Case Report

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Use of ER-REBOA™ to Reverse Traumatic Arrest After Non-Truncal Bleeding

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INTRODUCTION

For select trauma patients, resuscitative endovascular balloon occlusion of the aorta (REBOA) is an alternative to emergency thoracotomy with aortic cross-clamping [1–3]. The principal indication for this procedure is uncontrolled exsanguination from known abdominal or pelvic injuries [4]. However, as the following case demonstrates, REBOA may also be useful as an adjunct to resuscitating trauma patients in cardiac arrest due to hemorrhagic shock without truncal hemorrhage.

Case Report

A 41-year-old male was trapped in the cab of a semi-trailer truck following a front-impact, rollover collision in rural Ohio. The vehicle traveled down an embankment becoming intertwined with a guardrail and trees. One passenger was ejected at the site of impact and was taken to a local hospital. The local emergency medical services (EMS) called for additional assistance with extrication secondary to difficult terrain and suspected injuries. The patient was found to have multiple deep lacerations and concern for a head injury. Extrication was prolonged (>2 hours) and EMS reported significant blood loss at the scene. After extrication, the flight nurse and paramedics obtained intraosseous access. Secondary to concerns for traumatic brain injury, the patient was intubated with a 7.5 mm endotracheal tube and given 100 mcg fentanyl IV, 100 mg ketamine IV, 100 mg rocuronium IV, 40 mg etomidate IV. During transport, the flight team infused 2 liters of normal saline and administered tranexamic acid.

The patient arrived in the emergency department with a Glasgow Coma Score of 3T. The primary survey revealed a patent airway (7.5 ET 24 cm at teeth), bilateral breath sounds and palpable pulses in four extremities. The patient was found to have a scalp laceration and multiple deep lacerations in the upper extremity and proximal thigh. The initial vital signs were consistent with those given during transport (Table 1). The primary focused assessment with sonography for trauma (FAST) exam was negative. A chest and pelvis x-ray were performed (Figure 1) and an extended arterial blood gas (ABG) was obtained. The initial ABG was pH 7.22, pCO_2 30.2, PaO_2 318, HCO_3 12, base deficit 14.2, Hgb 6.2, K^+ 2, iCa^{2+} 1.2, glucose 240, and lactate 6.9.

As the trauma evaluation progressed, the patient became increasingly hypotensive (Figure 2). His blood pressure was 81/38 mmHg with a heart rate of 95 bpm.

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Table 1 Vitals throughout initial trauma care.

	Time	*Heart Rate*	*Respiratory Rate*	*Blood Pressure*
Scene*	10:48	108	22	99/65
Transport*	11:00	114	16	107/59
ED arrival*	11:14	109	12	133/98
Prior to arrest	11:24	122	26	42/31
Arrest	11:24	0	26	0/0
REBOA: initial	11:27	117	31	164/123
REBOA: resuscitation	11:33	104	14	151/102
Balloon down	11:35	112	13	140/98
Prior to CT	11:51	107	14	164/113

Note: Medflight team assumed care at 10:45 after >2 hours of extrication.
**Automated blood pressure cuff placed on right upper extremity. The remaining vitals are recorded from the right femoral arterial line.*

