Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) for Hemorrhagic Shock

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ABSTRACT This clinical practice guideline (CPG) reviews the range of accepted management approaches to profound shock and post-traumatic cardiac arrest and establishes indications for considering Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) as a hemorrhage control adjunct. The specific management approach – within the parameters of mission, resources, and tactical situation – will depend on the casualty's physical location, mechanism and pattern of injury, and the experience level of the surgeon. The optimal management strategy is best determined by the surgeon at the bedside.

BACKGROUND

- Hemorrhage is the leading cause of preventable death on the battlefield.[1–3] Hemorrhage can be broadly categorized as compressible or non-compressible depending on its location. Non-compressible torso hemorrhage (NCTH) arises from trauma to the torso vessels, pulmonary parenchyma, solid abdominal organs or disruption of the bony pelvis.[4] Because NCTH is both occult and not amenable to control by direct pressure, it is particularly lethal.[5]
- NCTH resulting in hypotension or shock does not improve with external cardiac compression.[6] Rather, in many cases, resuscitative aortic occlusion (RAO) is required prior to definitive exploration. This maneuver affords proximal hemorrhage control while increasing afterload and central aortic pressure until direct hemostasis can be achieved. RAO has traditionally required a left thoracotomy or a laparotomy for aortic exposure.[7–10] The resuscitative thoracotomy has a high mortality rate, significant potential for casualty and trauma team morbidity, and high resource utilization, due largely to the nature of the injuries leading to arrest.[11–13] Nonetheless, data from theater indicate that there is a reasonable probability of long-term survival and recovery following RAO in appropriately selected casualties[14] as described in the Emergent Resuscitative Thoracotomy CPG.[15]
- REBOA is an alternative approach to RAO in patients at risk of imminent cardiovascular collapse. This procedure is performed through a transfemoral arterial approach without the need for thoracotomy. Thus, this approach is particularly appealing when the focus of hemorrhage is infra-diaphragmatic in origin and no additional thoracic intervention is indicated.
- This technique was first described as a resuscitative intervention by Hughes in 1954 in three moribund combat casualties.[16] Since this early publication, REBOA has been further explored as a resuscitation adjunct by others.[17,18]
- In recent years, renewed interest in endovascular occlusion prompted detailed analysis of REBOA in the animal laboratory.[19,20] These experiments demonstrated the potential merits of REBOA with occlusion times of up to 90 minutes.[21]
- Significant improvements in endovascular equipment and growing experience in endovascular techniques have spurred renewed clinical interest in REBOA. Specific applications now include proximal aortic occlusion in the management of ruptured abdominal aortic aneurysm,[22] elective oncologic resections,[23] pelvic hemorrhage from gynecologic pathology,[24] and traumatic NCTH.[25–27] Thus, REBOA appears ideally suited to serve as a temporary, minimally invasive bridge to definitive surgical or endovascular hemorrhage control.
- Given that (1) the skill and technology for application of this technique may be available in the deployed or austere setting and (2) balloon aortic occlusion provides a less invasive and expedient means to control life-threatening hemorrhage in appropriately selected casualties, this intervention is now recommended as an option to temporarily control life-threatening hemorrhage in the setting of truncal, junctional and extremity injury until definitive surgical hemostasis can be achieved.

RAO IN TRAUMATIC ARREST AND PROFOUND SHOCK

Given the lack of large-scale human studies demonstrating the effectiveness of REBOA over other RAO techniques, the precise indications of this technology remain unclear.

