For emergency medicine and trauma professionals

WINTER 2017

TRAUMA rounds

Contents

In this issue of *Trauma Rounds,* experts from UPMC Presbyterian Trauma Center present advances in trauma care that employ minimally invasive strategies to stop trauma-related bleeding in cases of aortic transection and solid organ bleeding, as well as a feature on temporary Resuscitative Balloon Occlusion of the Aorta (REBOA). These advanced multidisciplinary techniques allow UPMC's trauma specialists to control bleeding with endovascular approaches, and with less morbidity and mortality compared to traditional open techniques.

Louis Alarcon, MD, FACS, FCCM

Medical Director of Trauma Surgery at UPMC Presbyterian

REBOA: A Novel Minimally Invasive Technique to Curtail Hemorrhage in Trauma Patients

by Matthew R. Rosengart, MD, MPH

Approximately 5-15% of trauma patients in the U.S. present in hemorrhagic shock, and a significant minority of these will exhibit hemodynamics that, in the absence of rapid correction, are not compatible with continued life beyond a few minutes.[1] Within the state of Pennsylvania and at UPMC Presbyterian, the prevalence is similar. Beyond the ABCs (airway, breathing, circulation) of resuscitation, which is the standard of practice in such circumstances — particularly in instances of an acute loss of perfusion prior to or at definitive care — is resuscitative left anterolateral thoracotomy with aortic cross-clamping. In the context of trauma, such measures have reported success in the salvage of human life of 17% (ranging from 2.7-37.5%) in cases of penetrating trauma and 4.6% (ranging from 0.6-60%) for blunt trauma. In studies evaluating abdominal trauma, survival rates of 4.5-9% have been reported.[2,3]

However, the procedure is exceedingly morbid, is notably user-dependent, necessitates a considerable allocation and consumption of resources — particularly as it relates to establishing effective aortic occlusion — and exposes health care personnel to the risks of blood-borne pathogens.[4] Needless to say, for some time the trauma community has been in want of a simpler and consistently effective method to address lower torso hemorrhage.

(Continued on Page 2)

UPMC Trauma Care System

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- UPMC Hamot, Level II
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REBOA *(Continued from Page 1)*

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a novel and minimally invasive technique to curtail hemorrhage to the subdiaphragmatic torso (i.e., abdomen and pelvis) in patients presenting in hypovolemic hemorrhagic shock. It is considered of particular utility in circumstances of hypotension and cardiovascular collapse that otherwise would merit resuscitative left anterolateral thoracotomy and aortic clamping. Similar to a non-tunneled central line, the device is placed in a modified Seldinger technique and is simple enough to be mastered by all personnel involved in the care of the critically injured patient. The apparatus is comprised of a 7-French introducer catheter and a 100 cm balloon-tipped occlusion catheter that is similar in design to a Swan-Ganz catheter (see Figure 1).

Through a sheath placed into the femoral artery, the balloon occlusion catheter is threaded and advanced to a predetermined position upstream of the estimated regional source of bleeding: 1) rostral to the iliac bifurcation for pelvic hemorrhage (see Figure 2); and 2) subdiaphragmatic for abdominopelvic bleeding.

Figure 1: Retrograde endovascular occlusion of the aorta (REBOA) catheter. Pictured here is the ER-REBOA™ Catheter, made by Prytime Medical Devices, Inc. *Image courtesy of Prytime Medical.*

An algorithmic calculation of balloon diameter with stepwise increases in the volume of instillate enables one to estimate final balloon diameter and thereby more accurately occlude the aorta. The use of radiopaque contrast and C-arm fluoroscopy confirms appropriate positioning (see Figure 3). The physiologic ramifications of successful and well-positioned occlusion should become manifest seconds after placement. A new handheld smartphone-based infrared imaging device is in development to assess the adequate level of aortic occlusion during REBOA.[5] Yes, even for the frantic resuscitation of the critically injured patient, "there's an app for that."