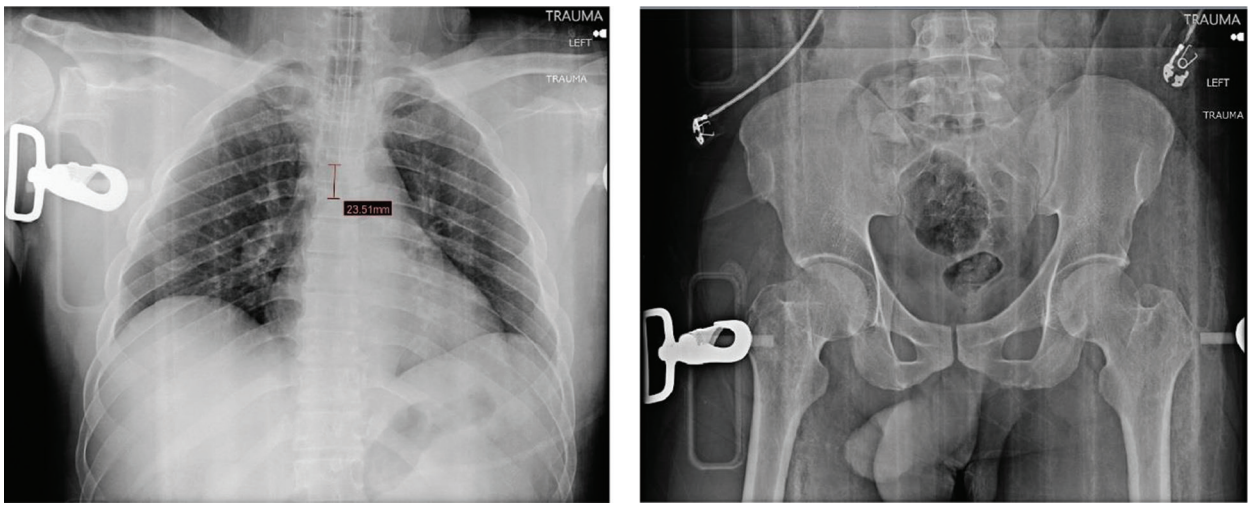

Figure 1 Initial chest and pelvis imaging.

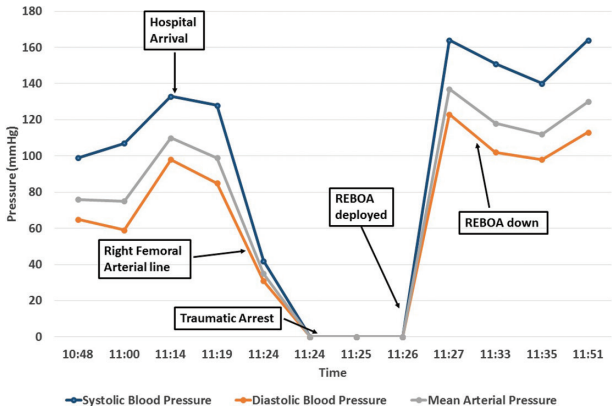

Figure 2 Blood pressure throughout trauma evaluation and resuscitation.

The trauma surgeon and advanced practice provider inserted a right femoral arterial line while the chief surgical resident placed a left subclavian 8.5 Fr single lumen resuscitation catheter. During placement of the arterial line, the patient's blood pressure dropped to 61/30 mmHg and the heart rate increased to 122 bpm. At approximately 10 minutes after arrival, the patient went into cardiac arrest (Figure 2). The patient had no arterial line waveform, but continued to have some cardiac activity on ultrasound evaluation.

Several team members worked in conjunction to expedite the resuscitation. The junior surgical resident started chest compressions while the nurse and chief resident started transfusion of two units of uncrossmatched packed red blood cells (PRBCs). The massive transfusion protocol (MTP) was initiated. The trauma surgeon upsized the femoral arterial line to a 7 Fr sheath and measured the catheter at 42 cm for Zone 1 deployment from the point of arterial access to the patient's sternal notch. An ER-REBOA™ catheter (Prytime Medical, Boerne, TX, USA) was inserted through the 7 Fr sheath after testing the balloon and flushing the catheter with the pressurized arterial line setup. The balloon was advanced and inflated with 11 ml of saline. The REBOA decision-to-inflation time was approximately 2.5 minutes, the time to secure the catheter was 3 minutes and the total occlusion time was 5 minutes. During the occlusion

