Endovascular Control of Pelvic Hemorrhage: Concomitant use of REBOA and Endovascular Intervention

Sakib M Adnan BS, R Adams Cowley Shock Trauma Center, University of Maryland Medical System, Maryland, USA; sakib.adnan@som.umaryland.edu

Philip J Wasicek MD, R Adams Cowley Shock Trauma Center, University of Maryland Medical System, Maryland, USA; pwasicek@som.umaryland.edu

Angela Crawford MD, R Adams Cowley Shock Trauma Center, University of Maryland Medical System, Maryland, USA; acrawford@som.umaryland.edu

Joseph Dubose MD, R Adams Cowley Shock Trauma Center, University of Maryland Medical System, Maryland, USA; joseph.dubose@umm.edu

Megan Brenner MD, R Adams Cowley Shock Trauma Center, University of Maryland Medical System, Maryland, USA; mbrenner@umm.edu

Thomas M Scalea MD, R Adams Cowley Shock Trauma Center, University of Maryland Medical System, Maryland, USA; tscalea@umm.edu

Jonathan J Morrison, PhD, FRCS, R Adams Cowley Shock Trauma Center, University of Maryland Medical System, Maryland, USA; jonathan.morrison@umm.edu
Conflict of Interest: Dr. Jonathan Morrison and Dr. Megan Brenner are clinical advisory board members for Prytime Medical Inc. The remaining authors have no conflicts of interest.

Sources of Funding: None

Corresponding Author:
Jonathan J Morrison, PhD, FRCS,
R Adams Cowley Shock Trauma Center
22 S. Greene Street
Baltimore, Maryland 21201
Telephone number: 443-750-0821
E-mail address: jonathan.morrison@umm.edu
Mailing Address: 22 S. Greene Street, Baltimore, Maryland 21201
Introduction

Pelvic ring fractures can be associated with major hemorrhage, with mortality rates approaching 33%\(^1,2\). Infra-renal (Zone 3) resuscitative endovascular balloon occlusion of the aorta (REBOA) is an adjunct designed to control pelvic inflow while sustaining the circulation until definitive hemostasis can be achieved. Endovascular angioembolization has become a common therapy in arterial bleeding,\(^3-6\) and its use is increasing.\(^7-10\)

However, the presence of a REBOA catheter presents challenges to accomplishing angioembolization of the pelvis. REBOA is performed through the retrograde cannulation of the common femoral artery (CFA) reducing perfusion to the contralateral (with respect to the REBOA catheter) femoral artery, making access difficult.\(^4\) Furthermore, with a balloon catheter at the bifurcation, it may prove difficult to navigate catheters and wires for intervention across this anatomical region. Lastly, with an inflated balloon reducing pelvic inflow, this will impact upon the performance of diagnostic angiography.

The objective of this procedures and techniques paper is to describe several strategies that can overcome these issues in patients with hemodynamically unstable pelvic hemorrhage who undergo REBOA.

Pelvic Angioembolization with Concomitant REBOA Use

The current paper is based upon experience acquired at a Level 1 Trauma Center where REBOA has been used in clinical practice since 2013. At this institution, the trauma service is supported by a dedicated vascular trauma team consisting of vascular-trained trauma surgeons.

Broadly, there are three technical issues to consider with an endovascular approach to pelvic hemorrhage in the setting of concomitant REBOA use: access, angiography and
intervention delivery. The latter two issues are partly dictated by the access site, and each option will be considered in turn, following a description of our institution’s REBOA practice.

REBOA Technique

An institutional protocol has been published previously\textsuperscript{11}, but in brief, all patients presenting with evidence of infra-diaphragmatic hemorrhage are considered for REBOA. Following a primary survey, patients with evidence of abdominal hemorrhage (eg: focused abdominal sonography in trauma (FAST) positive) or a pelvic fracture compatible with hemodynamic instability, have a femoral arterial line inserted. If the patient does not respond to transfusion, has no contraindication to REBOA (eg: thoracic aortic injury) and is felt to be at risk of imminent cardiac arrest, a REBOA catheter is inserted. For patients with abdominal hemorrhage, the balloon is positioned in the thoracic aorta (Zone 1) and for pelvic hemorrhage, it is inflated in the infra-renal aorta (Zone 3).

