Contemporary management of adult splenic injuries: What you need to know

Nicole L. Werner, MD, MS *and* **Ben L. Zarzaur, MD, MPH**

ABSTRACT: The spleen is a frequently injured organ, with over 40,000 adult splenic injuries occurring yearly. It plays an important role in the body's immune system, so surgeons should make every effort to perform splenic salvage when able. In blunt injury, indications for emergent splenectomy have not recently changed and include hemodynamic instability and peritonitis. A computed tomography (CT) scan with intravenous contrast is the preferred imaging modality for hemodynamically normal patients and should be used to classify the grade of injury and identify active bleeding and its stigmata. Nonoperative management has been successful for all grades of blunt injury (80–95%), but it is the job of the surgeon to carefully select the patient, in the context of their age, other associated injuries, and splenic CT findings, so this success rate remains high. Angioembolization is an important tool for splenic salvage that should be used when an actively bleeding vessel is observed on CT scan. Both proximal and distal embolizations are effective with no data to suggest that one is superior to the other. All patients selected for nonoperative management require close monitoring, which can include interval CT scans for high-grade injuries. Penetrating splenic injuries differ from blunt injuries because they are more likely to be surgically explored on presentation and they have a higher operative splenorrhaphy rate. (*J Trauma Acute Care Surg.* 2025;00: 00–00. Copyright © 2025 Wolters Kluwer Health, Inc. All rights reserved.)

KEY WORDS: Blunt splenic injury; nonoperative failure; angioembolization; penetrating splenic injury; splenic trauma.

For surgeons caring for patients following injury, no organ injury has created more consternation than the spleen. The pendulum has swung from operative to primarily nonoperative, as experience and technology have changed over time. The development and proliferation of multidetector computed tomography (CT) scanners and refinement of catheter-based diagnostic and embolization techniques have increased the options for management of patients with spleen injuries. While there are a multitude of retrospective and prospective studies, there are only a few randomized controlled trials to inform the care of these patients. This has led to variation in care and multiple dilemmas for the surgeons managing these injuries.

This is no small matter. With more than 40,000 adults suffering from spleen injuries each year,[1] the average trauma center will see more than 200 patients with these injuries yearly. This is more than any other solid abdominal organ. Because of the robust arterial blood supply, life-threatening hemorrhage requiring splenectomy occurs in up to 10% to 15% of patients. This has remained remarkably consistent for the past 25 years.[2] For the remainder of patients with injured spleens, nonoperative management is the standard. This is where a complex matrix of decision-making comes into play. This article will address the most common controversies in managing adult patients with spleen injuries.

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From the Department of Surgery, Division of Acute Care and Regional General Surgery, University of Wisconsin Hospital and Clinics, Madison, WI.

Address for correspondence: Nicole L. Werner, MD, MS, Department of Surgery, Division of Acute Care and Regional General Surgery, University of Wisconsin Hospital and Clinics, 600 Highland Ave, G5/332, Madison, WI 53792-3236; email: werner@surgery.wisc.edu.

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RELEVANT SPLENIC ANATOMY AND PHYSIOLOGY

Before getting into more controversial topics, it is best to have a detailed understanding of splenic anatomy and physiology because they both contribute to the management of patients with splenic injuries. The spleen is composed of three to five distinct segments, which are separated from each other with avascular planes. Each segment is supplied by its own segmental artery derived from the splenic artery.[3] Segments have a transverse pattern orientated from superior to inferior, although this anatomy cannot be determined on external inspection (Fig. 1). This segmentation explains why lacerations perpendicular to the segmental arteries result in greater hemorrhage as they cross multiple segments. It also explains why penetrating injuries to the spleen often result in the need for splenectomy since they frequently traverse multiple segments. It is important to note that segmental arteries typically do not interconnect, which is advantageous for achieving hemostasis with selective angioembolization or partial splenectomy.

The splenic capsule is composed of elastin and collagen and protects the spleen in blunt injury, as it has a higher tensile strength than the underlying parenchyma. Traditionally it was taught that the splenic capsule was thicker in children and thinned as patients aged. Cadaver studies suggest, however, that the splenic capsule thickens during the first two decades of life and then remains constant. The biggest change in the capsule with aging is that the percentage of elastin fibers decreases.[4] These anatomic changes have implications for splenic salvage in aging adult patients.

