

# A Case of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) Use in Penetrating Abdominal Aortic Injury

Meryl A Simon MD<sup>1,2</sup>, Rachel M Russo MD, MAS<sup>2</sup>, Anders J Davidson MD<sup>1,2</sup>,  
Edwin R Faulconer MBBS<sup>1,3</sup>, Erik DeSoucy DO<sup>1,2</sup>, Melissa N Loja MD<sup>2</sup>,  
M Austin Johnson MD, PhD<sup>2</sup>, Timothy Williams MD<sup>1</sup>,  
Joseph J DuBose MD<sup>1,2</sup> and David L Dawson MD<sup>1,2</sup>

<sup>1</sup>David Grant USAF Medical Center, Travis AFB, California, USA

<sup>2</sup>University of California Davis Medical Center, Sacramento, California, USA

<sup>3</sup>HQ Army Medical Services, Camberley, Surrey, UK

We present the successful utilization of resuscitative endovascular balloon occlusion of the aorta (REBOA) in a case of penetrating abdominal aortic injury. This allowed for hemorrhagic control and exposure of a large aortic defect at the level of the celiac access, which otherwise would have been difficult to control in an open fashion. Although use in this specific injury pattern in the literature is limited, REBOA can be a life-saving maneuver.

**Keywords:** Trauma; Penetrating; REBOA; Aorta

Received: 31 May 2017; Accepted: 23 July 2017

## Corresponding author:

Captain Meryl A. Simon USAF MC, Clinical Investigations Facility,  
David Grant USAF Medical Center, 101 Bodin Cir, Travis AFB,  
California, 94533, USA.

Email: masimon@ucdavis.edu

**Author contributions:** JJB was responsible for the concept. DLD was the operating surgeon. MAS drafted the manuscript. MAS, RMR, AJD, ERF, MNL, MAJ, TKW, JJB, and DLD were involved in critical revision of the manuscript. MAS has responsibility for the content.

**Conflicts of interest:** None.

**Funding:** This work is unfunded.

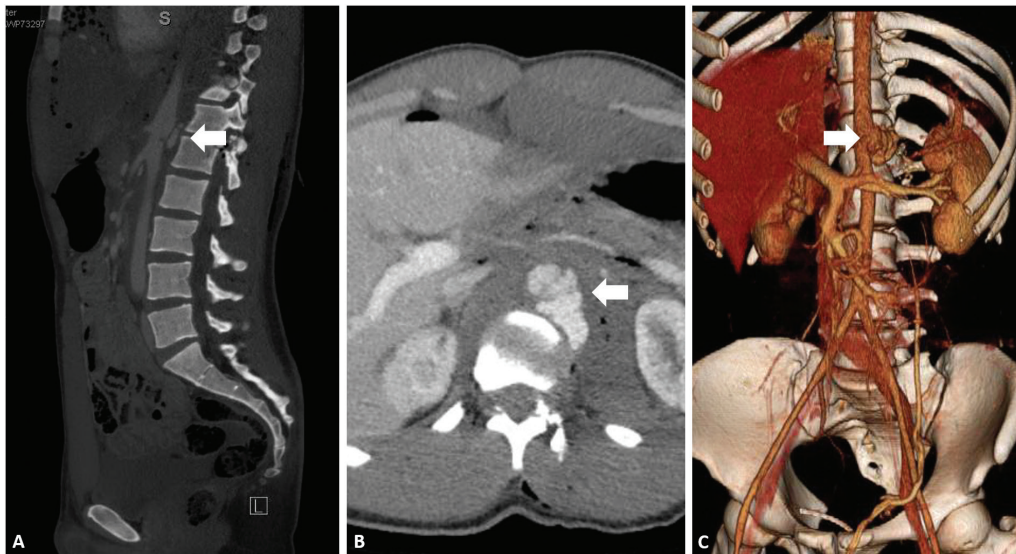
**Disclosure:** The views expressed in this material are those of the authors, and do not reflect the official policy or position of the US Government, the Department of Defense, the Department of the Air Force or the University of California.

