Narrative Review Article

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Partial Resuscitative Endovascular Balloon Occlusion of the Aorta and Intermittent Resuscitative Endovascular Balloon Occlusion of the Aorta

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Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a resuscitation procedure for severe hemorrhagic shock. While complete occlusion of the aorta could be effective for the control of blood flow, there is always a concern for ischemia-reperfusion injury of the distal organs from the balloon catheter. REBOA can control the degree of occlusion by changing the injection volume of the balloon catheter. Partial REBOA and intermittent REBOA are some of the strategies of REBOA, with which less ischemia-perfusion injury is done, rather than complete occlusion of the aorta, although evidence on partial REBOA and intermittent REBOA is still limited. This review aims to share the practical knowledge of partial REBOA and intermittent REBOA, thorough the current literature and Japanese multi-specialty expert consensus.

Keywords: *Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA); Partial REBOA; Intermittent REBOA*

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INTRODUCTION

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is not a hemostatic device [1,2]. It provides time until definitive hemostasis while avoiding cardiac arrest and stabilizing the hemodynamic state. Compared to resuscitative thoracotomy with cross-clamp, REBOA can control the degree of occlusion. Total occlusion of the aorta always has a concern for ischemia-reperfusion injury of the distal organs from the balloon catheter. Partial REBOA and intermittent REBOA are the strategies of the REBOA with which less ischemia-perfusion may be feasible.

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Zone 1 total occlusion may be needed in some critical situations; however, partial REBOA or intermittent REBOA with rapid and sufficient transfusion and immediate hemostasis could maintain hemodynamic stability and organ perfusion.

This review aims to share the practical knowledge of partial REBOA and intermittent REBOA, thorough the current literature and multi-specialty expert consensus in the Japanese Society of Diagnostic Interventional Radiology in Emergency, Critical care and Trauma.

Ethical Approval and Informed Consent

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

PARTIAL REBOA

REBOA can control the degree of occlusion by changing the injection volume of the balloon catheter. Partial REBOA is one of the strategies of REBOA, in which the distal blood flow of the balloon is conserved and the

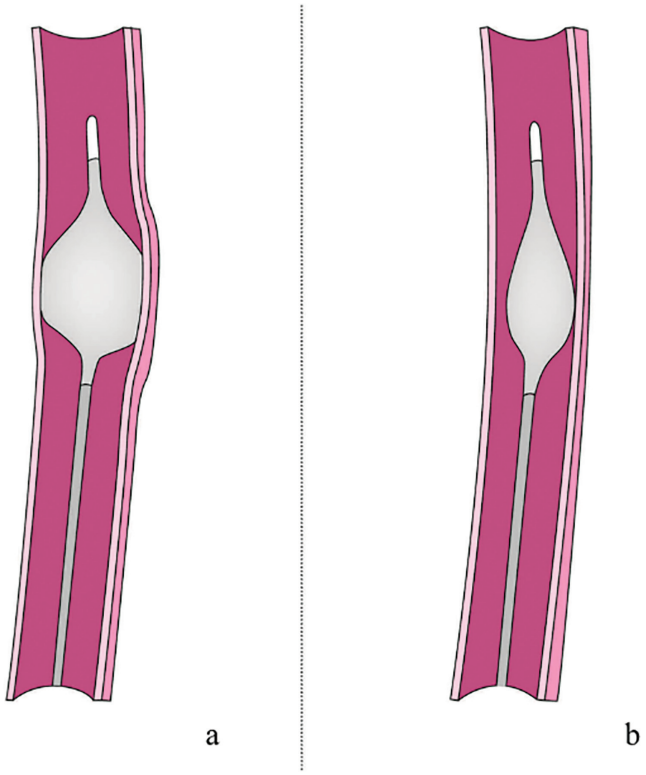

Figure 1 The schema of partial REBOA and total occlusion of the aorta. (**a**) In the situation of complete occlusion of the aorta, distal blood flow is restricted and ischemia-reperfusion injury is concerned. (**b**) Partial REBOA is able to maintain the distal blood flow of the balloon within the range of proximal perfusion kept.

range of proximal perfusion maintained (Figure 1) [3]. Partial REBOA could decrease ischemia-reperfusion injury because it could maintain the distal blood flow of the balloon and reduce ischemia of the intestine, liver, kidneys, and lower limbs [3,4]. Partial REBOA also achieves a mild change in blood pressure at the proximal side of the balloon and makes it possible to maintain continuous permissive hypotension [5]. In contrast, complete occlusion of the aorta could lead to proximal hypertension and increase the hemorrhage at the proximal side of the balloon [6]. Recently, studies concerning the effectiveness of partial REBOA have been increasingly published [7–17].