Physiologically, the spleen is the primary filter of senescent red blood cells from the bloodstream. The spleen also has a significant immunologic role. It produces opsonins and activates the complement immune pathway. It facilitates trapping and presentation of bacteria to resident lymphocytes producing immunoglobins. The spleen also is uniquely responsible for

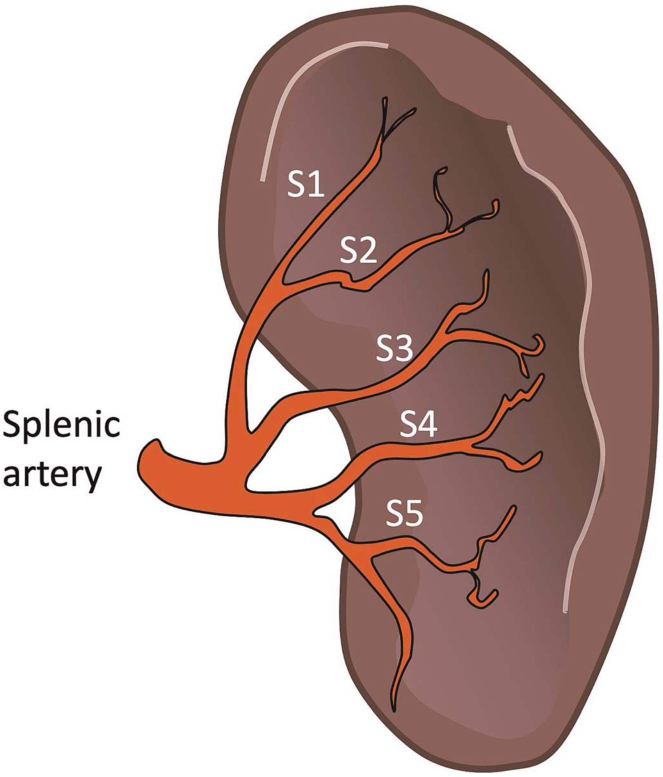

Figure 1. Segmental arterial supply of the spleen derived from the splenic artery.

clearance of encapsulated bacteria, namely, *Haemophilus influenzae* type B, *Streptococcus pneumoniae*, and *Neisseria meningitidis*. After splenectomy, all of these functions are lost. Lymph tissue found in the liver, thymus, and intestinal tract takes over some of the spleen's tasks, and circulating autoantibodies will bind to aged red cells and promote their phagocytosis by macrophages.[5] Without the spleen, the body is not as facile with control of infection from encapsulated bacteria, and patients are at risk for overwhelming postsplenectomy infection (OPSI) from these types of bacteria.[6] Overwhelming postsplenectomy infection has a 50% mortality; the lifetime risk ranges from 0.1% to 8.5%.[7,8] Immunization and patient education are the foundations of minimizing this risk. This risk also led to the desire to preserve the spleen via nonoperative management, which was not an option until the advent and proliferation of the CT scanner.

EVALUATION OF INJURY

Prior to the 1980s, the main way that spleen injuries were diagnosed was on laparotomy triggered by hemodynamic instability or positive diagnostic peritoneal lavage. Splenic salvage was attempted either with splenorrhaphy or partial splenectomy when able. Then, Focused Assessment with Sonography in Trauma (FAST) was developed and superseded the diagnostic peritoneal lavage, with the presence of intra-abdominal fluid on the FAST examination prompting exploration. It really was not until the late 1980s and early 1990s, as multidetector CT was developed, and the extent of the splenic injury could be more accurately assessed, that surgeons felt it was safe to manage patients with spleen injuries using a nonoperative approach.

Today, on admission, the choice of diagnostic technique is still based on the hemodynamic status of the patient. For hemodynamic instability, FAST is used, and when positive, patients are taken to the operating room, which may lead to splenectomy. When the patient is hemodynamically stable, a CT scan with intravenous contrast is considered the criterion standard for trauma evaluations.[9–11] Ideally, a dual-phase CT scan will be obtained. This includes the arterial and portal venous phases and allows detection of active bleeding as well as pseudoaneurysms, nonvascular injuries, and perisplenic hematomas. The sensitivity and specificity for splenic injuries with contrasted CT are near 97% to 100%.[12]

SPLENIC INJURY GRADING

The appearance of the spleen on CT scan allows for the grading of the injury. The classification scale most commonly used is the American Association for the Surgery of Trauma (AAST) Organ Injury Scale (OIS), last updated in 2018.[9] This OIS uses imaging, operative, or pathologic criteria (Table 1) to grade the injury from I (least severe) to V (most severe). Increased mortality, spleen-specific operative rate, and hospital charges have been associated with increasing OIS grades.[13,14] The 2018 update for the spleen was a major change from previous versions. For the first time, splenic vascular injuries were incorporated into the grading scheme. Splenic vascular injuries may be pseudoaneurysms or arteriovenous fistulas. Active bleeding may occur within the parenchyma of the spleen or outside of it. The presence of any of these vascular abnormalities upgrades an injury to at least grade IV. This change was made in recognition that patients with vascular abnormalities are at higher risk for an intervention including embolization and splenectomy.

