Case Report

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Partial Aortic Occlusion using Resuscitative Endovascular Balloon Occlusion of the Aorta (P-REBOA) in Ruptured Abdominal Aortic Aneurysm: A Case Report

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Ruptured abdominal aortic aneurysm is often a fatal event without immediate intervention for the associated hemorrhagic shock and impending cardiovascular collapse. We report a case of a ruptured abdominal aortic aneurysm managed with partially occlusive resuscitative endovascular balloon occlusion of the aorta (P-REBOA) as a means to gain proximal control and tailor blood pressure goals, while allowing time to obtain access and repair the ruptured aneurysm.

Keywords: *REBOA; Abdominal Aortic Aneurysm; Hemorrhagic Shock; P-REBOA*

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BACKGROUND

Although care for a ruptured abdominal aortic aneurysm (rAAA) has significantly improved in the last decade, it remains a nearly universally fatal event without immediate operative repair, with mortality rates ranging from 53% to 90% [1]. It is still the 13th leading cause of death in the United States [2]. Current treatment options for repair of an rAAA are open surgical repair and endovascular stent-graft repair (EVAR). The management of hemorrhagic shock from an rAAA is critical to the patient's outcome and aims primarily to not only keep the patient alive until the control of bleeding is achieved but also to restore organ perfusion [1]. Refractory hemorrhagic shock often mandates emergent aortic control typically done through an abdominal incision.

Resuscitative balloon occlusion of the aorta (REBOA) is considered a less invasive alternative for emergent aortic control and, recently, more often described in the trauma literature for the control of non-compressible torso hemorrhage. While the use of REBOA may prevent exsanguination and augment cardiac perfusion, the benefits must be weighed against the potential consequences of sustained complete aortic occlusion, primarily distal ischemia and reperfusion injury. The concept of partial REBOA (P-REBOA) is a potential strategy to minimize these potential consequences by allowing sustained low volume distal flow to the viscera and lower extremities while maintaining blood pressure and cerebral perfusion. This report describes the novel adaptation of P-REBOA for a patient in hemorrhagic shock from rAAA as a means to gain proximal control and tailor blood pressure goals while allowing time to obtain access and repair the ruptured aneurysm.

CASE REPORT

A 71-year-old male with a past medical history significant for hypertension and hyperlipidemia presented to

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an urban Level I trauma center's emergency department with hypotension to a systolic blood pressure of 80 mmHg by palpation, severe acute abdominal pain and distension. The patient's skin was cool and diaphoretic. An approximately 8 cm aortic aneurysm was identified by point-of-care ultrasound. Massive transfusion protocol was initiated. Computed tomography (CT) imaging confirmed a 9.6 cm ruptured aortic aneurysm with active bleeding into the retroperitoneum (Figure 1). The neck of the aneurysm appeared to be juxtarenal with no proximal landing zone to facilitate endovascular repair, making open surgical repair the only viable option. An associated large left-sided retroperitoneal hematoma was present from the L1 vertebrae to the lower pelvis.

As the vascular surgeon on call was not in-house, the patient was taken initially to the operating room (OR) for surgical control of bleeding by the acute care surgery team. Upon arrival at the OR, the patient's systolic blood pressure was noted to be 60 mmHg. However, the patient had preserved mental status. Due to this, it was decided to delay anesthesia induction and intubation. Under ultrasound guidance, right femoral arterial access was achieved and a 7 French (Fr) introducer was placed. An ER-REBOA catheter (Prytime Medical Devices, Boerne, TX) was then passed beyond the aneurysm sac, into the distal thoracic aorta above the diaphragm under fluoroscopic guidance. Simultaneously, a large bore central venous line, as well as a left radial arterial line, were placed. Both the radial arterial line as well the introducer side port were connected to pressure transducers on the anesthesia monitor. Satisfied with catheter positioning, the balloon was gradually inflated and the systolic pressure of the radial arterial line was noted to rise from 60 mmHg to a range between 80 and 90 mmHg. Satisfied with the patient's hemodynamics at this time, the focus shifted to assessing his physiologic ability to tolerate partial distal perfusion. Using the transduced arterial pressure from the introducer side port as a marker for distal perfusion, the balloon was slowly inflated by about 0.5 to 1 cc every 30 seconds until the side port arterial pressure decreased from 60 mmHg to range between 30–40 mmHg systolic. The patient's hemodynamic status was constantly re-assessed during this process of establishing P-REBOA.

