Vascular Trauma: Be Ready for Anything

Key devices that every interventionist should have on hand.

BY RICARDO YAMADA, MD; MARCELO GUIMARAES, MD; AND CLAUDIO SCHÖNHOLZ, MD

Trauma is the leading cause of death worldwide for those younger than 35 years of age.[1] One-third of the patients die from exsanguination.[2] Therefore, endovascular techniques to stop ongoing bleeding and prevent future blood loss should be available in any trauma center. In addition, iatrogenic trauma is an increasing problem in today's health care, and endovascular management of these lesions helps decrease associated morbidity. Given the multiple vascular injuries encountered in trauma patients, including dissections, transections, occlusions, pseudoaneurysms (PAs), and arteriovenous fistulas (AVFs), all of which can involve different vascular territories, the performing physician must be familiar with different devices, given that each lesion may need a specific approach for effective treatment.

VASCULAR ACCESS

The common femoral artery is the conventional access site in trauma patients. Arterial puncture with small-bore needles (21 gauge) under ultrasound guidance is current practice in most institutions. A combination of a micropuncture set and regular vascular sheath can then be used. Once access is gained, it is upsized to accommodate a 0.038-inch system using a 4-F transitional sheath. Alternatively, the Precision sheath (Terumo Interventional Systems) comes with a tapered needle (21 to 19 gauge) that accommodates a 0.021-inch wire. The sheath dilator unit is compatible with this 0.021-inch system, and therefore, there is no need for a transitional sheath. This eliminates one step of the procedure, saving time, which is very important in the treatment of trauma.

More recently, radial access has become more common in interventional practice. It is an important alternative when access to the groin is difficult (eg, in patients with pelvic binders). The Glidesheath Slender device (Terumo Interventional Systems) is specifically designed for radial access. Its outer diameter is reduced by 1 F, while the inner diameter equivalent is maintained; this is possible because it has a thinner wall compared to regular sheaths. It also comes with a shorter access needle and a less trauma-inducing microwire, allowing safer access to a small vessel such as the radial artery.

CATHETERS AND WIRES

Different diagnostic catheters and wires are available, and the choice relies more on personal preferences. In our practice, the "workhorse" catheters are the Mikelson, Tegtmeyer, KMP, Vert, and Cobra 2. If the radial approach is chosen, the Jacky catheter (Terumo Interventional Systems) offers a favorable angulated tip to access the descending thoracic aorta and selectively catheterize any visceral branch.

Microcatheters are mandatory devices in a trauma setting, because bleeding often comes from distal small arterial branches. There are multiple types of microcatheters with different characteristics, which affect the ease of catheter positioning within the targeted vessel and the selection of the embolic agent. The most important characteristics are inner lumen diameter, outer diameter, flexibility, and trackability. Microcatheters reinforced with integral coil or braids were shown to provide better trackability in tortuous anatomy compared to nonreinforced microcatheters.[3] Hydrophilic coating promotes easier navigation. Hence, trackability and coating tend to make catheter positioning quicker.

Catheters with a larger inner lumen diameter are required when using particulate embolic agents to avoid occlusion of the device by clumped particles. On the other hand, when using coils, a microcatheter with an inner diameter that is too large will allow the coil to be partially formed within the catheter, which can also lead to occlusion. Furthermore, size mismatch can result in superposition between the pushing wire and the coil, which can get stuck within the microcatheter and therefore cannot be deployed. Knowing microcatheter characteristics is an important step of the procedure, and not having the appropriate microcatheter can cause unnecessary delays.
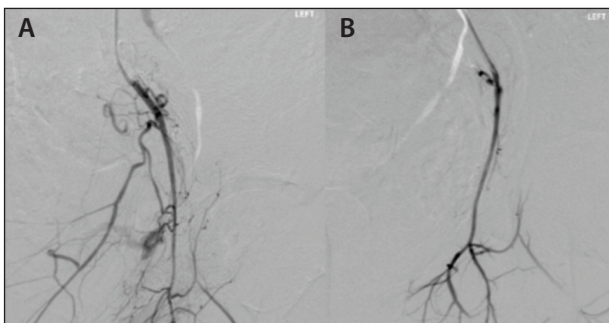
EMBOLIC AGENTS
Gelatin Sponges

Gelatin sponges are made from purified porcine or bovine skin or collagen and have inherent hemostatic properties. In the United States, gelatin sponges are commercially known as Gelfoam (Pfizer, Inc.) and were originally used for bleeding control during open surgical procedures by topical application. Later, Gelfoam was found to be a very versatile embolic agent and is now one of the most used devices for this purpose.[4]

The mechanism of action is believed to be related to the mechanical blockage of the vessel and induction of clot formation by thromboplastin release from platelets.[4,5] Because it is absorbable, Gelfoam is considered a temporary embolic agent, and vessel recanalization occurs in 4 to 6 weeks. This is a great advantage in trauma, where the goal is to achieve immediate bleeding control and not permanent occlusion of the vasculature.