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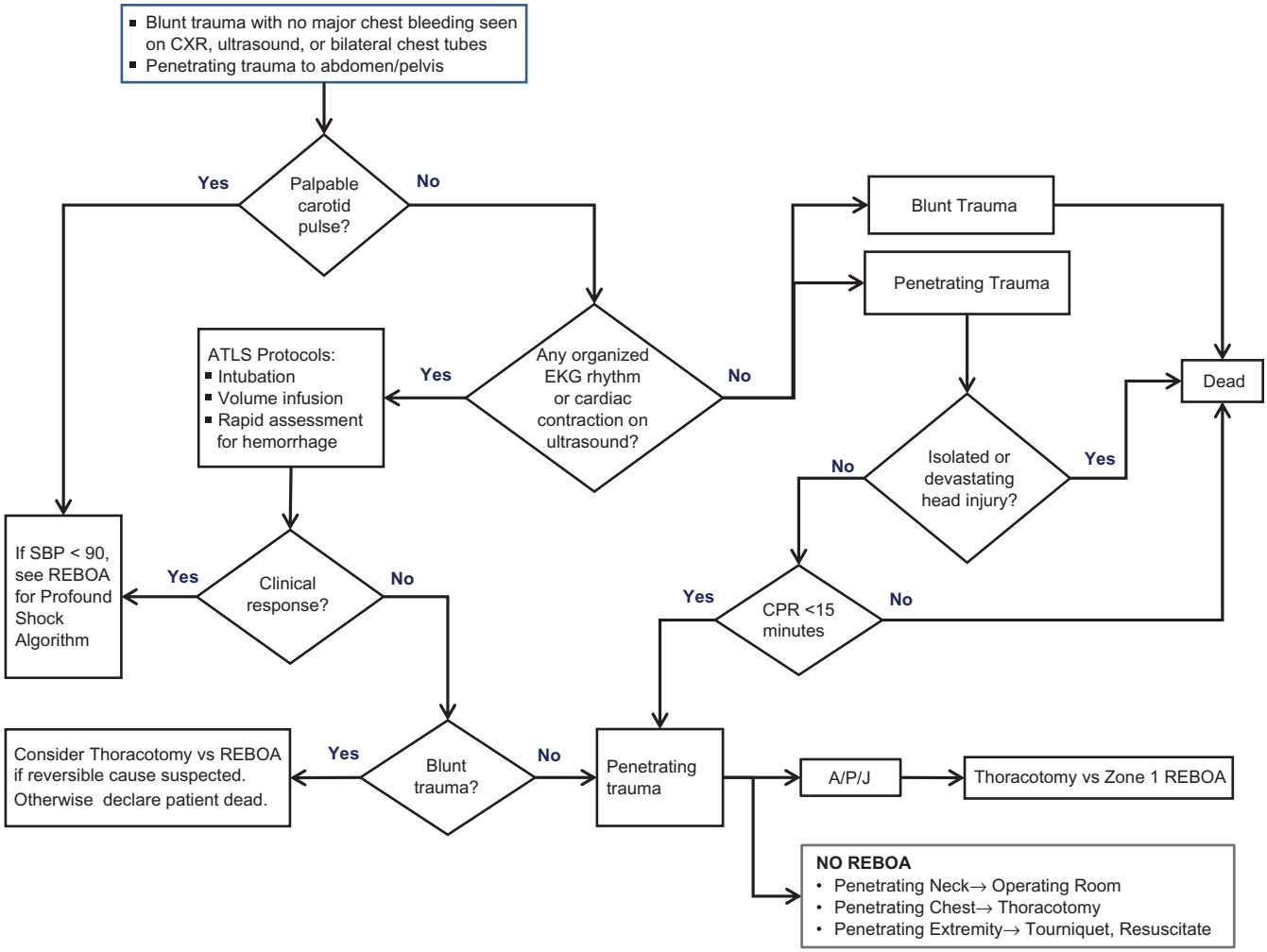

FIGURE 1. Recommended algorithm for ERT in traumatic arrest.

However, the suggested indications for REBOA are summarized below. These indications mirror the indications for resuscitative thoracotomy with the exception of shock or arrest secondary to penetrating chest trauma, which is preferentially treated with thoracotomy.[27]

Initial Management

Cardiac arrest in combat injury is most often caused by exsanguination. Initial management priorities include early control of hemorrhage and hemostatic resuscitation as described in the Damage Control Resuscitation CPG. Closed chest cardiac massage has little benefit if the intravascular space is empty. Thus, the initial focus in patients who present without a pulse must be to determine the following:

- Mechanism and pattern of injury.
- Duration of CPR.
- Presence of a pulse.
- Presence of an organized, narrow complex cardiac rhythm and/or organized cardiac activity by ultrasound exam.