The technique favored at our institution is to gain retrograde femoral access via ultrasound-guided access or surgical cutdown. The latter approach is strongly advocated in patients with an arrested circulation. Once the CFA is accessed with a needle, a Seldinger technique is used to place a 7 Fr sheath. This is used to facilitate the insertion of a wireless balloon catheter (ER-REBOA; Prytime Medical Inc, Boerne, TX), which has a compliant balloon mounted on a 6 Fr shaft. Insertion is performed using a landmarks technique with imaging confirmation, usually in the form of plain radiography.

In the setting of a hemodynamically unstable pelvic fracture, without competing priorities, patients are taken directly to a hybrid operating room to undergo angioembolization (coil, plugs or gelfoam). The overall clinical goal is to minimize balloon time (ischemic time)
while obtaining rapid hemostasis. In addition to angioembolization this may include operative and/or orthopedic intervention delivered in parallel.

**Endovascular Strategies in Pelvic Hemorrhage**

Access can be achieved in upper or lower extremity arteries, with the approaches most commonly used at our institution discussed below.

**Ipsilateral CFA Access**

In our practice, this is the least common access approach as it involves the deflation and removal of the REBOA catheter, especially as contrast cannot be injected via the side-arm of the sheath with a catheter *in situ*. This can be considered in patients who have become hemodynamically stable following resuscitation and can tolerate balloon deflation. These patients often do not have an arterial source of bleeding and the use of REBOA is largely resuscitative, while pelvic anatomy is reconstituted and intravascular volume replaced.

As the access sheath is 7 Fr, this will facilitate nearly all endovascular interventions and does not require adjustment. In our practice, we would use a 180 cm 0.035” Bentson wire to support the insertion of a 65 cm 5 Fr Omni-flush (side-hole) catheter at the aortic bifurcation (Table 1). The catheter is then used for both power-injected angiography (20 ml contrast bolus at 15 ml/sec) and to traverse the aortic bifurcation to selectively access the contralateral side if required (Figure 1).

**Contralateral CFA Access**

This is the most common endovascular approach where patients cannot tolerate balloon deflation. Cannulation of the contralateral femoral artery in this setting is challenging as the vessel is usually pulseless and may be significantly vasoconstricted. We would emphasize the
use of ultrasound-guided access or surgical femoral artery cutdown. Partial deflation of the REBOA catheter can introduce some flow into the vessel to aid cannulation; however, this is contingent on the patient’s physiological tolerance of this maneuver.

Following needle access, the insertion of a 5 Fr sheath will accommodate most initial endovascular procedures (eg: angiography and coil embolization). Again, the combination of a Bentson wire and an Omni-flush catheter can be used to obtain a pelvic angiogram (Table 1). If the balloon is inflated, the angiogram can be obtained using a hand injection of 10 mL of contrast. Due to the lower pressure, this technique will provide diagnostic quality images (Figure 2).

If the internal iliac artery (IIA) demonstrates contrast extravasation (or “blush”) on the same side as the Omni-flush catheter insertion, the catheter can be withdrawn until it engages with the origin of the IIA and then exchanged over a wire for an end-hole catheter such as a 65 cm 4 Fr Glide catheter. This will facilitate selective IIA angiography and intervention (eg: coil embolization).

If a blush is observed on the side of the REBOA catheter, then the Omni-flush catheter can be used to traverse the aortic bifurcation, using a soft steerable wire such as a 180 cm 0.035” angled glide wire. Once across the bifurcation, the Omni-flush catheter can be exchanged for a steerable glide catheter to facilitate selection of the IIA. This can be difficult due to the number of endovascular devices crossing the aortic bifurcation and is especially challenging in narrow bifurcations with a tight angle, as observed in young men. The female aortic bifurcation tends to have a wider angle and the vessels tend to be of a larger diameter in older patients, assuming no peripheral vascular disease. The cramped space also precludes advanced maneuvers such as the
formation of a Waltman loop, where an acutely angled catheter is deliberately reversed to an obtuse angle by means of a long redundant loop of catheter formed in the distal aorta.

