Original Article

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Successful and Unsuccessful Blind Placement of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) Catheters Through Damaged Arteries: A Report of Three Cases

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Background: Patients who receive resuscitative endovascular balloon occlusion of the aorta (REBOA) for temporization of exsanguinating hemorrhage may have occult injuries sustained to the iliac arteries or aorta which may pose increased risks in performing REBOA. Caution is essential in performing REBOA in these patients as the injuries are not clearly defined on admission. REBOA is currently performed in select centers without fluoroscopy, leading to blind placement of devices and an essential reliance on tactile feedback.
Methods: Patients admitted between February 2013 and July 2017 at a tertiary center who had a successful or unsuccessful blind placement of a REBOA catheter or wire through a damaged iliac artery or aorta were included.
Results: Three patients were identified. Two patients had successful placement of the REBOA catheter; one sustained injury to the external iliac artery and the other sustained injury to the abdominal aorta. Confirmation of catheter placement was obtained before balloon inflation, and the damaged vessels were identified upon immediate operative intervention. One patient had unsuccessful placement of the REBOA catheter during cardiac arrest despite accurate access of the common femoral artery (CFA).
Conclusions: Emergent, blind placement of wires and catheters past arterial injuries is possible but may result in procedural abandonment and/or arterial injury. Physical exam and/or tactile feedback should alert the surgeon to the possibility of arterial injury. Imaging confirmation should precede balloon inflation if at all possible.

Keywords: *Resuscitative Endovascular Balloon Occlusion of the Aorta; REBOA; Aortic Occlusion; Aorta; Trauma; Arterial Injury; Complication*

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INTRODUCTION

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is utilized as a temporary bridge to hemostasis by providing proximal control of the aorta for hemorrhage below the diaphragm. REBOA is utilized in trauma patients who sustain severe injuries causing non-thoracic torso hemorrhage. Given the critical condition of these patients, REBOA may be warranted immediately upon presentation to the hospital. In the pre-operative setting, it is frequently not feasible to perform REBOA under fluoroscopic guidance and placement of REBOA catheter and wires may be performed blindly without knowledge of potential major vascular injuries.

Prior to balloon inflation, imaging confirmation of the wires/catheters is highly recommended; however, expedient imaging confirmation may be deferred in patients in cardiac arrest actively undergoing chest compressions. In one multi-institutional study, 35% of patients did not receive imaging confirmation of device placement; and the majority of these cases were patients in arrest in whom closed chest compressions were not paused to obtain imaging [1].

Occult injuries to the femoral or iliac arteries, and even to the aorta, may lead to difficulty with successful blind placement of catheters and/or wires across these injuries. Despite a growing body of literature describing REBOA use in trauma patients [1–4], there is a paucity of literature describing successful or unsuccessful blind placement of catheters or wires across arterial injuries.

The objective of this study was to describe a single institution's experience with placement of endovascular devices blindly through injured vessels.

METHODS

This study is a retrospective case series using prospectively collected data and was approved by the Institutional Review Board of the University of Maryland, Baltimore.

Demographics and hospital course data were collected prospectively on all trauma patients, age ≥18 years old, who underwent REBOA at the University of Maryland Shock Trauma Center. Patients admitted between February 2013 and July 2017 at a tertiary center who underwent REBOA and were found to have aortoiliac injury within the trajectory of the devices were included. Patients who had unsuccessful REBOA attempts that were ultimately abandoned due to inaccurate placement as a result of original vascular injury were also included. Demographics and hospital course data were extracted from the medical record. REBOA related timing metrics were captured by available time-stamped videography in the resuscitation areas and operating theaters. REBOA was initially performed using a 12 French (Fr) sheath and the CODA® catheter (Cook Medical, Bloomington, IN). During the study period, there was a transition to using a smaller 7 Fr sheath with the FDA approval of a smaller profile catheter, ER-REBOA™ (Prytime Medical, Boerne, TX), which occurred in February 2016.

