2.1)[a]	3 (4.7)[a]	16 (27.1)[b]	< 0.001

*Missing values are present in the dataset.
[a,b]Values within a row with different superscript letters are significant at the 0.05 level.

Table 5. Complications for patients undergoing observation, embolization, or operative management of splenic trauma.

Parameter	Treatment Group			p value
	Observation Number (%)	Embolization Number (%)	Operative Number (%)	
Number of observations	169 (49.3)	78 (22.7)	96 (28.0)	---
Complications (any)*	31 (18.8)[a]	4 (5.3)[b]	37 (50.7)[c]	< 0.001
Pulmonary embolism*	1 (0.6)	0 (0.0)	2 (2.7)	0.191
Pneumonia*	13 (7.9)[a,b]	1 (1.3)[b]	9 (12.3)[a]	0.033
Wound infection*	2 (1.3)[a]	0 (0.0)[a]	9 (11.5)[b]	< 0.001
Dehiscence*	2 (1.2)	0 (0.0)	0 (0.0)	> 0.999
Other complications*	29 (17.6)[a]	4 (5.3)[b]	34 (46.6)[c]	< 0.001

*Missing values are present in the dataset.
[a,b,c]Values within a row with different superscript letters are significant at the 0.05 level.

Table 6. Hospital outcomes for patients undergoing non-operative, operative, and embolization management of splenic trauma.

Parameter	Treatment Group*			p value
	Observation	Embolization	Operative	
Number of observations	169 (49.3)	78 (22.7)	96 (28.0)	---
Mechanical ventilation	42 (24.9)[a]	9 (11.5)[b]	72 (75.0)[c]	< 0.001
Ventilator days†	7 (2,16.3)[a]	2 (2,9)[a]	4 (1.3,15)[a]	0.042
ICU admission	141 (83.4)	73 (93.6)	84 (87.5)	0.087
ICU days†‡	2 (1,6)[a]	2 (1,3)[a]	5.5 (2,18)[b]	< 0.001
Hospital length of stay	5 (3,10)[a]	4 (3,7)[a]	10 (3,21.8)[b]	0.001
Mortality	7 (4.1)[a]	2 (2.6)[a]	25 (26.3)[b]	<0.001

*Data are presented as Number (%) or Median (interquartile range).
†Only individuals with non-zero days included in analysis.
‡Missing values are present in the dataset.
[a,b,c]Values within a row with different superscript letters are significant at the 0.05 level.

Proximal vs Distal Embolization Outcomes. This study gathered data comparing proximal and distal splenic artery embolization. There were no differences in baseline admission vital signs, grade of splenic injury, or concomitant injuries between these groups (data not shown). There were significantly more patients with moderate hemoperitoneum that underwent proximal embolization (41.3% vs 11.8%, p = 0.045), although this difference was no longer seen in patients with severe hemoperitoneum (2.2% vs 11.8%, p = 0.213). Importantly, there was no difference in complication rates or hospital factors (ICU admission and length of stay, need for mechanical ventilation, and hospital length of stay) between these groups (data not shown).

DISCUSSION

The primary goal of this study was to compare treatment modalities for blunt splenic injury based on patient factors, physiology, splenic injury severity, and associated injuries based on radiographic findings. Our findings demonstrated that all three management strategies can be appropriate in the right clinical setting. Our treatment failure rates for observation (11.2% compared to 10% - 18%)[5,9,11,34] and embolization (0% compared to 0% - 8%)[9,11] are in line with the low end of other published data.

Prior studies have touted lower systolic blood pressure, higher ISS, lower pH, and greater need for pRBC transfusions as predictors for operative intervention.[4,35] This study supported these findings as seen in Table 2, although pH was not assessed. Increasing age, often using cutoff values of greater than 55 or greater than 65 years of age, has been described as both an indication for operative management and a predictor for failure of non-operative management,[3,16-18] while other studies refute these conclusions.[19-26] In this study, age was not different amongst the three groups, and the low failure rate of non-operative management suggested that age is not a determining factor for management decisions.

Radiographic parameters did not show any clear patterns amongst the three groups. Mild hemoperitoneum was the most common finding regardless of selected treatment modality, with moderate hemoperitoneum most frequent in the embolization group and severe in the operative group. However, embolization also was successful in treating patients with severe hemoperitoneum. In accordance, Wahl et al.[23] found that contrast extravasation or degree of hemoperitoneum visualized on CT scan did not accurately predict the need for intervention, be it operation or embolization.

