Original Article

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REBOA and the Open Abdomen

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Background: Uncontrolled hemorrhage is a significant cause of death worldwide. Rapid bleeding control is a major life saving goal. Resuscitative endovascular balloon of the aorta (REBOA) is a minimally invasive technique that temporarily occludes the aorta and achieves hemorrhage control.
Methods: We present a case series of patients that underwent emergent laparotomy due hemorrhagic shock and were stabilized intraoperatively using REBOA.
Results: Between December 2018 and September 2021, intraoperative REBOA was inserted in six patients. Etiologies included two postpartum hemorrhages, two gastrointestinal bleeds and two trauma cases. REBOA was positioned and inflated in the descending aorta (n = 3) and infrarenal aorta (n = 3). In all cases, REBOA resulted in immediate stabilization of blood pressure, enabling definitive treatment. Partial inflation was performed in all cases after initial stabilization. There was one minor access related complication, treated successfully. There was no mortality at 6 months follow up.
Conclusions: REBOA is another important resuscitative tool to be considered, also in the open abdomen. It allows for hemodynamic stabilization and enables definitive surgical repair of other major injuries.

Keywords: *REBOA; Open Abdomen; Partial Inflation*

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INTRODUCTION

REBOA is a technique for temporary stabilization of patients with non-compressible torso hemorrhage. This technique has been increasingly used worldwide during the past decade [1]. REBOA placement involves maneuvering a compliant balloon over the wire into the aorta where it is then inflated, obstructing blood flow into distal circulation [2]. The rate-limiting and crucial first step of the procedure is arterial access, usually via the common femoral artery (CFA). In trauma cases, arterial access is typically gained in one of three ways: a blind percutaneous approach using anatomic landmarks and palpation, ultrasound (US)-guided percutaneous access, or surgical cut-down to facilitate direct visualization and access. In patients with severe hemorrhage in need of REBOA placement, the percutaneous approach using anatomic landmarks and palpation, when compared with US-guided femoral access, was used more frequently without an increase in complications [3]. Percutaneous and surgical cut-down have similar safety profiles and outcomes when used appropriately in selected patients [4]. The use of REBOA as a bridge to definitive control for massive hemorrhage has provided promising results also in non-trauma patients [5].

Accumulative data suggest that hybrid management may be associated with a shorter time from arrival to intervention, lower rates of unfavorable outcomes and a reduced requirement for red blood cell transfusion as compared with conventional management of trauma patients [6]. However, in real life scenarios, patients with hemorrhagic shock do not always receive early arterial access nor reach a hybrid operating theatre. Therefore, REBOA is another important resuscitative tool to be considered, also in the open abdomen.

METHODS

We present a case series of patients with hemorrhagic shock in which REBOA was placed after laparotomy.

Ethical Approval and Informed Consent

Ethical approval was not required. The information has been anonymized and informed consent was not required.

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RESULTS

Between December 2018 to September 2021, intraoperative REBOA was placed in six patients. Etiologies of hemorrhagic shock included two postpartum hemorrhages, two upper or lower gastrointestinal bleeds and two trauma cases (one blunt and one penetrating). Tokai's rescue balloon (REBOA) was inserted by a vascular surgeon through a CFA cut-down, using an 8-Fr sheath. It was positioned and inflated in thoracic aorta Zone 1 (n = 3) and aortic bifurcation Zone 3 (n =3). In all cases, REBOA resulted in immediate stabilization of blood pressure allowing further definitive bleeding control. Partial inflation was applied in correlation to blood pressure. Five cases of REBOA were inserted without fluoroscopy and one case was performed in a hybrid suite with fluoroscopy. Heparin was not given systemically, the sheath was flushed with heparin solution. One minor access related complication occurred, with CFA local dissection and thrombosis that was repaired successfully after sheath removal. There was no major REBOA complications. All patients survived. No mortality was reported at 3 and 6 months follow up.

