Endovascular Management of Abdominal Solid Organ Trauma

Indications and embolic agents for successful noninvasive treatment.

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Endovascular management of blunt trauma to the abdominal solid organs is the standard of care for hemodynamically stable patients without signs of peritonitis.[1-3] This strategy is associated with less hospital cost, earlier discharge, fewer intra-abdominal complications, and a reduced transfusion rate, without increased morbidity.[4]

The high success rate of this approach is only possible with the use of angiography and embolization (A&E) as adjunctive therapy, when appropriate.[5,6] Awareness of the subgroup of patients who can benefit from endovascular management and familiarity with the technique is crucial to avoid additional risk and cost by not adding unnecessary procedures.

Although any solid intra-abdominal organ can be injured after blunt trauma, including the pancreas and adrenal glands, this discussion will be limited to the spleen, liver, and kidneys, as they represent the most relevant sources of bleeding that can lead to death.

PATIENT SELECTION

Splenic Trauma

According to the latest Eastern Association for the Surgery of Trauma practice management guidelines for blunt splenic injury, angiography should be considered for patients with an American Association for the Surgery of Trauma (AAST) grade > III, presence of contrast blush on abdominal CT, moderate hemoperitoneum, or clinical evidence of ongoing bleeding.[1]

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Hepatic Trauma

According to the latest Eastern Association for the Surgery of Trauma practice management guideline for blunt hepatic injury, angiography should be considered in patients with an AAST grade ≥ III, presence of contrast blush on CT, and evidence of hepatic venous injury.[2] A&E is also considered first-line therapy for patients who are transient responders to resuscitation,[7] which represents ongoing bleeding.

Renal Trauma

Similar to the other organs, A&E is indicated in stable patients if CT scan shows contrast blush, pseudoaneurysm, or arteriovenous fistula.[8] In addition, according to the 2014 American Urology Association guidelines, A&E should also be considered in hemodynamically unstable patients.[3]

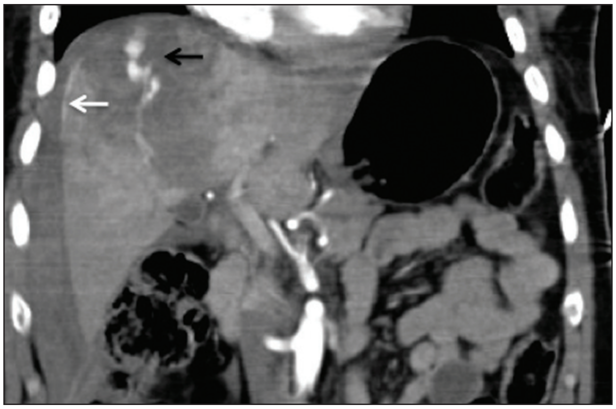

Figure 1. CT of the abdomen with coronal reconstruction showing an irregular area of contrast enhancement (black arrow), which is associated with contrast material extending into the subcapsular space (white arrow). These findings are consistent with contrast material extravasation and represent ongoing bleeding.

CT ASSESSMENT

The universal and most reliable CT finding of active bleeding is contrast material extravasation and should always prompt A&E. If found, so-called contained vascular injuries should also lead to A&E. These findings are well described for splenic lesions,[9,10] but can also be used in the setting of hepatic and renal traumatic injury.

Contrast extravasation is characterized by linear or irregular areas of contrast material enhancement with similar intra-arterial attenuation coefficient, which tends to expand on delayed phases (Figure 1). Contained vascular injuries or "nonbleeding" vascular injuries include pseudoaneurysm and arteriovenous fistula. Different from contrast material extravasation, those lesions tend to appear as well-circumscribed areas of high attenuation coefficient, usually surrounded by a hypodense region, with the tendency of turning isodense to the surrounding parenchyma on delayed phases (Figure 2).

Pseudoaneurysms are formed by an arterial wall injury, allowing blood extravasation that is partially contained by other surrounding structures. Therefore, these lesions are unstable; up to two-thirds of them may ultimately rupture, leading to unsuccessful endovascular management if not correctly treated.[9]

As shown by Boscak and colleagues,[11] dual-phase CT provides better overall performance to differentiate those types of lesions when compared to single-phase CT, although this may not change clinical management because patients with either contrast material extravasation or contained vascular injuries should be referred to angiography.

