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Prophylactic absorbable gelatin sponge embolization for angiographically occult splenic hemorrhage

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ABSTRACT

Nonoperative management of traumatic splenic hemorrhage includes the targeted administration of embolic agents. In certain instances where computed tomography angiography cannot exclude a bleed, prophylactic embolization with absorbable gelatin sponge has been used. In this retrospective case series review, we characterized the demographic data and clinical outcomes associated with 4 patients who underwent prophylactic transarterial splenic artery embolization after blunt abdominal trauma. Embolization was employed in cases where computed tomography angiography findings suggested at least a moderate splenic injury, and simultaneously where hemorrhage was not apparent during fluoroscopic angiography. Periprocedural hemodynamic status, technical success, and postoperative complications are discussed. The goal of this report was to discuss the safety and efficacy of prophylactic gelatin sponge embolization for occult splenic hemorrhage. In cases where a hemorrhagic site might be occult, this approach has the potential to minimize bleeding complications and the need for further intervention.

Introduction

Given the advancement and availability of imaging modalities and minimally invasive techniques, interventional radiology (IR) has assumed a role in cases of abdominal and pelvic trauma [1]. Nonoperative management of traumatic splenic hemorrhage has expanded to include transcatheter vascular embolization. In certain instances, these procedures have been shown to reduce vascular complications compared with conventional surgical management [2–6]. Here, we de-

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scribe the use of gelatin sponge embolization in cases were computed tomography angiography (CTA) showed evidence of hemorrhage that was not visualized during fluoroscopic angiography.

Generally, when CTA findings indicate an ongoing hemorrhagic process, fluoroscopic arterial angiography can be performed. If active contrast extravasation or pseudoaneurysm is seen on angiography, IR-guided embolization can be attempted. A potential limitation exists, however, because conventional angiography confirms only 80%-90% of imaging findings [7]. Although the lack of contrast visualization likely indicates the cessation of active bleeding due to interim internal tamponade, it is important to consider the possibility that hemorrhage has been masked by another cause, namely, vasospasm. Additionally, diagnostic CTA limitations with temporal resolution can preclude detection of subtle hemorrhage. For example, developing arterial transection and pseudoaneurysm might be missed if imaging is obtained early on [7]. In these instances, a therapeutic gray area exists. If fluoroscopic angiography fails to identify a bleeding site and there is still a high degree of clinical suspicion for hemorrhage, prophylactic embolization for an occult bleed should be considered.

This discussion is particularly relevant to splenic hemorrhage, because the spleen is the most commonly injured organ during blunt abdominal trauma [8]. Management in these cases is determined by several factors, including hemodynamic status, grade of injury, and presence of contrast extravasation on initial imaging. For hemodynamically stable patients, nonoperative management constitutes the standard of care [9–11]. However, this conservative approach fails in upward of 12%-15% of patients [9,11–13]. Given these data, prophylactic IR-guided embolization with absorbable gelatin sponge (Gelfoam) has the potential to reduce the need for further radiological or surgical intervention, especially in cases where hemorrhage cannot necessarily be excluded. Despite the lack of an official consensus on when to employ this approach, the general safety and efficacy of gelatin sponge embolization [14] may warrant expansion of its use in cases where an occult bleed cannot be excluded. In this retrospective case series review, we examined the outcomes of prophylactic embolization for CTA-evident splenic injury in several patients admitted to our level 1 trauma center.

Materials and methods

Institutional review board approval was obtained and a retrospective case series review was carried out. Our picture archiving and communication system and electronic medical record were accessed and used to identify patients who received prophylactic absorbable gelatin sponge embolization of the splenic artery after blunt abdominal trauma between March 2012 and July 2017 (n = 4). We would like to note that this sample represents a small subset of all patients undergoing splenic embolization during this time period. This sample specifically includes patients who underwent gelatin sponge embolization when CTA-evident hemorrhage was not confirmed in the IR fluoroscopy suite.