If contrast extravasation is demonstrated arising from either the common or external iliac and a covered stent-graft is considered an appropriate therapy, then the 5 Fr access sheath will almost certainly require switching out for a larger sheath. Most covered stent-grafts require between a 6 Fr and 12 Fr access sheath for delivery.

Once a hemostatic intervention has been performed, the balloon should be weaned and repeat angiography performed using a power injector. This latter point is important, as some arterial bleeding may be masked by the relative reduction in pelvic perfusion observed during REBOA. Crucially, no sheaths should be removed until the completion angiogram, as further intervention may be required, such as reinsertion of the REBOA catheter.

**Upper Extremity Access**

Traditionally, femoral access has been the most common site of arterial entry for endovascular intervention.\(^4\) However, with the availability of specialist low-profile sheaths, longer wires and catheters, upper limb access is becoming another option for pelvic intervention. This is especially helpful when the groin regions are either obscured by pelvic binders, or have additional injuries or endovascular devices deployed such as REBOA catheters.

Axillary or brachial access is well described in support of visceral intervention or for complex aortic aneurysm repair.\(^{12,13}\) However, as these vessels are end arteries, using this approach may require surgical exposure or operative repair in the event of access site complications. This has made upper limb access less popular in emergent circumstances. However, the availability of radial devices has changed this balance, as the hand has an excellent
collateral supply via the ulnar artery and palmar arches and is associated with significantly less access site morbidity compared to femoral, brachial or axillary approaches.\textsuperscript{14}

The radial approach has been utilized at our institution for over a year with minimal morbidity. Our practice is to assess the hand’s circulation using a Barbeau test, and to utilize a radial approach where the hand is found to have a good collateral circulation. The merits of a left or right radial approach are discussed in detail below.

\textit{Left or Right Radial Access}

The left radial approach affords the shorter distance to the pelvis compared with the right radial. The left radial also avoids traversing the aortic arch, which carries a theoretical embolic stroke risk, although this is not borne out in practice\textsuperscript{12,15,16}. However, we have found the left radial approach to be one of the least ergonomic, as it involves standing on the patient’s right side and reaching over to an adducted arm. The alternative involves standing on the patient’s left side with an abducted arm, which can conflict c-arm access to the patient, depending on your room arrangement.

In our institution, the right radial approach is the most ergonomic arrangement, which involves the surgeon standing on the patient’s right side with the arm supinated and abducted. This permits access to the radial while not impeding a left-sided c-arm, performing both 2-D and 3-D angiography. This arrangement will of course differ between facilities.

Regardless of laterality, the sequence of the procedure is the same. The radial artery is cannulated and a 260 cm 0.035” Bentson wire is used in combination with a 110 cm 4 Fr Jacky catheter to navigate into the abdominal aorta, just above the REBOA catheter. A 120 cm 6 Fr radial sheath is then advanced over the wire to above the balloon, whereupon the balloon is partially deflated, advanced above the sheath and then re-inflated (Table 2). This secures access to the pelvis, via the radial sheath, with the REBOA balloon above the distal end of the sheath.
The sheath then facilitates access to the pelvis for angiography and intervention, via the passage of a long catheter such as a 150 cm 4 Fr angled glide catheter.

It is the authors’ experience that an antegrade approach from above makes accessing either of the iliac arteries relatively straightforward. Importantly, when performing angiography, even with the balloon inflated, the use of power injection is preferred, as longer catheters have a greater resistance to flow (Figure 3).

