Splenic Artery Embolization for Patients with High-Grade Splenic Trauma: Indications, Techniques, and Clinical Outcomes

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Abstract

The spleen is the most commonly injured organ in blunt abdominal trauma. Patients who are hemodynamically unstable due to splenic trauma undergo definitive operative management. Interventional radiology plays an important role in the multidisciplinary management of the hemodynamically stable trauma patient with splenic injury. Hemodynamically stable patients selected for nonoperative management have improved clinical outcomes when splenic artery embolization is utilized. The purpose of this article is to review the indications, technical aspects, and clinical outcomes of splenic artery embolization for patients with high-grade splenic injuries.

Keywords

- ► interventional radiology
- ► trauma
- ► hemorrhage
- ► embolization
- ► spleen

The spleen is the most commonly injured organ in blunt abdominal trauma.[1] As the largest secondary lymphoid organ, the spleen plays an important role in immunologic and hematologic functions.[2] Typically, traumatic splenic injuries are managed in two cohorts, nonoperative and operative management. Patients who are hemodynamically unstable due to splenic trauma should undergo definitive operative management.[1,3] For hemodynamically stable patients, the management of splenic trauma has evolved toward splenic preservation in order to retain its important physiologic functions and avoid complications from splenectomy. In fact, the majority of patients with splenic trauma are now managed nonoperatively.[4] To this end, splenic artery embolization (SAE) has emerged as a powerful adjunct to the nonoperative management of splenic injuries. SAE improves splenic preservation rates in trauma patients selected for nonoperative management.[5–11] SAE can be performed proximally or distally within the splenic artery. Both techniques demonstrate similar clinical efficacy; however, proximal SAE (pSAE) is associated with lower rates of minor complications.[12–14] In this article, we discuss the role of SAE in the nonoperative management of blunt splenic trauma. We review the indications, relevant anatomy, technical aspects of SAE, and clinical outcomes of SAE in the trauma patient.

Diagnosis

Patients with blunt splenic trauma can present with left upper quadrant (LUQ) pain, abdominal distension, and/or hypotension.[15] They may exhibit referred pain to the left shoulder due to irritation of the phrenic nerve that innervates the ipsilateral diaphragm (i.e., Kehr's sign).[16] Abdominal wall or left lower chest wall tenderness, contusion, or instability are typical physical findings associated with splenic trauma.[17] However, it should be remembered that some patients with traumatic splenic injuries have an unremarkable physical examination. Therefore, proper evaluation and monitoring of blunt trauma patients must be conducted to detect less obvious injuries.

Common imaging modalities utilized to evaluate splenic trauma include radiography, ultrasound, and computed tomography (CT). Rib fractures secondary to blunt abdominal trauma, especially ribs 9 to 11, are a common cause of splenic injury, as the spleen is encapsulated by these lower ribs

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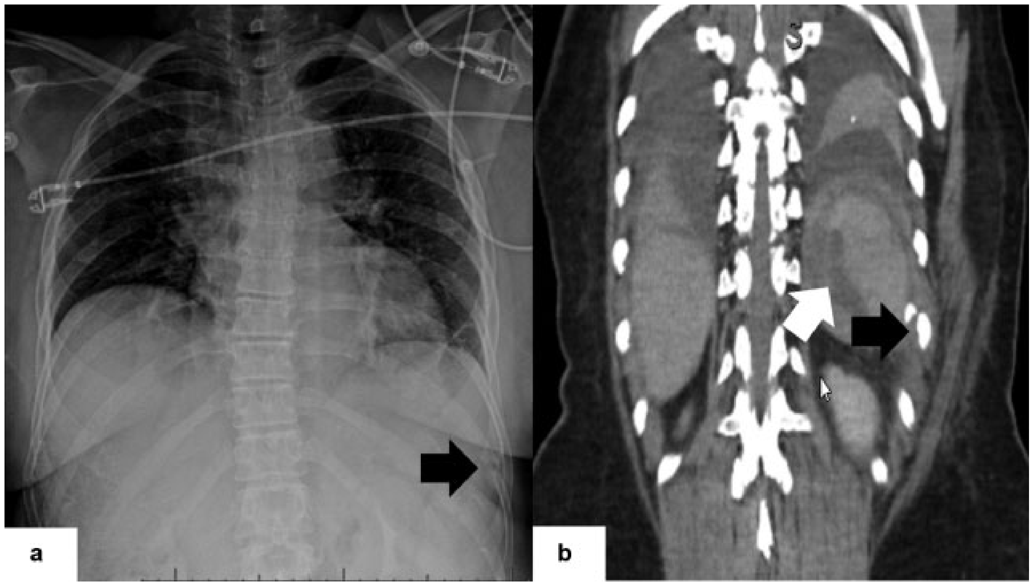