Gelfoam comes in small sheets and can be prepared in three different ways: small particles, torpedoes, and slurry. Torpedoes and particles are considered medium-size embolic agents and are intended to promote proximal embolization. On the other hand, a gelatin sponge in the form of slurry is considered a distal embolic agent, as it can reach further in the vasculature and also encompass a broad vascular territory. This is useful when multiple distal small branches are actively bleeding and selective catheterization is time consuming (eg, pelvic trauma) (Figure 1).

Coils

Coils can be classified according to size, shape, stiffness, mechanism of deployment, and hemostatic properties. Appropriateness of the coil is driven by the targeted vascular territory and its flow dynamics, and these characteristics should be taken into consideration when choosing a coil for a procedure (Figure 2).

Size of the coils varies from 2 mm X 2 cm to 32 mm X 60 cm, with different shapes including straight, cylindrical, conic, diamond, and three-dimensional. The delivery system ranges from 0.01 to 0.038 inches, and as previously mentioned, correct matching is mandatory to safely deploy the device. Small coils are useful to occlude small arterial branches such as those in the pelvis, while larger coils can, for example, be used to occlude the splenic artery in the setting of splenic trauma.

Pushable coils are better suited when there is minimal risk of nontargeted embolization. They have the advantage of low cost and quick deployment, which can be performed either by pushing a wire or injecting saline. On the other hand, detachable coils are used when misplacement is a major concern. With this mechanism, the physician can recover and reposition the coil if the initial location is not satisfactory.
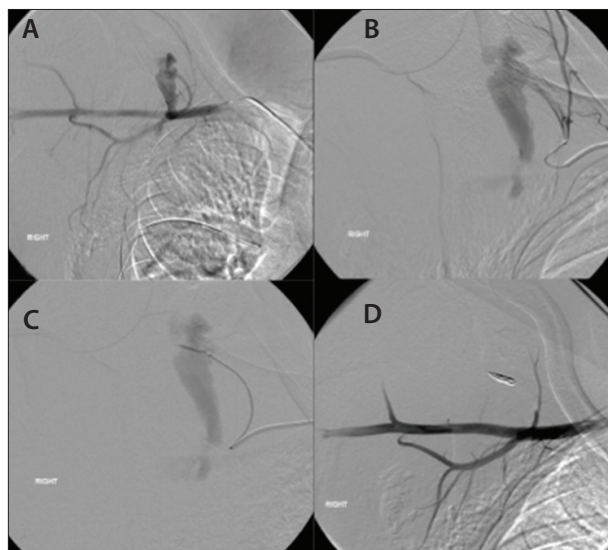
Figure 2. A patient with penetrating trauma to the right upper chest and neck, presenting with enlarging hematoma around the right shoulder. Selective angiography of the right subclavian artery demonstrated significant contrast extravasation (A). Superselective catheterization of a suprascapular branch confirms site of the vessel injury (B). After advancing the microcatheter distally, angiography is again performed to confirm the appropriate point of embolization, which should be as close as possible to the injury (C). Completion angiogram through the diagnostic catheter confirms successful occlusion of the branch without evidence of persistent bleeding. Note the pack of coils within the vessel. Pushable coils were used, as the risk of distal migration was minimal (D).

Figure 1. A patient with pelvic trauma and hemodynamic instability. Selective angiography of the left obturator artery demonstrates active contrast extravasation from a distal small branch (A). Embolization with Gelfoam slurry was performed, and occlusion of the distal branches was obtained with successful hemostasis (B).

Figure 3. A patient with recent percutaneous CT-guided liver biopsy presented a few hours later with a low hematocrit and a large hemothorax seen on CT. Selective right lower intercostal arteriogram demonstrated distal contrast extravasation (black arrow) (A). A microcatheter was introduced, but due to the increased tortuosity, distal access could not be obtained. With the catheter tip further away from the point of extravasation, a decision was made to use glue as the embolic agent (B). Completion angiogram after embolization confirms resolution of the bleeding. Note the cast of glue filling the proximal segment of the vessel (long black arrow) as well as the small branches distal to the point of extravasation (black arrowhead) (C).

