ULTRASOUND-GUIDED RESUSCITATIVE ENDOVASCULAR BALLOON OCCLUSION OF THE AORTA IN THE RESUSCITATION AREA

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Abstract—Background: In trauma resuscitation with resuscitative endovascular balloon occlusion of the aorta (REBOA), urgent and accurate placement of the catheter in the resuscitation area without fluoroscopy can shorten the time from admission to REBOA, allowing rapid, temporary control of bleeding. Discussion: The experience-based protocol in our center for ultrasound-guided REBOA in the resuscitation area without fluoroscopy is as follows: the femoral artery is punctured and a guidewire inserted; sonography is used to verify that the guidewire is in the abdominal aorta; the position of the balloon is confirmed with ultrasound after estimating the distance to the clavicle, and the pressure in the radial artery and sheath is used to monitor correct positioning; connect the pressure transducer to the catheter sheath for continuous monitoring of the blood pressure in the sheath, and inflate the balloon until the blood pressure tracing at the sheath has disappeared; check the pulse in the left radial artery, and withdraw the catheter slightly if the pulse in the radial artery is not palpable or is decreased (if this pulse is not palpable or decreased, the balloon is in the aortic arch). In this retrospective review of our REBOA protocol, between April 2012 and March 2016, 34 patients were enrolled. Two patients had complications, including dissection of the femoral artery in one and difficult percutaneous vascular access in another. Median time needed to complete the procedure was 8 min. Overall, 24 of 34 patients survived more than 24 h (72%), and overall mortality was 47%. Patients who lived more than 24 h, and then died had severe traumatic brain injury or septic shock. Conclusions: Ultrasound-guided REBOA is presented. Monitoring the blood pressure in the left radial artery allows us to determine adequate positioning of the balloon, and the blood pressure in the catheter sheath located in the femoral artery should also be monitored to prevent aortic injuries caused by the overinflation of the balloon. © 2017 Elsevier Inc. All rights reserved.

Keywords—trauma; hemorrhage; resuscitative endovascular balloon occlusion of the aorta

INTRODUCTION

Resuscitative endovascular balloon occlusion of the aorta (REBOA) can temporarily control massive subdiaphragmatic hemorrhage. In recent years, REBOA has been used in the management of patients with hemorrhage from a number of sources (1–3). There are reports using REBOA in the management of patients with ruptured abdominal aortic aneurysms, abdominal and pelvic trauma, gastrointestinal hemorrhage, postoperative hemoperitoneum, and postpartum hemorrhage (4–8).

As yet, there is no single best procedure to achieve fast and adequate positioning of the balloon catheter. In REBOA, accurate positioning is important to maximize the potential for hemorrhage control and improved survival, and limit the development of REBOA-associated complications. To achieve these goals, REBOA is generally
performed under fluoroscopy guidance (9). However, this often necessitates moving the patient from the resuscitation area to the radiology department. This transfer prolongs the interval from arrival to the completion of REBOA, and can lead to a variety of other problems. “Time is gold” for critically ill patients with massive hemorrhage, and a simple procedure to perform rapid and accurate REBOA in the resuscitation area without fluoroscopy is needed (10). The aim of this report is to present our protocol for REBOA in the resuscitation area without fluoroscopy. The catheter is inserted under ultrasound guidance. Correct balloon positioning is ascertained by blood pressure monitoring in the left radial artery, and adequate occlusion ascertained by monitoring the blood pressure measured from the catheter sheath.

DISCUSSION

Procedure

Device. The Block Balloon® (Senko Medical Instrument Mfg. Co., Ltd, Tokyo, Japan) is an intra-aortic balloon occlusion catheter, used in our center (Figure 1A). The catheter is 9Fr and is inserted through a 10Fr sheath. Because the balloon is folded and rolled before inflation, the sheath is larger than the catheter, which facilitates catheter insertion. A hard wire stylet accompanies the Block Balloon, which is inserted through the central lumen of the catheter (Figure 1B). When the balloon is inflated, the balloon moves along with blood flow, resulting in a shifted position. The insertion of the hard wire stylet through the central lumen of the catheter prevents this shifting of the balloon position caused by blood flow.