Cases

Case 1

A 28-year-old female presented with postpartum hemorrhage and hemodynamic deterioration after emergent cesarean section. She underwent an explorative laparotomy. Bleeding was identified from the uterus suture line and sutured. An hour later she deteriorated again and underwent re-exploration. An expanding retroperitoneal hematoma (Zone III) was found. Before transporting her to the angiography suite for possible embolization she was hemodynamically stabilized by massive blood transfusion and REBOA insertion through a left femoral cut-down. It was positioned and inflated in Zone 3 with immediate blood pressure stabilization, mean arterial pressure (MAP) increased from 60 to 112 mmHg. We transferred the patient to the angiography suite with full balloon inflation, then partial deflation in accordance with invasive MAP in the arterial line (AL). Full inflation time was about 15 minutes, and partial inflation was about 10 minutes. Angiography through the contralateral CFA revealed bleeding from the internal iliac artery (IIA) branch. Embolization was successfully performed and the patient was stabilized (Figure 1). The patient was discharged home a week later.

Case 2

A 35-year-old female with a history of Crohn's disease gave birth vaginally. Shortly afterward she started to complain about severe right flank pain with rapid hemodynamic deterioration. Immediate resuscitation with massive blood transfusion was initiated; however, she continued to deteriorate, and an emergent laparotomy was performed in a non-hybrid room along with CFA cut-down. REBOA was inserted through the right CFA, inflated in Zone 3 with immediate stabilization, and systolic blood pressure increased from 50 to 80 mmHg.

Upon exploration with midline laparotomy a large hematoma of the right kidney and abdomen was observed, along with lacerations of the inferior vena cava (IVC)

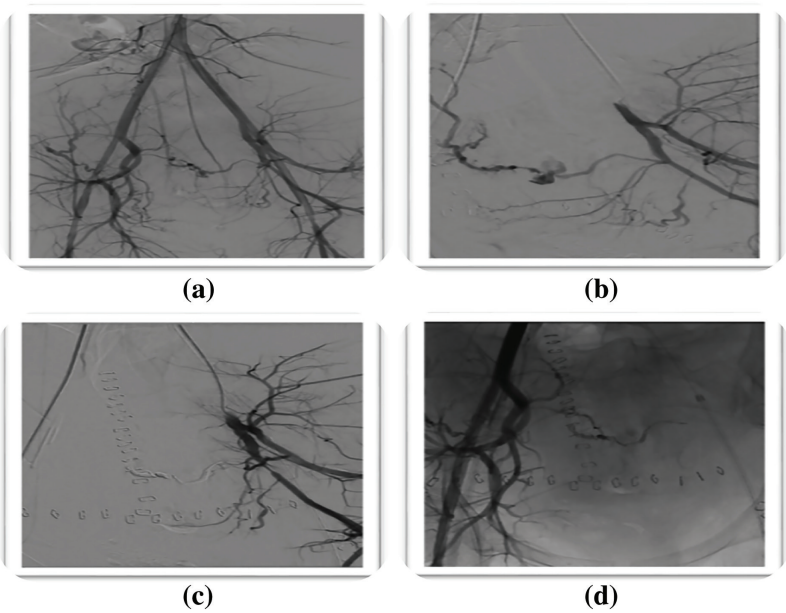


Figure 1 (**a**) Aortography through the right CFA, bleeding from IIA branch. (**b**) Selective left IIA angiography. (**c**) Selective embolization to the left IIA branch with onyx. (**d**) Selective right common iliac artery angiography.

near the origin of the right renal vein with active bleeding. REBOA at the aortic bifurcation reduced IVC bleeding and allowed for heart and brain resuscitation as she went into two episodes of ventricular fibrillation. Suture of IVC and right nephrectomy were performed. Total complete balloon inflation time was 20 minutes, whereas partial balloon inflation was applied intermittently for 60 minutes. The patient stabilized and was extubated on the same day and held her newborn on the next day.

Pathology confirmed fibromuscular dysplasia (FMD) with medial type and segmental thinning of the renal artery wall with rupture. Computed tomography of the abdomen, thorax and brain revealed dilatation of the left renal artery at the hilum, without other vascular pathologies. She was diagnosed with hypertension, stabilized successfully with medical treatment. Further follow up was recommended.