Figure 4. A patient with blunt trauma to the abdomen, resulting in two PAs of the right main renal artery (black arrows) (A). A balloon-expandable stent was placed encompassing the two lesions (B). Completion angiogram after stent deployment confirmed exclusion of both lesions and satisfactory distal flow (C).

Figure 5. A patient with penetrating trauma to the left upper chest and neck presenting with PA of the left subclavian artery (black arrow) and early filling of the subclavian vein, consistent with AVF (white arrow) (A). A self-expandable covered stent was placed across the lesion. Attention should be paid to the origin of the left vertebral artery to avoid inadvertent occlusion of this important vessel (B). Completion angiogram confirmed successful exclusion of the PA and AVF. The left vertebral artery remains patent (C).
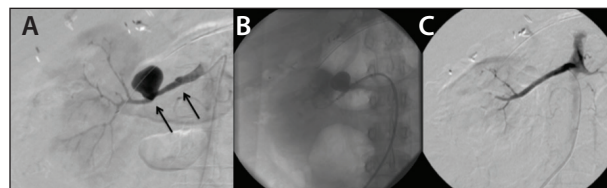
Vessel occlusion is achieved using a combination of mechanical blockage and induction of thrombosis. Fibered coils present with multiple synthetic filaments intended to capture circulating blood elements and induce thrombus formation. Examples of these coils are the VortX (Boston Scientific Corporation), Tornado (Cook Medical), and Concerto (Medtronic). Mechanical blockage can be improved with hydrogel-coated coils. Azur coils (Terumo Interventional Systems) are coated with an expandable hydrogel polymer, which undergoes maximum expansion within 20 minutes after contact with ionic solutions such as blood. Expansion leads to a progressive increase in coil diameter, resulting in a larger filling volume.[6,7]

The recently launched POD (Penumbra Inc.) is a coil-like device with a stiff tip, which allows for better anchoring of the embolic agent as it is being deployed and a soft body that facilitates packing. It is compatible with a 0.027-inch delivery system and can be used to occlude vessels up to 8 mm. Embolization of large vessels with high flow, such as the splenic artery, can be facilitated with this device.
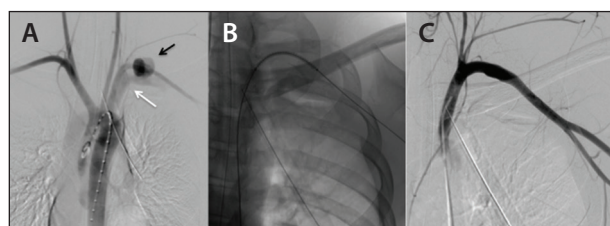
Liquid Embolic Agents
The most common liquid embolic agent used in trauma is n-butyl cyanoacrylate (Trufill, Cordis Neurovascular Inc.) commonly known as "glue." When in contact with ionic solutions such as blood, it polymerizes and solidifies, resulting in permanent vessel occlusion.[8]

The rate of polymerization is highly dependent on the dilution. Because it is not radiopaque, "glue" is mixed with ethiodized oil (Lipiodol, Guerbet LLC), and the polymerization process is faster with higher concentrations. Therefore, solidification will take place close to the catheter tip, resulting in a more proximal occlusion. If the desired level of embolization is distal to the catheter tip, the mixture should be more diluted (Figure 3).

Other important technical aspects of "glue" embolization are the rate of infusion and timing for catheter removal. Infusion should be slow to avoid reflux and nontargeted embolization. At the same time, the catheter should not remain in contact with the delivered agent for too long because it can get stuck within the vessel. Among all the embolic agents, "glue" probably has the longest learning curve, but it is a very useful option in certain cases.

STENTS AND STENT GRAFTS
In the setting of trauma, stents can be used for occlusions, dissections, transections, PAs, and AVFs. For dissections, the goal is to seal the entry point, allowing thrombosis of the false lumen and reexpansion of the true lumen. Bare-metal stents may fit well for this purpose, as the intimal flap can be tacked down by the deployed stent. Vessels susceptible to external compression should be addressed with self-expandable stents, while balloon-expandable stents can

be used in locations such as the origin of great vessels and visceral branches (Figure 4).