Fig. 1 (**a**) Chest radiograph obtained after a motor vehicle collision demonstrates a fracture of the left 10th rib (black arrow). (**b**) Coronal reformat image from a contrast-enhanced CT scan in the same patient demonstrates the fracture seen on radiography (black arrow) and hemoperitoneum from associated splenic trauma in the left upper quadrant (white arrow).

(►**Fig. 1**).[18] Plain radiography is helpful in evaluating the character of these ribs in the setting of trauma and provides a rapid method of chest and upper abdominal evaluation. Radiography may show other features associated with splenic trauma such as a left pleural effusion and medial displacement of the gastric bubble.[19] Yet, plain radiography is neither specific nor sensitive for splenic injury. Therefore, the initial examination typically includes the focused assessment with sonography in trauma (FAST) exam.[20] The FAST exam identifies the presence of intraperitoneal fluid, a sign of more serious injury that may necessitate aggressive management strategies. Signs of splenic injury identified on FAST exam include a hypoechoic rim around the spleen, which may represent subcapsular fluid or intraperitoneal perisplenic fluid, or fluid in Morrison's pouch (i.e., hepatorenal space).[21] Based on the results of the FAST exam, patients undergo CT to further elucidate and characterize splenic injuries. For simplicity in the acute setting, CT is often performed using intravenous (IV) iodinated contrast in the portal venous phase, but recent data suggest that the sensitivity of the examination for splenic injury improves with the use of an additional arterial phase.[22] The American Academy of Surgery and Trauma (AAST) has developed criteria to grade splenic injury on CT, which can be utilized to guide management of splenic trauma patients.[23,24] Commonly, grade III or higher injuries are considered high grade. Splenic injury is categorized by the degree of capsular laceration, subcapsular hematoma, intraparenchymal hematoma, vascular injury, and/or devascularization (►**Table 1**).

Table 1 The AAST Organ Injury Scale for the spleen

Grade	Injury type	Description of injury
I	Hematoma	Subcapsular, < 10% surface area
	Laceration	Capsular tear, < 1 cm parenchymal depth
II	Hematoma	Subcapsular, 10–50% surface area Intraparenchymal, < 5 cm in diameter
	Laceration	1–3 cm parenchymal depth, not involving a trabecular vessel
III	Hematoma	Subcapsular, > 50% surface area or expanding Intraparenchymal, > 5 cm or expanding Ruptured subcapsular or parenchymal hematoma
	Laceration	> 3 cm parenchymal depth or involving trabecular vessels
IV	Laceration	Involving segmental or hilar vessels and producing > 25% devascularization
V	Laceration	Shattered spleen
	Vascular	Hilar vascular injury that devascularizes spleen

Abbreviation: AAST, American Association for the Surgery of Trauma.
Source: Adapted from Rowell et al.[24]

Indications for Splenic Artery Embolization

Patients with hemodynamic instability due to splenic injury should be managed with splenectomy.[1,3] Apart from that, there is relative wide variability with regard to the management of hemodynamically stable patients with splenic injuries. Unfortunately, there is a lack of robust data in the literature to help guide patient selection in this clinical scenario. For example, case series, multivariate analyses, and one randomized trial have shown that SAE helps improve splenic preservation rates, although these prior reports have significant heterogeneity in patient selection from institution to institution.[5–11] Thus, patient selection for SAE in the trauma setting is largely institution dependent. When considering a patient for SAE, some important factors to consider include hemodynamic status, the grade of splenic injury, and any direct signs of

Fig. 2 Axial slice from a contrast-enhanced CT obtained after a motor vehicle collision demonstrates a splenic laceration with a pseudoaneurysm (white arrow).

