In-Theater Assessment of Resuscitative Balloon Occlusion of the Aorta (REBOA) Capabilities and Training

Alex Y. Koo, MD[1]; Jerry Hu, DO, PharmD[2]; Kyle Couperus, MD, MBA, BSN[3]; Jamie Eastman, BSN[4]; Thomas Kwolek, BSN[5]; Kyle Remick, MD[6]*

ABSTRACT

Background: Resuscitative endovascular balloon occlusion of the aorta (REBOA) is an endovascular technology indicated for temporarily controlling traumatic life-threatening, noncompressible abdominal, truncal, or pelvic hemorrhage. Through percutaneous access or cut-down to the femoral artery, an intra-aortic balloon catheter is fed into the aorta and inflated, occluding distal blood flow and, thus, bleeding. To determine specific barriers to REBOA in deployed environments, we conducted a quality improvement project and survey of ER-REBOA™ placement and monitoring capabilities at four medical treatment locations in Iraq and Kuwait during the spring of 2019. **Methods:** The primary objective was to evaluate each in-theater medical site's ability to deploy REBOA, which was defined as having a provider capable of placing REBOA and the minimum equipment necessary. The investigators interviewed providers and through self-reported surveys, determined the personnel capable of placing a REBOA. REBOA equipment and monitoring equipment were identified through direct inspection of sites and interviews with logistical and equipment staff. **Results:** A total of 113 individuals participated in the evaluation and training. Three of the four sites had the minimum training and equipment requirements to complete the procedure: one REBOA-capable provider, an unexpired ER-REBOA™ device, and an unexpired introducer catheter kit. Overall, 6 out of 32 physicians (18.7%) were capable of placing an ER-REBOA. **Conclusion**: This deployed site survey demonstrates that the minimal requirements and personnel for ER-REBOA placement were met at most studied locations in 2019. However, improvements in pre-deployment training of select medical personnel in REBOA and arterial blood pressure monitoring are recommended to ensure adequate resourcing and redundancy in training.

KEYWORDS: *REBOA; resuscitative endovascular balloon occlusion of the aorta; intra-aortic balloon; ER-REBOA; deployment; noncompressible hemorrhage*

Introduction

A current model for REBOA, cleared by the U.S. Food and Drug Administration (FDA) in 2016 is the ER-REBOA™ (Prytime Medical Inc., Boerne, TX), specifically created for advanced trauma management both on the battlefield and at civilian trauma centers.[1,2] The "ER" is named after the surgeons who helped develop the product. This unique endovascular technology is used for temporarily controlling traumatic life-threatening, noncompressible abdominal, truncal, or pelvic hemorrhage. REBOA is performed through percutaneous access or cut-down to the femoral artery. Then an intra-aortic balloon catheter is fed into the aorta and inflated, occluding distal blood flow and thus bleeding.[3–6] In situations where there are multiple surgical trauma casualties and limited damage control surgery resources or delayed transportation, REBOA can be deployed for temporary hemorrhage control for up to 30 or 60 minutes, when placed in zone 1 or 3, respectively.

While there have been considerable strides in battlefield hemorrhage control, noncompressible torso injuries still account for 13% of injuries sustained in Afghanistan and Iraq, with 17% of these injuries confirmed to have ongoing noncompressible hemorrhage.[7] Also, in a review of potentially survivable injuries, 50% were truncal hemorrhages. In resource-limited settings and/or prolonged transport times, REBOA can be implemented if there is delay in damage control resuscitation and/or surgery.[8]

Considerable challenges to the procedural success of REBOA include significant training and experience gaps in obtaining emergent arterial and venous access, placement depth, and management of endovascular occlusion in critically wounded patients.[9–11] Existing training programs of intra-aortic occlusion device placement, such as the American College of Surgeons' (ACS) Basic Endovascular Skills for Trauma (BEST), are often inaccessible to the wide range of military medical providers who may be required to perform the procedure or care for patients after placement. REBOA training is not formalized in any predeployment training platforms for military medical personnel. In addition, deployed environments create unique challenges for military medical personnel. Deployments involve frequent turnover of medical personnel of varying training and experience, constant battlefield movements, coalition partners, and nonstandardized predeployment training cycles across different deploying units.

We seek to determine the readiness of medical units to employ REBOA in deployed environments while also creating an educational opportunity for review and training in REBOA placement by subject matter experts.

*Correspondence to alex.koo@georgetown.edu

[1]**Dr. Alex Koo** is affiliated with the Department of Emergency Medicine, MedStar Georgetown University Hospital, Washington, DC and the Department of Emergency Medicine, MedStar Washington Hospital Center, Washington, DC. [2]**Dr. Jerry Hu** is affiliated with the Madigan Army Medical Center, Tacoma, WA. [3]**Dr. Kyle Couperus** is affiliated with the Department of Emergency Medicine, Madigan Army Medical Center, Tacoma, WA. [4]**Jamie Eastman** is affiliated with the United States Army. [5]**Thomas Kwolek** and [6]**COL (Ret) Kyle Remick** are affiliated with the Department of Surgery, Uniformed Services University of the Health Sciences, Bethesda, MD.

