

Delayed splenic pseudoaneurysm identification with surveillance imaging

Taylor E. Wallen, MD, Katherine Clark, RN, BSN, Matthew R. Baucom, MD, Rebecca Pabst, RN, BSN, Jennifer Lemmink, RN, MSN, Timothy A. Pritts, MD, PhD, Amy T. Makley, MD, and Michael D. Goodman, MD, Cincinnati, Ohio

BACKGROUND:	Recent studies have shown that nonoperative management of patients with splenic injury has up to a 90% success rate. However, delayed hemorrhage secondary to splenic artery pseudoaneurysm occurs in 5% to 10% of patients with up to 27% of patients developing a pseudoaneurysm on delayed imaging. The goal of our study was to evaluate the safety and utility of delayed computed tomography (CT) imaging for blunt splenic injury patients.
METHODS:	A retrospective evaluation of all traumatic splenic injuries from 2018 to 2020 at a single level 1 trauma center was undertaken. Patients were subdivided into four groups based on the extent of splenic injury: grades I and II, grade III, grade IV, and grade V. Patient injury characteristics along with hospital length of stay, imaging, procedures, and presence/absence of pseudoaneurysm were documented.
RESULTS:	A total of 588 trauma patients were initially included for evaluation, with 539 included for final analysis. Two hundred ninety-seven patients sustained grades I and II; 123 patients, grade III; 61 patients, grade IV; and 58 patients, grade V splenic injuries. One hundred twenty-nine patients (24%) underwent either emergent or delayed (>6 hours) splenectomy with an additional six patients having a splenorrhaphy on initial operation. Of the patients who were treated nonoperatively, 98% of grade III, 91% of grade IV, and 100% of grade V splenic injury patients underwent follow-up CT imaging. The mean $\pm$ SD time from admission to follow-up abdominal CT scan was 5 ± 4.4 days. Twenty-two pseudoaneurysms were identified including grade III (10 of 84), grade IV (7 of 22), and grade V (2 of 5) patients; of these patients, 33% of grade III and 30% of grade IV required subsequent splenectomy. Routine follow-up CT imaging after high-grade splenic injury identifies splenic artery pseudoaneurysm in a significant proportion of patients. Standardized surveillance imaging for high-grade splenic trauma promotes prospective identification of pseudoaneurysms, allowing for interventions to minimize delayed splenic injury complications. (<i>J Trauma Acute Care Surg.</i> 2022;93: 113–117. Copyright © 2022 Wolters Kluwer Health, Inc. All rights reserved.)
CONCLUSION:	
LEVEL OF EVIDENCE:	Therapeutic/Care Management; level IV.
KEY WORDS:	Splenic pseudoaneurysm; imaging; splenic injury; nonoperative management.

Blunt abdominal trauma affects 25% of all patients admitted after traumatic injury, with blunt splenic injury (BSI) affecting around 39,000 individuals annually within the United States.^{1,2} The current management strategies used for those with BSI include both operative and nonoperative strategies, with more than 80% of patients being successfully managed nonoperatively.¹ The practice of nonoperative management for BSI has been proven successful in both pediatric and adult trauma patients who remain hemodynamically stable without evidence of peritonitis.^{1,3,4} Since the implementation of computed tomography (CT) imaging, the practice patterns for intra-abdominal solid organ injury have changed drastically. Although the use of CT imaging has been strongly used in the initial management of BSI, the overall utility of follow-up CT imaging has been widely debated.

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From the Department of Surgery, University of Cincinnati, Cincinnati, Ohio.

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Address for reprints: Michael D. Goodman, MD, Department of Surgery, University of Cincinnati, 231 Albert Sabin Way, ML 0558, Cincinnati, OH 45267-0558; email: michael.goodman@uc.edu.

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The incidence of splenic artery pseudoaneurysm development ranges from 0.2% to 10.4% with an overall incidence of causing delayed hemorrhage in 2% to 27% of patients.^{5,6} Prompt identification and treatment of posttraumatic splenic artery pseudoaneurysm is warranted, as untreated pseudoaneurysms may cause delayed hemorrhagic shock and death. Current evaluation of practice patterns for Eastern Association for the Surgery of Trauma members found that only 14.5% of surgeons routinely perform in-hospital follow-up abdominal CT scans in BSI patients.⁷ Some authors argued that repeat CT scans are not needed especially for those with low-grade splenic injury as the risk of pseudoaneurysm formation is low. Others have argued that, although the risk of pseudoaneurysm development is low, the risk of missing a latent pseudoaneurysm with delayed rupture is much greater; as such, many patients treated nonoperatively receive repeated CT scan evaluation.^{8–10}

The goal of our study was to retrospectively review the management strategies used for BSI patients of all grades to determine the safety of nonoperative management and the effectiveness of intentional follow-up CT scan evaluation to identify latent splenic pseudoaneurysms. We hypothesized that a dedicated delayed CT-angiogram would appropriately identify splenic pseudoaneurysms after high-grade BSI, allowing for intervention before discharge from the index hospital admission.