DECIDING ON OPERATIVE VERSUS NONOPERATIVE MANAGEMENT

For a patient with splenic injury, the first decision for the treating surgeon is deciding between operative and nonoperative management. The two indications for operative management are persistent hemodynamic instability despite initial resuscitation and diffuse peritonitis.[10,11,15] Operative management can also be considered for moderate and severe splenic injuries, even when the patients are hemodynamically stable, at centers where intensive monitoring cannot be performed and/or when angioembolization is unavailable.[11]

Nonoperative management of blunt splenic injury is more common than operative management, with more than 80% of patients undergoing a trial of nonoperative management. Success of nonoperative management is high, ranging between 80% and 95% of patients, even with grade IV and V injuries.[16–19] The success of nonoperative management requires optimal patient care, judicious utilization of angioembolization, and, most importantly, proper patient selection. In the Eastern Association for the Surgery of Trauma (EAST) multi-institutional trial evaluating adults with blunt splenic injury, it was found that all-cause mortality increased from 4% in patients successfully managed nonoperatively to 16.5% in those who

TABLE 1. American Association for the Surgery of Trauma Spleen Organ Injury Scale 2018 Revision[9]

Grade	Imaging Criteria	Operative Criteria	Pathologic Criteria
I	• Subscapular hematoma <10% surface area • Parenchymal laceration <1 cm depth • Capsule tear	Same as imaging criteria	Same as imaging criteria
II	• Subcapsular hematoma 10–50% surface area; intraparenchymal hematoma <5 cm • Parenchymal laceration 1–3 cm	Same as imaging criteria	Same as imaging criteria
III	• Subcapsular hematoma >50% surface area; ruptured subcapsular or intraparenchymal hematoma ≥5 cm • Parenchymal laceration >3 cm depth	Same as imaging criteria	Same as imaging criteria
IV	• Any injury in the presence of a splenic vascular injury or active bleeding confined within the splenic capsule • Parenchymal laceration involving segmental or hilar vessels producing >25% devascularization	• Parenchymal laceration involving segmental or hilar vessels producing >25% devascularization	Same as operative criteria
V	• Any injury in the presence of splenic vascular injury with active bleeding extending beyond the spleen into the peritoneum • Shattered spleen	• Hilar vascular injury which devascularizes the spleen • Shattered spleen	Same as operative criteria

Grade is based on highest assessment made on imaging, at operation or on pathologic specimen. More than one grade of splenic injury may be present and should be classified by the higher grade of injury. Advance one grade for multiple injuries up to a grade III.

failed nonoperative management.[20] Thus, it is important for surgeons to understand the risk factors associated with failure of nonoperative management, so they can minimize failure and maximize splenic salvage on an individual basis.

Risk Factors for the Failure of Nonoperative Management

Fifty-five years and older was historically considered a contraindication for nonoperative management based on a study by Godley et al.[21] in 1996. The authors found that 10 of the 11 patients (91%) who were older than 55 years failed nonoperative management.[21] These results were complemented by a later study by Bee et al.[22] who also observed a higher failure rate in this age compared with younger patients, despite those older than 55 years having a lower injury grade. On their multivariate analysis, age 55 years and older was an independent predictor of failure of nonoperative management. Harbrecht et al.[23] performed a secondary analysis of an EAST multi-institutional study examining the contribution of age to outcomes and found that patients older than 55 years had a 2.5 times failure rate compared with those younger than 55 years. Even though age is a notable risk factor, there are studies showing that older patients can be safely managed nonoperatively. Cocanour et al.[24] performed a retrospective review of blunt splenic injury patients and found that patients who were 55 years and older had a similar failure rate to those younger than 55 years (17% vs. 14%). This study did note a higher mortality rate in patients 55 years and older (67% vs. 4%), but none of the mortalities were attributable to their splenic injury, concluding that nonoperative management was safe for this age group.[24] In addition, Barone et al.[25] studied patients 55 years and older and observed an acceptable failure rate of 17% in this cohort, also noting that those who failed nonoperative management were significantly younger than those successfully managed (60 vs. 72 years old). All of these results need to be tempered by the fact that most are retrospective studies and may reflect the practice patterns at the time more so than an actual increased risk. At this point, there is no recommendation for prophylactic removal of the spleen or embolization based solely on age.

Some CT findings are also associated with increased risk of nonoperative management failure. The quantity of hemoperitoneum, specifically moderate (250–500 mL) to large (>500 mL) volumes, is associated with increased failure rates.[26,27] Vascular injuries, which includes contrast blushes, pseudoaneurysms, or arteriovenous fistulae, also carry a higher risk.[28–31] The presence, number, and size of these abnormalities are important, as failure rates are 11% to 40% higher when they are visualized.[1] Subcapsular hematoma has mixed data regarding its association with nonoperative failure. Lopez et al.,[32] in a retrospective study of 312 patients, had a nonoperative failure rate of 5.9%, and in 80% of the failures, the patients had a subcapsular hematoma. But when Dreizin et al.[26] quantified the volume of the subcapsular hematoma in a separate retrospective study, they found it was not predictive of failure. At this time, patients with spleen injuries who have one or more of these findings on CT scan (Fig. 2) are at high risk for splenectomy in the near term (hours to days). Close observation of these patients in a monitored setting is warranted. For those with vascular abnormalities, angioembolization should be performed.