We categorized our sample based on injury mechanism, hemodynamic status, and nonoperative management. Additionally, demographic information, pertinent diagnostic imaging, and reported clinical outcomes were reviewed and summarized. These data were descriptive in nature because this small sample was not amenable to statistical analysis. All information was obtained via retrospective chart review. Each case was assessed for hemodynamic status and the need for additional intervention. Patients were also assessed for postprocedural complications, such as splenic infarction or abscess. In all 4 cases, prophylactic splenic artery embolization was successfully performed. Individual patient courses are described further. A comprehensive summary of interventional and clinical information can be seen in Table 1.

Patient/Case A

Patient A was a 45-year-old man presenting to the emergency department (ED) after a high-velocity motor-vehicle collision (MVC). The patient was stable upon admission with a recorded blood pressure and heart rate of 106/52 and 72, respectively. A contrast-enhanced whole-body CT scan was obtained during the early portal venous phase after rapid injection of intravenous contrast. Images revealed several rib fractures and perisplenic hematoma. Contrast extravasation was noted on CTA, suggesting active splenic vascular injury (Figs 1 A and B). Splenic injury was classified as grade 3 according to guidelines from the American Association for the Surgery of Trauma (AAST) [15]. IR was consulted and subsequent transarterial splenic angiography was performed after discussion with the trauma team. Femoral access was obtained using the Seldinger technique. A 5-French angled taper 0.038 in. (0.97 mm) hydrophilic cobra glide catheter (Terumo Medical Corporation, Somerset, NJ) was used to gain access to the celiac artery. Thereafter, selective angiographic runs were performed for vessel mapping. The splenic artery was then accessed utilizing a 0.035 in. (0.89 mm) angled glide catheter (Terumo Medical Corporation, Somerset, NJ). Selective angiography was again performed at this vascular level. Images obtained at multiple viewing angles did not demonstrate significant contrast extravasation or pseudoaneurysm formation (Fig. 1C). After discussion with the admitting team, it was determined that patient A might benefit from prophylactic embolization of the splenic artery. A 50% normal saline, 50% ioversol solution was created and mixed with Gelfoam (Pfizer, New York, NY) pledgets using syringes connected by a 3-way stopcock. A small volume of the resultant slurry was injected into the proximal splenic artery under fluoroscopic guidance until sluggish flow was observed, indicating that embolization of distal arterial branches had likely occurred. The main splenic artery remained patent (Fig. 1C). Postembolization hemodynamic stability was maintained. Chart review did not reveal any significant embolization-related complications. No additional surgery or intervention was preformed, and patient A was successfully discharged from the hospital.

Patient/Case B

Patient B was a 27-year-old man presenting to the ED after a high-velocity MVC. The patient was stable upon ad-

Table 1 – Summary of patient demographic, interventional, and clinical information

Characteristics	Patient A	Patient B	Patient C	Patient D
Age (y)	45	27	17	62
Sex	Male	Male	Male	Female
Whole-body CT scan (with contrast)	Yes	Yes	Yes	Yes
Scan phase	Portal venous	Portal venous	Portal venous	Arterial
Rib fracture diagnosed	Yes	No	Yes	Yes
Perisplenic hematoma	Yes	Yes	Yes	Yes
CTA contrast extravasation	Yes	Yes	Yes	No
AAST injury grade	3	4	3	3
Angiography performed	Yes	Yes	Yes	Yes
Angiography contrast extravasation	No	No	No	No
Splenic artery embolization site	Proximal	Proximal	Proximal	Proximal
Admission hemodynamic status	Stable	Stable	Stable	Unstable*
Admission blood pressure (mm Hg)	106/52	130/84	140/82	78/52
Admission heart rate (bpm)	72	95	92	97
Postprocedural hemodynamic status	Stable	Stable	Stable	Stable
Postprocedural complications	None	None	None	None
Postprocedural CT imaging	None	2 d, 2 mo	None	None
Fluoroscopy time (min)	11.6	19.7	5.0	38.5
Contrast (mL)	75	50	100	75
Additional intervention	None	None	None	None
Clinical course result	Discharge	Discharge	Discharge	Death

This table provides a summary of all patients in our electronic medical record who underwent prophylactic splenic artery embolization after trauma. Hemodynamic status reported is based on recorded clinical examination findings and vital signs. Injury grade is based on guidelines from the AAST (grades 1-5). Imaging findings, interventional outcomes, and clinical course are summarized here.
AAST, American Association for the Surgery of Trauma; CT, computed tomography; CTA, computed tomography angiography.
* Despite having periprocedural hemodynamic instability, patient D remained stable for several days after prophylactic embolization before ultimately expiring.