As with most novel technologies that offer hope for near-futile cases, the theoretical benefits of REBOA were widely embraced, and its use rapidly adopted despite a paucity of data supporting its benefit. Over time, however, data has amassed, typically from trauma registries that enable observational analyses comparing REBOA with other measures of resuscitation, including thoracotomy. In a retrospective analysis of two trauma centers, REBOA, as an

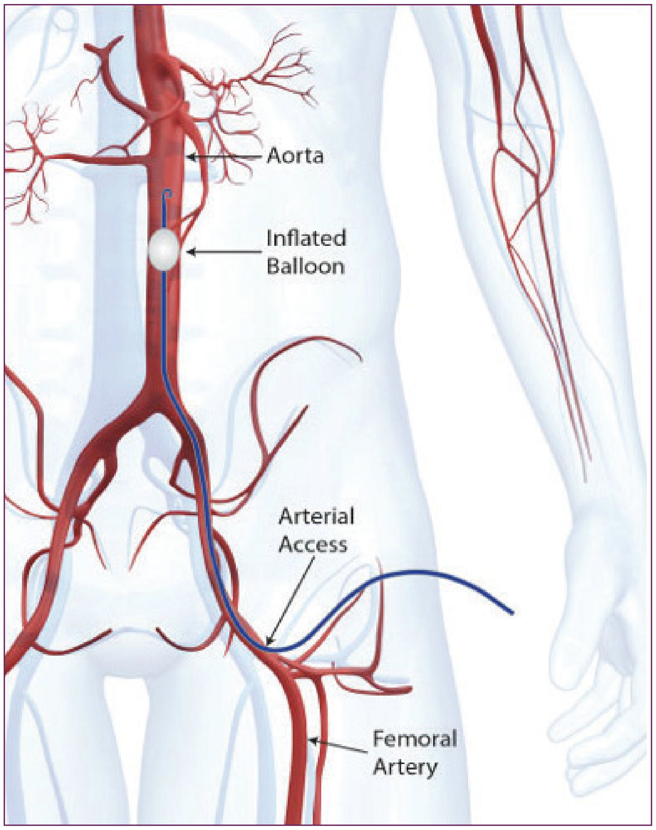

Figure 2: Advancement of REBOA catheter through a femoral arterial sheath and positioned rostral to the bifurcation of the iliac vessels. *Image courtesy of Prytime Medical.*

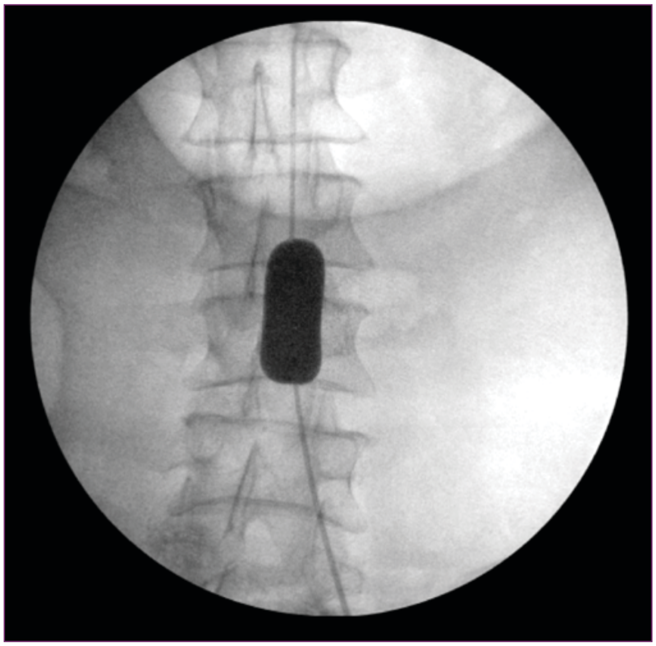

Figure 3: Fluoroscopic image of a REBOA catheter positioned rostral to the bifurcation of the iliac arteries at approximately the third lumbar level.

alternative to resuscitative thoracotomy for noncompressible truncal hemorrhage, was associated with reduced rates of death in the emergency department setting (26.7% vs. 62.5%, p<0.001) and improved overall survival (37.5% vs. 9.7%, p=0.003).[6]