RESULTS

Case 1

A 67-year-old male presented after being a pedestrian struck by a motor vehicle and was intubated in the field. Transport time to the hospital was 28 minutes. Upon arrival, the patient had bilateral chest tubes placed for decreased breath sounds with minimal output. Plain films of the chest and pelvis were negative. The patient's abdominal FAST exam was negative, but he had a distended abdomen. A femoral arterial line was placed and the patient was persistently hypotensive despite aggressive resuscitation. The arterial line was upsized for a 12 Fr sheath and a 0.035″ Amplatz Super Stiff™ (Boston Scientific, Marlborough, MA) guidewire was measured and inserted using external landmarks. A plain radiograph was obtained (Figure 1*a*) showing the wire in the appropriate location, and a CODA® catheter was inserted based on external landmarks. A plain radiograph was obtained (Figure 1*b*) showing the catheter with its radiopaque balloon markers in the appropriate position in zone 1 of the aorta (descending thoracic aorta). The balloon was then inflated. The patient's blood pressure improved from 50/30 mmHg immediately before balloon inflation to 80/48 mmHg and the patient was taken to the operating room emergently. The time from admission to the operating room was 75 minutes. An exploratory laparotomy demonstrated a large left-sided retroperitoneal hematoma. A left medial visceral rotation revealed a near transection of the aorta at the level of the left renal artery. The balloon catheter provided proximal control of the hemorrhage while the aortic transection was repaired primarily and the patient was able to tolerate total deflation of the REBOA balloon.

REBOA was performed intermittently, with a total occlusion time of 101 minutes. Unfortunately, while sheath removal and common femoral arterial repair was being performed the patient suffered cardiac arrest and subsequently expired due to extensive physiologic devastation despite transfusion of 35 units of blood products.

Case 2

A 48-year-old female presented after sustaining multiple gunshot wounds, including two bullet wounds in her left anterior flank and right lower quadrant of her abdomen. The patient suffered cardiac arrest en-route with successful return of spontaneous circulation, and was intubated by EMS in the field. On arrival, the patient was hypotensive and suffered cardiac arrest again 1.7 minutes after admission and subsequently underwent closed chest compressions in conjunction with REBOA. Severe

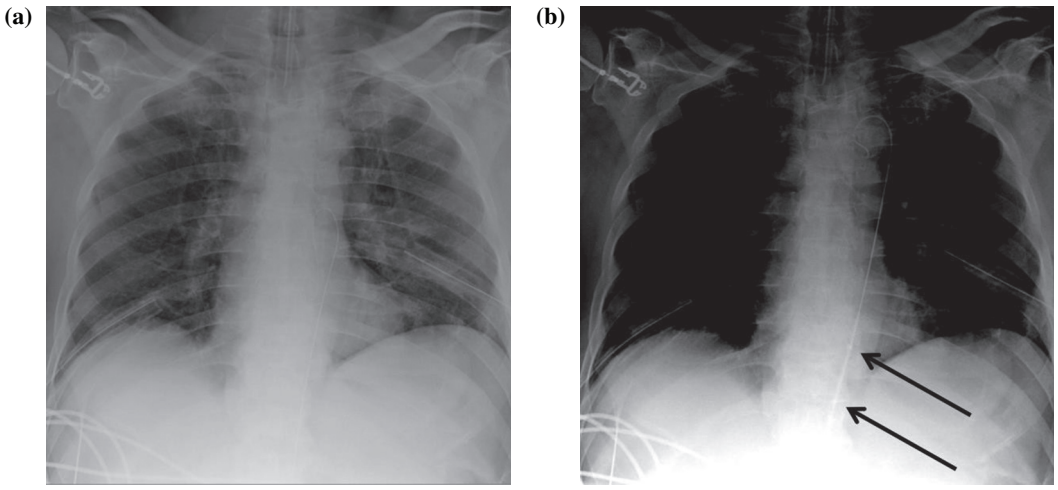

Figure 1 Chest X-ray confirmation of successful wire and catheter placement traversing a near-total abdominal aorta transection for REBOA. Image **a** demonstrates appropriate positioning of the wire before the CODA® catheter is inserted (Image **b**). Black arrows show the radiopaque markers of the balloon portion of the CODA® catheter, which provided supra-celiac aortic occlusion.

intra-thoracic hemorrhage was ruled out with an eFAST exam. A right femoral cut-down was performed and a 7 Fr sheath was inserted over a wire into the common femoral artery (CFA). Using external landmarks, an ER-REBOA™ catheter was inserted in zone 1, flushed, and connected to a systemic arterial line monitoring device. The balloon was inflated without radiography. The time from the start of the femoral cut-down to aortic occlusion by REBOA was 7.55 minutes. Chest compressions and advanced cardiovascular life support continued for approximately 3 minutes after balloon inflation until the return of spontaneous circulation occurred. Radiography at this time confirmed appropriate positioning of the ER-REBOA™ catheter in zone 1 of the aorta (see Figure 2), and the patient was taken emergently to the operating room where exploratory laparotomy demonstrated a large retroperitoneal hematoma. The balloon catheter was successfully deflated after a number of attempts with continued resuscitation (40 units of blood products). Upon successful balloon deflation, significant bleeding was identified from the abdominal right lower quadrant bullet wound. Exploration of the wound revealed injury to the anterior right external iliac artery. The ER-REBOA™ catheter was visualized traversing the injury and the posterior wall of the artery was intact. Vessel loops were placed proximal and distal to the injury and the REBOA catheter was removed. A shunt was placed in the right external iliac artery, the patient was left in discontinuity and abdomen was left open. The patient was transferred to an intensive care unit (ICU) with severe physiologic devastation and on vasopressors. The patient's family arrived soon after transfer to the ICU; and after conversation regarding the patient's guarded condition and prognosis, the decision to withdraw care was made and the patient expired soon after.