PATIENTS AND METHODS

Data Collection

Following an initial retrospective study of solid organ pseudoaneurysm development, an institutional protocol was changed to plan for dedicated repeat CT-angiograms for all grades IV and V solid organ injuries as well as grade III solid organ injuries with concern for contrast blush or pseudoaneurysm on admission CT.¹¹ A retrospective review of all traumatically injured patients who sustained blunt injury to the spleen was evaluated at a single level 1 trauma academic institution from 2018 to 2020. All patients who sustained splenic injury were further subdivided into four groups based upon the extent of splenic injury using the American Association for the Surgery of Trauma splenic injury scoring system: grades I and II, grade III, grade IV, and grade V.¹² The outcomes of interest included emergent versus delayed (>6 hours) splenectomy, splenorrhaphy, emergent or delayed (>6 hours) interventional radiology (IR) procedure, follow-up CT imaging, presence/absence of splenic pseudoaneurysm, and outcomes after identification of pseudoaneurysm. Patient demographics were collected through the electronic medical record including patient sex, weight, height, age, Injury Severity Score, Abbreviated Injury Scale score, inpatient admission unit, discharge location, and days to CT scan evaluation. Patients who sustained a grade I or II splenic injury were only included in follow-up imaging if they had a positive scan; otherwise, they were not included.

This study was performed and analyzed within the STrengthening the Reporting of OBservational studies in Epidemiology guidelines, which are referenced in the Supplemental Digital Content (Supplementary Data 1, <http://links.lww.com/TA/C424>).

RESULTS

Study Population Demographics

Five hundred eighty-eight patients were initially included in the study. Forty-nine patients experienced penetrating injuries and therefore were excluded, leaving a total of 539 patients for evaluation. The most common causes for blunt traumatic injury were as follows: motor vehicle collision, 55% (n = 298); fall, 16% (n = 89); pedestrian struck, 13% (n = 72); motorcycle collision, 9% (n = 49); and other, 5% (n = 31) (Supplemental Digital Content, Supplementary Data 2, <http://links.lww.com/TA/C425>). The mean $\pm$ SD age of the study population was 44 ± 19 years with a body mass index of 28.87 ± 8.40 kg/m² and 40% being female (n = 216) (Table 1). The average Injury Severity Score was 24.26 ± 13.15 , and the Abbreviated Injury Scale score of the abdomen was 3.07 ± 1.07 (Table 1). Two hundred ninety-seven patients were classified as having a grade I and II injury, 123 patients with grade III, 61 patients with grade IV, and 58 patients with grade V splenic injury. The mean $\pm$ SD hospital length of stay was 8.52 ± 8.65 days with the mean $\pm$ SD time to follow-up CT imaging being 5.0 ± 4.4 days (Table 1). Forty-six patients died (8.53%) during hospitalization. Nine patients died immediately upon arrival to the emergency department, with the remaining 37 patients who died during hospitalization: grade II, 40% (n = 15); grade III, 24% (n = 9); grade IV, 14% (n = 5); and grade V, 22% (n = 8). Mortality was not directly attributed to the splenic injuries alone. Of the patients who did not

TABLE 1. Patient Demographics, Injury Characteristics

Patient Demographics	Mean $\pm$ SD
Age, y	44.06 $\pm$ 18.9
BMI, kg/m ²	28.87 $\pm$ 8.4
% Female (n = 216)	40%
Hospital length of stay, d	8.52 $\pm$ 8.7
Injury Severity Score	24.26 $\pm$ 13.1
AIS abdomen	3.07 $\pm$ 1.1
% Death (n = 46)	8.5%
No. days from hospital admission to CT scan	5 $\pm$ 4.4

AIS, Abbreviated Injury Scale; BMI, body mass index.

receive follow-up imaging, 2 of 425 patients died during their initial hospitalization secondary to polytraumatic injuries and were transitioned to comfort care measures.