However, the American Association for the Surgery of Trauma just reported initial results of their prospective Aortic Occlusion for Resuscitation in Trauma and Acute Care Surgery (AORTA) registry.[7] Over a 16-month period, 114 patients underwent aortic occlusion (AO): REBOA, 46; open AO, 68. There was no difference in time to successful AO between REBOA and open AO: 6.6 minutes vs. 7.2 minutes. REBOA proved equivalent to open techniques in improving hemodynamics (67.4% vs. 61.8%), though modestly better at achieving hemodynamic stability (47.8% vs. 27.9%, p=0.014). Though not statistically significant, survival with REBOA was greater than open AO: 28.2% vs. 16.1%, p=0.12. As health care personnel acquire increased competency in REBOA placement, and data continue to be collected, it is likely that definitive evidence supporting REBOA use as a life-saving treatment will be made manifest. At UPMC, trauma surgeons use REBOA to temporarily control hemorrhage below the diaphragm as part of the operative management of life-threatening bleeding.

***Matthew R. Rosengart, MD, MPH**, is co-director of the Surgical Trauma Intensive Care Unit at UPMC Presbyterian and serves as associate professor of Surgery and Critical Care Medicine at University of Pittsburgh School of Medicine. He earned his medical degree from the University of Alabama at Birmingham.*

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Children's Hospital of Pittsburgh of UPMC Pediatric Surgeons

Front row (left to right): Juan Calisto, MD; George K. Gittes, MD; Gary Nace, MD; Barbara A. Gaines, MD; Michael J. Morowitz, MD; Kelly M. Austin, MD; and Dominic Papandria, MD

Back row (left to right): Marcus M. Malek, MD; Stefan Scholz, MD; Geoffrey Bond, MD; Kevin P. Mollen, MD; Aviva L. Katz, MD; Ward M. Richardson, MD; Luis De La Torre, MD; and Douglas A. Potoka, MD

Minimally Invasive Stent Grafting Has Become the Standard of Care for Blunt Thoracic Aortic Injury

by Nathan L. Liang, MD, MS, and Efthymios D. Avgerinos, MD, PhD

Blunt thoracic aortic injury (BTAI) due to trauma is an uncommon condition that traditionally carries a high mortality rate. Although the incidence is less than 1% of trauma admissions,[1] an estimated 75% of patients with BTAI die prior to hospital arrival, and the mortality rate after admission may be as high as 50% within the first 24 hours. Due to the massive polytrauma sustained in these situations, many patients present with additional life-threatening injuries and can be challenging to manage even in the setting of an experienced trauma center.

In most cases, BTAI is localized to the proximal descending thoracic aorta just distal to the left subclavian artery origin. The tethering of the aorta by the ligamentum arteriosum at this location predisposes the area to injury during severe blunt trauma, such as a rapid deceleration impact during a motor vehicle collision. In the trauma bay, diagnosis and identification of the location of BTAI is most often made by computed tomography. Modern CT scanners are fast and reliable and show associated soft tissue structures in addition to identifying injuries of the vasculature.

Severity of the aortic injury is graded on a four-point scale[2] ranging from local tearing of the arterial intima (Grade I, least severe) to uncontained rupture into the chest (Grade IV, most severe). Patients presenting with grades I-III are often hemodynamically stable, whereas patients with grade IV BTAI may be in extremis and require expeditious treatment. Regardless, the Society for Vascular Surgery[2] and the Eastern Association for the Surgery of Trauma[3] both recommend repair of grade II-IV injuries within 24 hours.

TEVAR: A New Standard of Care

Conventional surgery for the repair of TBAI prior to the use of endovascular stent grafts carried high post-procedure mortality rates, ranging from 19-28%, with associated spinal cord ischemia rates of around 9%. However, since the introduction of endovascular stent grafts, thoracic endovascular aortic repair (TEVAR) has become the standard therapy for BTAI. TEVAR involves the placement of an intravascular stent covered with prosthetic material over the area of injury, excluding the injury from the circulation and preventing further hemorrhage or rupture. This minimally invasive procedure offers several major advantages over conventional surgery, such as avoiding the need for a thoracotomy or cardiopulmonary bypass, and is able to be performed rapidly and with minimal sedation or anticoagulation. Current estimates place the post-procedure mortality rate of TEVAR for BTAI at less than 9%, which is often related to other severe injuries sustained during the original trauma.