Not surprisingly, higher-grade splenic injures are associated with an increased rate of nonoperative management failure.[17,20,30,33] Patients with multiple solid organs injuries are also at an increased failure rate. Malhotra et al.[34] evaluated 163 patients with blunt injury to both the liver and spleen comparing them with patients with a single organ injury. The patients with liver and spleen injuries had higher nonoperative failure rates (11.6% vs. 5.8%) along with higher injury severity scores, admission lactate levels, and lower systolic blood pressures.[34] Patients with concomitant spleen and traumatic brain injury (TBI) were previously considered to be higher risk of failure. This was

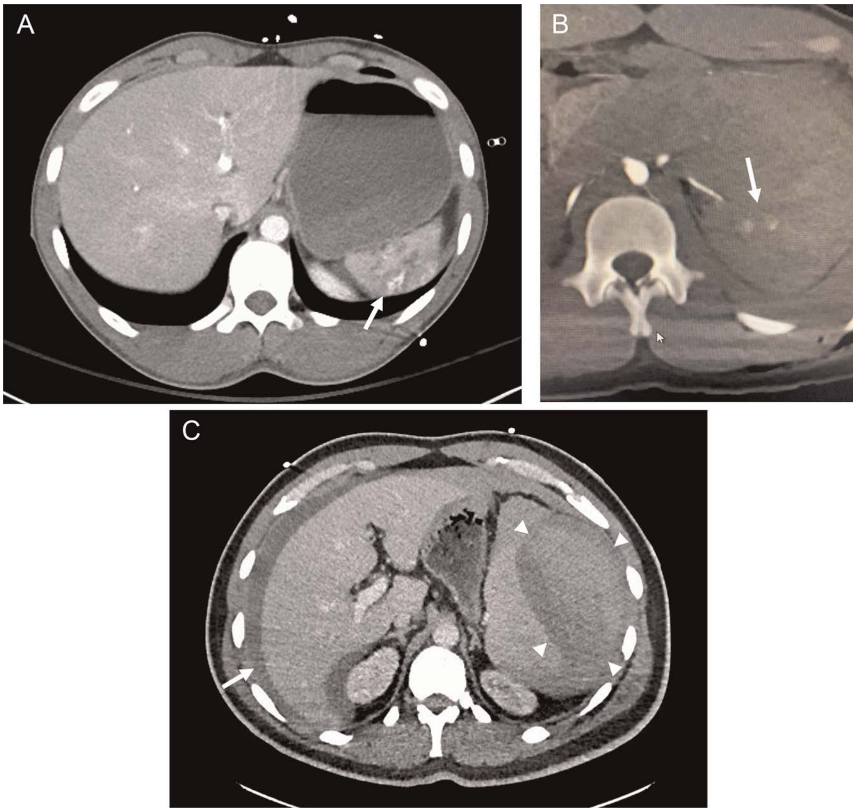

Figure 2. Computed tomography scan findings associated with increased risk of nonoperative management failure. (*A*) Active contrast extravasation. (*B*) Parenchymal pseudoaneurysm. (*C*) Large subcapsular hematoma (arrowheads) with moderate volume hemoperitoneum (arrow).

supported by a retrospective multi-institutional study by Velmahos et al.,[35] who found that the presence of TBI was an independent predictor of nonoperative management. This finding has been challenged by more recent studies that found that immediate splenectomy in patients with severe TBI was not associated with improved survival benefit independent of the injury grade.[36,37] These results should be seen in light of the retrospective nature of the data. This association may be due to widespread practice patterns in which thresholds for splenectomy are lower at some institutions in the setting of a head injury to avoid episodes of hypotension that might worsen the TBI. Currently, there is no recommendation to prophylactically remove or angioembolize a spleen solely because of the presence of a TBI.

ROLE OF ANGIOEMBOLIZATION IN NONOPERATIVE MANAGEMENT

Angioembolization is a diagnostic and therapeutic intervention used in the management of splenic injuries, as it can verify the presence of a vascular abnormality and selectively embolize the associated vessel. It is a means of controlling bleeding from splenic injuries and thus an important tool for improving the splenic salvage rate.[29,38] In the mid to late 1990s, the Memphis group, as well as the group at Shock Trauma in Baltimore, began to study splenic vascular abnormalities to improve splenic salvage. One of the first studies to identify splenic vascular abnormalities as a risk factor for failed nonoperative management was by Schurr et al.[31] In this retrospective study, they identified an increased odds of failure of nonoperative management with a splenic vascular abnormality identified on the admission CT scan. Interestingly, there were several vascular abnormalities missed in the initial scan and subsequently found at the time of laparotomy. This was thought to be a function of the CT scanning technology available at the time. The group in Memphis advocated for a repeat CT scan within 24 to 48 hours to identify progression or new formation of splenic vascular abnormalities that may not have been seen on the initial scan.[39]

At the same time, the group at Shock Trauma in Baltimore also identified splenic vascular abnormalities as a risk factor for nonoperative failure. They took a different approach. Instead of relying on the CT scan to identify all of the splenic vascular abnormalities, they used angiography for all patients with an AAST grade III or higher spleen injury (1994 definition). If a splenic vascular abnormality was identified on angiography, embolization was performed. The hypothesis for both groups was that vascular abnormalities were associated with higher nonoperative failure rates and embolization of these vascular abnormalities may increase splenic salvage. Review of data from these centers and others showed that embolization of patients with confirmed vascular abnormalities was associated with improved splenic salvage.[28,39–41] The only difference was that the Memphis group was using initial and repeat CT scans to identify patients with splenic vascular abnormalities and the Shock Trauma group was using angiography, which was the criterion standard at the time.