In terms of intervention, the largest sheath that a radial artery can accommodate is 7 Fr in size, which can facilitate angiography and the deployment of most coil and plug systems. The inventory of compatible stent-grafts is smaller, although some balloon-mounted grafts can be post-dilated to 11 mm (eg: Gore VBX, Atrium iCAST). An additional concern is the delivery system, which is often required to exceed 100 cm in order to reach the iliac vasculature.

Conclusions

We describe the technical considerations for endovascular interventions concurrent with REBOA use in patients with pelvic hemorrhage. Determining the access site for angiography and intervention is a major therapeutic consideration in pelvic hemorrhage, with options including upper and lower extremity arteries, each with practical considerations.

Lower extremity access affords the use of shorter systems, but can be more challenging in terms of vessel access and the maneuvering of wires and catheters. Upper extremity access can be a useful way of avoiding the groin region altogether, but involves specialist equipment and limits some endovascular interventions such as large diameter-covered stent-graft deployment. The use of upper or lower extremity access should be made on the basis of patient factors and clinical capability. Further research is required in this area in order to optimize the timely care of this critical patient group.
**Competing Interests Statement:** Dr. Jonathan Morrison and Dr. Megan Brenner are clinical advisory board members for Prytime Medical Inc. The remaining authors have no conflicts of interest.

**Author Contributions:**

Study conception and design: SA, PW, AC, JD, MB, TS, JM

Data Collection: SA, PW, JM

Data Analysis: SA, PW, JM

Interpretation of data: SA, PW, JM

Drafting of manuscript and critical revision: SA, PW, AC, JD, MB, TS, JM

**Funding:** None
Figure Legends

**Figure 1:** Ipsilateral CFA access with concomitant REBOA

**Figure 1a:** Complete occlusion with Zone 3 REBOA placement. Contrast is present in the balloon, permitting imaging.

**Figure 1b:** Digital subtraction angiography achieved through the ipsilateral CFA following removal of the REBOA balloon.

**Figure 2:** Contralateral CFA access with concomitant REBOA

**Figure 2a:** Pelvic radiograph demonstrating a lateral compression fracture and a left femoral arterial line inserted during the primary survey.

**Figure 2b:** Digital subtraction angiography via an Omni-flush catheter inserted through the right CFA demonstrating an inflated REBOA catheter inserted via the left CFA.

**Figure 3:** Antegrade endovascular access with concomitant REBOA

**Figure 3a:** Complex pelvic fracture with elements of vertical shear and lateral compression. A REBOA catheter is present via the right CFA.

**Figure 3b:** Example of a wire from the right radial into the aorta with a sheath being advanced towards the aortic bifurcation.

**Figure 3c:** Digital subtraction angiography via an upper limb vessel, with a REBOA catheter still inflated via the right CFA.
References


6. Ogura T, Lefor AT, Nakano M, Izawa Y, Morita H. Nonoperative management of hemodynamically unstable abdominal trauma patients with angioembolization and


**Figure 1**: Ipsilateral CFA access with concomitant REBOA

**Figure 1a**: Complete occlusion with zone 3 REBOA placement. Contrast is present in the balloon, permitting imaging.

**Figure 1b**: Digital subtraction angiography achieved through the ipsilateral CFA following removal of the REBOA balloon displaying contrast extravasation (arrow).
**Figure 2**: Contralateral CFA access with concomitant REBOA

**Figure 2a**: Pelvic radiograph demonstrating a lateral compression fracture and a left femoral arterial line (arrow) inserted during the primary survey.

**Figure 2b**: Digital subtraction angiography via an Omni-flush catheter inserted via the right CFA with an inflated REBOA catheter (arrow, proximal to the flush catheter) inserted via the CFA.
**Figure 3:** Antegrade endovascular access with concomitant REBOA

**Figure 3a:** Complex pelvic fracture with elements of vertical sheer and lateral compression. A REBOA catheter (arrow) is present via the right CFA, placed in Zone I.

**Figure 3b:** Example of a wire from the right radial into the aorta with a sheath being advanced towards the aortic bifurcation.

**Figure 3c:** Digital subtraction angiography via an upper limb vessel, with a REBOA catheter still inflated via the right CFA.