mission with a recorded blood pressure and heart rate of 130/84 and 95, respectively. A contrast-enhanced whole-body CT scan was obtained during the early portal venous phase after rapid injection of intravenous contrast. Images revealed perisplenic hematoma but no rib fractures. Contrast extravasation was noted on CTA, suggesting active splenic vascular injury. Splenic injury was classified as grade 4 according to guidelines from the AAST [15]. IR was consulted, and after discussion with the trauma team, transarterial splenic angiography was performed using the technique previously described in case A. Images obtained at multiple viewing angles did not demonstrate significant contrast extravasation or pseudoaneurysm formation. After a discussion with the admitting team, it was determined that the patient might benefit from prophylactic embolization of the splenic artery. Prophylactic splenic artery embolization was successfully accomplished using the technique described in case A. The main splenic artery remained patent. Hemodynamic stability was maintained after the procedure. Notably, patient B underwent additional CT imaging 2 days (Fig. 1E) and 68 days (Fig. 1F) post intervention as part of a medical workup for abdominal pain. Initial postintervention imaging at 2 days again showed the splenic laceration. Several peripheral wedge-shaped areas of nonenhancement suspicious for infarction were also seen; however, it was unclear if these were secondary to initial trauma or embolization. Also of note, the interval decrease in volume of perisplenic blood suggested cessation of active hemorrhage. Imaging obtained 68 days later revealed mostly resolved splenic lacerations with a few small areas of scarring, again deemed to be sequelae of either the initial vascular insult or subsequent embolization. No CT evidence of abscess was seen. The chart review did not reveal any significant embolization-related complications. No additional surgery or intervention was preformed and patient B was successfully discharged from the hospital.

Patient/Case C

Patient C was a 17-year-old adolescent boy presenting to the ED after a high-velocity MVC. The patient was stable upon admission with a recorded blood pressure and heart rate of 140/82 and 92, respectively. A contrast-enhanced whole-body CT scan was obtained during the early portal venous phase after rapid injection of intravenous contrast. Images revealed several rib fractures and a perisplenic hematoma. Contrast extravasation was noted on CTA, suggesting active splenic vascular injury. Splenic injury was classified as grade 3 according to guidelines from the AAST [15]. IR was consulted, and after discussion with the trauma team, transarterial splenic angiography was performed using the technique previously described in case A. Images obtained at multiple viewing angles did not demonstrate significant contrast extravasation or pseudoaneurysm formation. After a discussion with the admitting team, it was determined that the patient might benefit from prophylactic embolization of the splenic artery. Prophylactic splenic artery embolization was successfully performed using the technique described in case A. The main splenic artery remained patent. Hemodynamic stability was main-

