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Feasibility of REBOA—Resuscitative Endovascular Balloon Occlusion of the Aorta—in Trauma-Related Noncompressible Torso Hemorrhage at Two Metropolitan Trauma Centers

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Noncompressible torso hemorrhage (NCTH) involving the thoracic, abdominal, and pelvic regions from both blunt and penetrating trauma is recognized as a major cause of potentially preventable death. These patients have injuries not amenable to standard hemorrhage control techniques (tourniquets, wound packing, manual compression) and are at high risk of exsanguinating before undergoing definitive management in the operating theater or the interventional radiology suite. Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a minimally invasive early management strategy that may provide temporary hemorrhage control in hemodynamically unwell patients with torso hemorrhage and bridge to definitive hemostasis.

PROCEDURE, HISTORY, CONTROVERSY

REBOA is a method of hemorrhage control in which the operator inflates a compliant balloon to occlude the aorta following access via the common femoral artery. The principle behind this technique is similar to aortic cross-clamping but is much less invasive; downstream occlusion slows arterial hemorrhage and also redistributes systemic circulation above the diaphragm to improve perfusion of cerebral and myocardial tissue. As outlined by Stannard et al, the aorta can be occluded in zones I or III.[1] Zone I involves the descending aorta between the origin of the left subclavian and celiac arteries, and zone III is between the lowest renal artery and the aortic bifurcation. Zone II is a no-occlusion zone of the paravisceral aorta between the celiac trunk and the lowest renal artery.

Aortic balloon occlusion was first documented during the Korean War but was sidelined because of difficulties with balloon design and vascular access techniques.[2] With improved technology and smaller sheath size, aortic balloon occlusion is now used for hemorrhage control across a range of clinical settings, including NCTH.

REBOA is a controversial intervention in Australasia, if not globally. Uncertainty remains as to whether REBOA is a prehospital or in-hospital intervention or both, how best to undertake the procedure, indications for when REBOA should be performed, and which cohort of patients may benefit.

The REBOA literature predominately consists of case series. In one of the earliest series, Low et al in 1986 reported on 15 trauma patients with exsanguinating hemorrhage from gunshot wounds to the thorax.[3] Six patients were in cardiac arrest with ongoing cardiopulmonary resuscitation. The study describes technical success with vascular access and balloon deployment; however, only 2 patients were long-term survivors. Three years later, Gupta et al published a case series advocating for the use of intraaortic balloon occlusion vs resuscitative thoracotomy, describing intraaortic balloon occlusion as an effective, comparatively easy, and versatile method for proximal control despite its high complication rate.[4]

Since these historic studies, the REBOA technique has been refined, and as a result, technical success has improved. As Perkins et al noted in their 2016 review, the body of literature has expanded considerably as balloon occlusion has been applied more widely in the trauma setting.[5] The evidence suggests a trend for increased survival.

REBOA has been compared to resuscitative thoracotomy for control of infradiaphragmatic hemorrhage. In swine, White et al showed that both balloon and clamp occlusion improved mean arterial pressure, carotid blood flow, and brain oxygenation compared with no occlusion.[6] Compared to the animals with clamp occlusion, the animals with balloon occlusion had improved physiology and required less fluid and less inotropic support; no mortality difference was seen. In 2015, Moore et al published an observational study from 2 trauma centers in the United States comparing REBOA to resuscitative thoracotomy for noncompressible truncal hemorrhage. They found that patients who underwent REBOA had fewer early deaths (<24 hours) and emergency department deaths, as well as improved overall survival (37.5% for REBOA vs 9.7% for resuscitative thoracotomy).[7]

Finally, DuBose et al published a prospective analysis comparing open vs endovascular aortic occlusion in 114 patients

with traumatic injury (46 REBOA vs 68 open).[8] While the study results signaled improved mortality in the REBOA group (28.2% vs 16.1%), the difference was not significant. Although the Injury Severity Score (ISS) across the 2 groups was similar, patients undergoing open occlusion were more likely to have suffered penetrating trauma, to have lower systolic blood pressure (SBP), and to be in arrest at the time of occlusion, suggesting that the patient cohorts were not the same.

