Narrative Review Article

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Indication of Resuscitative Endovascular Balloon Occlusion of the Aorta in Non-Traumatic Hemorrhage

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Many blunt trauma injuries have multiple bleeding points and are accompanied by coagulopathy. In contrast, in a non-traumatic injury, the patient often demonstrates a single bleeding site that is rarely accompanied by coagulopathy. Thus, resuscitative endovascular balloon occlusion of the aorta (REBOA) is considered more effective in non-traumatic cases than in traumatic cases. In addition, in non-traumatic cases, REBOA may be used for central blood flow control during definitive hemostasis and prevention of expected massive bleeding. In such cases, REBOA should be used carefully to avoid complications. We describe the indications for and uses of REBOA in non-traumatic cases based on existing evidence.

Keywords: *Resuscitative Endovascular Balloon Occlusion of the Aorta; REBOA; Non-Trauma; Hemorrhagic Shock; Management*

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INTRODUCTION

In recent years, an increasing number of studies have described the efficacy of resuscitative endovascular balloon occlusion of the aorta (REBOA) for non-traumatic hemorrhagic conditions below the diaphragm, such as the rupture of abdominal aortic aneurysm (AAA), rupture of abdominal visceral pseudoaneurysm including postoperative bleeding, gastrointestinal bleeding, and obstetric crisis bleeding. Most injuries in Japan are blunt injuries, and many of them have multiple bleeding points that are accompanied by coagulopathy. On the other hand, in a non-traumatic state, the patient often demonstrates a single bleeding site that is less frequently accompanied by coagulopathy. Thus, REBOA is considered to be more effective in controlling bleeding in non-traumatic cases than in traumatic cases [1,2].

As with traumatic resuscitation, REBOA as a means of resuscitation in non-traumatic hemorrhagic conditions should also be used as a bridge to achieve definitive hemostasis. REBOA insertion should not delay the initiation of definitive hemostasis. In non-traumatic conditions, REBOA may be on standby to control central blood flow during hemostasis or used prophylactically to prevent expected massive bleeding. When using REBOA for these purposes, the indications for partial and intermittent occlusion should be considered aggressively to minimize ischemic time and maintain peripheral blood circulation. It is necessary to manage REBOA while closely monitoring the general condition until definitive hemostasis is completed and use it carefully to avoid complications as

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much as possible. The purpose of this review article is to understand the differences between traumatic and non-traumatic conditions and to explain the indications, procedures, and management of REBOA in each non-traumatic condition, such as ruptured abdominal aortic aneurysm (rAAA), upper gastrointestinal bleeding, and obstetric hemorrhage based on existing evidence.

Ethical Approval and Informed Consent

Ethical approval was not required. Informed consent was not required.

ABDOMINAL AORTIC ANEURYSM RUPTURE

Previous studies have demonstrated the efficacy of REBOA for managing infra-diaphragmatic hemorrhagic diseases such as AAA rupture and visceral artery pseudoaneurysm rupture postoperatively, necrotic pancreatitis, and other iatrogenic causes [3–7]. rAAA still shows significant mortality, Circulatory collapse is the leading cause of death in patients with rAAA,and almost half of patients die before hemostasis is achieved.

The efficacy of intra-aortic balloon occlusion for rAAA has been described as far back as 19501960s [8]. Progress of balloon devices [9] and modalities such as angiography suite or hybrid operative room [10] possibly contributed to increased utilization of REBOA for rAAA[11]. Recent systematic review demonstrated the use of REBOA in unstable rAAA patients undergoing emergency room may improve the survival and estimated the utilization rate of REBOA across the pooled population was 14% [12].

Utilization of REBOA for rAAA could be efficient for definitive treatment; however, the clinical practice of REBOA for rAAA in emergengent situation was still challenging. In this chapter, we guided optimal utilization of REBOA for rAAA with literature reviews.

Circumstances of REBOA for rAAA

Historically, patients with catastrophic physiologies by rAAA were not thought to be candidates for an endovascular approach [13] because of the extra time in preparing for an endovascular approach. Recent progress of diagnostic modalities such as angiography suite and/or hybrid theater could enable hypotensive patients with rAAA to undergo an endovascular approach and REBOA may contribute to extend the time needed to conduct endovascular repair. The team at Cincinnati University reported a protocol of REBOA for all hypotensive patients with rAAA in a hybrid operative room and survival has improved over time [10]. As described below, the deployment of REBOA into Zone 1 is challenging and should be conducted under fluoroscopic guidance in either way by brachial/axillary artery or femoral artery.