Subsequently, authors began publishing their experiences with prophylactic embolization of grades III through V spleen injuries regardless of the presence or absence of a splenic vascular abnormality.[28,42] This was an extension of the original idea that may have confused the exact role of angiography and embolization in the setting of blunt splenic injuries in adults. This has led to a proliferation of angiography, with rates increasing year over year, according to two studies that carefully looked at the use of angiography using data from the Trauma Quality Improvement Program. The earlier study by Dolejs et al.[43] showed no change in overall splenectomy rates over time despite the increased use of angiography. In a more recent study, Aoki et al.[19] noted that, for hemodynamically stable patients with isolated blunt splenic injury, increasing angiography utilization occurred at the same time as a decrease in overall splenectomy rates. For hemodynamically unstable patients, the association did not hold. The authors concluded that, for stable patients, a more liberal use of angiography may lead to improved splenic salvage.[19] It is important to note, however, that the only randomized controlled trial focused on the use of prophylactic embolization for grades III to V blunt splenic injury showed no difference in outcomes for patients who were randomized to prophylactic embolization versus observation.[44]

Thus, the primary indication for angioembolization remains the presence of an actively bleeding vessel (contrast "blush" outside the splenic parenchyma) or vascular abnormality noted on the initial CT scan for a patient who does not otherwise meet operative criteria.[28–30,38,45] Despite newer generation CT technology, there is still a chance of missing splenic vascular abnormalities because of issues with the timing of arterial contrast bolus on CT. That is why some still advocate for the routine use of angiography for higher-grade spleen injuries (grades IV and V).[15,46] Routine use of angiography in lower-grade splenic injuries is low yield.[16,41,47] Optimizing the timing of the contrast bolus to improve initial imaging or repeating a CT scan in 24 to 48 hours is likely a better strategy for identifying vascular injuries than pursuing invasive angiography as a screening tool or prophylactic embolization. In fact, an AAST survey of its members found that only 25% of respondents thought that grades IV and V splenic injuries should undergo mandatory angiography.[48]

Either proximal or distal splenic artery embolization can be used to achieve splenic hemostasis (Fig. 3). For proximal embolization, the goal is to decrease perfusion pressure by occluding the main splenic artery and enabling clot formation by decreasing flow.[49] It leaves intact several collateral arteries entering the splenic hilum and the upper and lower poles, preventing infarction of the spleen. For distal splenic artery embolization, a microcatheter is placed as distally as possible in the splenic artery branches before embolizing, stopping the bleeding but without affecting the perfusion to the remainder of the spleen. A meta-analysis comparing proximal to distal embolization techniques that included 11 different studies found that the failure rates between the two techniques were similar. They were also equivalent in regard to the incidence of infarctions and infections.[50]

Failure of angioembolization to stop bleeding in blunt splenic injury occurs in 5% to 15%.[41,50,51] Reasons why angioembolization fails are not well understood. It could be due to vascular injuries that were in spasm during the initial angiography that became symptomatic later or bled because of trauma-induced coagulopathy. Requarth and Miller[52] proposed that celiac artery stenosis could contribute in some cases. They performed a study measuring aortic and splenic artery pressures following proximal splenic artery occlusion. Patients with celiac stenosis had higher-than-expected splenic artery stump pressures. The authors hypothesized that the higher pressures were secondary to collaterals to the spleen that developed because of the stenosis, and the higher pressures could lead to delayed bleeding.[52] The value of repeat angioembolization when bleeding continues after the initial attempt is controversial. The Western Trauma Association (WTA) and EAST do not recommend repeat angiography,[10,15] but some studies have shown that it has been effective in small numbers of patients.[40,45,50,53] More research is needed to clarify when repeat angioembolization is appropriate, but at this time, if a patient suffers an episode of hemorrhagic shock after an initial angioembolization, it is our recommendation to remove the spleen.

Major complications inherent to angioembolization are low but not absent. These include splenic abscess (4%) and infarction (4.6%),[51] which can require splenectomy to manage. Arterial injury and pseudoaneurysms at the access site have also been reported. Minor complications include contrast-induced nephropathy (1.7%), fever (18.4%), and coil migration (3.9%).[51] These complications should be carefully considered after each angiography session.

