Successful Damage Control Resuscitation with Resuscitative Endovascular Balloon Occlusion of the Aorta in a Pediatric Patient

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Resuscitative endovascular balloon occlusion of the aorta (REBOA) is considered an emerging adjunct therapy for profound hemorrhagic shock, as it can maintain temporary stability until definitive repair of the injury. However, there is limited information about the use of this procedure in children. Herein, we report a case of REBOA in a pediatric patient with blunt trauma, wherein the preoperative deployment of REBOA played a pivotal role in damage control resuscitation. A 7-year-old male patient experienced cardiac arrest after a motor vehicle accident. After 30 minutes of cardiopulmonary resuscitation, spontaneous circulation was achieved. The patient was diagnosed with massive hemoperitoneum. REBOA was then performed under ongoing resuscitative measures. An intra-aortic balloon catheter was deployed above the supraceliac aorta, which helped achieve permissive hypotension while the patient was undergoing surgery. After successful bleeding control with small bowel resection for mesenteric avulsion, thorough radiologic evaluations revealed hypoxic brain injury. The patient died from deterioration of disseminated intravascular coagulation. Although the patient did not survive, a postoperative computed tomography scan revealed neither remaining intraperitoneal injury nor peripheral ischemia correlated with the insertion of a 7-Fr sheath. Hence, REBOA can be a successful bridge therapy, and this result may facilitate the further usage of REBOA to save pediatric patients with non-compressible torso hemorrhage.

Keywords: Shock, hemorrhagic; Balloon occlusion; Aorta; Child; Wounds and injuries
Introducción

La hemorragia es el factor más relevante de mortalidad potencialmente prevenible por trauma [1]. La intervalo entre el momento del daño y el control definitivo del sangrado es crítico en la reducción de la incidencia de muertes prevenibles. La occlusión endovascular de la arteria aorta en la resucitación (REBOA) es una terapia emergente adicional para el shock hemorrágico, ya que puede mantener estabilidad temporal hasta la reparación definitiva del daño. Sin embargo, hay información limitada sobre su uso en niños. Aquí, informamos un caso de REBOA en un paciente pediátrico con traumatismo contuso, donde la preoperatoria del REBOA jugó un papel crucial en la resucitación de control. Un paciente de 7 años experimentó paro cardíaco después de un accidente de tráfico, durante el cual fue un pasajero de asiento trasero. Después de 30 minutos de reanimación cardíaca y pulmonar, se logró la circulación espontánea. Se diagnosticó una hemorragia peritoneal masiva. Se destacó la inserción de un catéter de balón de 7 Fr en el aorta supracelíaca, lo que permitió la permesión de hipotensión mientras se realizaba la cirugía. Después de controlar el sangrado con resección del intestino delgado para avulsión mesentérica, la radiología mostró lesión cerebral hipóxica. El paciente murió por deterioro de coagulación intravascular dispersa. Aunque el paciente no sobrevivió, la escáner computarizado postoperatorio reveló que no quedaba lesión intraperitoneal ni isquemia periférica correlacionados con la inserción de un catéter de 7 Fr. Por lo tanto, el REBOA puede ser un puente terapéutico exitoso, lo que podría facilitar el uso futura del REBOA para salvar pacientes pediátricos con sangrado torácico no comprimible.

Llave palabras: shock, hemorrágico; balón de occlusión; aorta; niño; heridas y lesiones

Introducción

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Caso reportado

Un paciente de 7 años de edad con antecedentes médicos no relevantes experimentó paro cardíaco después de un accidente de tráfico, durante el cual fue un pasajero de asiento trasero. Después de 30 minutos de reanimación cardíaca y pulmonar, se logró la circulación espontánea. Presentaba shock hemorrágico debido a la lesión contusa del pecho izquierdo y abdomen. Los primeros respondientes realizaron intubación endotraqueal y drenaje torácico para el hem 너노 pneumothorax. Se esperaba un desenlace desfavorable debido a la suspecha de daño cerebral hipóxico causado por la parada cardíaca prolongada. Sin embargo, el paciente fue llevado a nuestro centro de trauma regional nivel 1 para el tratamiento óptimo considerando su edad. La prehospital time from injury to arrival in the trauma center was 120 minutes.