When partial REBOA is performed, the REBOA catheter is located at Zone 1 or Zone 3 appropriately after arterial access and the balloon is not inflated completely within the range of proximal perfusion maintained [18,19]. The degree of the partial occlusion is easily visualized if fluoroscopic guidance is available. However, in order to monitor the actual distal perfusion, a femoral sheath is placed at the other side of the REBOA for arterial pressure measurement. In other ways, a more than 1 Fr larger sheath for the REBOA catheter can measure distal arterial pressure using the side port of the sheath [18,20].

Although "partial REBOA" is used between "complete occlusion" and "no occlusion", there is no clear definition of occlusion strength. Furthermore, as mentioned above, hemorrhagic shock quickly changes the aortic diameter, and complete occlusion and partial occlusion can migrate towards each other. Due to this background, Matsumura et al. defined a clinically feasible and reproducible complete occlusion with an animal model using swine and proposed adjusting the occlusion strength of partial REBOA. In this report, complete occlusion is defined as "a condition in which the femoral artery pressure disappears", and the balloon injection volume at that time is recorded. It is proposed to present the occlusion strength of partial REBOA as a percentage of the balloon injection amount at the time of complete blocking. When the proximal and distal arterial pressures were measured under different conditions from 0% to 100%, it was reported that the proximal arterial pressure remained almost unchanged up to 100% after a 60% balloon volume. The occlusion at 60% balloon volume while leaving the distal blood flow suggests that occlusion strength can increase the proximal arterial pressure [18].

Furthermore, the diameter of the aorta was shown to be related to the circulating blood volume in animal experiments [21]. In patients with hemorrhagic shock, the diameter of the aorta on computed tomography or angiography is often reduced, which suggests a decrease in circulating blood volume. As hemorrhagic shock advances and circulating blood volume decreases, the diameter of the aorta could be reduced, and partial REBOA could accidentally change to complete occlusion of the aorta. Sufficient transfusion and prompt hemostasis are essential for maintaining partial REBOA [22]. Monitoring the pulse pressure of the femoral artery (distal pressure of the REBOA) could prevent accidental changes from partial REBOA to total occlusion. Conversely, total occlusion could shift to partial REBOA if the circulating blood volume increased with sufficient transfusion and hemostasis. The pulse pressure of the femoral artery could help adjust the degree of partial REBOA.

INTERMITTENT REBOA

Total occlusion of the aorta at zone 1 has been considered to be within 20–30 minutes of peripheral ischemia. When prolonged total occlusion is necessary, the strategy of temporarily deflating the balloon to resume perfusion to peripheral organs for a while and then reinflating the balloon could be considered. This procedure is called intermittent REBOA [23]. There has been no reported clinical established method of intermittent REBOA. In some animal experiments, the REBOA balloon was completely deflated and inflated at intervals during the complete occlusion of the aorta [24,25].

According to experiments using a swine model, intermittent REBOA caused less-severe organ injury and improved the survival rate compared to total occlusion of the aorta [26]. However, there is little definitive evidence

regarding intermittent REBOA. Furthermore, there is no established appropriate interval between deflation and inflation for intermittent REBOA. When intermittent REBOA is performed with insufficient fluid resuscitation, rapid deflation of the balloon can lead to significant blood pressure reduction [25]. Hypovolemia and ischemia-reperfusion damage due to peripheral ischemia, could lead to persistent severe hypotension and cardiac arrest in the worst situation. Intermittent REBOA has an inevitable significant influence on arterial circulation; therefore, the coalition of all physicians is essential when intermittent REBOA is performed.