Catheter Insertion Technique

The aortic balloon occlusion catheter is inserted through the femoral artery using the Seldinger technique using the following protocol, which incorporates ultrasound guidance rather than fluoroscopy (Figure 2):

1. The femoral artery is punctured and a guidewire inserted.
2. Sonography is used to verify that the guidewire is in the abdominal aorta (Figure 3).
3. The sheath is inserted over the guidewire.
4. The length of catheter needed is roughly estimated by measuring the distance from the femoral artery puncture site to the left clavicle.
5. The aortic balloon occlusion catheter is inserted over the guidewire to the estimated length.
6. Verify catheter position in the abdominal aorta and assure that the catheter tip is above the diaphragm by ultrasound imaging (Figure 4) (the target position of the balloon is zone 1 of the descending aorta; Figure 5) (11).
7. Connect the pressure transducer to the side port of the sheath for continuous monitoring of the blood pressure in the sheath, positioned in the femoral artery.
8. Insert the hard wire stylet into the central lumen of the catheter and inflate the balloon by injecting normal saline gradually until the blood pressure tracing at the side port of the sheath has disappeared (Figure 6).
9. Check the pulse in the left radial artery and withdraw the catheter slightly if the pulse in the radial artery is not palpable or is decreased (Figure 6) (if the pulse in the left radial artery is not palpable or decreased, the balloon is in the aortic arch).
10. Verify the position of the balloon in the descending aorta (zone 1) using transesophageal echocardiography, if needed (Figure 7) (consultation with an intensivist or anesthesiologist may be necessary, but the balloon in zone 1 is easily seen using transesophageal echocardiography).
11. If the catheter needs to be moved after initial positioning, deflate the balloon, reposition, inflate the balloon again, and check the pressure in the left radial artery.

Figure 1. Intra-aortic balloon occlusion catheter. (A) Block Balloon®. (B) The rigid stylet is placed through the central lumen.
In the resuscitation of patients suffering massive post-traumatic hemorrhage when REBOA is indicated, urgent and accurate placement of the balloon catheter is necessary to maximize the chance of survival. However, REBOA is generally performed under fluoroscopic guidance necessitating transfer from the resuscitation area to the radiology department (9). Placement of the balloon catheter in the resuscitation area without fluoroscopy may shorten the time from admission to REBOA, allowing rapid, temporary control of bleeding from sub-diaphragmatic injuries. In recent years, the ability to accurately introduce, position, and inflate REBOA devices without fluoroscopy has represented a paradigm shift, allowing this procedure to be performed in urgent settings (10). The rapid, temporary control of bleeding with REBOA in the resuscitation area may lead to improved outcomes.

Figure 2. Step-by-step procedure for resuscitative endovascular balloon occlusion of the aorta.

Figure 3. An axial view of the abdominal aorta using ultrasound imaging. The guidewire is shown in the abdominal aorta (arrow). IVC = inferior vena cava.
Technical Skills in Abdominal Ultrasound Imaging

Position the probe at the mid-upper abdomen and scan axial images of zone 2 of the abdominal aorta, which is usually located in front of the lumbar vertebra. Press the probe toward to the abdominal wall if a clear image is not scanned because of gas in the stomach or transverse colon. When the probe is pressed, the gas under the probe becomes free and a clear image can be scanned. If the wire is in zone 2 of the abdominal aorta, the wire is also scanned with artifact (Figure 3). After scanning the axial image of abdominal aorta, turn the probe 90 degrees in a clockwise direction, and a sagittal image is scanned. In this sagittal image, the wire is estimated to have been inserted in the descending aorta through zones 2 and 3 of the abdominal aorta, is identified (Figure 4).

Experience

In our center, REBOA has been performed in 34 patients with severe abdominal or pelvic trauma between April 2012 and March 2016. Their background is summarized in Table 1. Median age was 67.5 years and all patients suffered blunt trauma. Median interval to complete REBOA was 8 min. Median Injury Severity Score was high and median probability of survival calculated by the Trauma and Injury Severity Score methods was low (31%). The 24-h mortality was 29% and overall mortality was 47%, but 75% (3 of 4) of patients alive more than 24 h but ultimately died had suffered severe traumatic brain injury, and 25% (1 of 4) died due to septic shock related to an open pelvic fracture and pelvic osteomyelitis. Two patients (6%) developed complications related to REBOA. One had a femoral artery dissection and in the other, percutaneous access to the artery could not be gained (a cut-down procedure was performed and REBOA was completed).