vascular injury on CT, such as arteriovenous fistula (AVF), pseudoaneurysm (PSA), or contrast extravasation (►**Figs. 2** and **3**). Of course, the interventional radiologist should evaluate the patient for contraindications to SAE, such as uncorrectable coagulopathies. Our institutional approach to the management of patients with splenic trauma is summarized in ►**Fig. 4**. In short, all hemodynamically stable patients with high-grade splenic injury (i.e., grade III or higher injury) are referred to interventional radiology for SAE. Additionally, patients with CT evidence of contrast extravasation are treated with embolization, irrespective of the grade of injury. Alternatively, the Western Trauma Association has also published an algorithmic approach to the management of blunt splenic trauma.[25] Briefly, this algorithm directs hemodynamically stable patients to a contrast-enhanced CT. Patients with grade I to III injuries without direct signs of vascular injury are observed. Patients with grade I to III injuries with direct signs of vascular injury and patients with grade IV to V injuries regardless of direct signs of vascular injury are referred for angiography. Nonetheless, establishing and adhering to a multidisciplinary protocol for patients with splenic trauma has been shown to improve patient outcomes.[26]

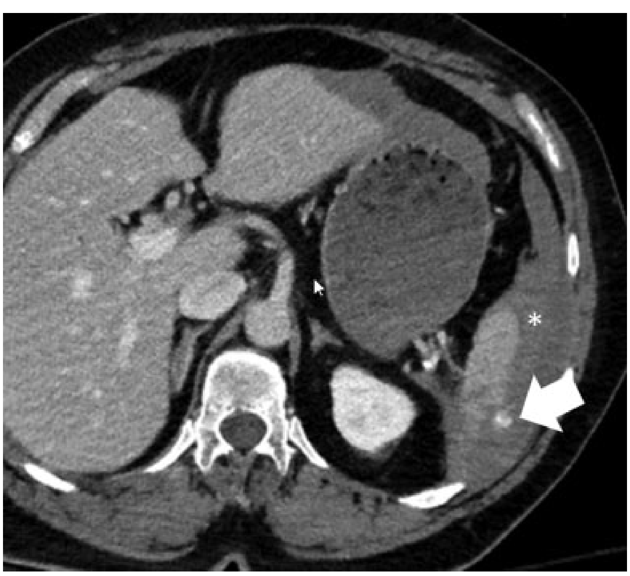

Fig. 3 Axial slice from a contrast-enhanced CT obtained after a motor vehicle collision demonstrates a splenic laceration with contrast extravasation from the spleen (white arrow) and associated hemoperitoneum (asterisk).

Anatomy

The splenic artery is the primary blood supply to the spleen, and the site of therapeutic embolization in SAE. Successful evaluation and treatment of blunt splenic trauma with SAE necessitates an understanding of the vascular anatomy (►**Fig. 5**). The most common origin of the splenic artery is the celiac trunk, which often arises from the abdominal aorta around the level of the 12th vertebra.[27] Less common origins include directly off the abdominal aorta (~8%; ►**Fig. 6**) and off the superior mesenteric artery (<1%).[28] The dorsal pancreatic artery is the first large branch of the splenic artery, often arising within the first few centimeters from the splenic artery origin. Less common origins of the dorsal pancreatic artery include the celiac trunk, common hepatic artery, and superior mesenteric artery.[29] It is important to recognize the most distal origin of the greater pancreatic artery as its connection to the dorsal pancreatic artery via the transverse pancreatic artery is an important collateral pathway for SAE. Other important vascular supply to the spleen includes the short gastric arteries and gastroepiploic arteries (►**Fig. 7**).[30,31] The right gastroepiploic artery is the terminal branch of the gastroduodenal artery (GDA) and has an anastomosis with the left gastroepiploic artery, a distal branch of the splenic artery.[28] The short gastric arteries are a group of small arteries that connect the splenic artery with left gastric artery.[31]

Embolization Technique

At our institution, arterial access is obtained using a micropuncture set (Terumo, Tokyo, Japan) under sonographic guidance. The right common femoral artery is the most common site for vascular access, but patient conditions such as the presence of arterial lines or pelvic binders could necessitate the use of the left common femoral artery or a transradial approach, respectively. After placing a vascular sheath over a wire, a 5-Fr diagnostic catheter such as a Simmons 1 (Terumo), RC2 (Cook, Bloomington, IN), or Cobra 2 (Cook) is used to select the celiac trunk. Celiac angiography at a rate of 5 cc/second for a total of 25 cc is performed to evaluate the arterial anatomy and to identify direct signs of vascular injury such as contrast extravasation, PSA, or AVF.