Al llegar, el paciente se encontraba en extremis, con una tensión arterial de 44/19 mmHg y pulsación arterial mínima. El escala de coma de Glasgow fue 3. Según el examen de reflejo de luz, los pupilas estaban fijas con un tamaño de 6 mm. El examen primario reveló el signo de cinturón y distensión severa en el abdomen inferior. A pesar de la resucitación óptima con cristaloides y sangre, se decidió realizar la REBOA. Se colocó el catéter de balón de 7 Fr en el vaso femoral común, ayudando a lograr la resucitación de control de la hemorragia.
transfusions, the patient did not have any hemodynamic response. The initial arterial blood gas analysis revealed a pH of 6.8, lactate of 12.2 mmol/L, and hemoglobin level of 3.8 g/dL. Only a small volume of blood drained through the indwelling chest tube. Thus, other major bleeding foci were suspected. Focused Assessment with Sonography for Trauma revealed massive intra-abdominal fluid collection. Thus, REBOA in Zone 1 was performed in the descending thoracic aorta under ongoing resuscitative measures [3]. A 7-Fr introducer sheath was placed in the left common femoral artery using the Seldinger technique. Then, a 7-Fr balloon catheter (RESCUE Balloon™, Tokai Medical Products, Aichi, Japan) was inserted along the guidewire. The balloon catheter tip was in the thoracic aorta as confirmed on serial radiography (Fig. 1A, B). The balloon was inflated with 5 mL of saline, which resulted in partial occlusion without inflated resistance in the syringe. The time from skin puncture to REBOA inflation was 8 minutes. The patient’s hemodynamic status improved after balloon inflation (Fig. 2). Thus, he was wheeled into the operating room 61 minutes after the initial presentation.

Crash laparotomy revealed mesenteric avulsion with small bowel ischemia and a 5-cm partial thickness laceration in the sigmoid colon. Numerous mesenteric arteries were lacerated. Considering these findings, we performed multiple small bowel resections without anastomosis and

![Fig. 2. Blood pressure measurements. The arrow indicates the time of REBOA inflation. REBOA: resuscitative endovascular balloon occlusion of the aorta, SBP: systolic blood pressure, DBP: diastolic blood pressure.](image)

![Fig. 3. Time course during REBOA performance (time interval from arrival). REBOA: resuscitative endovascular balloon occlusion of the aorta, SBP: systolic blood pressure.](image)

![Fig. 4. Postoperative computed tomography scan of the abdomen. (A) A 7-Fr balloon catheter was accurately positioned in the aorta (arrow), and the aortic diameter was about 12.7 mm. (B) There were no missed injuries or extravasation in the abdominal cavity. (C) A 7-Fr sheath placed in the left femoral artery (dotted arrow). Enhancement of the distal femoral artery indicated the absence of ischemic complications.](image)
primary repair of the sigmoid colon wall. To achieve a systolic blood pressure higher than 80 mmHg, the volume of the balloon, ranging from 8 to 3 mL, was adjusted by a balloon holder. The balloon was completely deflated, with a total time of 58 minutes, immediately after the patient’s vital signs stabilized during surgery. The operative time was 75 minutes, and the volume of blood loss during the surgery was approximately 1,500 mL. The patient received three units of packed red blood cells (pRBC) and five units of fresh frozen plasma before REBOA insertion, as well as six units of pRBC during surgery. The catheter and the introducer sheath were left in the femoral artery for possible usage after the completion of damage control with temporary abdominal closure (Fig. 1C). The patient was transferred to the intensive care unit for ongoing resuscitation and organ support (Fig. 3).

Thorough radiologic evaluations were immediately performed for adjuvant diagnosis. Abdominopelvic computed tomography (CT) did not reveal any missed solid organ injury or active bleeding. In addition, the REBOA catheter was accurately positioned in Zone 1, and there were no complications, including peripheral ischemia, attributed to REBOA placement (Fig. 4). However, severe hypoxic brain damage was noted on a brain CT scan. Unfortunately, the patient died secondary to multiorgan failure and deterioration of disseminated intravascular coagulation, possibly owing to the brain injury, approximately 19 hours after presentation.