In the setting of hepatic trauma, another finding that has been correlated with arterial injury is involvement of a major hepatic vein.[12] In this study, 88% of the cases with active hepatic arterial bleeding also had hepatic vein involvement, whereas in patients without active hepatic bleeding, only 34% had injury extending to a major hepatic vein. Therefore, the authors suggested that patients with grade IV to V lesions associated with hepatic vein involvement should be referred for angiography, even without evidence of contrast extravasation or pseudoaneurysm.

As previously mentioned, additional CT findings that also influence the indication for A&E are the AAST grade system and the severity of hemoperitoneum. AAST grade classifications are available to describe splenic, hepatic, and renal traumatic injuries. The severity of hemoperitoneum can be determined by dividing the peritoneal cavity in five compartments (perisplenic space, Morison's pouch, left and right paracolic gutters, and pelvis): *small* is defined as blood in only one or two spaces, *moderate* is

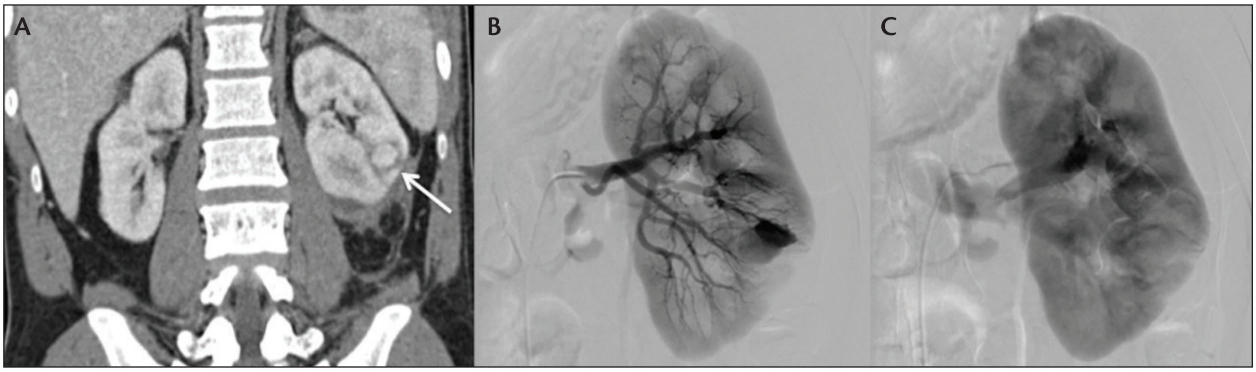

Figure 2. CT of the abdomen with coronal reconstruction showing a well-circumscribed lesion within the lower pole of the left kidney surrounded by hypodense parenchyma (white arrow; A). Catheter-based angiogram of the left kidney during late arterial phase confirming an oval-shaped lesion in the lower pole (B). Catheter-based angiogram of the left kidney during the venous phase, when the oval-shaped lesion is no longer visualized due to contrast washout (C). No increasing contrast blush is present, confirming the diagnosis of a pseudoaneurysm.

blood in three or four spaces, and *large* is blood in all five spaces.[10]

ANGIOGRAPHY AND EMBOLIZATION

Digital subtraction angiography should be tailored to the CT findings in order to minimize procedure time, radiation exposure, and volume of iodine contrast material. An initial anteroposterior view should be acquired, with the acquisition time long enough to visualize the venous return, including opacification of the portal system, in case of hepatic or splenic injuries. Selective catheterization with oblique views is extremely helpful, as it increases the sensibility for detection of vascular abnormalities. Similar to CT, angiographic findings include contrast material extravasation, pseudoaneurysm, and arteriovenous fistula (Figure 3). In addition, angiography has higher sensitivity for detecting arteriobiliary and arteriocalyceal fistulas. Abrupt arterial truncation can also be observed and could represent either vessel dissection or transection. The latter could lead to intermittent bleeding in cases of increasing pressure head in the arterial system, if the patient's hemodynamic status improves. Therefore, embolization should be considered in cases of traumatic arterial occlusion.[13]