At this point, the operator must decide whether to perform a pSAE or a distal SAE (dSAE). The decision to proceed with either pSAE or dSAE is largely operator dependent but can be influenced by two primary factors. First, prior studies have shown that both techniques result in similar rates of splenic salvage; however, pSAE is associated with a slightly

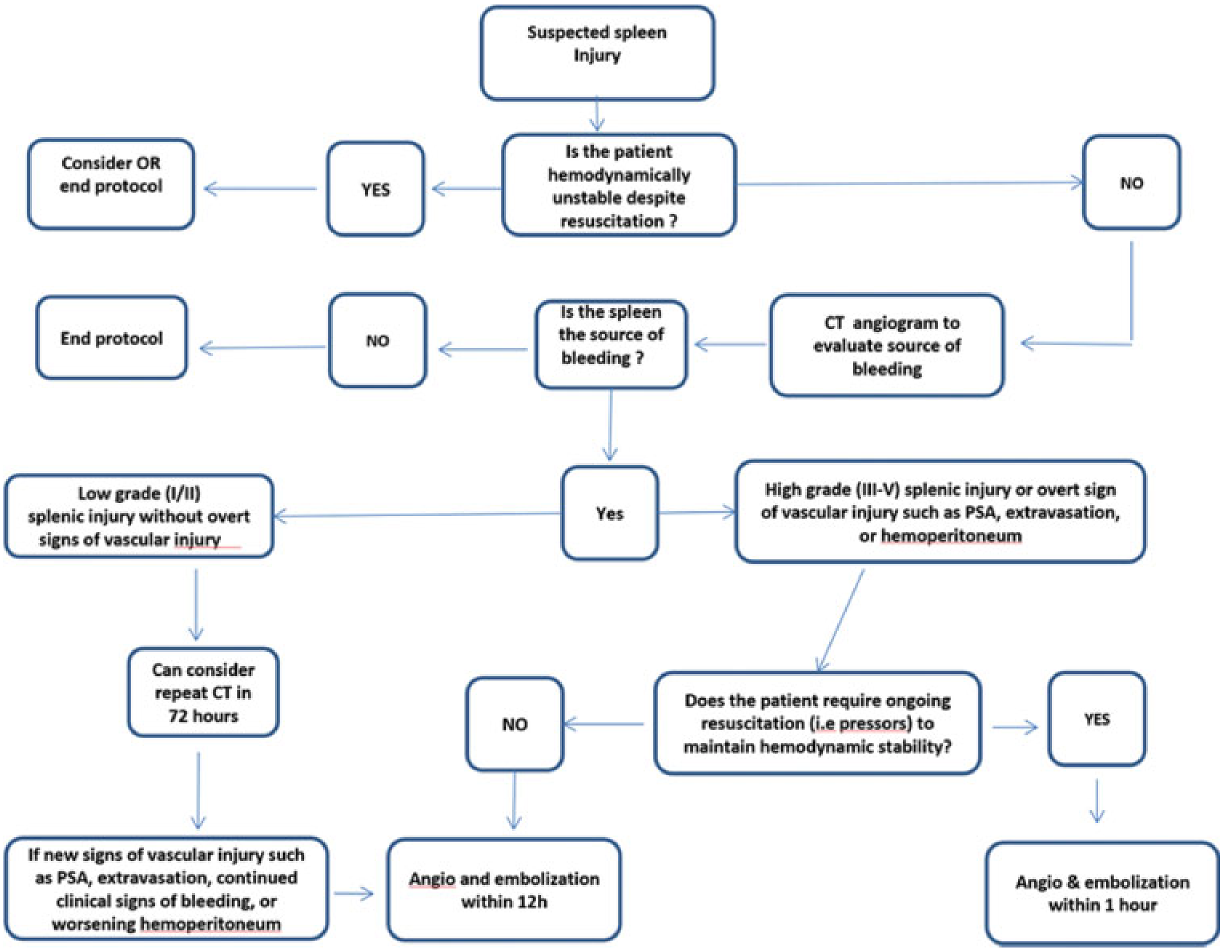

Fig. 4 Institutional protocol for the management of patients with splenic trauma.

