LEADING ARTICLE

Resuscitative endovascular balloon occlusion of aorta (REBOA): expanding the window of survival in massive bleeding

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Introduction

Exsanguinating haemorrhage is responsible for 30 to 40% of early deaths from trauma, and most of these deaths occur within the first few hours of injury [1]. A study by A. Alarhyem et al. in 2016 revealed a precipitous rise in trauma deaths in victims with high-grade injuries with pre-hospital time <30 min [2]. The tenet of limiting time at the scene with rapid transport to definitive care (scoop and run) within this time frame is unrealistic and requires a different approach. It is estimated that nearly half of the deaths in the resuscitation room of the National Hospital of Sri Lanka is due to unattended exsanguination from trauma to the torso. An immediate intervention to stop exsanguination from torso trauma has been the focus for several decades. Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) is being explored primarily for this purpose. Advancing this novel strategy to trauma victims in the early phase of care may expand the window of survival to definitive care.

First described for trauma patients during the Korean War, aortic balloon occlusion has been in clinical use for more than 25 years in the field of vascular surgery, mainly as part of the treatment algorithm in ruptured abdominal aortic aneurysms (rAAA) and endovascular aortic repair (EVAR) [3]. Due to developments in endovascular techniques and catheter technology, REBOA has emerged and gained popularity in the last few years as a method for bleeding control in trauma. It is a relatively simple, minimally invasive method to temporarily occlude the aorta aiming at reducing the bleeding, gaining hemodynamic stability and maintaining perfusion to the heart and brain, thus, fundamentally gaining time to definitive surgical management [4].REBOA is one of the tools of EndoVascular resuscitation and Trauma Management (EVTM), a multidisciplinary concept that has been developed in recent years and published in several high impact journals, textbooks and manuals (Figure 1) [5].

The EVTM concept aims to combine modern endovascular and hybrid techniques and procedures, such as REBOA with traditional Advanced Trauma Life Support (ATLS) and Definitive Surgical Trauma Care (DSTC) for early multidisciplinary evaluation, resuscitation, and definitive management of hemodynamically unstable patients. This concept does not replace traditional surgery but instead incorporates all available tools into a common trunk. These tools and REBOA are just one of them, maybe used in both traumatic and non-traumatic causes of hemodynamic instability and can also be used in pre-hospital or austere environments with limited resources to focus medical resources and attention on the appropriate needs of the patient [6].

Figure 1. The EVTM concept displaying all aspects and parts of this multidisciplinary, patient centered model.

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REBOA technique, indications, and contraindications

In general, REBOA is used for bleeding control in non-compressible torso haemorrhage and aims at maintaining systolic blood pressure >80 mmHg and mean arterial pressure >50 mmHg for adequate perfusion to the brain and heart. It can be used in the zone I (descending thoracic aorta), zone III (infra-renal abdominal aorta) and in certain situations in zone II (para-renal/visceral) or iliac arteries [4]. The procedure itself is considered to be minimally invasive and done via a common femoral artery vascular access. In reality, as REBOA occludes the aortic blood flow, it becomes a highly invasive procedure that causes significant physiological changes that may, in turn, cause significant reperfusion injury and even mortality [7]. In recent years, the concept of partial aortic occlusion (pREBOA) or intermittent use of REBOA (iREBOA) was developed in order to mitigate the ischemia-reperfusion injury followed by REBOA use (especially zone I REBOA) [8].

While its use has been described in trauma and vascular surgery, it also has a major role in non-traumatic bleeding and resuscitation as part of the EVTM concept [6], with indications and contraindications for its use continuing to evolve. Existing evidence from case reports, animal and cohort studies suggest its use in both blunt or penetrating trauma; gastrointestinal (GI), obstetric- and gynaecology-derived bleeding events; visceral aneurysm rupture; thoracic and abdominal aortic aneurysm rupture; post-abdominal surgery; iatrogenic injuries; and, potentially, in both traumatic and non-traumatic cardiac arrest [6,9]. The lack of level 1 evidence such as randomized controlled trials, however, prevent consensus. Currently, there is only one ongoing randomized controlled trial, the UK-REBOA trial, with results hoped to be published within the upcoming years [10].

Some claim that the use of REBOA should be limited, as aortic occlusion and hemodynamic control can be obtained by laparotomy or thoracotomy. This is true, however, both procedures have their obvious limitations. They require many years of training and a high level of surgical experience, have a high threshold to be performed, are difficult to accomplish outside of an operating theatre and result in tremendous surgical insult to the patient with a high risk of associated complications. Vascular access, on the other hand, is usually described as the rate-limiting step of REBOA [11].