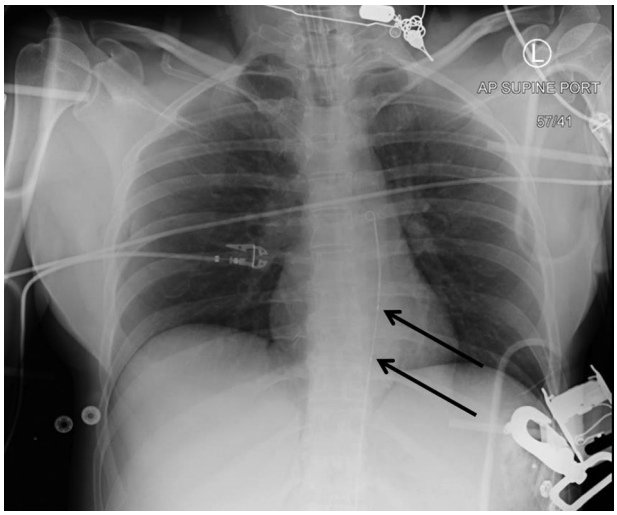

Figure 2 Chest X-ray demonstrating ER-REBOA™ catheter placement through a damaged external iliac artery and in the descending thoracic aorta. Black arrows show the radiopaque markers of the balloon portion of the ER-REBOA™ catheter, which provided supra-celiac aortic occlusion.

Case 3

A 22-year-old male sustained a gunshot wound to his lower back and was found unresponsive and transported to the hospital with ongoing CPR. On arrival, the patient had decreased breath sounds on the right, and a chest tube was placed with minimal output. An arterial line was placed in the right CFA and upsized to a 12 Fr sheath. A 0.035″ Amplatz Super Stiff™ guidewire and CODA® catheter were inserted. Abnormal tactile feedback was not noted while advancing the guidewire and catheter or with balloon inflation. A chest

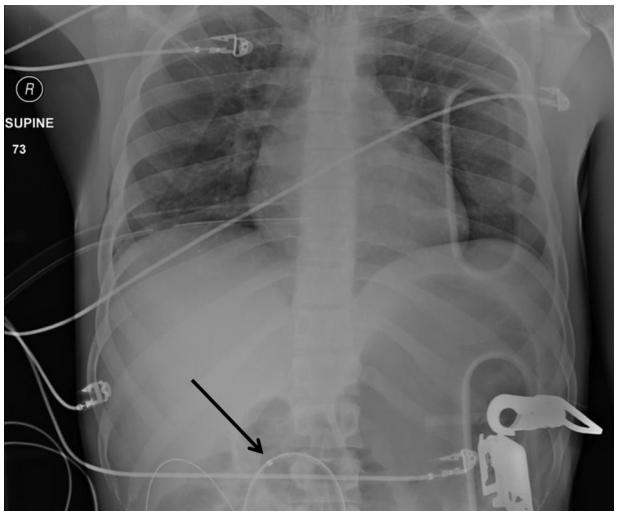

Figure 3 Plain film demonstrating unsuccessful appropriate CODA® catheter placement with the catheter coiled intra-abdominally. The black arrow demonstrates the CODA® catheter coiled within the abdomen.

x-ray was performed, which revealed incorrect placement of the CODA® catheter and guidewire (see Figure 3). The eventual position of the REBOA catheter and guidewire was attributed to an occult iliac artery injury given successful access and placement of the sheath in the CFA. Given the prolonged duration of cardiac arrest and unknown downtime without the return of spontaneous circulation, efforts ceased. Pelvic x-ray and a FAST exam were not performed. An autopsy report was not available.

DISCUSSION

Blind Catheter Placement and Balloon Inflation

Given the moribund status of these patients, REBOA is frequently warranted before specific injuries can be identified. Blind placement of catheters using external landmarks in CT imaging [5] and cadaver-based [6] studies is feasible. Successful blind placement and balloon inflation in the setting of injured and pathologic arteries (ruptured aortic aneurysms) has been previously reported [7,8]. Our institutional protocol recommends blind placement of the devices using external landmarks with imaging confirmation before balloon inflation, which has been largely successful and without complication [9]. Exceptions to this are patients in cardiac arrest at the time of REBOA, where the radiograph confirming device placement is obtained after the return of spontaneous circulation, or during a brief pause for a pulse check.