© 2017 CC BY 4.0 – in cooperation with Depts. of Cardiothoracic/Vascular Surgery, General Surgery and Anesthesia, Örebro University Hospital and Örebro University, Sweden

## INTRODUCTION

Hemorrhage remains a leading cause of death among victims of trauma, particularly when significant bleeding from non-compressible locations is instigated. Penetrating abdominal aortic injuries are a particularly devastating source of significant hemorrhage in this group, associated with an exceptionally high mortality. The expected mortality of those who survive transport to a medical facility after sustaining penetrating aortic injuries may range from 62% to over 75% [1,2].

Recent advances in balloon catheter design and endovascular techniques have facilitated expedient control of hemorrhage from non-compressible sources. The use of resuscitative endovascular balloon occlusion of the aorta (REBOA) has grown in popularity over the last decade for this purpose. Balloon catheters for REBOA can be positioned using either fluoroscopic guidance or external anatomic landmarks – making this hemorrhage control adjunct practical in the field, emergency room, or intraoperative settings. While more commonly



**Figure 1** Preoperative computed tomographic angiography (CTA) imaging of the aortic transection. (a) Sagittal and (b) axial sections showing the injury just cranial to the celiac axis. Active extravasation is seen into the retroperitoneum (white arrows). (c) 3D reconstructed image of the aortic injury (white arrow).

employed following blunt trauma, REBOA also has potential life-saving uses after penetrating injury, including some penetrating aortic injuries.

We describe a case where intraoperative zone I REBOA (mid-descending thoracic aorta) was used to provide proximal hemorrhage control for surgical repair of a ballistic injury to the supraceliac aorta.

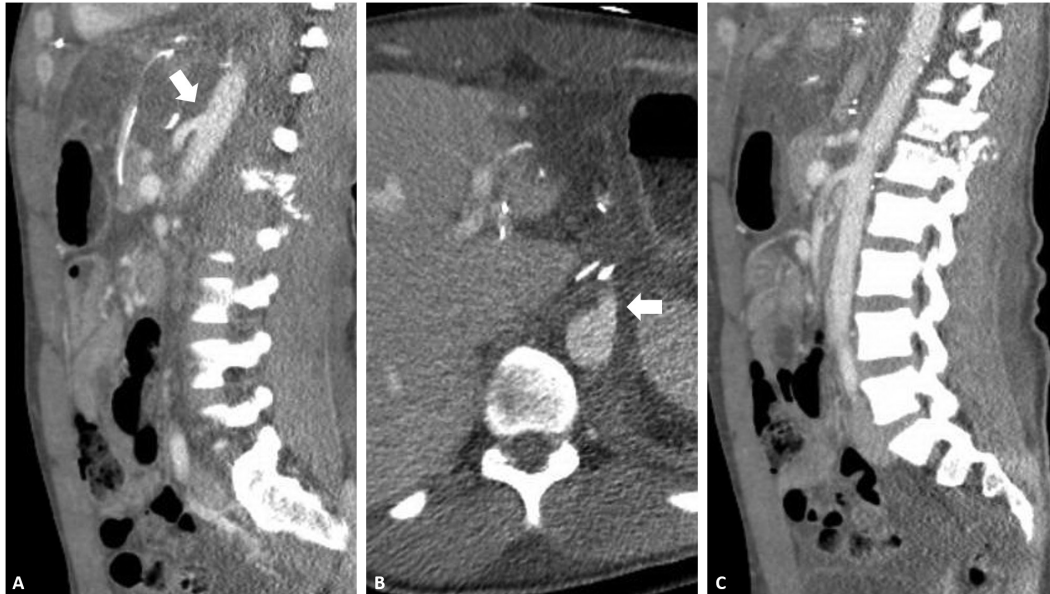
### Case Description

A previously healthy 24-year-old man with a self-inflicted gunshot wound to the anterior chest presented initially to a community hospital. He had a systolic blood pressure of 97 mmHg and heart rate of 130 beats per minute (bpm) on arrival. His hemoglobin level was 9.9 g/dL. During the initial resuscitation, he received two units of packed red blood cells (pRBCs), as well as tranexamic acid. Computed tomographic (CT) angiography demonstrated a large aortic pseudoaneurysm at the level of the celiac artery, with associated retroperitoneal hematoma. The superior mesenteric artery, renal arteries, and infrarenal aorta were patent (Figure 1).