The most recent guidelines from the Society for Vascular Surgery in 2011 and the Eastern Association for the Surgery of Trauma in 2015 have both recommended the use of TEVAR over open repair for the treatment of BTAI, with the Eastern guidelines strongly recommending the use of TEVAR in the absence of contraindications.[3] Both guidelines noted the rapid increase over time in the use of TEVAR in these situations, with recent estimates suggesting that 85% of treated patients underwent endovascular stent grafting in 2011, up from 65% in 2008. A recent multicenter prospective trial evaluating the usage of thoracic endovascular grafts for BTAI also showed a low overall rate of short- and long-term stent-graft related complications, supporting the continuing preferential usage of TEVAR in most situations.[4]

Currently, all major thoracic aortic stent grafts have received FDA approval to treat thoracic aortic lesions including BTAI. However, certain anatomic factors such as injury distance from the left subclavian artery origin, the radius of the aortic arch, or the size of access vessels may complicate TEVAR, necessitating adjunctive procedures such as left subclavian revascularization or even the need for an open surgical procedure in extreme cases of unsuitable anatomy.

Treatment of BTAI at UPMC

The Vascular Surgery Division at UPMC has performed more than 100 repairs of BTAI since 1999 and has exclusively utilized TEVAR for treatment of this condition since 2007, with more than 70 thoracic aortic stent-graft implantations for BTAI alone. Analysis of our outcomes through 2012[5] have shown a postprocedural mortality rate after TEVAR for BTAI of 6%, zero spinal cord ischemia complications, and a graft-related complication rate of less than 16% (8% required late open conversion). Most of the complications were related to graft malpositioning resulting either in coverage of the left subclavian artery or collapse.

The resources available at UPMC's trauma centers and close coordination between teams of trauma surgeons, emergency physicians, and vascular surgeons allow for rapid diagnosis and successful treatment of BTAI. Twenty-four hour availability of multiple specialized hybrid vascular operating suites enables high-resolution imaging and accurate stent-graft placement, while mobile fluoroscopic imaging systems allow for flexibility in combining TEVAR with concurrent repair or exploration of other traumatic injuries in the same setting.

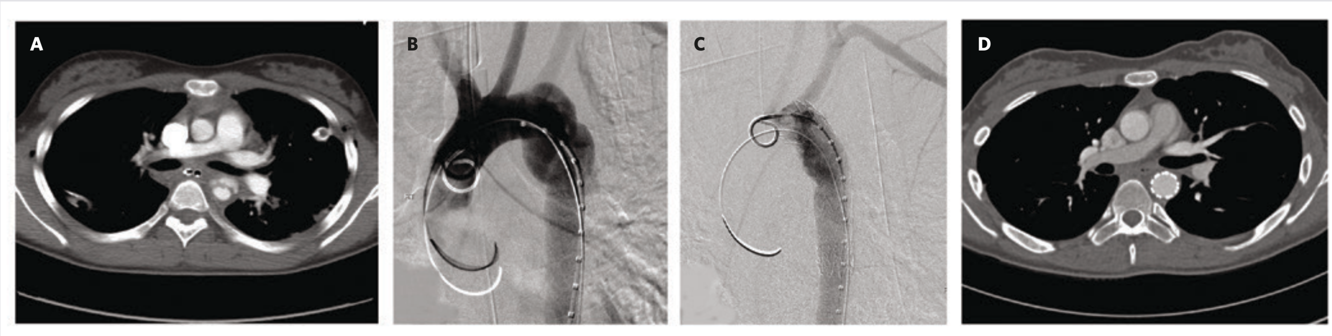


Figure 1: (A) Preoperative CT angiogram indicating the aortic transection; (B) Intraoperative angiogram; (C) Final angiogram after endograft deployment; and (D) Follow-up CT angiogram indicating good graft wall apposition and periaortic hematoma resolution.