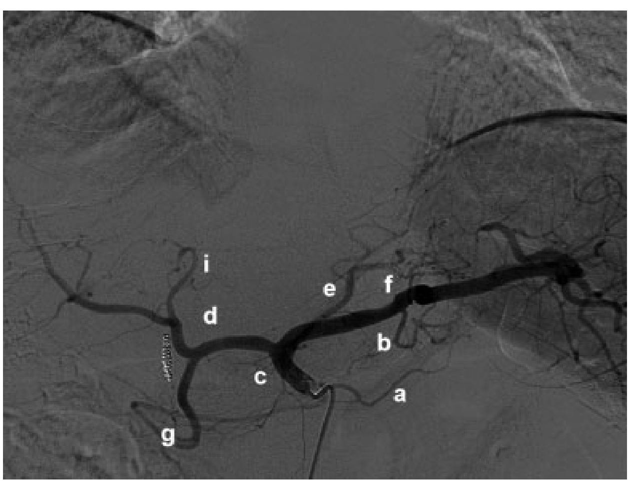

Fig. 5 Digital subtraction angiography of the celiac trunk demonstrates classic arterial anatomy, including the dorsal pancreatic artery (**a**), the greater pancreatic artery (**b**), the celiac trunk (**c**), the common hepatic artery (**d**), the left gastric artery (**e**), the splenic artery (**f**), the gastroduodenal artery (**g**), the right hepatic artery (**h**), and the left hepatic artery (**i**). The midsplenic artery in between the dorsal pancreatic artery and the greater pancreatic artery is the ideal site for proximal splenic artery embolization.

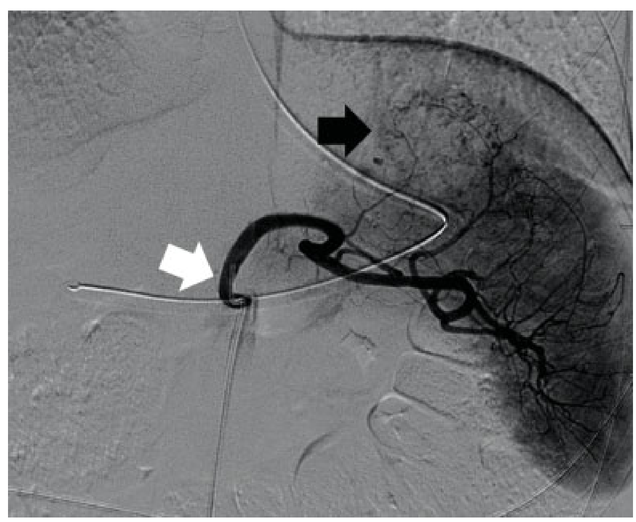

Fig. 6 Digital subtraction angiography obtained during splenic artery embolization for trauma shows the splenic artery arising directly from the abdominal aorta (white arrow), an anatomic variant. A splenic laceration with small pseudoaneurysms is seen in the upper pole of the spleen (black arrow).

lower rate of minor complications and shorter procedural times.[12–14,32] Second, some operators base their decision on the type of injury within the spleen. For example, patients with diffuse parenchymal injury may be treated with pSAE, while patients with focal areas of extravasation and/or a PSA might be treated with dSAE.[33] It should be noted that patients treated with both pSAE *and* dSAE have somewhat poorer outcomes compared to those treated with *either* pSAE