He was transferred to our American College of Surgeons Level I verified trauma center, arriving approximately 3 hours after initial injury. He was conscious upon arrival at our facility, with a Glasgow coma score of 15. Blood pressure was 102/78 mmHg with a heart rate of 134 bpm. After rapid evaluation, he was expediently taken to the operating room by trauma and vascular surgeons. Femoral and pedal pulses were absent bilaterally. His lower extremities were cool, pale, and without sensation or volitional movements.

A median sternotomy and laparotomy were performed. Percutaneous right common femoral arterial access was simultaneously obtained using ultrasound guidance. He developed profound hypotension after opening the abdomen, and an intra-aortic balloon (ER-REBOA, Prytime Medical Devices, Boerne, TX) was placed and inflated in the mid-descending thoracic aorta (based on external landmarks). His blood pressure stabilized after this intervention.

A left medial visceral rotation was then performed, facilitating the division of the left crus of the diaphragm and exposure of the aorta. A large posterio-lateral aortic defect was evident at the level of the celiac artery with contusion of the proximal celiac artery. The ER-REBOA catheter was visualized within the lumen of the aorta. The aorta was mobilized and compressed manually allowing the balloon to be deflated and withdrawn. A cross-clamp was then placed and the aorta was transected proximal to the injury. A 16-mm Dacron interposition graft (HEMASHIELD, Maquet) was anastomosed proximally to the descending thoracic aorta with continuous running 3-0 polypropylene suture and interrupted 4-0 pledgeted reinforcing sutures. The clamp was moved distally onto the graft. The aorta was then divided distal to the celiac artery. By transecting the aorta obliquely, the superior mesenteric artery (SMA) origin was preserved. The graft was tailored in a similar fashion and sewn end-to-end, again with running 3-0 polypropylene suture, incorporating the SMA origin into the suture line. The clamps were then slowly removed to allow for gradual restoration of distal aortic flow. The combined aortic balloon occlusion and cross-clamp time was approximately 60 minutes.



**Figure 2** Postoperative CTA imaging of the repaired aorta. The patent aorto-celiac bypass is seen in both sagittal (a) and axial (b) views (white arrows). (c) shows the intra-abdominal aorta in its entirety.

After the restoration of aortic continuity, an aorto-celiac bypass was constructed with a 6-mm polytetrafluoroethylene graft (GoreTex, WL Gore & Associates) using partial aortic graft clamping. In addition, partial hepatectomy for a grade 5 liver laceration and bilateral tube thoracostomies were performed. Injured splenic and left gastric arterial branches were ligated. An excess of 50 units of blood products were transfused during the operation, including 2.2 L autologous recovered blood (Cell Saver®, Haemonetics), 36 units of pRBCs, 20 units of fresh frozen plasma, four units of platelets, and one unit of cryoprecipitate. Other identified injuries not addressed during his initial operation included T12/L1 vertebral fractures and a left perinephric hematoma.

After aortic repair and management of intra-abdominal injuries, he was noted to have persistent absence of pedal pulses and no Doppler signals at the level of the ankles, but duplex ultrasound demonstrated patent arterial flow bilaterally to the level of the popliteal arteries. Given his profound peripheral vasoconstriction associated with intraoperative hemorrhagic shock and ongoing hypothermia and coagulopathy, the decision was made to continue resuscitation and warming and observe for improvement.

Postoperative monitoring during resuscitation in the intensive care unit (ICU) revealed lower extremity mottling with early right ankle rigor. The femoral sheath utilized for REBOA access had been left in place due to coagulopathy. It was noted that a transduced arterial waveform could no longer be transduced from its side port connection. A repeat duplex ultrasound scan in the ICU demonstrated thrombosis of the right external iliac artery. He was then returned immediately to the operating room. Thrombectomy was performed

through a right common femoral arteriotomy, retrieving extensive thrombus from the proximal and distal vessels. A second incision below the knee was performed for tibial artery thrombectomy through a popliteal arteriotomy. A two-incision, four-compartment fasciotomy was performed, with findings of non-viable soleus muscle.

Surgical exploration of the contralateral (left) popliteal artery was also performed. There was minimal thrombus retrieved from the popliteal and tibial arteries. Doppler signals were obtained at the left ankle level after thrombectomy, and posterior compartment musculature exposed through the incision appeared healthy. No fasciotomy was performed on the left side.