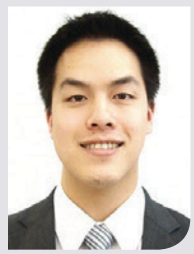
Case Presentation

A 19-year-old woman was admitted to the UPMC Presbyterian Emergency Department as a Level I trauma patient after falling from an eight-story height. Her fall was later determined to be a suicide attempt. In the trauma bay, she was hypotensive and required intubation and bilateral chest tubes. She had a pelvic fracture and a negative FAST, or focused assessment with sonography for trauma, exam. The FAST exam screens for blood around the heart or abdominal organs after a trauma. The patient was taken urgently to the operating room for an exploratory laparotomy with pericardial window. A liver laceration was repaired and her abdomen was closed with a wound vacuum-assisted closure (VAC). She underwent a full-body CT scan, revealing a thoracic aortic transection, liver laceration, mesocolonic hematoma, retroperitoneal hematoma/pelvic fracture, and right orbital floor fracture. She was immediately transferred to the endovascular suite and underwent percutaneous TEVAR (see Figure 1).

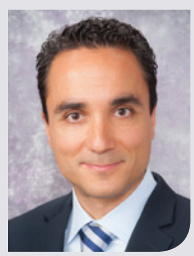
Her recovery was complicated by compartment syndrome, lactic acidosis, a urinary tract infection, and a Clostridium difficile infection, all of which were adequately controlled and treated prior to being discharged to the Children's Institute for continuation of rehabilitation and psychiatric care. The patient had fully recovered by her six-month follow-up appointment.

Conclusion

The mortality associated with BTAI has markedly decreased due to the introduction of endovascular technologies. Recent FDA approval of all major thoracic stent-grafts for the treatment of BTAI has cemented TEVAR as the current standard of treatment for anatomically appropriate candidates due to its rapidity and improved complication profile.



***Nathan L. Liang, MD, MS**, is a resident physician in the Division of Vascular Surgery, Department of Surgery at UPMC. He earned his medical degree from Texas A&M University.*



***Efthymios Avgerinos, MD**, is a vascular surgeon at UPMC. He completed his vascular surgery residency at the University of Athens in Greece and had clinical fellowships in London, UK, and Frankfurt, Germany before joining UPMC in 2011.*

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Percutaneous Endovascular Management of Acute Abdominal Visceral and Pelvic Bleeding in the Trauma Patient

by Joshua Pinter, MD, and Nikhil B. Amesur, MD

Internal bleeding is a significant cause of morbidity and mortality in trauma patients. Historically, urgent invasive surgery was often required to manage these patients, but recent advances in minimally invasive techniques have revolutionized trauma care. Percutaneous, catheter-directed techniques now play a critical role in the management of the acute trauma patient. Minimally invasive endovascular interventional techniques can help stabilize a patient in the acute setting, often eliminating the need for surgical interventions while the patient undergoes life-saving resuscitation.

Arterial Access

Percutaneous ultrasound-guided arterial access from a femoral or trans-radial approach allows the interventionalist quick access to the entire vascular system and provides the ability to deliver the appropriate treatment option to the bleeding site while minimizing collateral damage to tissue.

Embolic Agents

A wide variety of embolic agents are available. An ideal embolic agent is one that can be delivered quickly and easily through tortuous arterial anatomy and can reliably lead to hemostasis despite variations in vessel size, type of injury, and patient coagulation status. They can be divided into particulate, mechanical, and liquid agents. Embolic agents commonly used in the trauma setting include gelfoam, particulates, coils, plugs, and n-butylcyanoacrylate (NBCA) glue.

Absorbable gelatin sponge, or gelfoam, is a temporary agent that is supplied in sheets and can be cut into small pledgets or made into a slurry. Vessels embolized with gelfoam typically recanalize within days to weeks, making gelfoam an excellent choice to achieve hemostasis in small vessels.