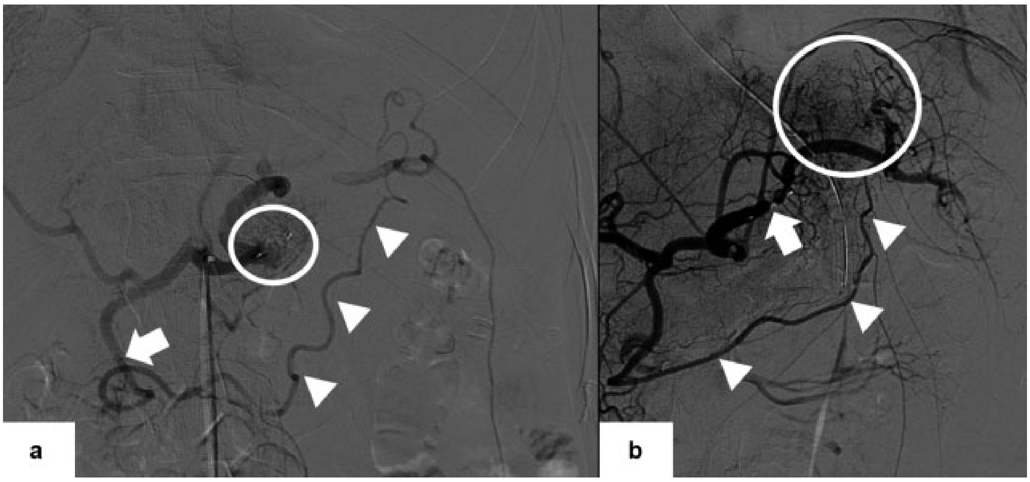

Fig. 7 (**a**) Digital subtraction angiography obtained during splenic artery embolization for trauma shows the gastroduodenal artery (white arrow) giving rise to the right gastroepiploic artery that anastomoses with the left gastroepiploic artery (white arrow heads) that provides collateral flow to the spleen after vascular plug deployment (white circle). (**b**) Digital subtraction angiography obtained during splenic artery embolization for trauma shows the short gastric arteries (white circle) and the right to left gastroepiploic artery pathway (white arrow heads) supplying the spleen after vascular plug deployment (white arrow).

Table 2 Summary of the main differences between proximal splenic artery embolization and distal splenic artery embolization

	Proximal	Distal
When	Multifocal injury No angiographic abnormality but splenic injury of grade III–V on CT	Focal vascular injury
Goal	Decrease splenic parenchymal perfusion pressure	Treat bleeding vessel
Advantages	Short procedure time Low radiation time	Selective embolization
Disadvantages	Inability to easily perform future embolization	Long procedure time Infarction, abscess
Embolic material	Coils, plugs	Coils, particles, gelatin sponge slurry, N-butyl cyanoacrylate
Complications	Coil migration	Splenic infarct, abscess

Abbreviation: CT, computed tomography.

or dSAE.[34] At our institution, all hemodynamically stable patients with grade III or higher splenic injuries, regardless of direct signs of vascular injury, are treated with pSAE. Some of the differences between pSAE and dSAE are summarized in ►**Table 2**.

In pSAE, vascular plugs or endovascular coils are placed in the midsplenic artery, distal to the origin of the dorsal pancreatic artery but proximal to the origin of the greater pancreatic artery (►**Fig. 8**). pSAE reduces the systolic arterial pressure experienced in the spleen, allowing it to heal, while a rich collateral supply from the dorsal pancreatic-transverse pancreatic-greater pancreatic artery pathway, the gastroepiploic arteries, and the short gastric arteries maintain adequate perfusion to the parenchyma.[32,33] Regarding the selection of an embolic agent for pSAE, both vascular plugs and endovascular coils have advantages and disadvantages. For instance, coils are familiar to most endovascular specialists, have a long history of efficacy, and can be deployed through a standard catheter or microcatheter. Yet, the use of coils within the high-flow splenic artery might lead to migration of the coil pack. On the other hand, the deployment of a single vascular plug is usually sufficient to provide hemostasis in the midsplenic artery but requires selective catheterization with a larger delivery system, which may be difficult or impossible in patients with atherosclerotic narrowing of the celiac artery or extreme tortuosity of the splenic artery. If appropriate stasis within the midsplenic artery is not achieved within a reasonable time, secondary embolic agents such as a gelatin sponge slurry can be administered. In theory, pSAE could complicate reintervention should the need arise, but this has not been a common occurrence in our institutional experience.

For dSAE, general embolotherapy principles are applied. The site or sites of vascular injury are selectively catheterized using a combination of wires and catheters. Once the catheter (or microcatheter) is appropriately positioned, embolization is performed. dSAE can be accomplished using a variety of embolic agents including N-butyl cyanoacrylate, gelatin sponge slurry, particles, vascular plugs, or endovascular coils. The endpoint for dSAE is stasis within the target vessel.

Fig. 8 (**a**) Digital subtraction angiography obtained during splenic artery embolization for trauma shows collateral flow to the spleen via the dorsal pancreatic-transverse pancreatic-greater pancreatic artery pathway (white arrow) after vascular plug deployment (black arrow). (**b**) Digital subtraction angiography obtained during splenic artery embolization for trauma shows collateral flow to the spleen via the dorsal pancreatic-transverse pancreatic-greater pancreatic artery pathway (white arrow) after endovascular coil deployment (black arrow).