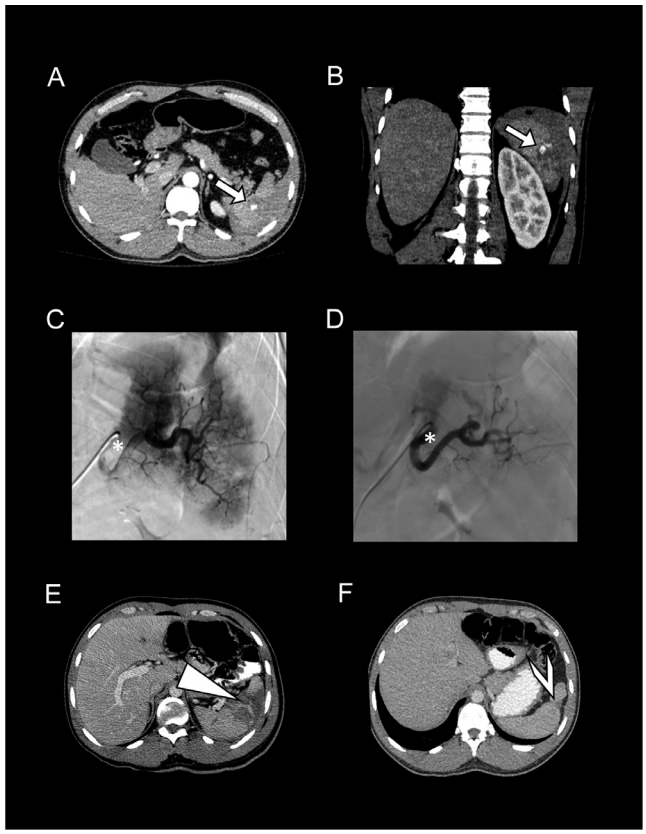

Fig. 1 – Imaging examples of splenic hemorrhage and angiography. This figure provides examples of computed tomography angiography and transarterial angiography findings in patients undergoing prophylactic splenic artery embolization. This is not intended to be a comprehensive overview of all patient imaging, but rather to provide visual context. (A and B) Computed tomography angiography evidence of an American Association for the Surgery of Trauma grade 3 splenic hemorrhage in patient A—specifically, there is perisplenic blood arising from a ruptured hematoma and contrast visualization, indicative of arterial extravasation versus pseudoaneurysm (white arrows). (C and D) Fluoroscopy segments of angiography performed in patient A, both pre- and post embolization, respectively. Of note, catheter placement and Gelfoam injection occurred at the proximal splenic artery (white asterisks), proximal to the dorsal pancreatic artery. The main splenic artery remained patent in all patients post embolization (D). (E and F) Axial sections of computed tomography scans obtained 2 and 68 days post intervention, respectively, in patient B. (E) A splenic laceration (white triangle) and resolving perisplenic fluid. (F) Resolving splenic laceration and a small area of scarring (white arrowhead).

tained after the procedure. The chart review did not reveal any significant embolization-related complications. No additional surgery or intervention was preformed and patient C was successfully discharged from the hospital.

Patient/Case D

Patient D was a 62-year-old man presenting to the ED after a high-velocity MVC. The patient was unstable upon admission with a recorded blood pressure and heart rate of 78/52 and 97, respectively. A contrast-enhanced whole-body CT scan was obtained. Unlike patients A, B, and C, patient D was scanned during the arterial phase, likely because of delayed cardiac output secondary to heart failure. Images revealed several rib fractures and a perisplenic hematoma. Contrast extravasation was noted on CTA, suggesting active splenic vascular injury. Splenic injury was classified as grade 3 according to guidelines from the AAST [15]. Patient D presented with multiple episodes of hypotension and tachycardia, necessitating fluid resuscitation upon arrival and again in the surgical intensive care unit. After a multidisciplinary discussion, it was determined that patient D might benefit from interventional angiography. Angiographic technique was carried out as previously described in case A. Images obtained at multiple viewing angles did not demonstrate significant contrast extravasation or pseudoaneurysm formation. After a discussion with the trauma team, it was determined that patient D might benefit from prophylactic embolization of the splenic artery. Prophylactic splenic artery embolization was successfully performed using the technique described in case A. The main splenic artery remained patent. Despite bouts of hemodynamic instability upon admission, the hemoglobin of patient D stabilized post embolization. However, this patient's hospital course was complicated by numerous extremity fractures, atrial fibrillation, respiratory distress, and multiple organ dysfunction syndrome. Patient D was ultimately provided comfort care until expiration.

Discussion

When a bleeding site is identified on CTA, IR-guided splenic embolization can be attempted. Catheter placement and embolic agent deployment can occur either in the proximal portion of the splenic artery or, more selectively, in a distal arterial branch. The proximal approach, with its associated ease and speed of embolic agent deployment, is ideal for patients with high-grade parenchymal injuries or multiple splenic lacerations [16,17]. Proximal splenic artery embolization facilitates hemostasis by reducing intrasplenic blood pressure, resulting in clot formation and healing [18]. Alternatively, the distal technique achieves hemostasis of isolated hemorrhage in terminal branches while maintaining perfusion to the remainder of the spleen [19,20]. Although this approach partially preserves splenic function, rebleeding may occur when initial vascular injuries go unnoticed because of vasospasm [18].