Few comparative studies have evaluated partial REBOA and intermittent REBOA. There is minimal evidence as to which of these two occlusion methods should be used. In a porcine hemorrhagic shock model, Johnson et al. studied a group with a 75-minute partial REBOA and a group with an intermittent REBOA after complete occlusion for 15 minutes and compared them [25]. There was no difference in survival between the two groups, but the partial REBOA group had a shorter complete occlusion time, and no rapid decrease in arterial pressure was observed. The method of transitioning to partial REBOA at the earliest possible stage, while observing hemodynamics after complete occlusion, will be easier to manage because hemodynamic fluctuations are less likely to occur. However, the evaluation of the safe occlusion strength in partial REBOA is currently insufficient.

LIMITATION

First, there have been no adequate studies on human concerning partial REBOA and intermittent REBOA. Although we have discussed the effectiveness of partial REBOA and intermittent REBOA, almost all the evidence is based on animal experts. We have presented a description based on the current literature and expert consensus, and we need more clinical studies to validate these ideas at present.

Second, in order to consider the partial REBOA and intermittent REBOA, balloon construction should be discussed. The balloon of the REBOA is commonly constructed by a compliant balloon. If a non-compliant balloon is selected, the balloon diameter is defined by the nature of the balloon catheter itself and the injection volume does not control the degree of the occlusion.

CONCLUSION

REBOA can control the degree of occlusion of the aorta, and partial REBOA and intermittent REBOA could allow safer management when compared to complete occlusion. While the definition and evidence of partial REBOA and intermittent REBOA have been limited, these methods could prevent less ischemia-reperfusion injury than complete occlusion of the aorta.

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). None of the other authors have any conflicts of interest to declare.

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Author Contributions

SH and YK were responsible for drafting, editing, and submission of the manuscript. TM critically appraised the manuscript. SH, YK, TM 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.

REFERENCES

[1] Sadeghi M, Nilsson KF, Larzon T, et al. The use of aortic balloon occlusion in traumatic shock: first report from the ABO trauma registry. Eur J Trauma Emerg Surg. 2018;44(4):491–501.
[2] Hörer TM, Skoog P, Pirouzram A, Nilsson KF, Larzon T. A small case series of aortic balloon occlusion in trauma: lessons learned from its use in ruptured abdominal aortic aneurysms and a brief review. Eur J Trauma Emerg Surg. 2016;42(5):585–92.
[3] Russo RM, White JM, Baer DG. Partial resuscitative endovascular balloon occlusion of the aorta: a systematic review of the preclinical and clinical literature. J Surg Res. 2021;262:101–14.
[4] Sadeghi M, Horer TM, Forsman D, et al. Blood pressure targeting by partial REBOA is possible in severe hemorrhagic shock in pigs and produces less circulatory, metabolic and inflammatory sequelae than total REBOA. Injury. 2018;49(12):2132–41.
[5] Heindl SE, Wiltshire DA, Vahora IS, Tsouklidis N, Khan S. Partial versus complete resuscitative endovascular balloon occlusion of the aorta in exsanguinating trauma patients with non-compressible torso hemorrhage. Cureus. 2020;12(7):e8999.
[6] Uchino H, Tamura N, Echigoya R, Ikegami T, Fukuoka T. "REBOA" - Is it really safe? A case with massive intracranial