The suggested use of REBOA has been mainly in-hospital [5,6,12]; however, pre-hospital use has been reported in around 60 known cases in military and selected civilian reports [13] as well as in some unpublished data. The pre-hospital use of zone I (descending thoracic aorta) occlusion with REBOA has previously been controversial, especially in the case of thoracic trauma. However, recent studies report that 3-10% of pre-hospital major trauma patients may benefit from the use of REBOA [14].

Complications of the procedure

As with open occlusion of the aorta, REBOA is also associated with some major complications. These can mainly be divided into complications associated with vascular access, balloon positioning and occlusion time. The previous need for large sheath sizes (10-12 Fr) was a critical factor for access-related complications, now less common with the newer REBOA devices that only require a 7 Fr sheath and only external compression on removal (Figure 2) [15]. Complications such as distal embolization, air emboli, dissection and peripheral ischemia are access related, but can generally be avoided to a large extent with proper training. This is also to an extent true regarding complications associated with balloon positioning and inflation, such as aortic dissection, overinflation and aortic rupture and perforation. Complications related to occlusion time are one of the greatest limitations to REBOA. Prolonged ischemia followed by reperfusion can result in multiple organ failure and death [7]. This is to some extent avoided with the use of pREBOA or iREBOA, however, still poses a severe risk. There are still no clinical major trials that show the benefit of these methods. The ABOTrauma registry, as the AORTA USA registry, are collecting data on REBOA use and data is published continuously from the registries.

Figure 2. The EVTM "REBOA 2 GO" bag. Always contains 2 REBOA catheters, one 7 Fr introducer, one 8 Fr introducer, one micro puncture set, one 8 Fr Angio seal.

To be able to perform REBOA in a correct and safe way requires proper training and a multidisciplinary team. It is important to remember that REBOA does not treat the bleeding patient but allows time for definitive management. We highly advise using REBOA as part of the EVTM concept. It is not a risk-free procedure, and if performed incorrectly can cause more harm than good. It is therefore paramount that REBOA is to be used in highly selected patients with the correct indications.

Sri Lankan perspective

In April of 2020, a virtual REBOA/EVTM training program was telecast live at 5 centres island-wide to familiarize vascular and general surgical trainees/surgeons with basic concepts and skillsets of REBOA. A cadaver-based training program was conducted at the Department of Anatomy, Faculty of Medicine, University of Colombo. Vascular surgeons and residents had hands-on training on fresh cadavers and performed ultrasound-guided femoral arterial puncture and insertion and inflation of the REBOA catheters at the specified zone in the aorta. Currently, we are designing a cadaver-based training model at the University of Colombo with guidance from the vascular surgical department at Örebro University Hospital, Sweden.

Challenges, strategies, and future projection

We believe that REBOA is a viable tool for trauma management in Sri Lanka. To achieve expected goals, we have identified the following issues to be addressed and to seek remedial strategies. Lack of island-wide Emergency Medical Services (EMS) with highly trained paramedics result in most survivable trauma victims perishing on the roads. The current Sri Lanka College of Surgeons endeavour to support the Ministry of Health project to expand and upgrade EMS and Accident and Emergency (A&E), should also include REBOA training and service provision at the early in-hospital trauma care. Paramedics should be trained to identify, resuscitate and keep alive exsanguinating REBOA candidates till the victim reaches A&E, where an activated REBOA team awaits to take over. When the system matures, pre-hospital REBOA will be a viable extension to the REBOA services.

Organizing 24/7 REBOA services at the National Hospital of Sri Lanka as a pilot project necessitates teams to be trained, logistics to be worked out and surgeons and anaesthetists to be connected with a shared vision. Following this pilot project, new centres should be identified and prepared for the next stage. Ministry of Finance and Health officials need to be briefed and convinced on the benefit of spending an initial capital to gain dividends to the economy by a number of life-years saved upon implementation of this and other trauma initiatives.

The high annual trauma workload in Sri Lanka will provide an opportunity to collate sizable experiences on REBOA in a short period of time and collaborative research endeavours will provide an opportunity to share Sri Lankan experience on a global platform. Global collaboration with a shared vision to refine REBOA is the aim of the EVTM leadership with the moto "*No ego, just good science and collaboration*".

All authors disclose no conflict of interest. The study was conducted in accordance with the ethical standards of the relevant institutional or national ethics committee and the Helsinki Declaration of 1975, as revised in 2000.

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