Although it is possible to accurately place devices blindly, inaccurate placement should be ruled out before balloon inflation is performed. Studies [8,10–12] have demonstrated the feasibility of transabdominal ultrasonography (including with the subxiphoid view), as well as transesophageal ultrasonography in placement confirmation. Despite previous reports of success [7,8] every attempt should be made to confirm catheter placement before balloon inflation.

Blind placement of wires or catheters in any patient is associated with risks including incorrect placement, initial or further damage of vessels including dissection and/or embolization, and additional injury could occur with blind inflation of an incorrectly placed REBOA catheter [13].

Table 1 Factors potentially associated with the ability to blindly place a catheter across arterial injuries.

Successful or Unsuccessful Blind Placement of Catheter Across Arterial Injury
Specific location of injury compared to trajectory of path of wire/catheter
Size, degree of tortuosity, and degree of stiffness or non-compliance of the vessel
Degree of injury to the vessel (transmural vs. non-transmural)
Percentage of the circumference involved, including complete transection
Alignment of proximal and distal injury-free segments
Intraluminal obstruction: presence of retained foreign bodies, severe atherosclerosis, thrombus
Presence of surrounding structures to allow injury to be contained (retroperitoneal vs. peritoneal)

Considerations in the Ability to Successfully and Blindly Traverse Injured Arteries

The incidence of arterial injuries that may adversely affect catheter placement in patients who meet criteria for REBOA, as well as factors that allow a catheter to successfully traverse an injured artery, have not been well studied. In our institutional experience, we have placed REBOA catheters in 104 patients with only the cases described in this series having this type of arterial injury. This suggests that the incidence of occult arterial injury preventing successful placement of the catheter may be low and therefore should not be a major deterrent in the decision to perform REBOA when the degree of suspicion of aortic or iliac arterial injury is not high. Physical exam and attention to the mechanism of injury and missile trajectory can suggest injuries to the iliac arteries. A decreased femoral pulse on one side, large pelvic retroperitoneal hematoma seen on eFAST exam, or open wounds with active bleeding in the pelvis can alert the physician to potential injury and avoidance of that side when performing REBOA. During the procedure, tactile feedback is the most important factor to ensure the safety of REBOA, and resistance or atypical behavior of indwelling devices should prompt troubleshooting, attempting from the contralateral groin, and/or abandonment of the procedure altogether.

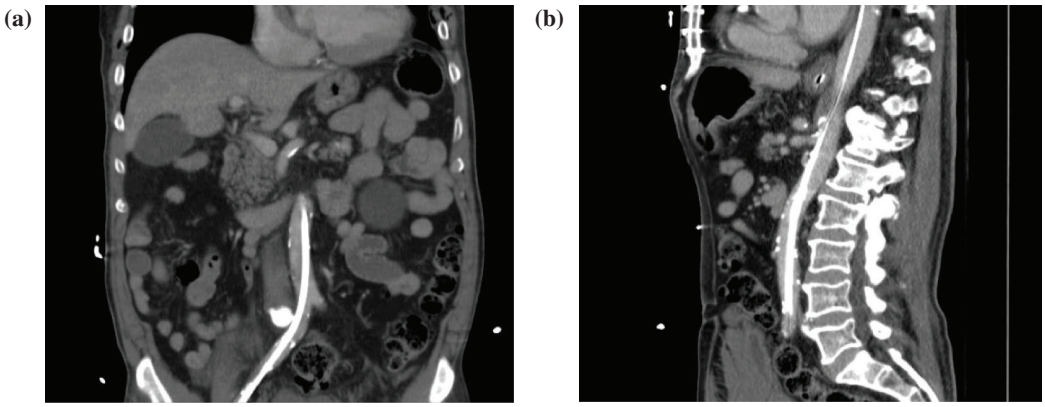

Figure 4 Coronal (image **a**) and sagittal (image **b**) CT images showing the course of the wire and CODA® catheter as it travels through the iliac artery and aorta. Note that the balloon was fully deflated during this CT scan. It demonstrates that at different points in the wire and catheter's course, it abuts different parts of the lumen wall while not abutting any part of the lumen wall at other locations.