CT Identification of Splenic Pseudoaneurysm and Management Strategies Employed

One hundred twenty-nine patients (24%) underwent either emergent or delayed splenectomy with an additional six patients having a splenorrhaphy on initial operation. Sixteen patients (3%) underwent emergent or delayed IR procedure (Table 2). Of all evaluated BSI patients, only 11 (2%) were diagnosed with definitive or possible splenic pseudoaneurysm on initial admission CT imaging (Table 3). One hundred fourteen patients with grade III or greater splenic injury received follow-up imaging. Ninety-eight percent of grade III patients, 91% of grade IV patients, and 100% of grade V splenic injury patients received follow-up imaging (Table 2). There were 22 new splenic pseudoaneurysms detected on follow-up imaging: 10 in grade III (11% of all grade III follow-up imaging patients), 7 in grade IV (29% of all grade IV follow-up imaging patients), and 2 in grade V (40% of all grade V follow-up imaging patients) splenic injured patients (Table 3). The percentages of detected splenic pseudoaneurysms in nonoperative patients were 1% in grades I and II, 11% in grade III, 29% in grade IV, and 40% in grade V injury (Table 3).

With regard to the grade III injury patients who received repeat CT imaging, 53% underwent repeat imaging because of concerns for either pseudoaneurysm development or for specific follow-up on the splenic injury, 26% of patients had follow-up CT imaging for abdominal pain/fevers/concern for abscess formation, and 21% of patients had repeat CT imaging to follow other traumatic abdominal injuries. Six of the grade III patients received follow-up imaging after initial hospitalization. Three patients received imaging because of clinical concerns for abdominal abscess formation, the other three were because of hypoxia and fall, and one patient had departed the initial hospitalization against medical advice.

Twenty-two patients underwent IR procedure after diagnosis of a splenic pseudoaneurysm on follow-up imaging: 67% of grades I and II patients (n = 4), 53% of grade III patients (n = 8), 80% of grade IV patients (n = 8), and 100% of grade V patients (n = 2) (Table 3). Four patients did not undergo splenic embolization, including three grade III patients and one grade V patient (Table 3), without subsequent clinical decompensation. Eight patients underwent a splenectomy after identification of

TABLE 2. Description of BSI Management by Grade

Grade of Splenic Injury	Total (n)	Splenectomy	Splenorrhaphy	IR Procedure	No. Patients Require Follow-up Imaging	% Follow-up Imaging
Grades I and II	297	4	6	3	—	—
Grade III	123	35	0	8	87	99
Grade IV	61	37	0	5	22	92
Grade V	58	53	0	0	5	100
Total	539	129	6	16	114	

splenic pseudoaneurysms on follow-up imaging: 33% of grade III (n = 5) and 30% of grade IV (n = 3) (Table 3). Decisions for IR intervention and splenectomy after pseudoaneurysm identification were based on collaborative decision making between the trauma and IR faculty taking the size, number, and location of the identified pseudoaneurysms.

DISCUSSION

In this retrospective review of all blunt abdominal trauma patients sustaining splenic injury at a single level 1 trauma center, we found that 75% of all patients were successfully managed nonoperatively regardless of splenic grade. Overall, only eight patients were considered failures of nonoperative management requiring splenectomy after 24 hours during their hospitalization (five grade III patients and three grade IV patients). With a new protocol for repeat CT in place, more than 90% of patients with grade III or higher splenic injuries had routine follow-up imaging, with 22 new splenic pseudoaneurysms identified. The average time from hospital admission to first follow-up CT scan was 5 days.

Routine use of follow-up CT scans in patients after BSI is not widely accepted. Authors including Lawson et al.¹³ and Shapiro et al.¹⁴ have provided evidence to support the abandonment of follow-up imaging in BSI patients who are otherwise hemodynamically stable without abdominal complaints, as they provide no further evidence to aid in patient management while hospitalized. Researchers used a standardized protocol for all BSI patients whereby, if patients displayed hemodynamic instability, they received follow-up CT imaging or, in asymptomatic patients, all BSI patients received follow-up imaging. They found that, of the 100 scans reviewed, only 10% of scans appeared to have worsened, warranting 3 patients to undergo splenectomy for late onset bleeding.¹⁴ In our study cohort, 114 patients required follow-up imaging with identification of 22 new splenic

pseudoaneurysms of which 18 patients had an IR procedure with intervention and 8 underwent a delayed splenectomy. Furthermore, Allins et al.¹⁵ found that, although a standardized protocol was also used for all BSI patients, the follow-up CT scan result was of limited use for clinical decision making and was not found to be the principal reason in the decision to operate. Researchers also found that CT scans were performed at variable intervals and strict adherence to protocol was underused.¹⁵ By contrast, we found in our study that we had 98% adherence for grade III, 91% for grade IV, and 100% for grade V BSI patients with respect to follow-up imaging. Based upon our cohort of patients, we recommend that routine follow-up imaging and dedicated CT with intravenous contrast should be performed in all BSI patients grades IV and above and selected grade III patients (those with small or possible pseudoaneurysm on initial CT imaging or those with concern for delayed bleeding), as the rate of pseudoaneurysm formation is 11% to 40% in these patients.