According to a recent review, the overall mortality of trauma patients undergoing REBOA was 75.0% (416 of 555) (this mortality was analyzed using only available data) (12). However, the overall mortality in our center is 47% (16 of 18), which is significantly less ($p < 0.001$). These data suggest that ultrasound-guided REBOA in the resuscitation area can reduce overall mortality.

Avoid Complications

REBOA has been associated with complications, including malposition, vascular injuries, organ ischemia,
and others. To avoid these complications, a reliable and safe REBOA technique is necessary.

**Position the balloon above zone 2 guided by ultrasound.** For adequate positioning of the balloon in the descending aorta (zone 1), identification of the guidewire or balloon catheter in the abdominal aorta is important. In this ultrasound-guided REBOA procedure, providers should identify it in the abdominal aorta (zone 2) by axial and sagittal ultrasonography scan. If it cannot be identified, the guidewire may be malpositioned. If they can, the balloon will be positioned above zone 2 through the guidewire in the abdominal aorta. The balloon catheter can be positioned above zone 2 using abdominal ultrasound imaging alone.

**Avoid occlusion of aortic arch.** For positioning the occlusion balloon in zone 1 (not in the aortic arch), the location of the tip of the catheter is important because occlusion of the aortic arch causes ischemia of the upper limbs or brain. Verification of the position of the balloon above the diaphragm is made by ultrasound imaging. However, the tip of the balloon catheter in zone 1 may not be visualized with abdominal ultrasound imaging. Using abdominal ultrasound guidance alone, occlusion of the aortic arch can occur. To avoid this complication, monitoring the blood pressure in the left radial artery is a part of the protocol for REBOA. When the balloon is successfully located in zone 1 with occlusion of the aorta, the pulse in the left radial artery is easily palpable and the blood pressure may be increased after inflation of the balloon. If the pulse in the left radial artery is not palpable or the blood pressure is decreased at the time of the balloon inflation, the balloon may be in the aortic arch with no blood flow to the arch branches. Thus, the position of the occluding balloon can be detected and successful positioning of the balloon in the zone 1 is assured by monitoring the blood pressure in the left radial artery.

The loss of a pulse oximetry trace in the lower extremity or the loss of a left brachial pulse is easy, common, and widely used, according to the review report (12). Use of the left radial artery monitoring for gauging malposition of the balloon, which is presented in this report has a small novelty. The left carotid artery or brachial artery is a second choice for monitoring, if the left radial artery is not available (e.g., amputated limbs). There is no answer about which monitoring is the best way for this purpose.
Avoid overinflation. Overinflation of the balloon can lead to an iatrogenic aortic injury, and may occur if the operator continues to inflate the balloon without noticing complete occlusion of the aorta. For safe and adequate balloon inflation, an objective indicator reflecting occlusion of the aorta is necessary. However, as yet, there is no single established indicator. Aortic occlusion by the balloon catheter is usually identified by the loss of femoral artery pulsation, elevation of the blood pressure in the radial artery, increased resistance in inflating the balloon, or the fluoroscopic guidance using a two-dimensional image. Despite careful conduct of the procedure, because of the absence of such an indicator, aortic rupture caused by overinflation of the balloon can occur.

Blood pressure measured at the side port of the catheter sheath (sheath pressure) may be an indicator of aortic occlusion. In the REBOA procedure presented here, the sheath pressure was continuously monitored during inflation and deflation of the balloon. As the balloon is inflated gradually, the blood flow in the iliac artery decreases and the sheath pressure also decreases. When the balloon is fully inflated and the aorta is completely occluded, the sheath pressure reaches a nadir and the waveform is almost flat (Figure 5). Thus, blood flow distal to the occluding balloon is monitored by measuring the blood pressure at the side port of the catheter sheath, and complete occlusion of the aorta is recognized with flattening of the waveform, which can be determined without additional invasive procedures or devices.