With hemodynamic control, the patient was safely intubated, prepared and draped for exploratory laparotomy. Approximately 1 L of blood was evacuated from the peritoneum. The small bowel was lateralized, exposing the ruptured aneurysm. The retroperitoneum was explored with dissection down to the aorta, and the iliac vessels were identified. Importantly, there was minimal active bleeding noted. At this point, the vascular surgeon arrived. The REBOA catheter was deflated and removed quickly to allow cross-clamping of a very short segment of the infrarenal aorta just above the neck of the aneurysm. The iliac vessels were also controlled. The aneurysm was opened and surgically repaired using a size matched bifurcated Dacron graft (Hemashield Gold, Maquet, Wayne, NJ). Total aortic occlusion time was approximately two hours, including REBOA time. A concomitant left hemicolectomy was required for bowel ischemia.

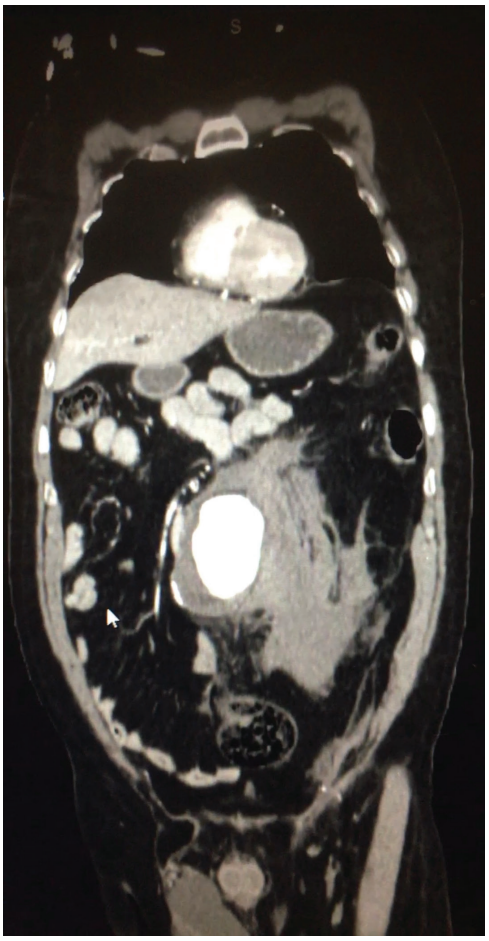

Figure 1 CT scan of the patient showing ruptured abdominal aortic aneurysm with active extravasation and retroperitoneal hematoma.

The operation was complicated by two episodes of ventricular fibrillation and asystole with the return of spontaneous circulation after brief cardiopulmonary resuscitation. These events occurred in the setting of opening the separate distal anastomoses and reperfusing their respective legs. The left distal limb developed an acute thrombus and required a catheter thrombectomy and redo of the anastomosis. During the course of the operation, the patient developed hypotension, coagulopathy and was requiring multiple pressors. The decision was made to leave the patient in bowel discontinuity, pack the abdomen open, and bring the patient to the surgical intensive care unit (SICU) – returning for a second look only if the patient stabilized.

His postoperative course was complicated by persistent hypotension and coagulopathy, acute respiratory distress syndrome, acute kidney injury, anuria and further

episodes of asystole. His next of kin eventually selected Do Not Resuscitate order and care was withdrawn on hospital day two.

DISCUSSION

Ruptured AAA is a cause of severe hemorrhagic shock, which carries substantial mortality [1,3]. The use of REBOA in traumatic non-compressible torso hemorrhage has seen the re-emergence of intra-aortic balloon occlusion, which was first introduced during the Korean War [4]. REBOA is considered in almost any case of intraabdominal or pelvic hemorrhage with impending cardiovascular collapse such as cases of penetrating injury to the abdomen or pelvis, blunt trauma without severe chest injury but with a positive focused abdominal sonography in trauma, severe hemorrhage from pelvic fractures, and lower extremity trauma with impending cardiovascular collapse [5,6]. Its use has also been described in cases of complex retroperitoneal hemorrhage, ruptured splenic artery aneurysm and hemorrhagic shock from ectopic pregnancy [1,7–9,14,20]. One case has even illustrated the successful use of REBOA *distal* to a ruptured thoracic aortic aneurysm, although this is currently considered unconventional [10]. Endovascular aortic occlusion has in some centers largely replaced performing an emergency department thoracotomy to assist with last-ditch resuscitative efforts for patients in end-stage hemorrhagic shock from trauma. Clearly a less invasive approach, the REBOA catheter has been refined to a smaller, guidewire free version, and no longer requires fluoroscopic guidance, known as ER-REBOA [11].