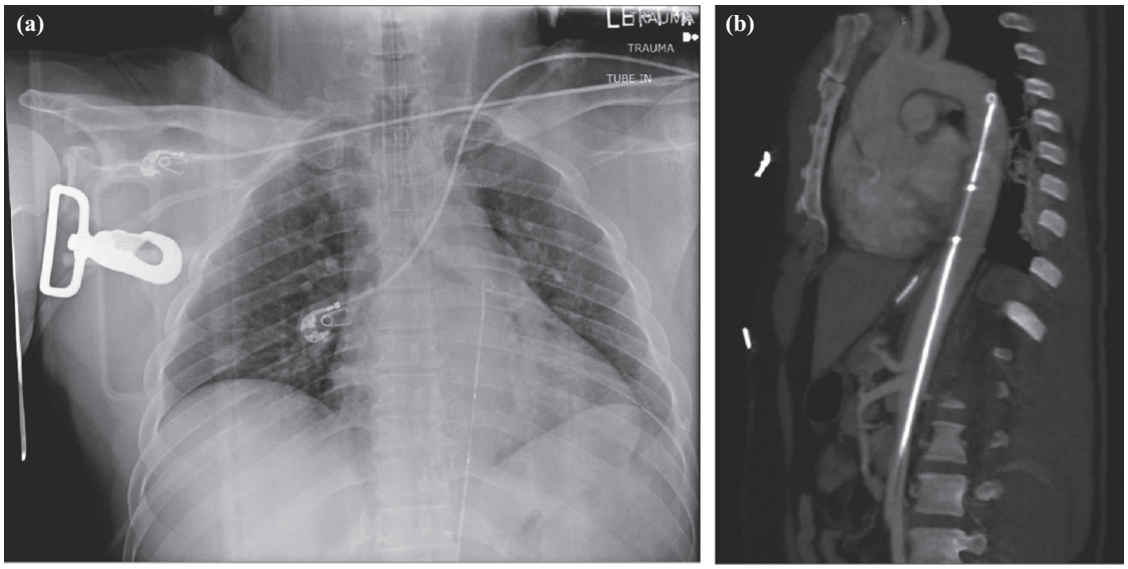

Figure 3 Portable chest x-ray (**a**) and CT chest (**b**) after Zone 1 ER-REBOA™ catheter placement.

period, the patient received two units of uncrossmatched PRBCs, 2 mg of epinephrine, 1 g of calcium, and 1 amp of sodium bicarbonate. Shortly after balloon inflation, the patient had return of spontaneous circulation (ROSC) with a narrow complex tachycardia.

After 5 minutes of resuscitation and monitoring, the ER-REBOA™ balloon was deflated. The institutional protocol is to slowly deflate the balloon while monitoring the proximal arterial pressure and waveform. In this case, the patient's mean arterial pressure remained >65 mmHg throughout deflation and the remaining time in the trauma bay. The trauma surgeon and chief resident ligated superficial unnamed bleeding vessels in the scalp, upper and lower extremity. Pressure was applied to the remainder of the wounds without continued significant blood loss. Repeat FAST examine and chest x-ray (Figure 3) revealed no further bleeding. The patient's resuscitation included four units of PRBC, no plasma or platelets and he received no further vasopressors. MTP was stopped after obtaining ROSC and confirming hemodynamic stability with balloon deflation. The patient was transferred for computed tomography (CT) scans (Figure 3). The images revealed no intracranial, aortic, thoracic, abdominal or retroperitoneal injuries.

The patient was transferred to the surgical intensive care unit (SICU). The REBOA catheter was removed and sheath pulled ensuring hemostasis with manual pressure for 30 minutes. The patient was extubated the following morning. There were no complications of the REBOA procedure. He received a plastic surgery consult for an upper extremity injury involving tendon damage and a complex scalp laceration. He went to the operating room for repair of these structures on hospital day one. He underwent physical, occupational, and speech therapy and was discharged to home with outpatient occupational therapy on hospital day three.

DISCUSSION

The combination of the rural location, difficult extrication and multiple trauma patients at the scene significantly prolonged the prehospital time for this patient. This is an otherwise healthy trauma patient who suffered substantial blood loss from non-truncal sites, resulting in hemorrhagic shock that progressed to traumatic arrest from seemingly minimal injuries. This is not the only case such as this described in the literature. In 2005, a large case series of both blunt and penetrating extremity injuries progressing to traumatic arrest was performed [5]. In that series, the patients who received CPR or resuscitative thoracotomy all died. Most trauma centers have patients that have arrested from isolated extremity bleeding, and all students are taught that scalp lacerations bleed profusely. This case is an example of how combining these seemingly non-lethal injuries with prolonged transport time resulted in a near fatal outcome. This may represent a potentially avoidable scenario by earlier recognition of hemorrhagic shock, early use of blood product resuscitation, limiting the use of crystalloid during transport and thus avoiding acidosis. This case highlights a few of the difficulties in prehospital trauma care and potential opportunities for improvement as a trauma system.