On the other hand, stent grafts are mostly used to treat complete transections, PAs, and AVFs.[9,10] The graft component of the device allows sealing of the vessel wall injury, inducing thrombosis of the PA or eliminating the abnormal communication with the venous structure in case of an AVF (Figure 5). Covered balloon- and self-expandable stents are available, and the choice between them again depends on the presence of external compression. Radial force, one of the most important characteristics of a stent, does not have much relevance in the setting of trauma, since the goal is not achieving patency of a chronic stenosis, but rather fixing a vessel wall injury. In our institution, the available self-expandable stent grafts are Viabahn (Gore & Associates) and Fluency (Bard Peripheral Vascular). In addition, Icast (Atrium Medical Corporation), a balloon-expandable covered stent, is available.

Thoracic Stent Grafts

Currently, with the increasing tendency of endovascular management for trauma to the thoracic aorta, it is important to be familiar with the stent grafts suitable for that location. Because of the proximity of the great vessels and angulation of the aortic arch, the device needs to allow precise deployment and conformation to the arch curvature in order to avoid unintended coverage of the great vessels, endoleak, and migration. Three devices are US Food and Drug Administration approved for trauma: the Conformable Gore TAG (Gore & Associates), Zenith Alpha (Cook Medical), and Valiant (Medtronic, Inc.). The Valiant thoracic stent graft has the Captivia delivery system, which allows for tip capture during deployment and distal repositioning if necessary. Overall, device diameters range from 21 to 46 mm. All thoracic stent grafts have a tapered configuration in which the diameter decreases distally to accommodate the usual smaller lumen of the mid-descending thoracic aorta compared to the proximal segment. This is important to avoid infolding of the stent graft, leading to acute occlusion.

VASCULAR CLOSURE DEVICES

As many trauma patients present with some level of coagulopathy due to severe acute hemorrhage, utilization of vascular closure devices (VCDs) can decrease the risk of further blood loss from access site complication. This also expedites patient care, as the patient can be transferred quicker to the unit or operation room, if needed.

VCDs can be classified according to the mechanism of action, which can involve sutures, collagen plugs, and clips. In our institution, we use Perclose (Abbott Vascular), which is a suture-based device, and Angio-Seal (St. Jude Medical,
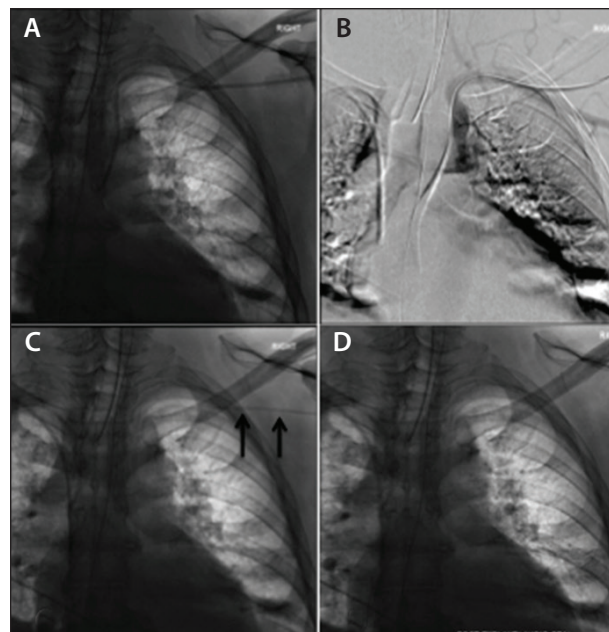
Figure 6. Scout film demonstrates the catheter in the left upper chest. Note the tip of the catheter overlying the descending thoracic aorta and not the superior vena cava (A). After replacing the line for a diagnostic catheter over a wire, angiography was performed confirming the entry site in the distal left subclavian artery (B). An Angio-Seal closure device is placed over the wire and deployed (black arrows) (C). Scout film after deployment of the closure device confirms catheter removal. The patient did not present with any signs of hemorrhage (D).

Inc.), which utilizes an intravascular bioabsorbable anchor and an extravascular collagen plug to seal the arteriotomy. Starclose (Abbott Vascular) utilizes a 4-mm nitinol clip implant to achieve hemostasis.