Insertion of REBOA

Left brachial artery or axillary artery

The left brachial artery or axillary artery approach is safe because REBOA does not pass through the AAA. However, with this approach, it sometimes takes longer to insert the sheath or guide the REBOA from the left subclavian artery to the descending aorta. Technical tips to guide the REBOA to the descending aorta by adjusting the tip of the catheter and advance the guidewire to the descending aorta or pull-through method.

The placement of REBOA via the left upper extremity enables stable aortic occlusion without downstream migration, which could be dangerous during laparotomy. The upper extremity REBOA creates a dry operative field without the direct aortic clamp [8]. The adverse effect of the left upper artery approach is the possibility of arterial dissection at the origin of the left subclavian artery, which is thought to be caused by mechanical damage owing to proximal pressure elevation and elevated arterial pulse after balloon inflation.

Femoral artery

The advantage of the femoral artery approach is that it is safer and more accessible than the left upper extremity approach. REBOA via the brachial artery cannot be deployed without fluoroscopy. However, the femoral artery approach can be performed using ultrasound or a portable X-ray. Radiography confirms that the guidewire is in the aorta, and that the tip has passed the ruptured aneurysm. The guidewire may proceed to the extraluminal space (extra-aortic space) and deteriorate the ruptured aneurysm. Therefore, it is reasonable to proceed with the guidewire using fluoroscopy.

In AAA patients in particular, downstream migration is more apparent because AAA patients often have an expanded aorta with strong tortuosity. In cases of strong tortuosity, it is sometimes difficult to re-insert the stylet into the REBOA, so it will be necessary to switch from the femoral artery approach to the left upper artery approach. Using the femoral approach as the first access in the emergency room and later switching to the left brachial approach with fluoroscopy could be a practical strategy.

After REBOA Deployment

After REBOA deployment and inflation, the patient should undergo immediate definitive treatment for rAAA. Three randomized controlled trials (RCTs) have studied the optimal treatment for ruptured aneurysms, EVAR or open surgical repair [15–17]. Taking together these RCTs, the obvious difference in 30-day mortality was not noted. Especially, the populations among these RCTs, hypotensive patients who had benefit from REBOA were not included and further prospective study was warranted.

UPPER GASTROINTESTINAL BLEEDING

Previous studies have reported the use of REBOA for upper gastrointestinal bleeding (UGIB) of non-variceal hemorrhage due to conditions such as gastric ulcers, duodenal ulcers, and malignant disease [18–20]. The anatomical consideration of REBOA may be adapted to inferior gastrointestinal bleeding such as diverticulum bleeding, but these cases rarely have an extreme shock-state, and there have been no previous reports.

The origin of arterial bleeding in UGIB is branches of the celiac artery or the superior mesenteric artery (SMA), such as the gastric artery, gastroepiploic artery, or gastroduodenal artery. The balloon catheter is positioned in Zone 1. The femoral artery approach is the first choice of treatment. The most typical indication is treatment failure of endoscopic therapy. A previous case report demonstrated resuscitation after cardiac arrest following REBOA deployment [21].

Subsequent definitive treatments include endovascular therapy (angioembolization or stent graft), endoscopic therapy, or surgical hemostasis. The proximal control by REBOA is feasible and effective in any of the above. When endovascular therapy is chosen, switching from Zone 1 REBOA to selective balloon occlusion in the celiac artery or SMA is a better option to localize the ischemic areas, resulting in the reduction of ischemia-perfusion injury.

There have been no reports of REBOA use in patients with variceal UGIB. This benefit is not expected anatomically. To date, the use of REBOA in UGIB have been indicated only in cases of arterial bleeding.

OBSTETRIC HEMORRHAGE

Prophylactic Use in Elective Cesarean Delivery

Selective balloon catheters can be placed in the bilateral internal iliac arteries or common iliac arteries in elective cesarean section cases with abnormal placentae, such as placenta previa or placenta accreta. A decrease in intraoperative bleeding is expected due to bilateral selective balloon occlusion. Many publications have reported REBOA use in elective cesarean sections and their effectiveness in reducing intraoperative bleeding in recent years [22–27]. REBOA is more feasible than bilateral selective balloon occlusion, owing to its simplicity.