CARE COMPONENTS OF NONOPERATIVE MANAGEMENT

Monitoring the Patient

Patients with blunt splenic injuries should have tracking of vital signs and serial physical examinations to monitor for

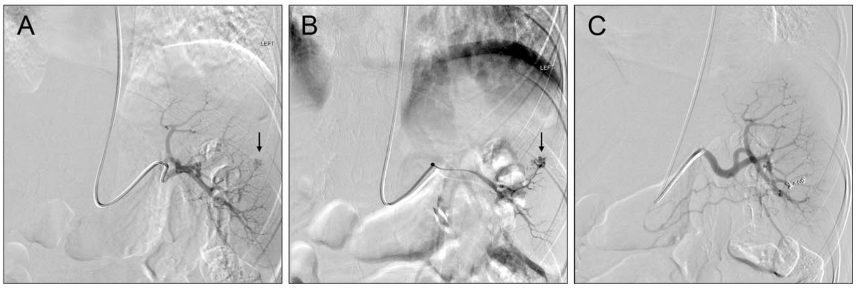

Figure 3. Patient with blunt splenic injury who underwent angioembolization for contrast blush on CT scan. (*A*) The diagnostic angiogram confirms the active bleed. (*B*) Selective angiogram of the splenic segment with bleeding. (*B*) Completion angiogram after distal coil deployment.

ongoing or recurrent bleeding. The vital signs can indicate bleeding without overt instability when the heart rate becomes increasingly tachycardic or if there is a rise in diastolic blood pressure indicating a narrow pulse pressure. There have been no dedicated studies focused on the optimal hemodynamic monitoring of these patients. Similarly, consensus opinion is to trend hemoglobin levels every 6 hours for at least 24 hours for all grades of injury.[15,48] For grades III through V,[15] these same experts all agreed that checks should be extended to at least 48 hours and these patients warrant intensive care admission for initial monitoring. Recently, some authors have advocated for hemodynamic monitoring only without serial hemoglobin checks, as this has been done successfully in the pediatric population.[54] Our recommendation is to perform continuous hemodynamic monitoring and serial examinations for at least 24 hours in grades III to V injuries in a location that facilitates this type of monitoring. For lower-grade injuries, intermittent hemodynamic monitoring along with serial examinations is recommended. Serial hemoglobin monitoring should be at the discretion of the treating surgeon for all injury grades.

Venous Thromboembolism Prophylaxis

Patients sustaining blunt splenic injuries transition to a hypercoagulable state approximately 48 hours after injury.[55] This risk must be balanced with starting chemical venous thromboembolism (VTE) prophylaxis and potentially exacerbating bleeding when attempting splenic salvage. A recent meta-analysis by Murphy et al.[56] included 10 studies with over 14,000 patients who compared early (≤48 hours) to late (>48 hours) initiation of VTE chemoprophylaxis in adults with blunt splenic, liver, and/or kidney injury. The odds of nonoperative failure were no different between the early and late groups in the splenic subgroup analysis. They also found significantly lower odds of VTE when patients received early VTE prophylaxis (odds ratio, 0.51; 95% confidence interval, 0.33–0.81).[56] Similar findings of reduced rates of VTE without increased bleeding complications with chemophrophylaxis initiated in the first 48 hours in patients with blunt solid organ injury were also found in a recent AAST prospective multi-institutional study.[57] Published recommendations disagree regarding the start of VTE prophylaxis: the WTA recommends it within 24 hours of injury,[15,58] the AAST Critical Care Consensus statement recommends it within 48 hours,[59] and the World Society of Emergency Surgery recommends starting within 48 to 72 hours.[60] Based on these data, starting VTE prophylaxis 24 hours after injury is safe.

Activity Restrictions

Bedrest was used extensively in the early adoption of nonoperative management of spleen injuries. There are no prospective or randomized data to support this practice. The retrospective data that exist are hard to interpret because the exposure (walking or moving around the room) is difficult to measure with accuracy. More important is avoiding direct blows to the abdomen and flank. We do not recommend bedrest for spleen injury alone.

After discharge, most practitioners continue to restrict patient activity in the outpatient setting for a period of time.[61] Savage et al.[62] showed that grades I and II splenic injuries had a shorter mean time to healing compared with more severe grades III to V injuries (12.5 vs. 37.2 days). Interestingly, a small proportion (9.3%) had a worsening of injury on outpatient follow-up CT scans.[62] Thus, those with grades III to V injuries should avoid activities that might result in a blow to the abdomen or flank for at least 6 to 8 weeks.

Failure of Nonoperative Management

The term *failure of nonoperative management* is frequently used but inconsistently defined. Peitzman et al.[20] defined it as a patient admitted with the diagnosis of blunt splenic injury with planned nonoperative management who later required laparotomy. Others have broadened the definition, changing it to invasive procedures such as angioembolization or splenectomy after an initial observation period.[41] This lack of consensus matters more academically when comparing studies than it does clinically. Patients who fail nonoperative management present in a variety of ways: hemodynamical instability, image-documented splenic hemorrhage, down-trending hemoglobin levels, persistent pain, and abscess. Failure typically happens early after injury. A National Trauma Data Bank study showed that 97% of splenectomies happened within 5 days of blunt splenic injury.[17] In addition, an AAST multi-institutional prospective study found that, in patients managed nonoperatively for 24 hours, the risk of splenectomy during the index admission was 3.1% and 0.27% over the next 180 days.[45] There is no consensus for the optimal treatment strategy in failed nonoperative management, as some surgeons repeat imaging, while some proceed to the operating theater.[63]

WHEN AND WHO SHOULD UNDERGO FOLLOW-UP IMAGING?

