

# Crossing the Rubicon: REBOA and Endovascular Hemorrhage Control in 2022

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Resuscitative endovascular balloon occlusion of the aorta (REBOA) continues to prove its value as a tool to temporize refractory hemorrhagic shock secondary to non-compressible truncal hemorrhage, as first described by Lieutenant Colonel Carl W. Hughes in 1954 during the Korean War [1]. Early descriptions of the use of balloon aortic occlusion were case reports and series looking at mixed trauma and non-trauma settings. A systematic review of these reports by Morrison et al. [2] did not show a clear reduction in hemorrhage-related mortality. The debate on balloon aortic occlusion continued with studies in support of the use of REBOA [3–7] and studies expressing concern for the safety and efficacy of REBOA due to an association with increased mortality and access-site related complications [8–10]. The subsequent initiation of endovascular and REBOA catheter-specific courses in the past decade has led to a greater implementation and widespread adoption of the use of these devices and multiple collaborative efforts including the AAST Aorta Occlusion for Resuscitation in Trauma and Acute Care Surgery (AORTA) Registry, the international ABO Trauma Registry, ER-REBOA Catheter study and UK REBOA Trial. Since then, analyses from the AORTA Registry show that REBOA is indeed a viable alternative to open aortic occlusion [11], can assist with management in severe pelvic fractures [12] and may even offer a survival benefit in select patient populations [13,14].

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**Disclosure:** The opinions expressed in this article are those of the authors, and do not reflect the opinions or official policy of any affiliated medical center or other organization.

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The authors in this edition of JEVTM have done an excellent job investigating and surveying the impact of the use of REBOA across a broad range of indications and patient populations, as well as examining new technologies, approaches and algorithms for endovascular hemorrhage control. The breadth of topics covered in the papers for this edition give a thorough review of REBOA and its current best practices, explaining indications for REBOA in the trauma setting but also beyond trauma, methods for proper deployment of the catheter, cutting-edge techniques to reduce ischemia-reperfusion injury, and future direction for the use of balloon aortic occlusion.

The indications for the use of REBOA have been well-described in trauma patients [15], and the indications and contraindications are reviewed in detail by Ishida et al. They address and provide great discussion on current controversial topics such as the use of REBOA in chest trauma, intracranial hemorrhage, pediatric trauma, and the prehospital setting. The authors in this paper also make a thoughtful, critical point to remind us that REBOA itself is not the ultimate step in the treatment of uncontrollable hemorrhage but the bridge to definitive hemorrhage control. They correctly state that REBOA is “not a magical device” and transport to the operating theater or angiography suite should not be delayed. The review by Seno et al. then provides an excellent global overview of the procedural steps, techniques, and tips and tricks for successful arterial access and REBOA placement and deployment.

The use of REBOA has been implemented in multiple non-trauma clinical settings such as ruptured abdominal aortic aneurysms, obstetric hemorrhage, upper gastrointestinal bleeding, and elective pelvic tumor resections. Shinozuka et al. state that patients with non-traumatic sub-diaphragmatic hemorrhage usually demonstrate a single bleeding site and are rarely accompanied by coagulopathy making these patients good candidates for controlled, even partial or intermittent, aortic occlusion. When properly deployed and monitored, REBOA can be an extremely useful tool to help control or prevent expected massive hemorrhage. Matsumura and Shinozuka’s paper

continues to describe in more detail the endovascular strategies in achieving hemostasis in obstetrics and point out the additional advantage of the use of zone 3 REBOA with its potential risk reduction of operative injury to the ureter or bladder in a damage control operation. Given the high risk of maternal death from hemorrhage due to placental abnormalities and post-partum hemorrhage in settings with less robust capabilities, REBOA may be an ideal adjunct in the most austere setting to decrease these preventable deaths. A second paper by this same author highlights the high level of care and respect that we must have for the utilization of these devices, and an understanding of the associated complication profile as well as techniques to minimize or mitigate these adverse events. Sugiyama et al. then provide a thorough review of the numerous common and uncommon complications associated with REBOA, including access-site complications, iliac and aortic injury, malpositioning of the balloon, intracranial hemorrhage, and limb ischemia or compartment syndromes. In addition to outlining these issues, they provide helpful advice on recognizing and managing these complications.

In a pair of nicely written papers, Nagashima et al. discuss two critical issues in endovascular trauma management. In the first, they outline the indications, techniques, pros and cons of endovascular aortic occlusion versus thoracotomy and aortic cross-clamping, and a rational approach to making these time-critical decisions. In the second, they cover the under-appreciated but foundational aspects of obtaining safe and rapid early femoral arterial access to facilitate rapid REBOA placement and deployment if and when it becomes needed. This is an area that is often glossed over in discussions and courses on REBOA, but it represents one of the greatest “Achilles heels” of this technology in terms of both effective rapid deployment and the risk of major or even limb-threatening complications. We hope that these complications become less frequent and less severe as we gain increased familiarity and expertise in femoral access and in early recognition of developing complications, and as we move to smaller sheaths and devices such as the newly US Food and Drug Administration approved 4-French REBOA catheter.

One of the most interesting and surely most controversial papers in this edition is the piece by Miyauchi et al. discussing the use of REBOA as a bridge to performing whole body computed tomography (WBCT). While the traditional teaching and paradigm of REBOA has been that it should be used as a temporizing therapy to bridge the unstable patient to either the operating room or the angiography/interventional radiology suite, we agree with these authors that there are select patients who may be best served by immediate WBCT after REBOA deployment. This would include the patient with instability from a source that remains unclear or unidentified after the initial evaluation, the patient with a high suspicion for traumatic brain injury that may require urgent operative

intervention, the geriatric patient with coagulopathy, or the polytrauma patient with multiple compartment injuries but unclear order of prioritization or need for operative hemorrhage control. In order for this approach to be successful there must be a highly streamlined and well-rehearsed system in place that includes rapid movement to and performance of the WBCT, immediate imaging review and interpretation, continuous close monitoring with the ability to provide ongoing resuscitation, and the capability to abort and move expeditiously to the operating room or angiography suite if the patient becomes unstable. We would also draw a distinction between this approach in a patient with a zone 1 REBOA, where even a short increase in occlusion time carries major morbidity, versus a zone 3 REBOA, where longer occlusion times are better tolerated.

Finally, Hitomi et al. provide a brief but very well written review of the emerging concepts of partial and intermittent REBOA. We believe this area is one of the most exciting and promising for addressing the main limiter of more widespread adoption and utilization of REBOA, the resultant physiologic insult and ischemia-reperfusion injury that results from complete aortic occlusion. For the patient already in hemorrhagic shock, a zone 1 occlusion time of more than 30 min carries a high mortality, and a time of more than 60 min is almost universally fatal. The techniques of intermittent balloon inflation/deflation or partial controlled balloon deflation both aim to strike a balance between providing some perfusion distal to the area of occlusion but minimizing ongoing or recurrent hemorrhage below the balloon. Although there is a reasonable body of well-done large animal translational research for both of these approaches, data in human patients remains scant and anecdotal. It is also important to note that the standard REBOA catheters that have been used over the past decade were not designed to allow for fine or titratable control of flow with partial deflation, and it was not until very recently that we have had second generation devices that were designed to facilitate partial REBOA. We look forward to further accumulation of data and experience as more of these devices and techniques are utilized in human patients in both trauma and non-trauma settings. We also congratulate Dr. Hörer and the JEVTM as it enters its fifth year of publication and look forward to more exciting, novel, and groundbreaking work in future editions.

### 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 have no conflicts of interest to declare and have received no financial or material support related to this manuscript.

### Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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