**DISCUSSION**

The exact indications for REBOA placement are still debated. According to a joint statement from the American College of Surgeons Committee on Trauma and the American College of Emergency Physicians, the indications for REBOA are as follows [4]:

1. Patients arriving with traumatic life-threatening hemorrhage below the diaphragm, causing hemorrhagic shock, who are unresponsive or transiently responsive to resuscitation

2. Patients arriving in arrest from injury due to presumed life-threatening hemorrhage below the diaphragm

In our case, the patient fulfilled the indications for RE-BOA by not responding to resuscitation and by presenting with massive hemoperitoneum caused by blunt trauma. However, there are no existing clinical guidelines or protocols regarding the patient’s age, and whether these indications apply to pediatric patients has not been fully elucidated.

The major challenge in using REBOA in children is the selection of a proper introducer sheath and balloon catheter [5]. The aortic diameter and length in adults have been actively investigated for the utilization of REBOA. However, the relevance of these data for pediatric patients is unclear. The caliber of the common femoral artery grows with age and is associated with body mass and sex in adolescents [6]. However, the application of these findings to smaller children is limited. Furthermore, the inflation volume of REBOA should be appropriate to prevent vascular injuries, such as dissection, perforation, and rupture. In our case, the feasibility of placing a 7-Fr balloon catheter in a child with an aortic diameter of only 12.7 mm was validated (Fig. 3A). Carrillo et al. [7] showed the appropriate REBOA balloon inflation volumes for each Broselow category for Zones 1 and 3. Based on this study, to block aortic flow by 50%, the optimal inflation volume in Zone 1 for a child who is 130 cm tall is 5.5 mL. In our case, the maximal inflation volume was 8 mL, which would be considered overinflation according to the previous study. The volume is also in accordance with the manufacturer’s instructions, indicating that an inflation volume of 11 mL can establish a 20-mm balloon diameter (Table 1). However, the use of existing aortic occlusion balloons in children is arguable in terms of size. Thus, utmost caution is required when inflating the REBOA catheter in pediatric patients to prevent vascular complications. Unfortunately, no REBOA catheter for aortas with a diameter <15 mm is yet commercially available. There have been case reports of the off-label usage of Fogarty and 16-G Foley catheters to control vascular injuries in pediatric patients.

**Table 1.** Balloon inflation parameters of the RESCUE balloon™ (Tokai RB-167080-E, Tokai Medical Products, Japan) (unpublished data)

<table>
<thead>
<tr>
<th>Balloon diameter (mm)</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
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<tr>
<td>Inflation volume (mL)</td>
<td>11</td>
<td>15</td>
<td>21</td>
<td>28</td>
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prior to the development of REBOA [8,9]. Although these catheters cannot be used as alternatives in actual clinical settings, the further accumulation of data could help in the development of pediatric endovascular balloons.

As there are several pediatric case reports worldwide, the use of REBOA in children may be widely accepted in the near future. An angioplasty balloon was deployed into the aorta via a 7-Fr sheath to improve the hemodynamic status of a 9-year-old girl, and this procedure eventually bought time for aortic endovascular stenting for aortoesophageal fistula repair [10]. A Japanese team inserted an infrarenal aortic occlusion balloon catheter via a 10-Fr sheath for the primary repair of lacerated aortic bifurcation in a 12-year-old boy [11]. In our case, the patient did not survive. Nonetheless, REBOA can still be considered safe and feasible when a 7-Fr sheath is used, as shown in our patient, who is the youngest patient yet reported in whom REBOA was performed. However, more systematic high-quality studies must be conducted to assess the outcome and prognosis of REBOA in pediatric patients. Future studies should include morphometric analyses to completely validate the safety of the procedure. Developing a generalized protocol by building upon these novel experiences may open a new frontier in bridging therapy between injury and ultimate bleeding control in children.

REFERENCES