Anticoagulation was initiated postoperatively, however, arterial signals did not return in the distal right lower extremity, despite arterial patency to the level of the popliteal artery. A staged right above the knee amputation was performed two weeks later, after clear demarcation of the level of viability.

The patient spent 10 days in the ICU. His course was complicated by acute renal failure requiring temporary hemodialysis. He was diagnosed with an incomplete T11 spinal cord injury with minimal sensation below the injury level. He underwent two weeks of inpatient rehabilitation and was discharged home mobile in a wheelchair and able to perform minimal assist transfers. Postoperative CT imaging at 2 weeks showed a patent aortic reconstruction without dissection or aneurysmal dilatation (Figure 2).

## DISCUSSION

This case describes a patient who suffered a self-inflicted penetrating aortic injury from a gunshot wound. Aortic



hemorrhage was initially contained due to tamponade by the closed abdomen, but upon surgical exploration active hemorrhage ensued. REBOA served as a life-saving adjunct for the rapid control and hemodynamic support of this uncontrolled hemorrhage in an anatomically unfriendly situation.

Recent clinical series have demonstrated the potential utility of REBOA for control of hemorrhage at non-compressible sites. Still, there remain practical concerns about hazards with REBOA use. This case illustrates one of these hazards – that the inserted catheter may traverse a segment of known or unrecognized aortic disruption. This risks an extra-luminal passage of the balloon catheter, which would render balloon occlusion ineffective for vascular control, as well as have the potential to extend the aortic injury or even cause *de novo* injury to surrounding structures. In this case, the balloon was correctly positioned without difficulty or technical complication.

There is a paucity of literature on REBOA use in penetrating abdominal aortic injury. Gupta et al. reported their experience with intra-aortic balloon occlusion in patients after penetrating missile injuries to the abdomen [3]. This early series offers examples of several cases where REBOA was successfully utilized in penetrating aortic trauma. Eleven patients sustained injuries to the abdominal aorta. Of those, two arrived with pulseless electrical activity and were declared dead after initial attempts at surgical resuscitation. Three patients arrived in profound shock (systolic blood pressure less than 60 mmHg) and underwent balloon occlusion preoperatively. Two of those three survived to discharge and the third died on postoperative day 3 due to coagulopathy and multiple system organ failure. Of note, one of the two survivors failed balloon placement due to the catheter exiting the aorta at the site of injury, and underwent thoracotomy with aortic cross clamping instead. The remaining six patients underwent balloon placement intra-operatively for hypotension unresponsive to resuscitation. Three of those six survived to discharge. In one case the balloon did exit through the injury during the celiotomy but was able to be successfully redirected. One patient died intra-operatively, while the remaining two died on postoperative days 39 and 92.

Our case was complicated by lower extremity ischemia and the need for amputation. Factors contributing to the severe acute limb ischemia included the severity of shock, temporary aortic occlusion with REBOA use and subsequent clamping, and continued presence of a 7-French sheath in the common femoral artery in the hours after operation. The risk of this complication may have been increased by a postoperative hypercoagulable state, due to physiologic responses to injury and resuscitation with plasma, cryoprecipitate, platelet transfusions, and tranexamic acid administration.

There are other cautionary tales regarding common femoral access in the trauma setting. Saito et al. retrospectively reviewed their REBOA use for trauma in

Japan from 2007 to 2013 [4]. Twenty-four blunt trauma patients underwent balloon occlusion for hemodynamic instability with hemoperitoneum or pelvic ring fractures or both. The balloon was placed through a 10-French sheath after either ultrasound guidance or blind percutaneous arterial access. Three patients (12.5%) required amputation on the side of vascular access. In one case, access followed multiple unsuccessful attempts, and angiography revealed a concomitant vascular injury that, although repaired, contributed to the need for amputation two days later. The other two patients each sustained injury to the amputated side: one had a femur fracture with extensive soft tissue damage, one had a pelvic fracture requiring embolization for bleeding and open common femoral access through the injured groin.