Complications were observed most frequently in the operative group, including wound infection, pneumonia, and other complications (e.g., deep vein thrombosis, urinary tract infection), as expected with emergent major abdominal surgery. These complications could be due either to the concomitant injuries and higher overall Injury Severity Score or related to the surgery itself. The need for advanced interventions was also highest in the operative group, as well as longer length of ICU and hospital stay. These results likely would be expected as this group was more severely injured as evidenced by a higher ISS, lower Glasgow Coma Scale score, and higher incidence of hemodynamic instability upon admission. Prior data from this institution demonstrated lower complication rates with splenic artery embolization compared to operative intervention.[6] Interestingly, the embolization group displayed fewer complications than the patients that were observed, as well as a lower need for mechanical ventilation, contrary to previous data.[36] The reason for this is unclear, although it may be due to an unwillingness of staff to allow borderline patients to leave the close observation and direct control of the ICU situation. There was no difference in complication rate between proximal and distal embolization groups. Mortality was highest in the operative group and low and relatively equal in the non-operative groups.

The secondary aim of this study was to evaluate differences between proximal and distal splenic artery embolization. Our data showed no differences in baseline admission characteristics between these groups. Evaluation of pre-procedural imaging indicated that there were significantly more patients with moderate hemoperitoneum undergoing proximal splenic artery embolization; however, this difference was not seen in patients with severe hemoperitoneum. There was a technical success rate of 100%, with embolization completed in all instances and no need for repeat embolization or operative intervention. This compared to a success rate of 91% - 95% in other studies,[37,38] with some data showing a trend toward a greater rate of re-bleeding in distal embolizations.[38] Location of embolization and material used were left to the interventional radiologist's discretion, so the selection in each circumstance may be a matter of preference or other unknown factors. Previous literature ascribed a greater rate of splenic abscesses and infarctions to distal splenic artery embolization, but this was not captured in this study as we included only in-hospital complications.

This study had several limitations, first of which were the limitations inherent with any study of retrospective design and the subsequent availability of data being limited to that which were present in the patient's medical record. Small sample size and data from a single institution limited the generalizability of these findings. The relatively small number of treatment failures prevented robust multivariate analyses from being performed to elucidate factors that are predictive of treatment failures while adjusting for differences between groups. Only data from the index hospital admission were included, which could have resulted in the omission of some complications that presented after discharge.

Prospective studies are needed to determine the optimal treatment of blunt splenic injury based on measurable data such as admission criteria or imaging findings. Taken as a whole, the low failure rates of observation and embolization with comparatively low complication rates suggested that avoiding the physiologic insult of surgery may provide substantial benefit. The wide variation in degree of hemoperitoneum treated with operative intervention may indicate over-utilization of surgical intervention in mild or moderate hemoperitoneum. Additionally, fewer complications in the embolization group relative to the observation group may indicate that a proactive treatment such as embolization may provide benefit over a period of observation, particularly in patients with severe hemoperitoneum; however, complications measured were biased towards those expected with operative intervention rather than embolization. Prospective studies should be completed to further clarify these factors. Cost studies also would help with economic decision-making. Development of a predictive model hopefully would account for fewer unnecessary operations, avoiding the risk and complications associated with surgery, and improve the success rate of embolization and non-operative management.

CONCLUSION

In conclusion, this study demonstrated low rates of treatment failure in the observation and embolization groups, consistent with the lower end of other published data. The rate of complications was lowest amongst the embolization groups, with no difference between the proximal and distal splenic artery embolization groups, making it an attractive treatment option in appropriately selected patients.

REFERENCES

[1] Amirkazem VS, Malihe K. Randomized clinical trial of ligasureTM versus conventional splenectomy for injured spleen in blunt abdominal trauma. Int J Surg 2017; 38:48-51. PMID: 28034773.

[2] Raikhlin A, Baerlocher MO, Asch MR, Myers A. Imaging and transcatheter arterial embolization for traumatic splenic injuries: Review of the literature. Can J Surg 2008; 51(6):464-472. PMID: 19057735.