Case 3

A 24-year-old male presented with multiple gunshot wounds to the abdomen and lower extremity. On admission to the emergency room he was hemodynamically unstable, resuscitation was initiated without improvement and emergent laparotomy was performed. A Zone I expanding retroperitoneal hematoma was observed. REBOA was inserted through right CFA cut-down, inflated in Zone I, with immediate blood pressure stabilization from MAP 47 mmHg to 107–115 mmHg and subsequent partial inflation within a few minutes. Total partial inflation time was 20 minutes. A large laceration of the infra renal IVC without posterior wall involvement was detected and sutured (Figure 2). The patient was discharged to rehab 2 weeks later.

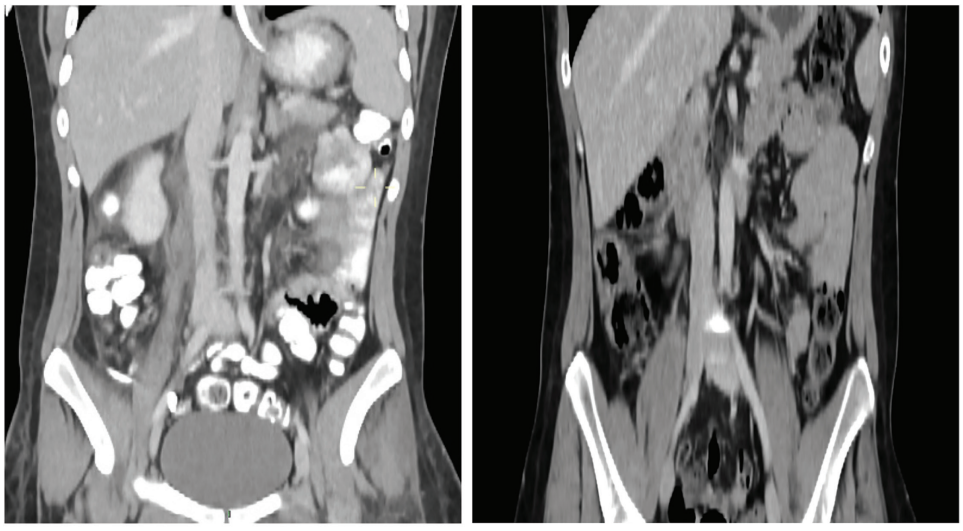
Case 4

A 29-year-old male, after a fall from a height, presented with multiple pelvic fractures. He was hemodynamically unstable, underwent emergent laparotomy with retroperitoneal hematoma. REBOA was inserted through the right CFA and inflated in Zone III, using partial inflation. Massive blood transfusion protocol, pelvic packing and external fixation was performed. REBOA was fully deflated and the patient was hemodynamically stable. After sheath removal, CFA and distal pulses were nonpalpable. CFA dissection with local thrombosis was successfully repaired. The patient was discharged to rehab a few weeks later.

Case 5

A 66-year-old male presented with poorly differentiated adenocarcinoma of the pancreas and underwent a Whipple's operation. One week later he presented with hemorrhagic shock, and he underwent selective angiography without an obvious bleeding source. He continued to be unstable and was taken immediately for laparotomy. A large hematoma without active bleeding was found in addition to pus, and repair of the pancreatic anastomosis was performed. He was treated with broad-spectrum antibiotics, in addition to massive blood transfusion and vasopressors. A follow up computed tomography angiography (CTA) was performed 2 days later, and no active bleeding was demonstrated.

A few days later, massive bleeding in the drains (500 ml within a few minutes) occurred with severe hemodynamic deterioration despite massive blood transfusion and increasing doses of vasopressors. He was taken again for emergency exploratory laparotomy. REBOA



(a) **(b)**

Figure 2 (**a**) Coronal CTA view with patent inferior vena cava (IVC) with local residual thrombus at the repair site, the patient received oral anticoagulation. (**b**) CTA 3 months later, patent IVC without residual thrombus.