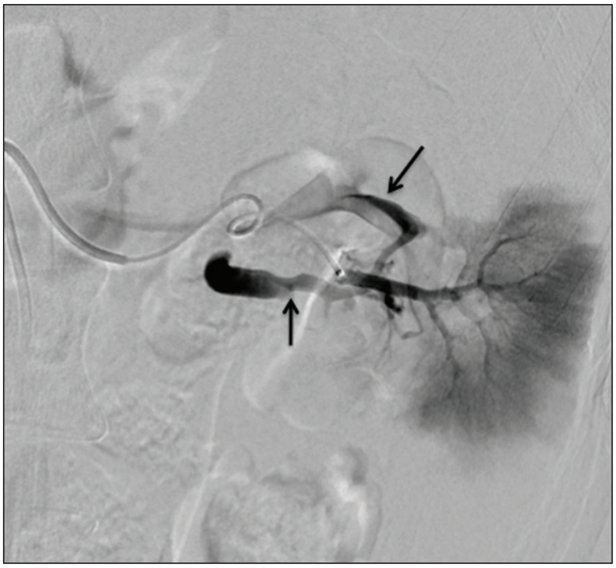

Figure 3. Superselective angiography through a microcatheter positioned within an interlobar artery of the left kidney during the late arterial phase showing early venous return (black arrows). This is consistent with the presence of an arteriovenous fistula.

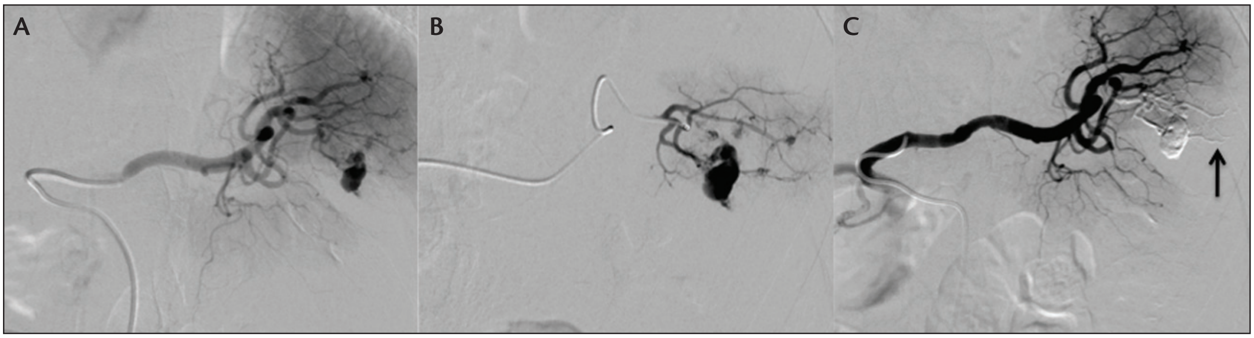

Figure 4. Selective angiogram of the splenic artery showing abnormal contrast blush in the mid-third of the spleen (A). Superselective angiogram through a microcatheter positioned within a parenchymal branch demonstrating not only the large lesion previously seen, but also multiple abnormal foci of contrast blush arising from different branches (B). Due to the multiplicity and distal location of these lesions, cyanoacrylate was chosen as the embolic agent because of its capability to reach multiple distal areas. A postembolization image showing the cast of glue filling the large lesion as well as other multiple branches (C). Note how far this embolic agent can reach (black arrow), depending on the dilution used.

Splenic Embolization

Different techniques have been used to treat splenic trauma, including proximal, distal, and combined splenic embolization. In terms of effectiveness in achieving hemostasis, the difference between these techniques has not been shown.[14,15] Overall, distal embolization has been used when focal parenchymal contrast material extravasation or contained vascular lesions are found. Due to the amount of splenic collateral circulation, proximal embolization would not be effective in treating a distal lesion due to the potential risk of back bleeding.

Proximal embolization is used when no focal lesions are present and in the setting of severe traumatic injury (grade IV/V). Proximal embolization has also been described when multiple bleeding sites are present, making selective embolization more challenging and time consuming. In theory, that would allow clot formation by decreasing parenchymal arterial flow to those multiple injured sites.[14]

Distal embolization is associated with a higher incidence of complications, including abscess and pseudocyst formation.[16] This is due to parenchymal infarction, as the result of terminal branches occlusion. Even with the increased risk for infarction, distal embolization is always recommended when a focal parenchymal lesion is identified.

On the other hand, proximal embolization can lead to ischemic pancreatitis, as the pancreas is supplied by proximal branches of the splenic artery (dorsal pancreatic and pancreatic magna arteries). Therefore, when considering proximal embolization, those vessels need to be identified, and the embolic device should be placed distal to their origin.