[3] Renzulli P, Gross T, Schnüriger B, et al. Management of blunt injuries to the spleen. Br J Surg 2010; 97(11):1696-1703. PMID: 20799294.

[4] Van der Cruyssen F, Manzelli A. Splenic artery embolization: technically feasible but not necessarily advantageous. World J Emerg Surg 2016; 11(1):47. PMID: 27625701.

[5] van der Vlies CH, Hoekstra J, Ponsen KJ, Reekers JA, van Delden OM, Goslings JC. Impact of splenic artery embolization on the success rate of nonoperative management for blunt splenic injury. Cardiovasc Intervent Radiol 2012; 35(1):76-81. PMID: 21431976.]

[6] Bruce PJ, Helmer SD, Harrison PB, Sirico T, Haan JM. Nonsurgical management of blunt splenic injury: Is it cost effective? Am J Surg 2011; 202(6):810-816. PMID: 22137139.

[7] Haan JM, Bochicchio GV, Conway A, Bochicchio KM, Scalea TM. Splenic embolization decreases infectious complications and resource utilization compared to splenectomy in severely injured patients. Kans J Med 2014; 7(2):50-57.

[8] Haan JM, Marmery H, Shanmuganathan K, Mirvis SE, Scalea TM. Experience with splenic main coil embolization and significance of new or persistent pseudoaneurym: Reembolize, operate, or observe. J Trauma 2007; 63(3):615-619. PMID: 18073609.

[9] Mayglothling JA, Haan JM, Scalea TM. Blunt splenic injuries in the adolescent trauma population: The role of angiography and embolization. J Emerg Med 2011; 41(1):21-28. PMID: 19181474.

[10] Miller PR, Chang MC, Hoth JJ, et al. Prospective trial of angiography and embolization for all grade III to V blunt splenic injuries: Nonoperative management success rate is significantly improved. J Am Coll Surg 2014; 218(4):644-648. PMID: 24655852.

[11] Olthof DC, Joosse P, Bossuyt PM, et al. Observation versus embolization in patients with blunt splenic injury after trauma: A propensity score analysis. World J Surg 2016; 40(5):1264-1271. PMID: 26718838.

[12] Olthof DC, van der Vlies CH, Joosse P, van Delden OM, Jurkovich GJ, Goslings JC; PYTHIA Collaboration Group. Consensus strategies for the nonoperative management of patients with blunt splenic injury: A Delphi study. J Trauma Acute Care Surg 2013; 74(6):1567-1574. PMID: 23694889.

[13] Ong AW, Eilertson KE, Reilly EF, et al. Nonoperative management of splenic injuries: Significance of age. J Surg Res 2016; 201(1):134-140. PMID: 26850194.

[14] Sabe AA, Claridge JA, Rosenblum DI, Lie K, Malangoni MA. The effects of splenic artery embolization on nonoperative management of blunt splenic injury: A 16-year experience. J Trauma 2009; 67(3):565-572. PMID: 19741401.

[15] Moore EE, Cogbill TH, Malangoni M, Jurkovich J, Champion HR. Injury Scoring Scale: A resource for trauma care professionals. The American Association for the Surgery of Trauma. Chicago, IL. Available at: http://www.aast.org/Library/TraumaTools/InjuryScoringScales.aspx. Accessed April 4, 2019.

[16] Banerjee A, Duane TM, Wilson SP, et al. Trauma center variation in splenic artery embolization and spleen salvage: A multicenter analysis. J Trauma Acute Care Surg 2013; 75(1):69-75. PMID: 23778441.

[17] Godley CD, Warren RL, Sheridan RL, McCabe CJ. Nonoperative management of blunt splenic injury in adults: Age over 55 years as a powerful indicator for failure. J Am Coll Surg 1996; 183(2):133-139. PMID: 8696544.

[18] Jeremitsky E, Smith RS, Ong AW. Starting the clock: Defining nonoperative management of blunt splenic injury by time. Am J Surg 2013; 205(3):298-301. PMID: 23351507.

[19] Bhullar IS, Frykberg ER, Siragusa D, et al. Age does not affect outcomes of nonoperative management of blunt splenic trauma. J Am Coll Surg 2012; 214(6):958-964. PMID: 22521669.