Follow-up imaging after blunt splenic injury managed nonoperatively is typically performed for one of two reasons. First, the patient has clinical signs that they are failing nonoperative management. Repeat CT scan will evaluate for worsening subcapsular hematoma, blood within the peritoneal space, or active extravasation and help the treating surgeon to decide if it is appropriate to convert from nonoperative to operative management. Unless there is a protocol in place to trigger repeat imaging to screen for vascular abnormalities, relying on symptoms to trigger a repeat CT scan is a reasonable approach.

The second reason providers will repeat imaging is to evaluate for the interval development of arterial pseudoaneurysms. Weinberg et al.[39] found that performing an interval CT scan 24 to 48 hours after injury detected pseudoaneurysms that were not present on the initial scan in 5% of patients. In addition, all grades of splenic injuries in their study developed pseudoaneurysms on interval imaging.[39] Other groups have shown that the incipience of pseudoaneurysms on repeat imaging is greater with higher grade injuries.[64,65] Thus, the WTA currently recommends repeat imaging in patients with grade III injury or higher and for those with a documented pseudoaneurysm before discharge.[15]

The natural history of pseudoaneurysms is not well understood, and it is not clear that the presence of arterial pseudoaneurysm leads to delayed splenic rupture. In a WTA multi-center trial of patients with blunt splenic injury with vascular abnormalities, the proportion of patients undergoing splenectomy was similar in those who were observed and those who were managed with initial angiography and embolization, with both groups having a 7% risk of splenectomy.[53] In a recent publication by Radding et al.,[66] they described a series of 255 blunt splenic injuries over a 5-year period that underwent angiography for findings on admission CT scan. Nearly one third of patients with pseudoaneurysms on admission CT had no identifiable lesions on angiogram performed within the first 24 hours. Among those who did undergo angioembolization, perfusion of a pseudoaneurysm was visualized in close to 50% of patients on subsequent repeat CT scan at 48 to 72 hours, with none of these patients failing nonoperative management.[66] The study suggests that persistent perfusion of pseudoaneurysm alone does not indicate failure of nonoperative management. In an editorial responding to the findings of this manuscript, Aoki et al.[19] made three points that describe the current dilemma. They pointed out that the location of embolization (distal vs. proximal) is important to report in this type of manuscript, as embolization location might influence pseudoaneurysm filling. They also point out that there is a general lack of information about the natural history of splenic pseudoaneurysms with or without treatment. Furthermore, they state that they "do not believe that there is clear evidence to support any specific strategy for the management of pseudoaneurysm following blunt splenic injury."[67] It is clear that more multi-institutional studies are needed on this highly debated topic to understand the significance of pseudoaneurysms after blunt splenic injury.

OPERATIVE MANAGEMENT

At surgical exploration, splenectomy is performed when the spleen is confirmed to be a source of hemorrhage. It should also be performed in patients with ongoing hypotension and multiple abdominal injuries. The technique does not significantly differ from when it is performed electively for hematologic diagnoses except in the speed of its completion.

Splenorrhaphy should be considered by the surgeon at exploration when the spleen is injured but does not meet the indications for splenectomy.[68] Before attempting to repair the spleen, it should be completely mobilized, including the division of the short gastric arteries and lienocolic ligament. Next, the injury should be graded by a scale first proposed by Shackford et al.[69] (Table 2), which directs the approach used for splenorrhaphy. Grades I and II injuries start with simple compression and application of cautery or coagulating laser. If these injuries continue to bleed, suture repair should be performed by reapproximating the parenchyma and capsule with a continuous stitch; a 0 polyglactin 910 or chromic are common suture choices. If the capsule of the spleen tears when tying down the suture, an omental flap or pledgets should be used to reinforce the repair. For grade III injuries, wrapping the spleen with absorbable mesh can help compress the spleen allowing for larger lacerations to be suture repaired without tension. If grade IV injuries are found, partial splenectomy is an option. The segmental artery or arteries feeding the injured area are dissected free and ligated. This will devascularize segments of the spleen and demarcate the portion to be resected. For all grades, suture ligation of bleeding parenchymal vessels and hemostatic agents can be used adjunctively. In practice, splenic salvage is uncommonly performed, as the intraoperative threshold for splenectomy is low. When splenorrhaphy fails, it has twice the odds of mortality compared with successful splenorrhaphy.[70]

TABLE 2. Splenic Injury Grading System Used to Guide Operative Decision Making for Splenorrhaphy

