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"What's in a Name?" A Consensus Proposal for a Common Nomenclature in the Endovascular Resuscitative Management and REBOA Literature

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The emerging techniques of REBOA and other Endovascular Trauma Managment (EVTM) concepts has introduced new terminology to the medical vernacular. As research in this field continues, the authors propose a common baseline nomenclature for the initial core essentials of EVTM concepts.

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INTRODUCTION

The emergence of endovascular devices for the management of hemorrhage holds considerable promise in both civilian and military settings, resulting in the increasing discussion of endovascular trauma management (EVTM; www.jevtm.com) concepts [1–13]. One early success of this innovation has been the development of the resuscitative endovascular balloon occlusion of the aorta (REBOA) technique. The goals of REBOA are to prevent or reverse hemodynamic collapse by minimizing ongoing bleeding from injured vascular beds and expediently restore adequate perfusion pressure to the heart, lungs, and brain. The application of this technique has demonstrated clinical successes for both trauma victims and non-trauma patients suffering from life-threatening hemorrhage due to gastrointestinal bleeding, obstetric bleeding, and iatrogenic vascular injury. Expanding indications may also include non-hemorrhagic scenarios, including cardiac arrest and sepsis.

Following these initial successes [1,2,4,6–12], innovators in both translational and clinical research have begun to explore potential improvements to the initially described technique for REBOA [3,5,12,13]. New low-profile devices specifically engineered for trauma use, novel techniques designed to mitigate the risks of prolonged aortic occlusion, and even the exploration of REBOA utilization in a variety of patient environments have all been described [5]. While this pace of innovation is exciting, it has also introduced new challenges in the form of a rapidly expanding lexicon of terms and acronyms that can prove confusing and inconsistent.

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While recognizing the dynamic nature of this clinical evolution, the authors propose the adoption of a common lexicon for use in the shared literature of endovascular resuscitation and REBOA use. Acronyms are wonderful tools when utilized discerningly. These literary devices save space in word limit restricted abstract and manuscript submissions and are often quite "catchy". Yet over reliance on acronyms, can contribute to significant confusion. As this specifically applies to the realm of endovascular resuscitation, we propose that the use of common acronyms be reserved primarily for the description of specific techniques, and more sparingly for basic physiologic tenets that support the conduct of these procedures.

The authors generally agree that the use of specific acronyms that describe the *location* of use for endovascular bleeding management adjuncts lends itself to the potential for a confusing litany of terms. For example, the terms "pre-hospital", "austere", "remote" and "out-of-hospital" could all serve as portions of REBOA acronym prefixes (i.e. PH-, A-, R- or OOH-REBOA). Similarly, a variety of location specific suffixes could contribute to confusion in the vernacular. It is our opinion that these types of acronym conventions should generally be avoided.

PHSYIOLOGIC PRINCIPLES NOMENCLATURE

Regional Endovascular Perfusion Optimization (REPO)

Regional endovascular perfusion optimization, or REPO, is a term designed to emphasize the hypotensive distal organ perfusion with optimization of proximal perfusion to critical organs (brain, heart) proximally. Many readers may be familiar with the term "hypotensive resuscitation" to not "pop the clot" as employed in the care of patients prior to definitive surgical control of hemorrhage. REPO represents a regional approach to the use of this physiologic principle afforded by the fact that the location of an endovascular occlusion can be variable within the vascular tree. As a principle, REPO (proximal to the bleeding site) could be considered the foundational principle behind the majority of endovascular bleeding management strategies described to date.

While REPO could, theoretically, be achieved by a variety of the techniques described later in this manuscript, the optimal goal of REPO is to introduce stable low volume flow to an injured vascular territory in such a way that minimizes hemorrhage but preserves organ viability. This strategy could be applied to the regulation of aortic flow at various levels or even in the endovascular control of more distal branch vessels. By maintaining a stable flow to the targeted injured vascular territory, fluid resuscitation can be performed in a judicious manner to promote normal physiology proximal to the level of flow restriction. Ultimately, the theoretical benefit of this therapeutic approach is to *optimize* perfusion to the greatest extent both proximal and distal to the level of flow restriction in the face of uncontrolled vascular injury, while minimizing bleeding from the injured vessel. We recommend that the acronym REPO is utilized to describe the application of this specific physiologic principle.