Consideration of other techniques to avoid complications. In this historical review of REBOA, 1 patient with difficult percutaneous vascular access was encountered. Real-time ultrasound-guided puncture of the femoral artery can help overcome this difficulty. This procedure is commonly used to insert a central venous catheter in the intensive care unit and we consider that this technique can be applied to access to femoral artery.

REBOA provider. The ultrasound-guided REBOA procedure described here is usually performed by well-trained emergency physicians in the resuscitation area. Previously reported cases of REBOA, guided by fluoroscopic imaging, were performed by trauma surgeons, and interventional or vascular specialists (9). Abdominal ultrasound is commonly used for screening for abdominal disease such as abdominal aortic aneurysms (13,14). Some training is needed, but ultrasound imaging of the
abdominal aorta by an emergency physician can be used to visualize the abdominal aorta and determine the presence of abdominal aortic aneurysms (15). In recent paper by Guliani and colleagues, it was shown that a surgeon can reliably identify a central aortic guidewire in both transverse and sagittal orientations during the focused abdominal sonography for trauma procedure (16). Focused abdominal sonography for trauma and emergency ultrasound imaging of the abdominal aorta are also routine and necessary skills for emergency physicians. These physicians can readily expand their ultrasound capabilities to include ultrasound-guided REBOA without fluoroscopy.

In this protocol for REBOA, verification of the balloon position in the descending aorta using transesophageal echocardiography is recommended, if needed and available. Commonly, transesophageal echocardiography is not available in emergency department or resuscitation area. Consultation with an intensivist or anesthesiologist is needed. However, in our center, when a trauma code is activated, the trauma team including an intensivist and trauma physician comes to the resuscitation area. Our trauma code brings easy access to transesophageal echocardiography, which might be limited in other emergency areas. Therefore, we recommend the use of ultrasound-guided REBOA in the resuscitation area.

Table 1. Summary of Trauma Patients Undergoing Resuscitative Endovascular Balloon Occlusion of the Aorta

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>REBOA (n = 34)</th>
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<tr>
<td>Age, y, median, IQR</td>
<td>67.5 (53–82)</td>
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<tr>
<td>Sex, male, n (%)</td>
<td>22 (64.7)</td>
</tr>
<tr>
<td>Mechanism, blunt, n (%)</td>
<td>34 (100)</td>
</tr>
<tr>
<td>Injury Severity Score, median (IQR)</td>
<td>50 (36–59)</td>
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<tr>
<td>Revised Trauma Score, median (IQR)</td>
<td>6.233 (5.146–7.108)</td>
</tr>
<tr>
<td>Provability of survival, %, median (IQR)</td>
<td>31.4 (9.9–65.1)</td>
</tr>
<tr>
<td>Interval to complete REBOA, min, median (IQR)</td>
<td>8 (5–10)</td>
</tr>
<tr>
<td>Complications, n (%)</td>
<td>2 (5.9)</td>
</tr>
<tr>
<td>Femoral artery dissection</td>
<td>1</td>
</tr>
<tr>
<td>Difficult percutaneous vascular access</td>
<td>1</td>
</tr>
<tr>
<td>Overall mortality, n (%)</td>
<td>16 (47.1)</td>
</tr>
<tr>
<td>24-h mortality, n (%)</td>
<td>10 (29.4)</td>
</tr>
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IQR = interquartile range; REBOA = resuscitative endovascular balloon occlusion of the aorta.
departments without access to intensivists or anesthesiologists for trauma management in the resuscitation area.

**Study Limitations**

The REBOA protocol presented is just an experience-based procedure in a single center. Additional study of this procedure is necessary and must be focused on safety, its effect on the post-injury interval to complete REBOA, and the patient outcomes. Despite several protocols for REBOA use, there is a paucity of prospective, comparative data to inform physicians as to the optimal approach. High-quality, prospective clinical trials are needed to address this gap in the resuscitation literature.

**CONCLUSIONS**

Ultrasound-guided REBOA is presented, which enabled us to perform REBOA in the resuscitation area without patient transport to the radiology department for fluoroscopy. Monitoring the blood pressure in the left radial artery allows us to determine adequate positioning of the balloon, and the blood pressure in the catheter sheath located in the femoral artery should also be monitored to prevent aortic injuries caused by overinflation of the balloon.

**REFERENCES**