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Trends in Aortic Occlusion and How to Minimize the Risk of Complications in REBOA

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Resuscitative endovascular balloon occlusion of the aorta (REBOA) increases proximal aortic pressure in order to maintain central organ perfusion pressure, and simultaneously regulates distal arterial flow by endovascular aortic occlusion, which is applied during subdiaphragmatic hemorrhage. This article briefly introduces the history of REBOA and discusses its potential effectiveness and harmfulness. The article also mentions the technical aspects of REBOA, and reconsiders the term "REBOA" and "resuscitation." The risks of aortic occlusion and ischemia-reperfusion injury have not been fully elucidated. It is hoped that REBOA can be used appropriately as a powerful option for the resuscitation of hemorrhagic patients and save the lives of as many patients as possible. The Society of Diagnostic and Interventional Radiology in Emergency, Critical Care, and Trauma will publish continuous medical education articles on REBOA.

Keywords: *Resuscitative Endovascular Balloon Occlusion of the Aorta; REBOA; Complication*

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INTRODUCTION

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a resuscitative maneuver using a balloon catheter through the femoral artery. It increases the proximal aortic pressure in order to maintain central organ perfusion pressure, and simultaneously regulates distal arterial flow by endovascular aortic occlusion. REBOA has been applied to subdiaphragmatic hemorrhage. It enables less invasive aortic occlusion in contrast to resuscitative thoracotomy with an aortic cross-clamp (RTACC) [1,2].

Ethical Approval and Informed Consent

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

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HISTORY OF REBOA

The history of aortic balloon occlusion dates back to the Korean War in the 1950s [3], and the devices have been commercially available in Japan since the 1990s. The device has been recognized as "Intra-aortic balloon occlusion (IABO)" [4], which has been used during resuscitation in severe hemorrhagic shock in torso trauma or postpartum hemorrhage, as a proximal control during surgery, and for prophylactic purposes in high-risk cesarean sections. The aortic occlusion device is not recognized globally, and there has not been a standard indication for use; rather it depends on the institutional or operator's policy.

The term "resuscitative endovascular balloon occlusion of the aorta (REBOA)" was first published in the Journal of Trauma in 2011 [5]. Since then, the global trend of aortic balloon occlusion devices has drastically changed. The Block Balloon™ (Senko Medical Instrument, Tokyo, Japan) has been on the market, and it is compatible with a 10 Fr sheath [6]. Since this catheter was not available outside Japan, the Coda® Balloon Catheter (Cook Incorporated,. Bloomington, IN, USA) or Reliant™ Stent Graft Balloon Catheter (Medtronic,, Minneapolis, MN, USA) were used in some European countries and in the United States. The Rescue Balloon® (Tokai Medical Products, Aichi, Japan) [7], a small profile 7 Fr sheath compatible catheter, was launched in

Japan in 2013 and became available internationally. The ER-REBOA™ Catheter (Prytime Medical, Boerne TX, USA) [8] was approved and launched in the United States, after which it rapidly spread globally. The REBOA Balloon Kit™ (REBOA Medical AS, Norway) [9] and the COBRA-OS™ (FrontLine Medical Technologies, ON, Canada) [10] followed, and the development of new technology and device competition is still ongoing.

EFFECTIVE OR HARMFUL?

REBOA appears to be effective in the resuscitation of severe hemorrhagic shock patients, and many have experienced cases in which they felt it was lifesaving [11,12]. In cases of splenic injury without chest trauma, REBOA may be a better alternative to RTACC for resuscitation, instead of rushing for splenectomy. It also helps to prevent sudden hemodynamic collapse at the time of laparotomy. In post-partum hemorrhage, it may function as a proximal control tool to create a dry operative field, to decrease the intraoperative blood loss and transfusion [13–16].

However, improper use of REBOA is harmful and can easily lead to complications and life-threatening situations. In addition, database analysis has reported that there is no solid evidence that the use of REBOA contributed to improved survival outcomes, but rather that it was harmful [17–19]. In a super-aging society like Japan, REBOA is often placed in high-risk elderly patients with vascular stenosis, calcification, and tortuosity. If the procedure and management after placement is not understood, complications will occur [20]. Understanding physiological and anatomical adaptations are not sufficient to unlock the potential value of REBOA. It is essential to establish a consistent medical care system that includes resuscitation, hemostasis, and intensive care for patients with hemorrhagic shock.