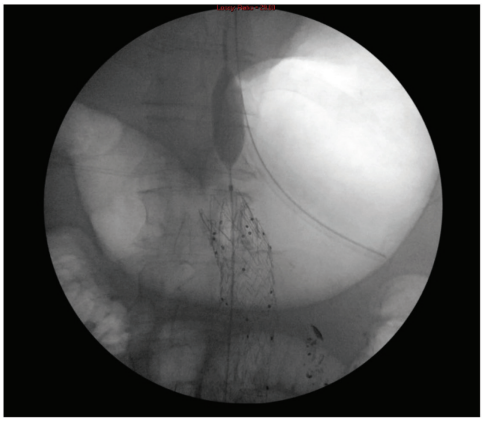


Figure 3 Fluoroscopy image, REBOA at Zone 1. The tip of the crown is on the superior mesenteric artery level, and the balloon is inflated in the supra celiac aorta.

was inserted through the right CFA and placed in Zone 1, facilitating resuscitation and definitive treatment. Invasive blood pressure was monitored through the radial AL, and the mean arterial blood pressure was 55 mmHg which increased to 75–80 mmHg after REBOA inflation. Exploration of the source of bleeding with partial and intermittent REBOA deflation in accordance with blood pressure allowed for detection of the bleeding source, primary repair of the common hepatic artery and ligation of the gastroduodenal stump was performed. Total full inflation time was 15 minutes. The patient had a prolonged recovery in intensive care unit and a surgical ward, and was discharged a few weeks later.

Case 6

A 72-year-old male had a history of elective endovascular aortic repair (EVAR) in 2010 and endovascular repair of a type I endoleak in 2018. He presented with upper gastrointestinal bleeding and severe hemodynamic instability that did not respond to massive blood transfusion protocol and increasing vasopressors doses. Therefore he was taken directly for emergent exploratory laparotomy. The differential diagnosis was ruptured abdominal aortic aneurysm, aortoenteric fistula or other upper gastrointestinal bleeding pathology. Simultaneously, laparotomy and REBOA insertion through a right CFA cut-down were performed. REBOA was positioned and inflated under fluoroscopy in the supra celiac aorta, with an increase of systolic blood pressure (SBP) of 60 mmHg to 80 mmHg (Figure 3). Afterwards, REBOA was temporarily deflated and angiography was performed to rule out aortic-related pathologies. Exploratory laparotomy was performed and a duodenal ulcer with active bleeding was found and repaired.

DISCUSSION

We present a subgroup of patients who required intraoperative proximal aortic control due to uncontrolled massive bleeding from various causes. REBOA presents advantages in comparison to an aortic clamp and there are a few reports that support this claim. Abe et al. showed that REBOA might be a favorable alternative method to aortic cross-clamping (ACC), especially for severe trauma below the diaphragm [7,8]. Prolonged aortic occlusion results in distal ischemia, which can exacerbate cellular injury following balloon deflation and reperfusion [9].

Current recommendations suggest that occlusion time should be less than 30 minutes [10,11]; this is not always practical due to the injury complexity. The technique of partial REBOA (P-REBOA) allows for a low-volume aortic flow around the partially deflated balloon minimizing the effects of distal ischemia. This REBOA technique was first described by Johnson et al. in 2016 [12], who, using a porcine hemorrhagic shock model, demonstrated that P-REBOA is associated with a more physiological hemodynamic profile than complete REBOA [13].

Animal studies suggest that P-REBOA can effectively maintain central perfusion with minimal metabolic burden and less adverse hemodynamic changes [14,15]. Other studies suggest that P-REBOA allows prolongation of the intervention time to over 60 minutes in Zone I [16], as well mitigating the hemodynamic liability of total occlusion and rapid balloon deflation [13].

Madurska et al. demonstrated that prolonged P-REBOA is associated with less organ failure than complete REBOA. P-REBOA might be a useful tool in safely prolonging REBOA while avoiding the detrimental consequences of prolonged complete occlusion [17]. Infrarenal REBOA avoids dissection of aortic bifurcation in a hostile abdomen, achieving control through the groin. Such dissection can increase the risk of other venous (inferior vena cava and iliac vein) injury, and sympathetic innervation damage.

REBOA is another resuscitative tool in our toolbox to be considered also in the open abdomen. REBOA allows for rapid hemodynamic stabilization and definitive multiteam surgical repair of major injuries with less morbidity.

Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.
(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Author Contributions

All authors contributed to the manuscript writing.

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