REBOA has been shown to increase central and proximal perfusion, restore hemodynamic stability and provide a little more time for operative preparation and planning for hemorrhage control [14,15]. However, prolonged complete aortic occlusion has its limitations and consequences such as organ injury, distal ischemia, and death [16,17]. There is also the potential of cardiac and pulmonary failure and worsening of traumatic brain injury due to supraphysiologic proximal perfusion [18,19]. These effects can make weaning from complete occlusion difficult and potentially lethal.

One strategy to mitigate some of the consequences of complete aortic occlusion is to allow persistent low volume distal flow to the viscera and lower extremities. This concept of P-REBOA has been shown in animal studies to have an improved hemodynamic response, allow longer occlusion times, and encourage small increases in intracerebral and proximal perfusion pressures compared to complete occlusion [20,21]. Moreover, the implementation of P-REBOA may improve the efficacy of resuscitation and, in patients who tolerate it, allow for preserved critical organ perfusion above the balloon and a hypotensive state below, potentially decreasing the incidence of distal ischemia and damage from reperfusion injury [22,23]. Other possible benefits of P-REBOA include extension of survival and the possibility of visualizing contrast blushes during (CT) angiography that would otherwise not be visualized with complete aortic occlusion [19,22]. In countries such as Japan, P-REBOA is performed more often than complete REBOA [2,20]. A suggested approach has been to start with complete REBOA to allow for clot formation, followed by deflation and further resuscitation using P-REBOA to allow some distal perfusion [19,23–25]. Finally, a recent novel study has incorporated automated extracorporeal circuits with complete REBOA in a swine model of uncontrolled hemorrhage to regulate proximal aortic pressure and provide controlled distal aortic perfusion [18].

P-REBOA requires arterial access, which can be accomplished using an ultrasound-guided percutaneous stick. After the introduction of a 7-Fr vascular access sheath, the ER-REBOA catheter can then be inserted. A Coda balloon (Cook Medical, Bloomington, IN) can be used instead but requires upsizing to a 12-Fr sheath, cumbersome wires and also imaging guidance for accurate placement – qualities not easily adaptable to most trauma bays. The depth for ER-REBOA can easily be determined using radiography or external landmarks [12,13]. Distal thoracic aorta positioning can be accomplished by placing the occlusion balloon over the sternal notch and externally measuring the distance to the entry point on the sheath. Similarly, for distal abdominal aortic occlusion, the occlusion balloon is placed at the level of the umbilicus and measured to the femoral access point. Once intra-arterial positioning is satisfactory, the balloon is gradually inflated while continuously monitoring blood pressure feedback via the device's arterial line. Connecting the side port on the arterial access sheath to a pressure transducer will allow monitoring of distal perfusion pressure. Alternatively, a contralateral femoral arterial line may be inserted and used.

Although prospective Level I evidence is not yet available, early retrospective data support the use of REBOA in controlling hemorrhagic shock. Preoperative deployment of REBOA for complete aortic occlusion in nontraumatic abdominal hemorrhage has been described before [26]. However, in the case presented here, specifically deploying P-REBOA preoperatively not only allowed proximal control of hemorrhage in an already unstable patient but also provided some degree of distal perfusion to critical organs. Moreover, the temporal stabilization of vitals allowed the acute care surgeon to start the intraabdominal access and exposure and prepare the field for the necessary vascular repair. This report offers a paradigm shift in urban trauma centers where an in-house surgeon has the ability to manage shock in nontraumatic intraabdominal hemorrhage with adjuncts such as REBOA. Although the patient in this case ultimately did not survive, the pragmatic approach used can in similar situations provide several benefits. It can potentially lead to a decreased need for

referral to another hospital and decreased time to abdominal incision when a vascular surgeon is not immediately available. In addition, knowing there is proximal aortic control, flexibility in the length of operation may be increased and possibly mitigation of reperfusion injury given modest amounts of distal perfusion.

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