Endovascular Perfusion Augmentation for Critical Care (EPACC)

Although the authors generally agree that location specific nomenclature should not be used while describing techniques, *endovascular perfusion augmentation for critical care* (EPACC) has been developed to describe a physiologic state, the critically ill patient, and not a specific location, the Intensive Care Unit. This term describes the optimization of cardiac output, restoring euvolemia, and normal vascular tone, using endovascular adjuncts in critically ill patients with systemic hypotension from a non-hemorrhagic source or during the critical care phase after hemorrhage control has been obtained.

While vasopressors and fluid resuscitation have proven the mainstay of care in this unique patient population, responsiveness to these interventions is frequently protracted – with significant time spent outside the target hemodynamic endpoints. In many instances, these endpoints are never attained despite maximal intervention. For patients in distributive forms of shock, such as sepsis, ischemia-reperfusion injury, and anaphylaxis, the inability to restore adequate systemic vascular resistance can result in refractory hypotension. This common clinical scenario has led to some researchers considering the use of partial aortic occlusion to provide mechanical pressure augmentation and this technique has been described in large animal models. Initial clinical case reports have begun to describe the potential of this technology, even though this novel and emerging concept has not yet been refined to such an extent that it has seen mainstream acceptance. However, EPACC is likely to prove an important term in the evolving vernacular of endovascular resuscitative management. We recommend the term EPACC be used when describing the application of endovascular resuscitation in the care of critically ill patients without ongoing hemorrhage, analogous in many ways to the use of an intra-aortic balloon pump (IABP) and extra-corporeal membrane oxygenation (ECMO) in this setting.

SPECIFIC TECHNIQUE NOMENCLATURE

Resuscitative Endovascular Balloon Occlusion of the AORTA (REBOA) and Aortic Balloon Occlusion (ABO)

While the technique of balloon occlusion for the purpose of achieving hemorrhage control and restoring perfusion to the heart, lungs, and brain is far from a new concept, it is presently undergoing a clinical renaissance [1–13].

The term REBOA was first introduced in 2011 [14,15] and has gained progressive adoption internationally. Based on its original description and use of the term in the literature, REBOA represents *complete* occlusion of the aorta, such that there is no aortic flow permitted beyond the inflated balloon. As the name implies, this strategy is meant to serve as a resuscitative effort. In that context, REBOA embodies a therapeutic intervention that can be applied to the physiologically deranged patient. While it has been widely touted for use in hemorrhagic shock, the term REBOA may be appropriately applied to aortic balloon occlusion in alternate shock states. However, the term REBOA does not necessarily encompass the use of balloon occlusion for prophylactic purposes, such as in high-risk surgical interventions or for planned vascular control during elective vascular surgery.

This therapy does imply a specific balloon catheter type or manufacturer, but inherently it represents endoluminal occlusion of the aorta with a balloon or balloon catheter as opposed to some other occlusion device like open aortic clamping. Based on its present clinical use, REBOA represents an endovascular balloon fully inflated to result in complete occlusion.

Internationally, the term "aortic balloon occlusion," or ABO, has been applied in an analogous fashion, however, this terminology does not convey the clinical context within which the technique is applied clinically. In essence, the acronym "ABO" generally describes a generic "technique" that embodies complete aortic occlusion irrespective of the context, whereas REBOA is more descriptive in indicating the intent of that therapy. For the purposes of resuscitation from shock due to any cause, the term REBOA more accurately embodies the purpose of the intervention.