Permanent particulate agents include spherical and irregularly shaped micro-particles available in various sizes from 40µm to 1200µm. These particles are delivered through a catheter and carried with the blood flow until they lodge in the vascular tree. Smaller particles carry a higher risk of tissue infarction, as they extend further out into the arterial territory and may occlude end arteries.

Mechanical occlusion devices include coils and plugs. Coils are flexible metal devices that work by causing mechanical obstruction within the artery. They are often wrapped with Dacron™ to promote thrombosis. When coils are used, they often need to be placed both distal and proximal to the bleeding site to prevent back flow to the injured vessel from collaterals.

NBCA glue polymerizes rapidly in the presence of ionic solutions. Glue is typically diluted in Lipiodol, also known as Ethiodol, to delay polymerization and allow visualization under fluoroscopy. Advantages of glue include: flow-directed delivery, excellent visibility under fluoroscopy, rapid deployability, and lack of reliance on the patient's intact coagulation cascade. Among its disadvantages, glue has a relatively steep learning curve and the potential for non-target embolization.

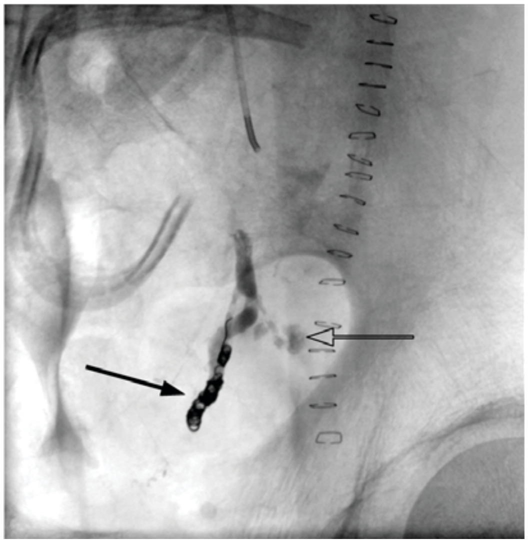


Figure 1: Glue embolization of a large extravasation from a branch of the anterior division internal iliac artery after pelvic fracture. Coils were placed (closed arrow) and a rapid polymerization time was chosen to prevent flow of glue distally within the obturator and pudendal arteries. Extravasation of the glue cast confirms closure of the arterial defect (open arrow).

Spleen Treatment

The spleen is the most commonly injured intra-abdominal organ, with splenectomy traditionally the mainstay of treatment. However, asplenia can lead to impaired immunity which in the long-term can cause post-splenectomy infection. Splenectomy performed during laparotomy for trauma is also associated with a 50% increase in the rate of post-operative infections.[1] Non-operative management for stable patients is widely accepted, especially in younger patients. Reported rates of splenic salvage in stable patients after embolization range from 70-97%.

Risk factors for failure of non-operative management include age over 55 years, grade IV or V injury, presence of portal hypertension, and CT findings of pseudoaneurysm, vascular lake/blush, and extravasation.

Splenic artery embolization is performed for hemodynamically stable patients with grade IV or V injury and in patients with lower grade injuries with CT findings mentioned above. For lower grade injuries without concerning findings on the initial CT scan, close interval follow-up is performed with embolization considered based on CT findings.

The pattern of splenic injury seen angiographically can vary from focal bleeding and pseudoaneurysm formation to diffuse injury and intraparenchymal pseudoaneurysms with regions of devascularized tissue. In cases of diffuse splenic injury with multiple areas of bleeding or the "starry-sky pattern," a proximal embolization technique is employed to decrease the arterial pressure head in the splenic artery to allow the organ time to heal. In cases of focal splenic bleed or pseudoaneurysm formation, superselective embolization may be performed to treat the pseudoaneurysm.

Complications that may occur with splenic artery embolization include fever, left pleural effusion, recurrent hemorrhage, splenic infarction, and splenic abscess formation. Splenic infarction accounts for up to 10% of these complications, but is rarely of clinical consequence unless it leads to abscess or severe uncontrolled pain.