hemorrhage possibly due to endovascular balloon occlusion of the aorta (REBOA). Am J Case Rep. 2016;17:810–3.
[7] Necsoiu C, Jordan BS, Choi JH, et al. Mitigating ischemia-reperfusion injury using a bilobed partial REBOA catheter: controlled lower-body hypotension. Shock. 2021;55(3):396–406.
[8] Madurska MJ, McLenithan A, Scalea TM, et al. A feasibility study of partial REBOA data in a high-volume trauma center. Eur J Trauma Emerg Surg. Published online ahead of print, 5 January 2021. doi: 10.1007/s00068-020-01561-4.
[9] Kinslow K, Shepherd A, Sutherland M, McKenney M, Elkbuli A. Resuscitative Endovascular balloon occlusion of the aorta (REBOA) use in animal trauma models. J Surg Res. 2021;268:125–35.
[10] Kemp MT, Wakam GK, Williams AM, et al. A novel partial resuscitative endovascular balloon aortic occlusion device that can be deployed in zone 1 for more than 2 hours with minimal provider titration. J Trauma Acute Care Surg. 2021;90(3):426–33.
[11] Zilberman-Rudenko J, Behrens B, McCully B, et al. Use of bilobed partial resuscitative endovascular balloon occlusion of the aorta is logistically superior in prolonged management of a highly lethal aortic injury. J Trauma Acute Care Surg. 2020;89(3):464–73.
[12] Hoareau GL, Beyer CA, Caples CA, et al. Automated partial versus complete resuscitative endovascular balloon occlusion of the aorta for the management of hemorrhagic shock in a pig model of polytrauma: a randomized controlled pilot study. Mil Med. 2020;185(11–12):e1923,e30.
[13] Kauvar DS, Schechtman DW, Thomas SB, et al. Effect of partial and complete aortic balloon occlusion on survival and shock in a swine model of uncontrolled splenic hemorrhage with delayed resuscitation. J Trauma Acute Care Surg. 2019;87(5):1026–34.
[14] Reva VA, Matsumura Y, Samokhvalov IM, et al. Defining degree of aortic occlusion for partial-REBOA: A computed tomography study on large animals. Injury. 2018;49(6):1058–63.
[15] Russo RM, Neff LP, Lamb CM, et al. Partial resuscitative endovascular balloon occlusion of the aorta in swine model of hemorrhagic shock. J Am Coll Surg. 2016;223(2):359–68.
[16] Davidson AJ, Russo RM, DuBose JJ, Roberts J, Jurkovich GJ, Galante JM. Potential benefit of early operative utilization of low profile, partial resuscitative endovascular balloon occlusion of the aorta (P-REBOA) in major traumatic hemorrhage. Trauma Surg Acute Care Open. 2016;1(1):e000028.
[17] Okumura E, Tsurukiri J, Oomura T, Tanaka Y, Oomura R. Partial resuscitative endovascular balloon occlusion of the aorta as a hemorrhagic shock adjunct for ectopic pregnancy. Am J Emerg Med. 2016;34(9):1917.e1–2.
[18] Matsumura Y, Higashi A, Izawa Y, et al. Distal pressure monitoring and titration with percent balloon volume: feasible management of partial resuscitative endovascular balloon occlusion of the aorta (P-REBOA). Eur J Trauma Emerg Surg. 2021;47(4):1023–9.
[19] Johnson MA, Neff LP, Williams TK, DuBose JJ. Partial resuscitative balloon occlusion of the aorta (P-REBOA): clinical technique and rationale. J Trauma Acute Care Surg. 2016;81(5 Suppl. 2):S133-s7.
[20] DuBose JJ. How I do it: Partial resuscitative endovascular balloon occlusion of the aorta (P-REBOA). J Trauma Acute Care Surg. 2017;83(1):197–9.
[21] Jonker FH, Mojibian H, Schlosser FJ, et al. The impact of hypovolaemic shock on the aortic diameter in a porcine model. Eur J Vasc Endovasc Surg. 2010;40(5):564–71.
[22] Johnson MA, Williams TK, Ferencz SE, et al. The effect of resuscitative endovascular balloon occlusion of the aorta, partial aortic occlusion and aggressive blood transfusion on traumatic brain injury in a swine multiple injuries model. J Trauma Acute Care Surg. 2017;83(1):61–70.
[23] Kuckelman JP, Barron M, Moe D, et al. Extending the golden hour for Zone 1 resuscitative endovascular balloon occlusion of the aorta: Improved survival and reperfusion injury with intermittent versus continuous resuscitative endovascular balloon occlusion of the aorta of the aorta in a porcine severe truncal hemorrhage model. J Trauma Acute Care Surg. 2018;85(2):318–26.
[24] Morrison JJ, Ross JD, Houston Rt, Watson JD, Sokol KK, Rasmussen TE. Use of resuscitative endovascular balloon occlusion of the aorta in a highly lethal model of noncompressible torso hemorrhage. Shock. 2014;41(2):130–7.
[25] Johnson MA, Hoareau GL, Beyer CA, et al. Not ready for prime time: intermittent versus partial resuscitative endovascular balloon occlusion of the aorta for prolonged hemorrhage control in a highly lethal porcine injury model. J Trauma Acute Care Surg. 2020;88(2):298–304.
[26] Kuckelman J, Derickson M, Barron M, et al. Efficacy of intermittent versus standard resuscitative endovascular balloon occlusion of the aorta in a lethal solid organ injury model. J Trauma Acute Care Surg. 2019;87(1):9–17.