A Team Approach to Endovascular Management of Hemorrhagic Shock

Keys to developing a coordinated and seamless approach to managing intraperitoneal hemorrhage and shock from prehospital care through endovascular treatment.

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No other scenario requires a greater degree of urgent multispecialty care than managing bleeding and shock, whether from an injury or as the end result of vascular disease. Without intervention, bleeding results in hypovolemia, loss of oxygen-carrying capacity, and a terminal cardiac dysrhythmia. Often referred to as *exsanguination shock,* death from bleeding is especially frustrating for providers when it occurs in a patient without other life-threatening conditions or injuries. In these cases, if bleeding cannot be stopped and resuscitation cannot be initiated, a patient who otherwise may have survived and recovered expires from blood loss (ie, a potentially preventable death).

Traditionally, a patient's hemorrhage-related death outside of a fixed and well-equipped operating room was considered nonpreventable (ie, nothing could have been done to save the patient). This passive and resigned approach was challenged by the United States military, and epidemiologic data from the recent wars showed that up to 25% of deaths on the battlefield occurred from hemorrhage alone (ie, no other life-threatening injury).[1] These findings, combined with an urgency to save lives, led the military to recognize this category of mortality referred to as "potentially preventable death." Research and development and care system efforts were focused on mitigating potentially preventable death from bleeding.[2] The results of these efforts include the multidisciplinary approach to the bleeding patient and recently, as it pertains to torso hemorrhage, the selective use of endovascular techniques such as resuscitative endovascular balloon occlusion of the aorta (REBOA) and embolization.[3-5]

This article focuses on the team approach to using endovascular methods to manage intraperitoneal hemorrhage and shock. Many of the most important aspects of the team or systems approach to managing patients in hemorrhagic shock are the same regardless of the anatomic source or cause of bleeding.

THE MULTIDISCIPLINARY TEAM

Prehospital Providers and System

For bleeding patients to have a chance at survival, they need to be met and transported by expert prehospital providers. This part of the multidisciplinary team must be adept at applying measures to control bleeding, securing the airway, establishing vascular access, initiating volume replacement, as well as patient transport. For extremity or pelvic fracture bleeding, manual options include direct compression (with or without a topical hemostatic agent) and application of a tourniquet or a special pelvic binder. Measures to control torso hemor-

rhage in the prehospital setting are limited, although the use of REBOA by specialized emergency medical services teams in the United Kingdom has been reported.[6] In addition to bleeding control measures, prehospital teams are expert at gaining vascular access and administering fluids (eg, crystalloids and, in some cases, blood or blood products) in limited amounts so as not to cause or worsen bleeding (ie, principles of hypotensive resuscitation). At the same time, transport of the patient using the most available and capable mode (eg, ground vs rotary wing) to the best treatment facility is necessary.

Facility-Based Providers and System

Once the patient arrives at the hospital, he or she is met by a multidisciplinary team of technicians, nurses, and physicians, all of whom have been versed in the necessary steps of managing hemorrhagic shock. In addition to initiating a standardized transfusion protocol with available blood products (packed red blood cells, plasma, and platelets), this team works to confirm and extend any life-saving interventions performed in the prehospital setting (ie, control of extremity bleeding, establishing vascular access, and securing the airway). At the same time, this team combines a secondary survey (physical examination) with the use of quick imaging tools to assess the anatomic source of torso bleeding (ie, x-rays of the chest, abdomen, or pelvis).