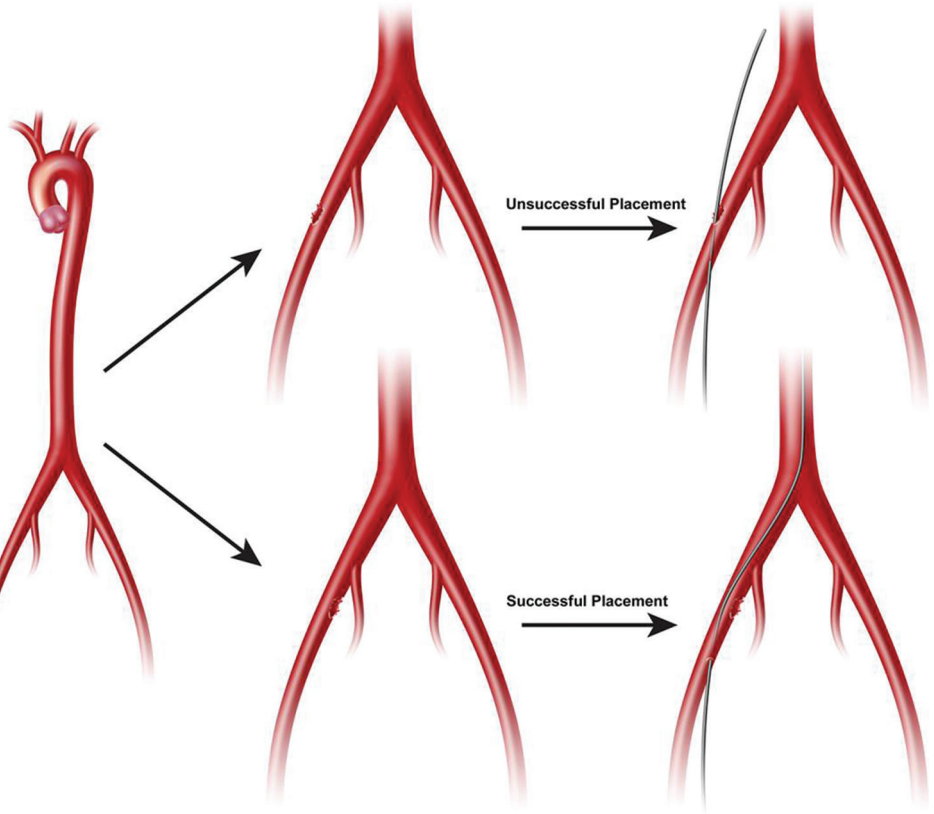

Figure 5 Illustration of how different injuries may potentially allow for successful vs. unsuccessful blind wire/catheter placement past the injuries.

Multiple factors are likely involved with the ability of a catheter or wire to traverse an arterial injury, as listed in Table 1. The specific characteristics of the patient and their arteries vary from patient to patient. These factors change with age, gender, and cardiovascular comorbidities, among other factors [5,14]. The course of a patient's arteries, as well as the properties of the catheter or wire, result in the catheter or wire abutting different aspects of the lumen wall at different locations, as seen in Figure 4. This may explain, in part, the ability of wires and catheters to traverse some arterial injuries, but not others, as illustrated in Figure 5. The incidence of arterial injury preventing accurate placement of catheters and wires for REBOA may be low. Nevertheless, efforts should be made to confirm catheter and wire placement before balloon inflation.

Considerations in Performing REBOA via Brachial or Common Femoral Arterial Access

Blind advancement of wires or catheters through the brachial artery into the aortic arch may lead to inaccurate placement such as into the ascending aorta, left ventricle, coronary arteries, as well as other branches of the aortic arch. The platform guidewire utilized for REBOA would require an additional steering catheter to ensure correct cannulation into the descending aorta. This angle from left subclavian to descending aorta is acute and without at least visualization under fluoroscopy, as well as additional steps and devices, is not feasible in the resuscitation area. The ER-REBOA is a wire-free device which is not steerable and intended to be inserted into relatively linear projectiles. Additionally, the performance of REBOA through brachial artery access has led to embolic events [7]. Obtaining access to the brachial artery is more difficult than accessing the CFA due to diameter and anatomy [14,15]. In addition, both percutaneous and open surgical brachial artery access is an unfamiliar skillset to most acute care surgeons. The safest access for REBOA given the patient population, available devices, skillset of the providers, and location of the procedure, is the CFA.

Only in the rarest of circumstances can REBOA via brachial access be safe and effective. Current clinical data supports CFA access as the preferred method as complications have been relatively minor, and almost all attempts through the CFA have resulted in successful aortic occlusion [1,16].

CONCLUSIONS

Blind placement of wires and catheters through arterial injuries for REBOA is feasible but may require procedural abandonment or result in iatrogenic arterial injury. Physical exam and tactile feedback should alert the surgeon to the possibility of arterial injury and possible unsuccessful placement of devices.

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