Spleen Injury Grade	Description
1	Capsular tear or minor parenchymal laceration
2	Capsular avulsion or moderate parenchymal laceration
3	Major parenchymal fracture or laceration or through-and-through gunshot or stab wound
4	Severe parenchymal stellate fracture, crush, bisection, or hilar injury
5	Shattered or crushed spleen

Autotransplantation of the spleen may be considered in patients who become hemodynamically normal after splenectomy. This procedure has been described in many variations but essentially it takes undamaged portions of the spleen and cuts them transversely into segments that are sewn to the greater omentum (Fig. 4). Small published case series have shown that this approach can result in return of splenic filtration function and Ig levels to normal ranges.[71] There is no sufficient evidence that autotransplantation provides meaningful protection against OPSI.[72]

In a minority of patients, laparoscopic splenectomy may be considered. It should only be used in hemodynamically stable patients; proposed indications include patients who are at high risk of nonoperative failure, failed angioembolization where the anatomy is prohibitive for coil deployment, or when the patient has persistent bleeding after embolization requiring ongoing blood transfusion.[73] Data to support this are limited to single-center retrospective studies,[74] which have reported success even in all grades of injuries.

OTHER CONSIDERATIONS IN SPLENIC INJURY

Immunization

Immunization against *H. influenzae* type B, *S. pneumoniae*, and *N. meningitidis* should be given after splenectomy. They are effective in reducing the incidence of OPSI, although the timing of these vaccinations is debated. The Center for Disease Control recommends waiting 14 days postoperatively; this is based on a randomized control trial of trauma splenectomy patients that found inferior vaccine efficacy if administered within 14 days of surgery.[75] For practical reasons, most perform these immunizations before discharge to guarantee an initial vaccination[76] without reliance on follow-up. Immunizations are not recommended for patients managed nonoperatively. A recent systematic review and meta-analysis evaluated the immune function of splenic injury patients managed with angioembolization and found that there was no difference in immune markers between angioembolization patients and normal controls.[77]

Penetrating Splenic Injuries

Penetrating splenic injuries are significantly less studied than their blunt counterpart. Emergent exploration is common and is indicated for hemodynamic unstable or patients presenting with peritonitis. When the patient is hemodynamically stable, many will still routinely explore these patients given their increased probability of injuries. Consideration of nonoperative management should only be given to highly-selected patients

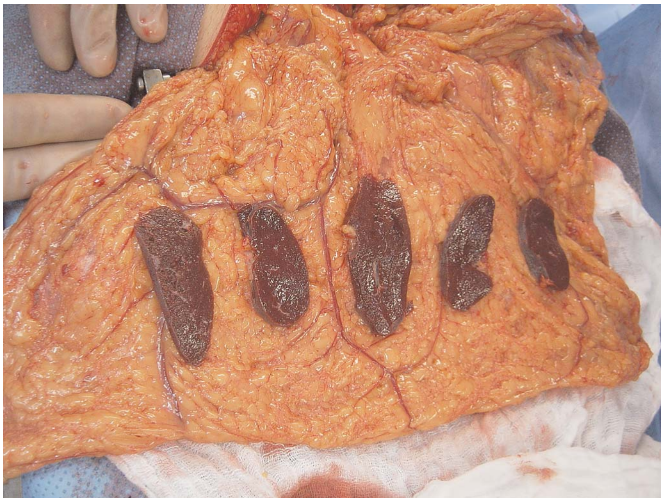

Figure 4. Autotransplantation of portions of the spleen onto the greater omentum.

in well-equipped and experienced trauma centers, as the failure rate is moderate.[78] Surgically, penetrating splenic injuries are managed similarly to blunt injuries. The rate of operative splenorrhaphy is higher, approximately 25%,[79] which is likely due to lower-grade splenic injuries being taken to the operating theater. The mortality of penetrating splenic injuries is not different from the blunt splenic injury patients.[80]

CONCLUSION

The spleen is a commonly injured organ. It plays an important role in the immune system, so surgeons should make every effort to perform splenic salvage. In blunt injury, indications for emergent splenectomy have not recently changed and include hemodynamic instability and peritonitis. Computed tomography scan with intravenous contrast is the preferred imaging modality for hemodynamically normal patients and should be used to identify the grade of injury and signs of active bleeding. Nonoperative management has been successful for all grades of blunt injury, but it is the job of the surgeon to carefully select the patient, in context of their age, other associated injures, and splenic CT findings, so this success rate remains high. Angioembolization is an important tool for splenic salvage, which should be used when an actively bleeding vessel is observed on CT scan. All patients selected for nonoperative management require close monitoring, which can include interval CT scan for grades III, IV and V injuries. Penetrating splenic injuries differ from blunt injury because it is more common that they are surgically explored and have a higher splenorrhaphy rate.

AUTHORSHIP

N.L.W. and B.L.Z. contributed in the literature search. N.L.W. and B.L.Z. contributed in the writing. N.L.W. and B.L.Z. contributed in the critical revision.

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DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/E311).

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