Two studies using propensity-score matched groups from the Japan Trauma Data Bank provide the largest experience to date on the use of REBOA as an adjunct for hemorrhage control in NCTH.[9,10] Both studies observed that the use of REBOA increased mortality with similarly matched patients who did not undergo REBOA. In other words, patients who received REBOA had a higher mortality compared to similar patients who did not receive REBOA. While these may be the most comprehensive studies to date, they are subject to several significant limitations. The studies are based on registries that did not capture important data regarding the use of REBOA, including the indication for REBOA (prophylactically, as part of damage control resuscitation, because of delays in definitive intervention), the time of insertion, zone of occlusion, method of occlusion (complete or partial), and, importantly, duration of occlusion. It seems unlikely that REBOA was used as part of a damage-control strategy with apparent delay to definitive intervention, which may increase the risk of mortality.

As yet, no randomized controlled trials have been conducted, although the recently commenced UK-REBOA trial should provide some much-needed direction.[11]

RETROSPECTIVE AUDIT AT TWO TRAUMA CENTERS

To determine if a cohort of patients in Brisbane, Queensland, Australia could benefit from REBOA for NCTH, we conducted a retrospective audit of the city's 2 major trauma centers. Trauma registry databases for the Princess Alexandra Hospital and the Royal Brisbane and Women's Hospital were analyzed (from November 2008 and January 2011 to November 2016, respectively). As a measure of trauma load, the Princess Alexandra Hospital admitted 5,104 trauma patients for the 2016/2017 financial year, with 513 patients having an ISS >12, and the Royal Brisbane and Women's Hospital admitted 2,193 trauma patients for 2017, with 438 patients having an ISS >12. All adult patients (>17 years) with NCTH and SBP ≤90 mmHg were considered for inclusion in the audit. For each potential patient, demographic, injury mechanism, hemodynamic status, imaging, definitive management, and mortality data were collected. Exclusion criteria were major thoracic hemorrhage or suspected thoracic aortic injury, major head injury, bleeding that was successfully controlled with less invasive methods, or traumatic arrest prior to presentation to a hospital without return of spontaneous circulation. Each patient's suitability for REBOA was ultimately determined by an emergency physician using clinical judgment, with SBP and likely source of bleeding as the 2 most important considerations. Patients who died before they reached the hospital were not included.

We identified 60 patients for whom REBOA may have been indicated on arrival at the hospital or 6-8 patients per annum at the 2 major trauma centers. These patients had a median lowest pre-hospital SBP of unrecordable (UR) (interquartile range [IQR] UR to 70 mmHg) and a median lowest SBP in the emergency department of 53 mmHg (IQR UR to 62 mmHg). The median ISS was 39.5. Ninety percent of the patients had suffered blunt trauma, most commonly road traffic accidents and falls from height, and the focused assessment with sonography for trauma (FAST) scan was positive for 75% of patients. Mortality was 31.7% (19 patients), with most deaths occurring in the operating theater or intensive care. Uncontrolled hemorrhage from NCTH was responsible for 9 deaths (47.3% of all deaths) or approximately 1 patient per year across both major trauma centers for patients who reached the hospital alive. REBOA has the most potential benefit for this patient cohort.

However, our audit questions whether REBOA should be considered for patients with NCTH who arrive at the hospital alive in Brisbane. Costs are associated with implementing a new procedure, including protocol development, upskilling of clinicians, skill maintenance, and equipment. The procedure is not risk-free, and the learning curve with its associated procedural complications requires a volume of patients to master. Our audit suggests that a sufficient volume of patients in Brisbane may not be present at this point to justify the costs and risks described above. Furthermore, despite the absence of REBOA in our current system and the patients' high ISS, the study demonstrated that very few patients who arrive at the hospital alive in Brisbane die as a consequence of NCTH.

This audit is limited by its retrospective nature, meaning that the research team was not blinded to the patients' outcomes before they were included in the database. Consequently, we may have underestimated or overestimated which patients would have received REBOA across the 2 centers if these decisions were being made in real time. Although we attempted to correct for this bias by using inclusion/exclusion criteria that could be used in real time, the results need to be interpreted with this limitation in mind.

NEXT STEPS

If the use of REBOA in Brisbane is to be progressed, it should be undertaken as part of a prospective research trial with clear inclusion criteria. Ideally, the trial should be a randomized controlled study and include patients in both the pre-hospital and in-hospital settings. Given the low numbers of patients who would meet the inclusion criteria (which may also exist in other metropolitan areas in Australia), a multicenter study would be necessary and would take quite a few years. We look forward to the completion of the multicenter UK-REBOA trial to provide future direction.

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