Based on these data, a decision either for or against RAO can be made using the algorithm is presented in Figure 1. If RAO is to be performed, closed chest cardiac massage can continue while the surgeons are preparing for this procedure. If RAO is not to be performed, resuscitative efforts should cease unless there is a compelling reason to consider a non-traumatic arrest.

Early identification of patients who are at risk for profound shock or traumatic arrest is also essential as early application of REBOA prior to impending arrest may lead to improved outcomes (Fig. 2). Casualties who lost vitals in the field and underwent CPR for some period of time followed by return of spontaneous circulation should be considered high risk for repeat traumatic arrest.

In addition, the following indicators of a need for massive transfusion can indicate others at high risk for profound shock or traumatic arrest:

- SBP < 90: T < 35.5
- HR > 120: INR >1.5

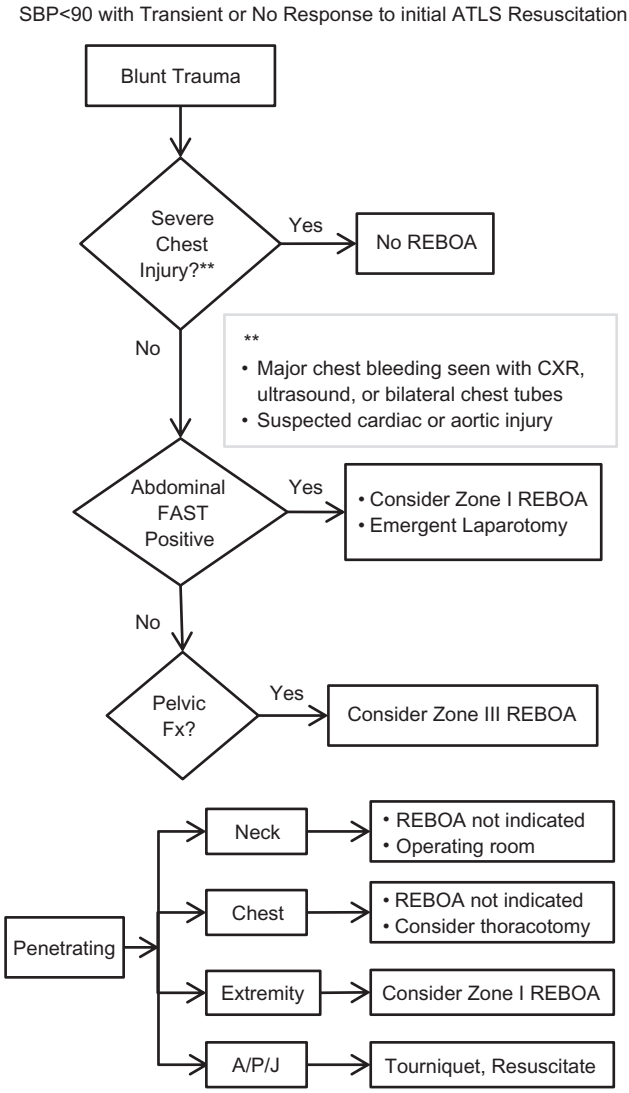

FIGURE 2. Algorithm for the use of REBOA for profound shock. REBOA: Resuscitative Endovascular Balloon Occlusion of the Aorta; ATLS: Advanced Trauma Life Support; ROSC: Return of Spontaneous Circulation; CXR: Chest X-Ray; EFAST: Extended Focused Assessment with Sonography for Trauma; FAST: Focused Assessment with Sonography for Trauma; A/P/J: Abdomen/Pelvis/Junctional Lower Extremity. Zone I REBOA: placement of aortic balloon in the thoracic aorta (insert catheter to 46 cm or measure the balloon to mid sternum/P-tip to sternal notch) Zone III REBOA: placement of aortic balloon directly above the aortic bifurcation (insert catheter to 27 cm or measure to the level of the umbilicus).