[20] Clancy TV, Ramshaw DG, Maxwell JG, et al. Management outcomes in splenic injury: A statewide trauma center review. Ann Surg 1997; 226(1):17-24. PMID: 9242333.

[21] Cocanour CS, Moore FA, Ware DN, Marvin RG, Duke JH. Age should not be a consideration for nonoperative management of blunt splenic injury. J Trauma 2000; 48(4):606-612. PMID: 10780591.

[22] Nix JA, Costanza M, Daley BJ, Powell MA, Enderson BL. Outcome of the current management of splenic injuries. J Trauma 2001; 50(5):835-542. PMID: 11371838.

[23] Smith JS Jr, Cooney RN, Mucha P Jr. Nonoperative management of the ruptured spleen: A revalidation of criteria. Surgery 1996; 120(4):745-751. PMID: 8862387.

[24] Smith JS Jr, Wengrovitz MA, DeLong BS. Prospective validation of criteria, including age, for safe, nonsurgical management of the ruptured spleen. J Trauma 1992; 33(3):363-369. PMID: 1404503.

[25] Velmahos GC, Chan LS, Kamel E, et al. Nonoperative management of splenic injuries: Have we gone too far? Arch Surg 2000; 135(6):674-681. PMID: 10843363.

[26] Velmahos GC, Zacharias N, Emhoff TA, et al. Management of the most severely injured spleen: A multicenter study of the Research Consortium of New England Centers for Trauma (ReCONECT). Arch Surg 2010; 145(5):456-460. PMID: 20479344.

[27] Killeen KL, Shanmuganathan K, Boyd-Kranis R, Scalea TM, Mirvis SE. CT findings after embolization for blunt splenic trauma. J Vasc Interv Radiol 2001; 12(2):209-214. PMID: 11265885.

[28] Omert LA, Salyer D, Dunham CM, Porter J, Silva A, Protetch J. Implications of the "contrast blush" finding on computed tomographic scan of the spleen in trauma. J Trauma 2001; 51(2):272-278. PMID: 11493784.

[29] Smith HE, Biffl WL, Majercik SD, Jednacz J, Lambiase R, Cioffi WG. Splenic artery embolization: Have we gone too far? J Trauma 2006; 61(3):541-546. PMID: 16966984.

[30] Foley PT, Kavnoudias H, Cameron PU, Czarnecki C, Paul E, Lyon SM. Proximal versus distal splenic artery embolisation for blunt splenic trauma: What is the impact on splenic immune function? Cardiovasc Intervent Radiol 2015; 38(5):1143-1151. PMID: 26139039.
[31] Malhotra AK, Carter RF, Lebman DA, et al. Preservation of splenic immunocompetence after splenic artery angioembolization for blunt splenic injury. J Trauma 2010; 69(5):1126-1131. PMID: 21068617.
[32] 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. PMID: 25185578.
[33] Skattum J, Naess PA, Gaarder C. Non-operative management and immune function after splenic injury. Br J Surg 2012; 99(Suppl 1):59-65. PMID: 22441857.
[34] Peitzman AB, Harbrecht BG, Rivera L, Heil B; Eastern Association for the Surgery of Trauma Multiinstitutional Trials Workgroup. Failure of observation of blunt splenic injury in adults: Variability in practice and adverse consequences. J Am Coll Surg 2005; 201(2):179-187. PMID: 16038813.
[35] Wahl WL, Ahrns KS, Chen S, Hemmila MR, Rowe SA, Arbabi S. Blunt splenic injury: Operation versus angiographic embolization. Surgery 2004; 136(4):891-899. PMID: 15467676.
[36] Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: A 5-year experience. J Trauma 2005; 58(3):492-498. PMID: 15761342.
[37] Frandon J, Rodière M, Arvieux C, et al. Blunt splenic injury: Outcomes of proximal versus distal and combined splenic artery embolization. Diagn Interv Imaging 2014; 95(4):825-831. PMID: 26081719.
[38] Schnüriger B, Inaba K, Konstantinidis A, Lustenberger T, Chan LS, Demetriades D. Outcomes of proximal versus distal splenic artery embolization after trauma: A systematic review and meta-analysis. J Trauma 2011; 70(1):252-260. PMID: 21217497.

Keywords: trauma, blunt injury, splenic artery, therapeutic embolization, splenectomy