Postpartum Hemorrhage

Multiple criteria for the diagnosis of postpartum hemorrhage (PPH) are used worldwide. Classical PPH is defined as blood loss of more than 500 mL following vaginal birth or more than 1,000 mL following cesarean delivery. The Japanese guideline focuses on vital sign abnormalities (oliguria, peripheral malperfusion), shock index ≥1.5, or coagulopathy (obstetrical disseminated intravascular coagulation score ≥8 points or fibrinogen level ≥150 mg/dL) in obstetric critical bleeding. The guidelines refer to hemostatic procedures, uterine compression sutures, interventional radiology (angioembolization, REBOA), vaginectomy, and total hysterectomy. PPH includes not only atonic hemorrhage, but also birth canal lacerations and uterine inversion. Hemostatic procedures differ according to etiology. Even among atonic hemorrhages, the hemostatic strategy is based on the bleeding site, the presence or absence of retained placenta, and delivery mode (vaginal delivery or cesarean section).

Indication and purpose

Recently, there have been reports describing the effectiveness of REBOA for PPH [28,29]. REBOA may be used more proactively to manage PPH in the future. However, providers must bear in mind that application of REBOA is not equal to establishment of hemostasis; it is solely a temporary measure controlling arterial blood flow. PPH is often accompanied by coagulopathy, as observed in polytrauma. In both cases, hemorrhage and coagulopathy must be simultaneously managed promptly. The resuscitation team must have close contact with the blood bank, and a massive transfusion protocol (MTP) must be initiated.

Atonic hemorrhage is the most frequent cause of PPH. Hemostatic procedures for atonic hemorrhage include the intrauterine balloon (e.g., Bakri® postpartum balloon), angioembolization of the uterine artery, and hysterectomy. Administration of oxytocic agents, tranexamic acid, and early activation of the MTP are also crucial. REBOA works as a bridge to angioembolization or hysterectomy and also functions as a proximal control during the operation.

Approach and pitfalls

The femoral artery approach is usually the first choice. There are some pitfalls specific to patients with PPH. First, the lower abdomen is stretched during the postpartum period, leading to low puncture. Ultrasound guidance is recommended to identify the common femoral artery and not the superficial femoral artery. Second, the lithotomy position is the standard for obstetric pelvic examination, where femoral puncture is impossible. The resuscitation and obstetric teams should create a consensus in advance. The patient needs to maintain the supine split-leg position during the puncture procedure at the groin. After sheath placement, the leg on the sheath side shall be extended to avoid bending the sheath. Only the contralateral leg should be raised, and the sheath side remains extended during pelvic examination.

Level of the balloon occlusion

Zone 3 is the standard occlusion level in patients with PPH. In case of impending cardiac arrest, the level of the

balloon occlusion should be Zone 1 to increase the proximal blood pressure, even when Zone 3 is anatomically sufficient to regulate the arterial flow. The ovarian artery may strongly supply the pregnant uterus. Although Zone I occlusion is required to regulate the ovarian artery flow, bilateral uterine artery control through Zone 3 REBOA is usually sufficient. The risk of Zone 1 REBOA must be considered, as it can cause ischemia of the visceral organs. The level of aortic occlusion must be chosen according to the hemodynamics, assumed bleeding site, and risk of ischemia.

Although REBOA insertion without fluoroscopy guidance has been reported, accurate Zone 3 placement while going in blind or with ultrasound guidance is technically difficult because Zone 3 is a short segment. The umbilicus is an external landmark of the aortic bifurcation. After placement, the balloon position should be checked with radiography or fluoroscopy before inflation.

The following are the technical tips for blind positioning in Zone 3. First, aim at a slightly higher level (approximately 30 cm) without fixing the catheter. Next, inflate the balloon to complete occlusion. Then, deflate a little (create a partial REBOA). Thereafter, draw the catheter back gently until resistance is met (the balloon is on the aortic bifurcation). Finally, inflate the balloon at Zone 3. This procedure is called the blind Zone 3 placement, but it has the risk of scratching the aortic wall. Another risk is balloon migration to the common iliac artery ("Zone 4") when the balloon is deflated excessively. Common iliac occlusion does not regulate pelvic arterial flow and induces lower-limb ischemia on the sheath side.

Multidisciplinary cooperation is the key to successful management and it involves multiple specialties: airway and respiratory management, pelvic examination and intrauterine balloon, massive transfusion, arterial access, REBOA, angioembolization, and surgery.

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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

Yosuke Matsumura was a clinical advisory board member of Tokai Medical Products (2015–2017). The other authors declare that they have no conflicts of interest.

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Author Contributions

KS and MA was responsible for drafting, editing, and submission of the manuscript. YM critically appraised the manuscript. KS, MA, KI, MT, and YM contributed to the critical revision of the manuscript for important intellectual content and provided intellectual input to the research and manuscript. All authors read and approved the manuscript.

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