The previously mentioned devices are labeled to close arteriotomies up to 8 F, but some are being used to close much larger accesses (> 16 F). This is the case for Perclose, which allows total percutaneous endovascular repair of thoracic aorta injuries, where large sheaths are required.[11] Two Perclose devices are partially deployed at 90° apart before the large sheath is introduced. This technique expedites the procedure, as femoral cutdown is not required. Again, time is key in treating trauma patients; therefore, it is important to provide this option when anatomically feasible.[12]

Another use of VCDs is in the setting of inadvertent arterial line insertion when placing central venous access. Despite the increasing use of ultrasound-guided venous puncture, misplacement of a central venous line is still a common problem in any institution. Most of the time, the entry site is the subclavian or brachiocephalic arteries, which are deep major vessels that cannot be externally

compressed (Figure 6). Suture- or collagen plug–based devices can be used for this purpose.[13] An important technical consideration in using these devices is the distance between the skin and the entry point in the artery, as the working shafts for the Perclose and Angio-Seal devices are 7 and 9 cm long, respectively. Therefore, patients with a subcutaneous tract longer than previously mentioned are not candidates for this approach. This can be measured by CT.

CONCLUSION

As trauma can involve any vascular territory and results in different types of vascular injuries, angiographic findings can be unpredictable, and the physician should be prepared for everything. Therefore, familiarity with all the tools available in the endovascular armamentarium is key to effectively treat patients in this acute scenario. Gelfoam, coils, and glue are the most common devices used in trauma, along with covered stents. ■

Ricardo Yamada, MD, is with Vascular & Interventional Radiology, Medical University of South Carolina in Charleston, South Carolina. He has stated that he has no financial interests related to this article. Dr. Yamada may be reached at yamada@musc.edu.

Marcelo Guimaraes, MD, is with the Medical University of South Carolina in Charleston, South Carolina. He has disclosed that he is a consultant for Terumo Interventional Systems.

Claudio Schönholz, MD, is with the Medical University of South Carolina in Charleston, South Carolina. He has disclosed that he is a consultant for Gore & Associates.

1. World Health Organization. Health statistics and information systems: global health estimates (GHE). Available at: http://www.who.int/healthinfo/global_burden_disease/en/. Accessed December 16, 2015.
2. Evans JA, van Wessem KJ, McDougall D, et al. Epidemiology of traumatic deaths: comprehensive population-based assessment. World J Surg. 2010;34:158-163.
3. Zoarski GH, Mathis JM, Hebel JR. Performance characteristics of microcatheter systems in a standardized tortuous pathway. AJNR Am J Neuroradiol. 1998;19:1571–1576.
4. Loffroy R, Guiu B, Cercueil JP, Krausé D. Endovascular therapeutic embolisation: an overview of occluding agents and their effects on embolised tissues. Curr Vasc Pharmacol. 2009;7:250-263.
5. Jenkins HP, Senz EH, Owen H, et al. Present status of gelatin sponge for control of hemorrhage. J Am Med Assoc. 1946;132:614-619.
6. Ding YH, Dai D, Lewis DA, et al. Angiographic and histologic analysis of experimental aneurysms embolized with platinum coils, Matrix, and HydroCoil. AJNR Am J Neuroradiol. 2005;26:1757-1763.
7. Pelage JP. Angiographic and pathologic comparison of hydroCoils vs. fibered coils mechanisms of occlusion and mid-term recanalization in an animal model. Presented at the Global Embolization Symposium and Technologies (GEST) meeting; May 3–6, 2012; New York, New York.
8. Pollak JS, White RI Jr. The use of cyanoacrylate adhesives in peripheral embolization. J Vasc Interv Radiol. 2001;12:907-913.
9. Schönholz C, Krajcer Z, Carlos Parodi J, et al. Stent-graft treatment of pseudoaneurysms and arteriovenous fistulae in the carotid artery. Vascular. 2006;14:123-129.
10. Schönholz CJ, Uflacker R, De Gregorio MA, Parodi JC. Stent-graft treatment of trauma to the supra-aortic arteries. A review. J Cardiovasc Surg (Torino). 2007;48:537-549.
11. Krajcer Z, Matos J. Totally percutaneous endovascular abdominal aortic aneurysm repair: 30-days result from the Independent Access-Site Closure Study of the PEVAR trial. Presented at the 9th Current Trends in Aortic and Cardiovascular Surgery Interventions Conference; April 26–27, 2013; Houston, Texas.
12. Mousa AY, Abu-Halimah S, Nanjundappa A, et al. Current update on the status of totally percutaneous aneurysm repair. Vasc Endovascular Surg. 2013;47:409-414.
13. Guimaraes M, Uflacker R, Schonholz C, et al. Use of percutaneous closure devices in the removal of central venous catheters from inadvertent arterial catheterizations. J Cardiovasc Surg (Torino). 2008;49:345-350.