A recent meta-analysis reviewing splenic artery embolization for blunt injury found that the proximal approach reduced the risk of compilations, including infarction, rebleeding, abscess formation, and contrast-induced nephropathy. It was also noted in the same meta-analysis that the distal approach might miss segmental bleeds due to hematoma-induced vasospasm, thereby increasing the risk of rebleeding [21]. Both techniques have been used successfully; how-

ever, the proximal approach is more commonly employed. Ultimately, this decision is at the interventionist's discretion. In our sample, catheters were placed in the proximal splenic artery, and a slow injection technique was used to prophylactically embolize small terminal branches. This approach afforded a higher degree of assurance that any potential occult bleeds were embolized, regardless of arterial level or branch. This slow injection technique was particularly important for patient A, where catheter tip placement was proximal to the dorsal pancreatic artery [20,22]. As this approach relies on recruitment of collateral pancreatic and gastric arteries to preserve splenic perfusion and to prevent total infarction, embolization should ideally occur distal to the origin of the dorsal pancreatic artery.

When treating patients with embolization, a wide variety of embolic agents can be employed [23]. Selection depends on the desired clinical application and outcome, and whether temporary or permanent embolization is preferred [24,25]. The mechanisms and utility of these various agents have been described [18,23,26,27]. In our reported cases, occult hemorrhage could not be excluded via angiographic fluoroscopy. Because a definitive bleeding site could not be ruled out, but injuries were characterized as AAST grade 3 or higher, the decision was made to prophylactically embolize using Gelfoam.

Gelfoam is cost-effective, versatile, and has a proven clinical track record of over 30 years [23]. This sterile compressed hemostatic sponge can be easily and quickly cut into pledgets or torpedoes and prepared into a slurry. This slurry can then be injected proximal to a hemorrhagic site. The relatively large size of this material, unlike Gelfoam powder or microparticles, ensures that a cast will form in a relatively proximal vessel [22]. The structural matrix of this slurry promotes clotting and vessel obstruction, thereby decreasing the pressure head and hastening thrombogenesis at the site of the traumatic injury. Notably, the transient nature of Gelfoam results in vessel recanalization in as little as 2 weeks. This is advantageous in the setting of trauma since initial hemostasis can be achieved without deterring tissue recovery [28,29]. Given this favorable profile and the injury status of these patients, prophylactic embolization was attempted to minimize future bleeding complications and the need for further intervention.

Despite the utility and advantages of embolization, rare complications do exist. Gelfoam has been associated with infection due to air trapping [30]. Thus, prophylactic antibiotics are sometimes used, although they were not administered in these cases, given the lack of clinical effectiveness data in this regard. Additionally, it has been suggested that Gelfoam powder, with its smaller 40- to 60-μm particle size, can cause tissue infarction and necrosis due to distal arteriolar embolization. This risk has also been demonstrated when using larger particles, necessitating size optimization to prevent unintended ischemia [31]. Although these procedures always carry a risk of adverse events, complications are generally rare. In this study, notable splenic artery embolization complications, including splenic abscess formation, pancreatitis, persistent hemorrhage, and postembolization syndrome [32] were not observed.

Despite our documented favorable outcomes, we recognize several limitations of the present study, notably our small sample size. Additionally, because of the retrospective nature of the study, postintervention imaging was not performed in all patients. A future controlled study should obtain more robust splenic measurements both before and after intervention. Although these data might lack generalizability, they are still clinically relevant, because prophylactic embolization has been shown to be successful in nontraumatic splenic cases [33–35], as well as in the setting of pelvic trauma [34,36,37] and birth complications [38]. Notably, studies have demonstrated favorable outcomes using nonselective prophylactic embolization in cases of pelvic fractures and associated hemodynamic instability where there is failure to identify arterial lesions [39,40]. Additionally, postintervention tissue ischemia and necrosis secondary to nontarget embolization may be reduced with the use of transient embolic agents, such as Gelfoam [23]. Although the management of pelvic trauma is multidisciplinary, arterial embolization has become the standard of care at many institutions [34].