Depending on the patient's injuries, he or she may next be treated in an interventional radiology suite or a traditional operating room. In some institutions, features of these rooms have been combined into a hybrid endovascular operating room. Regardless of the physical site of care, it is important that resuscitation continue unabated. Having a team mentality of continuous resuscitation—one that includes providing anesthetic and intensive care support while moving the patient between different care settings—is required to avoid unnecessary morbidity and mortality. Uninterrupted resuscitation is typically spearheaded by nursing and anesthesia providers, but it is critical for all providers (ie, emergency medicine, surgery, and radiology) to communicate to ensure that resuscitation continues en route to and during the subsequent invasive procedure(s) (eg, laparotomy, placement of stent graft, or embolization of bleeding). These measures include but are not limited to ensuring that blood product administration continues through functioning intravenous lines, vital signs are monitored accurately, and adequate ventilation and oxygenation are being achieved. Although the lineup will vary among institutions, a coordinated approach within an accountable learning health system is required to provide bleeding patients the optimal chance for survival and recovery.

THE PROCEDURES

Prompt, Proactive, Proper Femoral Artery Access

The most important step to using endovascular devices to manage hemorrhage is to establish access to one or both femoral arteries. In certain scenarios, this is accomplished during the earliest phase of care in the resuscitation or emergency department. Regardless of whether access is achieved by a medical technician, nurse, or physician, this should be performed using a preplanned and protocol-driven approach. Emphasizing common steps and equipment improves the safety and efficacy of the procedure regardless of the qualifications and experience of the team member performing it.

Preplanned and standardized procedures for femoral artery access include having access kits at the ready that include a hollow-tip needle, wire, and a catheter that can accommodate a 0.035-inch guidewire for "upsizing" to a larger sheath as needed. It is also necessary to have a team member prepare a pressurized bag of crystalloid solution and pressure tubing that will connect the catheter to the arterial pressure monitor. Common protocols often require handheld ultrasound guidance to provide options for when the access attempt goes awry. In our institutions, femoral artery access is established using handheld B-mode ultrasound and a micropuncture kit, which includes a 21-gauge hollow-tip needle, a 0.018-inch guidewire, and a catheter with a 4- or 5-F outer diameter.

Once in place, the catheter is either connected to the pressure tubing and monitor or upsized to a larger sheath right away using a 0.035-inch guidewire. Establishing prompt, proactive, protocol-driven femoral artery access provides the multidisciplinary care team with the greatest number of options to manage the bleeding and shocked patient, from monitoring blood pressure to rapidly upsizing to a larger sheath for REBOA or other catheter-based interventions.

REBOA for Intraperitoneal Bleeding

Positioning and inflating a compliant balloon catheter in the aorta to support central or proximal perfusion in the hemorrhaging patient is an effective resuscitation adjunct in some clinical scenarios of bleeding and shock.[7,8] REBOA is not a definitive hemorrhagic control maneuver but instead works as a bridge while transfusions are initiated and the source of bleeding can be identified and stopped. In this context, REBOA is used for a brief period of time, either pre- or intraoperatively, until open or endovascular hemorrhage control can be accomplished.

Depending on the source of bleeding, a REBOA catheter can be positioned either in the descending thoracic

aorta (zone 1) or the infrarenal aorta (zone 3).[5] Zone 1 deployment is necessary for intraperitoneal sources of bleeding such as high-grade solid organ injury (ie, liver, kidney, spleen) or bleeding from a named visceral vessel. Zone 3 deployment is reserved for bleeding and shock associated with a high-grade pelvic fracture or from the junctional femoral area. Although the exact source of bleeding is often unknown, using the physical exam and a few basic imaging modalities can provide enough information to inform the provider whether to position the balloon in zone 1 or 3.

In our institutions, the physical examination is used to identify chest, abdomen, and/or pelvic injuries and is simultaneously informed with x-rays of the chest and pelvis. The Focused Assessment with Sonography in Trauma (FAST) exam is also quickly performed to assess for the presence of blood in the peritoneal cavity. Results from these assessment tools are quickly combined with results of hemodynamic testing to determine whether REBOA will be an appropriate resuscitative adjunct. In most cases, REBOA is used in patients who are in persistent shock or are transient responders to volume resuscitation and have a negative result on chest x-ray (ie, no large effusion), no pericardial fluid on the FAST exam, and have either hemoperitoneum and/or a severe pelvic fracture. Zone 1 positioning and inflation is used for patients with intraperitoneal hemorrhage, and zone 3 REBOA is used for scenarios of severe pelvic fracture (*see the article by Drs. Rajani and Benarroch-Gampel in this issue for further reading*).