Delayed onset of pseudoaneurysm formation is a well-known complication after BSI, affecting 5% to 35% of patients.^{10,16,17} The most feared complication after nonoperative management of BSI patients is delayed splenic rupture. The overall mortality of simple splenic rupture is around 1%; however, the risk of mortality increases 10-fold when found to develop in a delayed fashion.¹⁸ Muroya et al.¹⁶ found that 15.4% of patients with BSI presented with delayed formation of splenic pseudoaneurysm with 30.4% occurring in grade II splenic injuries and 18.4% occurring in grade III splenic injuries and recommended follow-up CT within 1 week of BSI to ensure adequate visualization of delayed splenic pseudoaneurysm, even in low-grade injury patients (grade II or III), to prevent delayed splenic rupture. In our study population, we identified 22 delayed splenic pseudoaneurysms, 11% in grade III, 31% in grade IV, and 40% in grade V patients. Similarly, we found that the average time to follow-up imaging was 5 days with more than 91% compliance

TABLE 3. Management of Splenic Pseudoaneurysm Based Upon Grade of Splenic Injury

Grade of Splenic Injury	Splenic PSA on Initial Imaging	Splenic PSA on Follow-up Imaging	% PSA Detected in All Patients Without Undergoing Splenectomy	IR Procedure	% Patients Had Delayed IR Procedure After PSA Detection	Repeat Imaging	Splenectomy
Grades I and II	3	3	1	4	67	0	0 (0%)
Grade III	5	10	11	8	53	7	5 (33%)
Grade IV	3	7	29	8	80	3	3 (30%)
Grade V	0	2	40	2	100	0	0 (0%)
Total	11	22	—	22	—	10	8

PSA, pseudoaneurysm.

with grade III injury and higher. Because there continues to be discordance on the recommendations for follow-up imaging, especially for low-grade splenic injury patients, it becomes increasingly important to review internal management practices and create a standardized protocol based upon the patient population being treated.^{19–21} At our institution, we routinely plan to repeat CT imaging for all grade IV and V BSI patients. However, in this retrospective review, we have shown a significant proportion of patients with grade III injury that could benefit from follow-up imaging to prevent long-term complications. As such, we recommend routine follow-up imaging at 5 days after admission for all grade IV and V injuries with select grade III (indications as stated above) repeat CT based on characteristics of the admission CT to achieve maximal identification of delayed pseudoaneurysm formation.

Our study does have its limitations. First, this study is retrospective and includes evaluation of a single institutional practice for BSI patients. As such, the data may be difficult to generalize to all trauma center experiences because our patient population may be vastly different than other level I centers. However, we identified more than 500 patients with varying BSI, which aids in the applicability of our analysis to make recommendations. Second, for all grades I and II splenic injury patients, we did not capture all patients who received follow-up imaging; we only identified those who had positive CT scans for pseudoaneurysm formation. Therefore, we are unable to make any additional conclusions about our practice patterns for low-grade splenic injury patients because it is difficult to determine how frequently these low-grade patients were reimaged. Third, over the study period, we have used up to four CT imaging machines with differing capabilities for imaging size and number of slices obtained per image. Because this study is retrospective, the use of each specific scanner was not identified and so we cannot comment on the importance of specific CT technology regarding optimal identification of splenic pseudoaneurysms. Furthermore, at our institution, the protocol of follow-up imaging includes a CT scan with intravenous contrast. We do not currently use ultrasonography for high-grade splenic trauma patients because this modality has not been proven to be superior to CT imaging and may also be difficult to adequately survey deep visceral vessels such as the splenic arterial system.^{22–24} Lastly, we recognize that some of the follow-up CT imaging that was documented was ordered for other reasons outside of pseudoaneurysm detection such as to evaluate for infection or progression of other nonsplenic injuries.

In conclusion, we found that routine follow-up CT imaging after splenic injury identifies splenic artery pseudoaneurysm in a significant proportion of patients. Standardized surveillance imaging for high-grade splenic trauma promotes prospective identification of pseudoaneurysms, allowing for interventions to maximize splenic preservation. Based on this retrospective review, we recommend routine follow-up imaging for BSI patients grades III and above to identify latent splenic pseudoaneurysm formation and prevent potential complications secondary to this pseudoaneurysms and delayed splenic rupture.

AUTHORSHIP

T.E.W. contributed in the literature search, data analysis/interpretation, data collection, and writing. K.C. contributed in the data collection and

data analysis. M.R.B. contributed in the data analysis and manuscript revisions. R.P. contributed in the data collection and data analysis. J.L. contributed in the data collection and data analysis. T.A.P. contributed in the manuscript revision and data interpretation. A.T.M. contributed in the manuscript revision and data interpretation. M.D.G. contributed in the critical revision, data interpretation, writing, and study design.

DISCLOSURE

The authors declare no conflicts of interest.

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