Recent retrospective studies suggest that limb ischemia after REBOA is a rare event with appropriate training and careful access. The Aortic Occlusion for Resuscitation in Trauma and Acute care surgery (AORTA) registry reported their initial experience with 46 patients in which REBOA was utilized across eight trauma centers [5]. Over 50% of the access sites in this series utilized a 12-French or larger sheath. Percutaneous femoral artery access was guided by palpation or external landmarks alone in 28%; ultrasound guidance was used in 11%; fluoroscopy was used in 2%. In the majority of cases, however, surgical exposure of the femoral artery was used for access. Access site complications included one pseudoaneurysm and two cases of distal embolization, but no patients required amputation. It is important to note that all providers who placed the devices in these 46 patients were either board certified vascular surgeons or trauma/acute care surgeons who had been trained in REBOA use with a standardized curriculum and practical instruction. Another recent retrospective review also showed that REBOA can be implemented safely. This paper looked at 48 patients over a 5-year period where both 7-French and 14-French systems were utilized, and although the 14-French sheaths required arteriotomy repair after removal, no amputations were seen [6]. While complications do appear to be minimized through the use of a smaller sheath size, our case highlights that they still can occur, especially when compounded by an extended duration of use.

To minimize the risk for access site and limb ischemia complications of REBOA, safe arterial access practices should be followed. This includes the use of ultrasound-guided access whenever feasible, use of the smallest sized sheath needed to accommodate the balloon catheter, and early sheath removal once the balloon is no longer needed. One way to implement this is to remove the sheath prior to leaving the operating room after repair. One of the most common complications of early sheath removal is likely to be pseudoaneurysm, which by comparison may be less morbid than an ischemic limb from arterial thrombosis or embolism. Direct catheter arteriography or duplex ultrasound scanning should be used if there is any concern for arterial thrombosis or embolization. As a matter of

practice, adequate training is also likely to mitigate the risk for complications of REBOA use, including instruction provided by the American College of Surgeons Basic Endovascular Skills for Trauma (BEST) course [7].

## CONCLUSION

REBOA can provide expedient and effective control of hemorrhage from non-compressible sources. In the vascular surgery realm, REBOA has already demonstrated the ability to dramatically decrease mortality in ruptured aneurysm management [8] compared to traditional options for proximal control approaches via either thoracotomy for aortic clamping or laparotomy and supraceliac exposure. Some traumatic aortic injuries may be analogous, presenting a similar challenging source of non-compressible hemorrhage. Trauma surgeons should be trained in the use of REBOA and should have this option in their armamentarium for surgical management of aortic injury.

## REFERENCES

- [1] Demetriades D, Theodorou D, Murray J, et al. Mortality and prognostic factors in penetrating injuries of the aorta. *J Trauma*. 1996;40:761–3.
- [2] Lopez-Viego MA, Snyder III WH, Valentine RJ, Clagett GP. Penetrating abdominal aortic trauma: a report of 129 cases. *J Vasc Surg*. 1992;16:332–6.
- [3] Gupta BK, Khaneja SC, Flores L, et al. The role of intra-aortic balloon occlusion in penetrating abdominal trauma. *J Trauma*. 1989;29:861–5.
- [4] Saito N, Matsumoto H, Yagi T, et al. Evaluation of the safety and feasibility of resuscitative endovascular balloon occlusion of the aorta. *J Trauma Acute Care Surg*. 2015;78:897–904.
- [5] Dubose JJ, Scalea TM, Brenner M, et al. The AAST Prospective Aortic Occlusion for Resuscitation in Trauma and Acute Care Surgery (AORTA) Registry: data on contemporary utilization and outcomes of aortic occlusion and resuscitative balloon occlusion of the aorta (REBOA). *J Trauma*. 2016;81:409–19.
- [6] Taylor Iii JR, Harvin JA, Martin C, Holcomb JB, Moore LJ. Vascular complications from resuscitative endovascular balloon occlusion of the aorta (REBOA): life over limb? *J Trauma*. 2017;83:S120–S123.
- [7] Brenner M, Hoehn M, Pasley J, et al. Basic endovascular skills for trauma course: bridging the gap between endovascular techniques and the acute care surgeon. *J Trauma*. 2014;77:286–91.
- [8] Starnes BW, Quiroga E, Hutter C, et al. Management of ruptured abdominal aortic aneurysm in the endovascular era. *J Vasc Surg*. 2010;51:9–18.