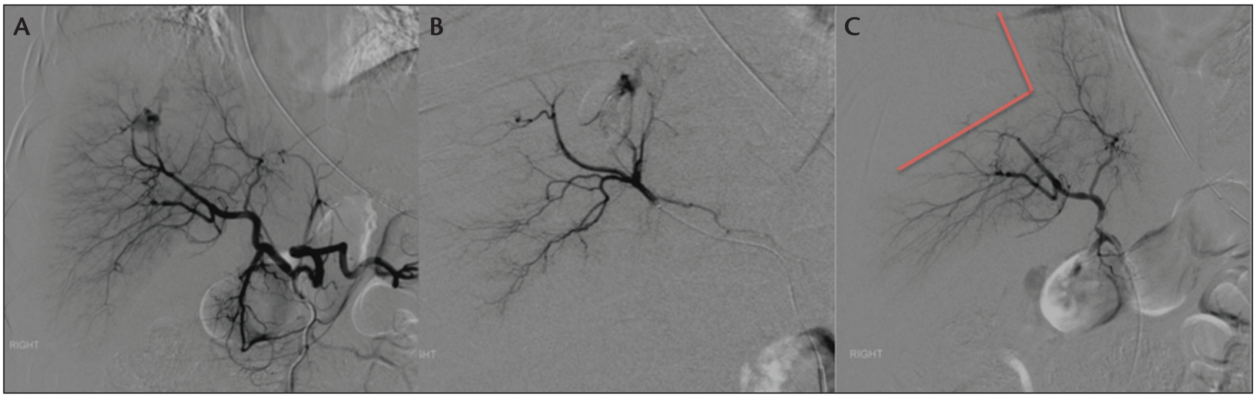

Figure 5. Celiac trunk angiogram on the same patient as shown in Figure 1 confirming contrast extravasation from the liver parenchyma (A). Superselective angiogram through a microcatheter positioned within a segmental branch shows the source of the bleeding (B). Gelatin sponge was the chosen embolic agent. A postembolization image shows resolution of the contrast extravasation (C). Note the wedge-shaped area of arterial devascularization after segmental vessel occlusion. Most of the time, this has no clinical significance due to the hepatic dual blood supply.

Endovascular management of traumatic injuries of solid intra-abdominal organs is part of the practice of every trauma center.

For distal embolization, a microcatheter is used coaxially for superselective catheterization of the target vessel, and embolization can be performed with coils, gelatin sponge, or glue. Among the variety of coils available, pushable fiber coils are the most often used because they are less expensive, they are faster to deploy, and the risk of coil migration is not substantial. Usually, choosing a coil 1 mm bigger than the vessel is sufficient to achieve adequate sealing and to avoid distal migration. Gelatin sponge can be used in the form of a slurry. For this, the bar of the embolic agent is cut in small pieces and mixed with contrast material through a three-way stopcock connected to two syringes.

Cyanoacrylate, known as *glue*, is an adhesive liquid embolic agent that can also be used for distal embolization. The agent solidifies when it comes in contact with an ionic solution such as blood, and the time for solidification depends on the applied dilution. The agent should be mixed with lipiodol, which is a nonionic material that provides radiopacity for the solution. Usually, a 50/50 mixture is utilized; if faster solidification is desired, a higher proportion of glue should be used. To avoid solidification within the delivery catheter, the system should be filled with a solution of 5% dextrose. Finally, the mixture is injected for a few seconds; removal of the catheter should not be delayed in order to avoid catheter entrapment (Figure 4). The advantages of glue are its low cost, availability, and effective distal embolization, whereas the biggest disadvantage is the potential risk of having the catheter stuck within the vessel.

For proximal embolization of the splenic artery, coils and vascular plugs are the agents of choice. When using coils, 1 to 2 mm upsizing is recommended. In contrast to distal embolization, detachable coils play a more important role, as the main splenic artery is a calibrous high-flow vessel. In this situation, distal migration is more detrimental because large parenchymal areas can be infarcted.

Vascular plugs require significant upsizing, usually 40% bigger than the vessel. Depending on the size of the chosen plug, the delivery system can be as small as a 4-F diagnostic catheter. However, larger devices will require larger delivery systems. This can add some difficulty to the procedure, as the splenic artery is a tortuous vessel, and proper system positioning and stabilization can be challenging.