Kidney Treatment

Renal arterial injuries are primarily managed using endovascular techniques. Surgery is reserved for those who are too hemodynamically unstable to transfer to the angiographic suite or for cases that cannot be treated by endovascular means due to technical factors.[2]

Renal arterial injuries are ideally embolized as selectively as possible to preserve nephrons. The renal artery and its branches are functionally end arteries without significant collateral supply, and therefore super-selective embolization with micro-coils is the technique of choice for most injuries. For dissection of the main renal artery or proximal branches, a stent may be placed to avoid sacrificing a large territory with coils.

Complications related to renal artery embolization include renal infarction, abscess formation, postembolization syndrome, and transient postembolization hypertension. Significant infarcts or abscesses are rare with superselective treatment.

Liver Treatment

Standard management for liver injury in unstable patients involves hepatic packing with arterial embolization, often a useful adjunct after laparotomy. Hepatic vein and portal venous injuries are associated with a high mortality and usually necessitate surgical repair even in hemodynamically stable patients.

Lower grade injuries are typically managed non-operatively with angio-embolization indicated for ongoing arterial bleeding or pseudoaneurysm. Hepatic arteries form an extensive network of intrahepatic venous collaterals, which are not apparent angio-graphically. If a catheter can be advanced across the site of arterial injury, coils may be employed. Otherwise, a liquid or particulate agent is preferred to both occlude the injured vessel and prevent continued extravasation via flow from intrahepatic collaterals.

High-grade liver injuries by nature involve extensive biliary and vascular disruption. This may be exacerbated by embolization. Additionally, portal venous flow is quickly compromised in shock patients due to alterations in splanchnic blood flow. Therefore, hepatic infarction is common after arterial embolization, occurring in up to 40% of patients. Subsequent abscess or bile leakage often requires percutaneous drainage or even surgical intervention.[3]

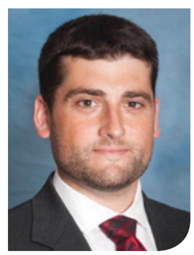
Pelvis Treatment

Pelvic fractures carry a high mortality burden of up to 25%. Surgical control of hemorrhage in the pelvis is difficult to achieve and can lead to a loss of tamponade effect. The bleeding source may be arterial, venous, or osseous. Evidence of persistent bleeding after temporary pelvic stabilization with a binder suggests the presence of an arterial injury. Indications for urgent angiography include hemodynamically unstable patients in which intraperitoneal sources of hemorrhage have been conclusively excluded or with pelvic hematoma seen during laparotomy, and stable patients with extravasation identified on CT scan with no other injury that would require immediate surgery.[4]

If no bleeding is identified in patients with a pelvic binder in place, the arteriogram should be repeated after loosening the binder to look for an occult bleeding source.[5] Embolization is generally very well tolerated due to the rich network of arterial collaterals present in the pelvis. Complications may include tissue ischemia, abscess, and regional paresthesia. If gluteal vessels are embolized, buttock and thigh claudication are possible complications.

Conclusion

The management of the bleeding trauma patient is evolving. Minimally invasive percutaneous catheter-directed treatment options play an important role in the trauma armamentarium and can be employed quickly in a variety of settings. Early utilization of these techniques is an important aspect of modern trauma care. At UPMC, an expert multi-disciplinary team of trauma surgeons and other subspecialists provides trauma patients with the most advanced hemorrhage control techniques.



***Joshua Pinter, MD**, is a physician in the Department of Radiology at UPMC and serves as an assistant professor of Radiology at University of Pittsburgh School of Medicine. He earned his medical degree from State University of New York Upstate Medical University.*

***Nikhil B. Amesur, MD**, is the associate chief of Vascular and Interventional Radiology at UPMC Presbyterian. He serves as a professor of Radiology at University of Pittsburgh School of Medicine and is program director of the UPMC Interventional Radiology Residency and Fellowship Programs as well as associate program director for the Diagnostic Radiology Residency Program. Dr. Amesur earned his medical degree from Tufts University School of Medicine.*

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