We recommend that the term REBOA should be applied to scenarios where complete balloon occlusion of the aortic is being performed for resuscitating a physiologically deranged patient, be it from hemorrhage, sepsis or cardiac causes. We propose that the acronym REBOA is utilized preferentially in this setting, largely replacing the older ABO acronym except in those specific settings where an aortic balloon is employed prophylactically for elective/preventative indications.

Partial REBOA (P-REBOA)

Several clinical and translational reports suggest that partial aortic flow restoration via partial aortic occlusion may serve to simultaneously mitigate the adverse effects of aortic occlusion on both proximal and distal vascular beds, while aiming to limit ongoing hemorrhage in the bleeding patient [3,5,13]. In general, these researchers and clinicians have described this therapeutic strategy as partial REBOA or P-REBOA. However, application of P-REBOA has been heterogeneous and the methodology to perform it remains ill-defined. Currently, there is no clear consensus on how to titrate the degree of balloon occlusion, nor is there a widespread acknowledgment of which physiologic parameters should be utilized to guide this titration (i.e. pressure above or below the balloon).

At least one method to manually titrate the degree of occlusion based on the pressure below the balloon has been described. It has also been shown in translational models that a direct linear correlation exists between distal aortic pressure and aortic flow beyond the balloon, allowing the end user to titrate downstream flow using conventional pressure-based monitoring techniques. Regardless of the technique used to perform P-REBOA, the current clinical experience is lacking and is confined to case reports.

Despite the difficulty in optimally codifying this technique, we recommend the term P-REBOA be used to describe the general approach of partial balloon catheter inflation for the purpose of resuscitating the physiologically deranged patient, with the dual goal of minimizing downstream ischemic injury while limiting hemorrhage. As no reporting standards currently exist, P-REBOA should be used to describe any attempt at partial balloon inflation/deflation within this clinical context.

Intermittent REBOA (I-REBOA)

An alternative approach to mitigate the consequences of sustained aortic occlusion is the concept of intermittent REBOA or I-REBOA. I-REBOA represents the cyclical full inflation and full deflation of a balloon catheter in the care of the physiologically deranged patient. This represents a binary approach to resuscitation, where aortic occlusion is repeatedly toggled from "on" to "off" to minimize the ischemic burden to downstream tissues. As with P-REBOA, the application of I-REBOA remains ill-defined, with similar challenges regarding quantification, data capture, and reporting.

We recommend that the term I-REBOA should be used to describe the intentional cyclical and complete inflation and deflation of a balloon catheter in the care of the physiologically deranged patient.

Endovascular Variable Aortic Control (EVAC)

As clinical and translational experience with endovascular trauma management continues to mature, investigators have suggested that the precise and responsive regulation of aortic flow may have significant utility in achieving more optimal regional endovascular perfusion optimization at a variety of anatomic locations and clinical settings. The term *endovascular variable aortic/arterial control* or EVAC refers to this emerging technique of precision flow regulation of the aorta or branch vessels across the full spectrum from full occlusion to the unimpeded restoration of arterial flow.

Translational data have demonstrated that EVAC can effectively be utilized to achieve REPO in experimental

large animal models. To date, experimental use of EVAC is reliant on intelligent automated physician-assist systems that can make microliter balloon volume adjustments every few seconds based on pressure/flow above and below the balloon. While the technologic requirements for this precise control are possible, they are not approved for use by the bedside provider, the impending nature of this innovation warrants inclusion of the term "EVAC" in the proposed common nomenclature of endovascular resuscitative management.

We recommend that the term EVAC is utilized to describe the technique of physician assist modalities that afford precise aortic or arterial flow regulation across the full spectrum of flow.

CONCLUSION

Innovation in the development and employment of endovascular resuscitative adjuncts continues at an impressive pace. The evolution of devices and concepts involved in these efforts will, inevitably, lead to a growing lexicon of endovascular intervention for resuscitation. These present naming conventions represent only the beginning of what we believe to be a bright future for the field.

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