As previously stated, expeditious use of REBOA is predicated on appropriate femoral artery access that can be transitioned to a larger sheath to accommodate the balloon catheter. Although any over-the-wire, compliant, large vessel balloon catheter can accomplish this maneuver, newer REBOA-specific catheters have been developed with features that make their use more amenable in the emergency setting. As an example, the Prytime ER-REBOA catheter (Prytime Medical Devices, Inc.) does not require over-the-wire positioning and thus is smaller (6 F) and eliminates the need for a long 0.035-inch wire during an emergency situation. The ER-REBOA catheter also has external markers to measure and track depth of insertion and includes an open lumen to transduce pressure, allowing for proactive placement as an arterial monitor with balloon occlusion capability in particularly precarious scenarios.

As with other phases of care for the bleeding patient, use of REBOA as a resuscitative adjunct requires a multidisciplinary team approach. In our institutions, steps are taken to proactively educate the emergency care team (technicians, nurses, and physicians) on the intricacies of REBOA, from proper femoral artery access to the content and location of the REBOA kit to attendant measures to be taken once a REBOA catheter is in place. Proactive training improves efficiency of the team in the often-chaotic scenarios in which REBOA is chosen as a resuscitative maneuver. Finally, in our institutions, REBOA is used as part of a practice guideline written and agreed upon by the different specialties that are involved in its use.

Other Endovascular Techniques to Manage Intraperitoneal Hemorrhage

A full account of endovascular techniques used to manage intraperitoneal hemorrhage and shock is beyond the scope of this article. However, like REBOA, catheter-based management of intraperitoneal hemorrhage is best performed by a team (eg, technicians, nurses, physicians) and guided by protocols that standardize the rapid evaluation, movement, and treatment of these injury patterns, whether treatment takes place in an interventional radiology suite, an operating room, or a new hybrid endovascular operating room. The most common cause of hemoperitoneum following trauma is a high-grade injury to the liver, kidney, or spleen (ie, solid organ injury). As such, a system seeking to include endovascular techniques in its armamentarium should be equipped with protocols that outline the transition from diagnostic, vascular access, and resuscitation (ie, REBOA) maneuvers performed in the emergency department to performance of diagnostic and therapeutic visceral or pelvic arteriography.

Transitioning the patient through the phases and locations of care should include continuous monitoring and resuscitation, regardless of where arteriography is performed. If solid organ bleeding is amenable to endovascular treatment, it most commonly requires selective or semiselective embolization using one or more modalities, such as coils, plugs, or thrombotic material. As such, having the inventory and practiced operating or interventional room staff who understand these devices is critical to their rapid and effective use. Lastly, because these patients are unstable and prone to cardiovascular collapse, use of endovascular devices to control intraperitoneal bleeding should include preestablished bailout options such as REBOA and or laparotomy if the catheter-based approach is unsuccessful.

CONCLUSION

The role of endovascular techniques to manage intraperitoneal hemorrhage and shock has expanded.[9-13] Multidisciplinary teams should develop a coordinated and seamless approach (prehospital through emergency

department to operating room) that includes life-saving interventions, resuscitative fluids, versatile femoral artery access (with or without REBOA), and diagnostic assessment to determine the anatomic source of bleeding. With a focus on uninterrupted monitoring and resuscitation, patients can be transported to an appropriately equipped operating room, interventional suite, or hybrid location for attempts at catheter-based bleeding control. Training and use of predetermined protocols and guidelines, including bailout options if the catheter-based approach fails, helps to improve team function and increase effectiveness in saving lives using endovascular techniques. ■

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