The balloon is usually positioned in zone 1 or zone 3 according to the hemodynamics and assumed injury sites. Zone 1 extends from the origin of the left subclavian artery to the celiac trunk, zone 2 extends from the celiac trunk to the lowest renal artery, and zone 3 exists from the lowest renal artery to the aortic bifurcation [5,21]. Hemodynamics and injury sites are uncertain in trauma cases. Considering the hemodynamics (urgency of cardiac arrest), chest trauma (especially aortic injury), and arterial access, we should consider choosing REBOA or RTACC correctly, or converting RTACC to REBOA [22]. On the other hand, there are some non-traumatic cases for which REBOA is indicated. Zone 3 REBOA contributes to resuscitation in the patients with post-partum hemorrhage [14]. The elective use of REBOA also decreases blood loss and transfusion during cesarean delivery in the placenta accrete [16]. REBOA can be used in abdominal aortic aneurysm and gastrointestinal bleeding [23,24]. In both traumatic and non-traumatic cases, REBOA is used as a bridge to definitive hemostasis, for proximal control, or for prophylactic purposes.

TIPS AND PITFALLS IN TECHNICAL PROCEDURES OF REBOA

The procedure of REBOA is relatively simple, but REBOA providers need to master the knowledge and skills needed to minimize the risk of complications [20]. The REBOA operator needs to choose several procedural options: arterial access (blind, ultrasound-guided, cut-down), imaging modality during the procedure (ultrasound, X-ray, fluoroscopy), positioning of the balloon (external landmark, vertebral body with fluoroscopy), and location (resuscitation room, angiography suite, operation room). There are several balloon-volume adjustment methods: blind injection until tactile feedback, pre-determined volume, and titration based on the femoral arterial pulse pressure. Each adjustment method differs in terms of accuracy, reproducibility, safety, and feasibility. The operator should always prepare plans B or C in the case of any difficulty.

THE TERM "REBOA"

Now, let us return to the consideration of the term "REBOA". Is this device really "resuscitative"? Does this device merely occlude the aorta? To answer these questions, we need to reconsider the meaning of "resuscitation".

"Resuscitation" during a cardiac arrest comprises chest compressions, adrenaline administration, defibrillation, and airway management [25,26]. "Resuscitation" for trauma assumes a broader situation and is a process of achieving physiological stability in the primary survey. Aortic balloon occlusion may work effectively in the process of "resuscitation". Aortic occlusion to avoid cardiac arrest in hemodynamic instability is truly "resuscitative". Such "resuscitative" REBOA has been compared to resuscitative thoracotomy and aortic cross-clamp [2,11].

There are many ways to use an aortic balloon occlusion catheter. In addition to resuscitative use, intraoperative proximal control in slightly more stable patients and prophylactic use in elective cases are other indications for aortic balloon occlusion. Even after responding to the fluid or transfusion, the aortic occlusion catheter provides safe intrahospital transport to the operating room as a partial occlusion or deflation.

In this way, the REBOA catheter has more potential in a non-resuscitative situation. In addition, REBOA does not contribute to resuscitation during a hemorrhagic shock. It is just a bridge to definitive hemostasis. Proper and safe use of aortic balloon occlusion, including proximal control [27] and prophylactic use [15], should always be carried out in front-line clinical practice without being overwhelmed by the term "resuscitative" in "REBOA".

CONCLUSION

The risks of aortic occlusion and ischemia-reperfusion injury have not been fully elucidated. REBOA should

only be used when really needed. In many situations, resuscitation and hemostasis without the use of REBOA is the best choice. It may not be available, depending on the patient's anatomy and the procedure environment. We strongly hope that REBOA can be used appropriately as a powerful option for resuscitation of hemorrhagic patients and can save the lives of as many patients as possible. The Society of Diagnostic and Interventional Radiology in Emergency, Critical Care, and Trauma will publish continuous medical education articles on REBOA.

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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