In summary, this retrospective case series review summarizes our single-center experience performing prophylactic splenic artery embolization in 4 trauma patients. Proximal splenic artery angiography was performed as indicated by positive CTA findings. When a high degree of clinical suspicion for hemorrhage existed in the light of absent contrast extravasation during transcatheter angiography, prophylactic Gelfoam embolization was successfully accomplished. Postprocedural hemodynamic status was achieved in all patients. No significant postembolization complications were noted. In the future, a larger, multicenter study assessing the clinical utility of prophylactic embolization for occult moderate and high-grade splenic hemorrhage is warranted.

REFERENCES

[1] Zealley IA, Chakraverty S. The role of interventional radiology in trauma. Br Med J 2010;340:5.

[2] Garza-Berlanga A, Lopera J. Interventional radiology: interventions and techniques in trauma. Current Trauma Rep 2016;2(3):159–64.

[3] Maher MM, McNamara AM, MacEneaney PM, Sheehan SJ, Malone DE. Abdominal aortic aneurysms: elective endovascular repair versus conventional surgery—evaluation with evidence-based medicine techniques. Radiology 2003;228(3):647–58.

[4] Loffroy R, Favelier S, Pottecher P, Estivalet L, Genson PY, Gehin S, et al. Transcatheter arterial embolization for acute nonvariceal upper gastrointestinal bleeding: indications, techniques and outcomes. Diagn Interv Imaging 2015;96(7–8):731–44.

[5] Tsurukiri J, Ohta S, Mishima S, Homma H, Okumura E, Akamine I, et al. Availability of on-site acute vascular interventional radiology techniques performed by trained acute care specialists: a single-emergency center experience. J Trauma Acute Care Surg 2017;82(1):126–32.

[6] Scott AR, Gilani R, Tapia NM, Mattox KL, Wall MJ, Suliburk JW. Endovascular management of traumatic peripheral arterial injuries. J Surg Res 2015;199(2):557–63.

[7] Asensio JA, Trunkey DD. Current therapy of trauma and surgical critical care. 2nd ed. Elsevier; 2015.

[8] Davis JJ, Cohn I, Nance FC. Diagnosis and management of blunt abdominal trauma. Ann Surg 1976;183(6):672–8.

[9] Haan JM, Biffl W, Knudson MM, Davis KA, Oka T, Majercik S, et al. Splenic embolization revisited: a multicenter review. J Trauma 2004;56(3):542–7.