The patient in our case, fortunately, did not arrest until shortly after arrival at the trauma center. We had recently instituted a REBOA training program for our physicians and staff. Our training program consisted of a lead trauma surgeon who demonstrated skills and interest in the technology. A small group of surgeons was chosen to attend the basic endovascular skills for trauma (BEST) course in Baltimore, MD. These individuals subsequently trained the remaining surgeons and hospital staff. Guidelines were adopted from the Joint

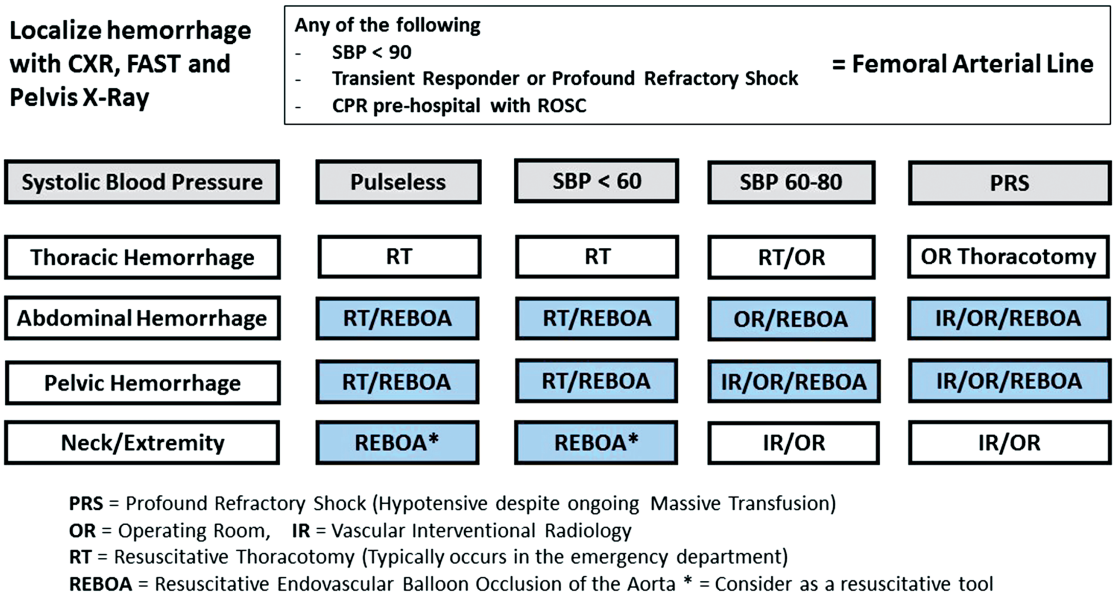

Figure 4 Guideline for approach to hypotensive trauma patients.

Trauma System Clinical Practice Guideline [6] and reviewed for implementation by leaders of our multidisciplinary trauma team (Figure 4). A combination of didactics and hands-on simulation were utilized to train providers. We included the emergency department physicians and staff, SICU and operating room staff, house staff, trauma advanced practice providers and nursing teams in REBOA training sessions. Initial implementation was complicated by difficulties in packaging an ER-REBOA kit, training trauma nursing staff to assist with the arterial line set up, and obtaining catheters for locations outside the trauma bay. After months of training, implementation and use throughout multiple hospital locations we learned that investment into REBOA specific procedure carts (much like "crash" carts) that include all necessary supplies for arterial access and deployment of an ER-REBOA was effective for deployment and efficient for restocking.

Our patient benefited from the location of arrest, preparation of the resuscitative team and continued simulation with the institutions REBOA protocol. The interesting aspect, in this case, is that he did not have truncal hemorrhage, the classic indication for REBOA. After repeat FAST exams, several CXRs and because of continued hemodynamic stability after REBOA placement, ultimately a CT revealed no evidence of intrathoracic, abdominal or pelvic injury, obviating the need for other invasive procedures. This case is a good example of how temporarily reducing a patient's effective circulating volume along with blood product resuscitation enabled us to break the cycle of hemorrhagic shock while maintaining brain and cardiac perfusion. Similar results have been shown in aortic occlusion in non-traumatic cardiac arrest animal models [7]. In these models, the occluded aorta was found to increase coronary and cerebral perfusion and associated with a significant increase in ROSC and good neurologic outcome. In our case, this resuscitative technique allowed more deliberate noninvasive interrogation and planning of next steps. Without the immediate hemorrhage control capability provided by the ER-REBOA™, this patient would have had a thoracotomy and likely a laparotomy, without identification of injury. Because we had trained our entire trauma team for rapid REBOA placement, this patient went home in three days with minimal morbidity. This case highlights use of the ER-REBOA™ in a non-traditional fashion, but demonstrates how this capability is evolving, and becoming part of the routine care we provide for bleeding patients.

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