A meta-analysis published by Schnüriger and colleagues[14] showed wide variation of failure to achieve homeostasis from 0% to 33.3%, with a pooled overall failure of 10.2%. A more recent publication including 50 patients demonstrated similar results, with an 8% failure rate, but without a statistically significant difference among the techniques (proximal vs distal).[15]

According to the same meta-analysis, the most common complications were infarction and infection, with an incidence of 0% to 19.8% and 0% to 1.9%, respectively. Frandon and colleagues reported a 4% infarction and 16% infection rate.[15] Schnüriger also showed that minor complications were more associated with distal embolization, which was also demonstrated by Ekeh and colleagues.[16]

Finally, one additional issue has been raised in regard to the patient's immune system status after splenic embolization. Initially, there was a concern that embolization in the setting of blunt splenic trauma would affect the immune system in a similar fashion to splenectomy. However, studies have shown no difference in the immunologic profile of patients who underwent splenic embolization compared to control groups.[17-19]

Hepatic Embolization

Different from embolization of the spleen, hepatic embolization is mostly performed distally after selective catheterization of the main branches of the proper hepatic artery or even superselectively with access into segmental branches. Therefore, coils, glue, and gelatin sponge are the embolic agents of choice, and vascular plugs play a minimal role (Figure 5).

Although the liver parenchyma has a dual blood supply from the portal vein and hepatic artery, isch-

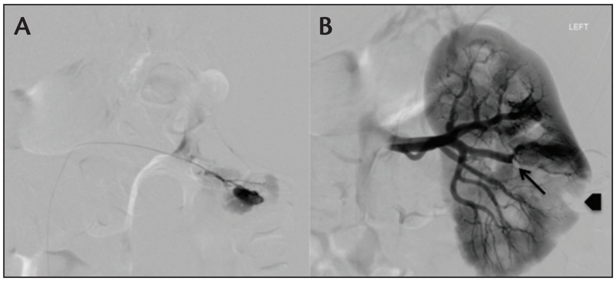

Figure 6. Superselective angiogram through a microcatheter positioned within the interlobar branch in the same patient as shown in Figure 2, again showing the pseudoaneurysm (A). An image after coil embolization showing exclusion of the lesion from the circulation (B). Note the pack of coils producing total occlusion of the vessel (black arrow) and minimal tissue devascularization after superselective embolization (arrowhead).

emic complications can occur after hepatic artery embolization. A recent series demonstrated that 16% of the patients who underwent embolization required debridement of necrotic liver parenchyma.[20] This could be explained by associated traumatic focal injury to the portal venous system, leading to complete lack of blood supply. Gallbladder ischemia was also an important complication, occurring in 16% of the patients, all of them requiring cholecystectomy. The best way to avoid these complications is by pursuing superselective embolization, limiting the devascularized area. To avoid gallbladder ischemia, the takeoff of the cystic artery should be identified and the catheter positioned beyond that level. In > 63% of patients, the cystic artery will arise from the right hepatic artery and, less commonly, from the proper hepatic artery or left hepatic artery.[21]

Renal Embolization

Among all of the organs described so far, the kidney is the least forgiving in terms of tissue infarct due to the irreversibility of nephron loss and potential long-term renal dysfunction. In addition to the ischemic injury caused by embolization, those patients are at risk for contrast-induced nephropathy and acute tubular necrosis due to hypovolemic shock. Fortunately, coaxial use of a microcatheter allows superselective catheterization of the injured vessel, minimizing normal parenchymal compromise.

Similar to the liver and spleen, the use of different types of embolic agents has been described, including coils, gelatin sponge, glue, and polyvinyl particles.[22] Among them, coils offer better delivery control and are therefore the preferred agent to avoid nontarget embolization. Pushable coils are well suited for this use, but for more complex lesions, detachable coils can be used to increase the safety of the procedure, despite their higher cost (Figure 6).

Technical and clinical success rates have been described as high as 90% and 79%, respectively.[23] Regarding tissue compromise, Sofocleous and colleagues calculated a gross estimated parenchymal loss in < 30% of patients based on a comparison between pre- and postembolization arteriograms.[22] In this series, no patient with an initial normal creatinine level developed renal failure after the procedure. Other adverse events described in the literature are renal artery dissection (7.5%), pyrexia (9%), pain (5%), and abscess formation (1%).[23]

CONCLUSION

Endovascular management of traumatic injuries of solid intra-abdominal organs is part of the practice of every trauma center. Familiarity with the indications and available embolic agents is crucial to improve outcomes while avoiding additional unnecessary risk and cost to the patient's care. ■

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