[10] Wallis A, Kelly MD, Jones L. Angiography and embolisation for solid abdominal organ injury in adults—a current perspective. World J Emerg Surg 2010;5:13.
[11] Holden A. Abdomen-interventions for solid organ injury. Injury 2008;39(11):1275–89.
[12] Moore HM, List A, Holden A, Osborne TM. Therapeutic embolization for acute haemorrhage in the abdomen and pelvis. Australas Radiol 2000;44(2):161–8.
[13] Gavant ML, Schurr M, Flick PA, Croce MA, Fabian TC, Gold RE. Predicting clinical outcome of nonsurgical management of blunt splenic injury: using CT to reveal abnormalities of splenic vasculature. AJR Am J Roentgenol 1997;168(1):207–12.
[14] Rasuli P, Moosavi B, French GJ, Petrcich W, Hammond I. Splenic artery embolization in blunt trauma: a single-center retrospective comparison of the use of gelatin sponge versus coils. AJR Am J Roentgenol 2017:W1–6.
[15] Homann G, Toschke C, Gassmann P, Vieth V. Accuracy of the AAST organ injury scale for CT evaluation of traumatic liver and spleen injuries. Chin J Traumatol 2014;17(1):25–30.
[16] Franco F, Monaco D, Volpi A, Marcato C, Larini P, Rossi C. The role of arterial embolization in blunt splenic injury. Radiol Med 2011;116(3):454–65.
[17] Bessoud B, Denys A, Calmes JM, Madoff D, Qanadli S, Schnyder P, et al. Nonoperative management of traumatic splenic injuries: is there a role for proximal splenic artery embolization? AJR Am J Roentgenol 2006;186(3):779–85.
[18] 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):464–72.
[19] Lagana D, Carrafiello G, Mangini M, Fontana F, Dizonno M, Castelli P, et al. Endovascular treatment of splenic artery aneurysms. Radiol Med 2005;110(1–2):77–87.
[20] Imbrogno BF, Ray CE. Splenic artery embolization in blunt trauma. Semin Intervent Radiol 2012;29(2):147–9.
[21] Rong JJ, Liu D, Liang M, Wang QH, Sun JY, Zhang QY, et al. The impacts of different embolization techniques on splenic artery embolization for blunt splenic injury: a systematic review and meta-analysis. Mil Med Res 2017;4:12.
[22] Bauer JR, Ray CE. Transcatheter arterial embolization in the trauma patient: a review. Semin Intervent Radiol 2004;21(1):11–22.
[23] Vaidya S, Tozer KR, Chen J. An overview of embolic agents. Semin Intervent Radiol 2008;25(3):204–15.
[24] Lubarsky M, Ray C, Funaki B. Embolization agents-which one should be used when? Part 2: small-vessel embolization. Semin Intervent Radiol 2010;27(1):99–104.
[25] Lubarsky M, Ray CE, Funaki B. Embolization agents-which one should be used when? Part 1: large-vessel embolization. Semin Intervent Radiol 2009;26(4):352–7.
[26] Cil B, Peynircioglu B, Canyigit M, Geyik S, Ciftci T. Peripheral vascular applications of the Amplatzer (R) vascular plug. Diagn Interv Radiol 2008;14(1):35–9.
[27] Beaujeux R, Laurent A, Wassef M, Casasco A, Gobin YP, Aymard A, et al. Trisacryl gelatin microspheres for therapeutic embolization .2. Preliminary clinical evaluation in tumors and arteriovenous malformations. AJNR Am J Neuroradiol 1996;17(3):541–8.
[28] Owen RJT. Embolization of musculoskeletal bone tumors. Semin Intervent Radiol 2010;27(2):111–23.
[29] Wang YXJ, De Baere T, Idee JM, Ballet S. Transcatheter embolization therapy in liver cancer: an update of clinical evidences. Chin J Cancer Res 2015;27(2):96–121.
[30] Patel AA, Solomon JA, Soulen MC. Pharmaceuticals for Intra-arterial Therapy. Semin Intervent Radiol 2005;22(2):130–8.
[31] Lopera JE. Embolization in trauma: principles and techniques. Semin Intervent Radiol 2010;27(1):14–28.
[32] Upadhyaya P. Conservative management of splenic trauma: history and current trends. Pediatr Surg Int 2003;19(9–10):617–27.
[33] Spigos DG, Jonasson O, Mozes M, Capek V. Partial splenic embolization in the treatment of hypersplenism. AJR Am J Roentgenol 1979;132(5):777–82.
[34] Barentsz MW, Vonken EPA, van Herwaarden JA, Leenen LPH, Mali WPTM, van den Bosch MAAJ. Clinical outcome of intra-arterial embolization for treatment of patients with pelvic trauma. Radiol Res Pract 2011;2011 935484.
[35] Hadduck TA, McWilliams JP. Partial splenic artery embolization in cirrhotic patients. World J Radiol 2014;6(5):160–8.
[36] Tanizaki S, Maeda S, Hayashi H, Matano H, Ishida H, Yoshikawa J, et al. Early embolization without external fixation in pelvic trauma. Am J Emerg Med 2012;30(2):342–6.
[37] Fu CY, Wang YC, Wu SC, Chen RJ, Hsieh CH, Huang HC, et al. Angioembolization provides benefits in patients with concomitant unstable pelvic fracture and unstable hemodynamics. Am J Emerg Med 2012;30(1):207–13.
[38] Sivan E, Spira M, Achiron R, Rimon U, Golan G, Mazaki-Tovi S, et al. Prophylactic pelvic artery catheterization and embolization in women with placenta accreta: can it prevent cesarean hysterectomy? Am J Perinatol 2010;27(6):455–61.
[39] Hoffer EK. Transcatheter embolization in the treatment of hemorrhage in pelvic trauma. Semin Intervent Radiol 2008;25(3):281–92.
[40] Khanna P, Phan H, Hardy AH, Nolan T, Dong P. Multidisciplinary management of blunt pelvic trauma. Semin Intervent Radiol 2012;29(3):187–91.