Clinical Outcomes

Studies show high success rates for the nonoperative management of splenic trauma using SAE compared to nonoperative management without SAE.[5–11] A summary of meta-analyses and the single randomized trial are found in ►**Table 3**. In a recently published prospective trial, 133 patients were randomized to either SAE or observation.[11] To be included, patients had to have a grade III injury *and* an injury severity score of ≥15 and/or large volume hemoperitoneum, grade IV injury, or a grade V injury with persistent vascularization of the spleen. Patients with a grade V injury without vascularization to the spleen or with direct signs of vascular injury were excluded. Investigators found that 32.3% of patients in the observation group eventually required either splenectomy or embolization. Additionally, patients in this cohort had a longer length of stay compared to those who underwent SAE. A multivariate analysis of more than 10,000 patients found that the overall failure rate of nonoperative management was 8.3%.[7] In this analysis, the failure of nonoperative management showed a statistically significant increase for patients with grade IV and V injuries when SAE was not used. In a retrospective multicenter study involving 1,275 patients, SAE was found to significantly increase the likelihood of splenic salvage.[5] Studies have also shown that the immunologic functions of the spleen are preserved after SAE.[35–37] Preserving the immunologic function of the spleen after SAE is of particular importance as postsplenectomy sepsis is a potentially fatal infection.[38] Pneumococcal, meningococcal, and *Haemophilus influenzae* type B (Hib) vaccinations are

Table 3 Summary of meta-analyses and a single randomized controlled trial evaluating outcomes of splenic artery embolization in blunt splenic trauma

Study	No. of patients	Study type	Outcomes
Banerjee et al[5]	1,275	Meta-analysis	Splenic artery embolization improves splenic salvage and results in fewer failures of nonoperative management
Requarth et al[7]	10,157	Meta-analysis	Splenic artery embolization increases splenic salvage in patients with grade IV and V injuries with fewer failures of nonoperative management
Arvieux et al[11]	133	Randomized controlled trial	32.3% of patients randomized to observation eventually required splenectomy or embolization and splenic artery embolization decreased length of stay
Schnüriger et al[12]	479	Meta-analysis	No difference in splenic salvage, rebleeding, or major complications between distal and proximal embolization. Distal embolization had more minor complications
Rong et al[34]	876	Meta-analysis	Lowest complications with proximal embolization but highest with combined proximal and distal embolization

required after splenectomy, as these patients are particularly susceptible to encapsulated organisms due to diminished phagocytic function.[39] Splenectomy patients also typically receive prophylactic antibiotics to accommodate the immunologic deficiency. These prophylactic measures are not necessary after SAE, which further highlights the value in this nonoperative intervention.[40]

Major complications of SAE include infection, infarction, device migration, or rebleeding that necessitate splenectomy.[41] Minor complications can include pleural effusions, fever, and device migrations that do not require splenectomy.[42] One multicenter analysis found the rates of major and minor complications to be 20 and 23%, respectively.[43] When considering complications, patient selection for SAE is paramount. As an example, retrospective analyses have found that as many as 40% of patients who experienced a major complication after SAE were likely inappropriately triaged to nonoperative management.[44,45] When comparing pSAE and dSAE, one meta-analysis including 476 patients found no statistical difference between the two techniques with regard to major complications, but dSAE had higher rates of minor complications, particularly splenic infarction.[12] A more recent meta-analysis including more than 800 patients demonstrated that major complications were higher in patients undergoing dSAE (28%) than pSAE (18%).[34]

Conclusion

Interventional radiology plays an important role in the multidisciplinary management of the trauma patient with splenic injury. Hemodynamically stable patients who are selected for nonoperative management have improved clinical outcomes when SAE is utilized. Patient selection is influenced by institution-specific referral patterns; however, all hemodynamically stable patients with high-grade splenic injuries are referred to interventional radiology for SAE in our institution. Both pSAE and dSAE are associated with high rates of technical and clinical success, an acceptable safety profile, and preservation of the immunologic functions of the spleen.

Conflict of Interest
A.J.G. is a speaker and consultant for Boston Scientific, a consultant for Varian, a speaker for Terumo, and receives research support from Penumbra. None of the other authors have conflicts of interest to disclose.

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