– Positive abdominal Focused Assessment with Sonography for Trauma (FAST): base deficit >6
– Penetrating mechanism: Hgb < 11

Resuscitative Thoracotomy

Open aortic occlusion is best performed through a left anterolateral thoracotomy (See Emergent Resuscitative Thoracotomy CPG).

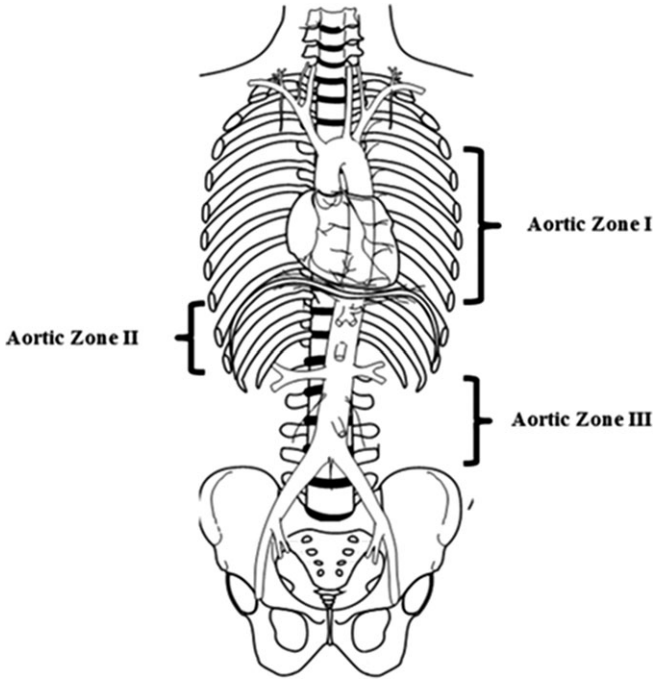

FIGURE 3. Aortic zones.

Trans-abdominal Aortic Occlusion

The aorta can also be occluded trans-abdominally at any point along its length. It can be occluded with either application of a clamp or compression with a retractor or manually. In obese patients with a large volume of hemoperitoneum or other intra-abdominal pathology, a trans-thoracic approach to the aorta is sometimes preferable. As with all other forms of RAO, restoration of aortic perfusion should be carefully coordinated with the rest of the team to minimize the effects of re-perfusion and blood volume shifts.

REBOA

As described above, REBOA is an alternative approach to resuscitative thoracotomy in some cases of traumatic arrest. Furthermore, REBOA can be performed pre-emptively in patients with high-risk injury patterns and unstable physiologic parameters as described above. In this way, REBOA can be proactive rather than reactive in the appropriately selected patient. The indications for REBOA are summarized in Figure 1 for traumatic arrest and Figure 2 in cases of profound shock. A schematic of the aortic anatomy is presented in Figure 3. If proximal aortic occlusion is required, this is termed REBOA I whereas distal aortic occlusion is termed REBOA III.

RESOURCES AND TECHNIQUES

A detailed discussion of the technical approach to REBOA can be found in the landmark publication by Stannard, Eliason, and Rasmussen.[28]

In brief, REBOA can be considered in five sequential steps:

1. Arterial access and positioning of sheath
2. Selection and positioning of the balloon
3. Inflation of the balloon
4. Deflation of the balloon
5. Sheath removal

The essential equipment for REBOA, appropriate technical steps, and considerations can be found in the full CPG.

FUTURE CONSIDERATIONS

A retrospective capability gap analysis of the UK Joint Theatre Trauma Registry suggests that as many as one in five severely injured casualties may have wounds that are amenable to treatment with REBOA.[29] Limitations to widespread use of this approach in an austere environment currently include the need for a large 12 Fr sheath, the relatively cumbersome over-the-wire insertion technique, and limited surgeon expertise. However, in the near future, a low profile occlusion balloon with an integrated wire is expected to enter production.[19] Furthermore, external landmarks are undergoing validation for REBOA insertion[30,31] and surgeon training in REBOA is ongoing at multiple centers.[32–35] All of these advances should facilitate appropriate clinical evaluation of REBOA to determine the optimal use of this resuscitation adjunct in the military setting.

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