Methods

To determine specific barriers to REBOA in deployed environments, we conducted a survey of ER-REBOA placement and monitoring capabilities at four medical treatment locations in Iraq and Kuwait during the spring of 2019. This project was initiated as a quality improvement project in the Iraq/Syria theater. We completed site surveys, focus group discussions, and integrated a REBOA simulation curriculum with the ER-REBOA in-theater. Focus was placed on the physician and support staff familiarity with placing the device, as well as the supply readiness at the deployment locations for REBOA.

The primary objective was to evaluate each medical site's ability to deploy REBOA, which hinged on two factors. First, the medical site must have a provider capable of placing REBOA, whether through attending the BEST course or familiarization training. Second, there must be the minimum equipment necessary to deploy REBOA, namely the ER-REBOA device and the introducer catheter kit. The device and kit must be stored according to the manufacturer's recommendations, which was in a cool, dark location away from direct sunlight. Familiarization training was defined as consensus agreement by the investigators KC and KR for a provider to 1) understand when to place a ER-REBOA and 2) place an ER-REBOA either through training other than the BEST course or having successfully placed it in a patient. Investigators interviewed medical leadership and providers and conducted surveys of providers to determine those capable of placing REBOA (Table 1 and Appendix 1). The secondary objectives included evaluating support personnel for formal training (or comfort level) assisting in the management of a patient with an ER-REBOA device in place and arterial pressure monitoring capabilities for the REBOA. Secondary objectives were evaluated by the investigators through interviews and survey results of support personnel and visualization of arterial pressure monitoring equipment.

The investigators and advisors for this quality improvement project consisted of two vascular surgeons, one trauma surgeon (BEST course instructor), two emergency medicine physicians (one who had completed the BEST course and one with familiarization training in ER-REBOA placement), and two registered nurses with formal training in ER-REBOA placement.

We completed four site surveys (three in Iraq, one in Kuwait) during the spring of 2019. These sites were selected based on their critical access and location in theater at that time (within range of readily available transportation/project time constraints).

Data was collected and stored in Excel 16 (Microsoft, Redmond, WA) and reviewed by two investigators after completion.

While not a primary or secondary objective, the study investigators created a training curriculum to educate participants on ER-REBOA placement and monitoring as part of a quality improvement initiative. After completing the site survey, the investigators gave a didactic-simulation session for physicians and support staff. The curriculum consisted of 1.5 hours of lecture describing pathophysiology, indications, contraindications, complications, management, transport considerations, and discontinuation of ER-REBOA. It was followed by a hands-on simulation segment with two simulated cases (zone 1 and zone 3). Both cases required the team to correctly select a zone, deploy, and monitor an ER-REBOA in a pressured simulation mannequin model. A test was administered at the end for knowledge retention (Appendix 2).

TABLE 1 *Data Collection Methods*

Objective	Evaluation of objective
Provider(s) with capability training? (defined as Basic Endovascular Skills for Trauma course or familiarization training)	Investigator deliberation and consensus based on: • Focused interviews with medical leadership at each location (including available additional medical assets on post) • Individual discussions with providers during training • Survey results (Appendix 1)
• Equipment assessment • ER-REBOA™ device • Compatible Introducer Catheter Kit • Arterial Pressure Monitoring Capability (Compass device or pressure tubing, arterial line transducer, and a compatible monitor) • Femoral arterial lines for early placement	• Direct inspection of resuscitation bays, intensive care unit equipment areas, operating rooms, and medical storage • Interviews with on-site logistics personal and relevant medical staff
Support personnel for formal training or comfort	Survey results (Appendix 1)

The simulation mannequin model used was the Prytime Medical™ STAAR (Simulation Trainer for Arterial Access and ER-REBOA), which includes a pulsatile flow loop. This model offered clinically similar conditions for arterial access training and simulated ER-REBOA placement. Providers placed the ER-REBOA while nurses or medics assisted in setting up an arterial pressure transduction/monitoring system. The arterial pressure monitoring device was the ZOLL® M Series® defibrillator (ZOLL Medical Corporation, Chelmsford, MA).

The protocol was reviewed and granted exemption by the local institutional review board. The manuscript was reviewed and approved by the Public Affairs Office and the institutional Operations Security (OPSEC) Representative.

Results

We evaluated four deployed locations: two Role 2 medical treatment facilities (MTFs) with Forward Resuscitative Surgical Team (FRST) augmentation in Iraq: one Role 3 MTF in Iraq, and one Role 3 MTF in Kuwait.

A total of 113 individuals participated in the evaluation and training (Table 2). While all sites had the minimum training and equipment requirements to complete the procedure (one REBOA-capable provider, an ER-REBOA device, and an introducer catheter kit in proper storage), one site only had expired ER-REBOA devices and kits. This site was deemed unable to deploy a REBOA. Overall, 6 of 32 (18.7%) of physicians were capable of placing an ER-REBOA, whether attending the BEST course or with familiarization. Of 81 medical support staff (nurses and medics), 1 (1.3%) reported ER-REBOA support proficiency, and 17 (20.9%) reported proficiency with arterial pressure transducer set-up and management.

TABLE 2 *Demographics of Participants*

Provider type	No. of participants
Physician	32
Medic	54
Physician assistant	4
Nurse practitioner	2
Certified registered nurse anesthetist	2
Nurse	19

Equipment Requirement

While all four sites had ER-REBOA devices and introducer catheter kits, none of the sites had a complete complement of manufacturer-recommended equipment (Table 3). One facility only had expired introducer kits, as aforementioned. One facility (Role 2/FRST) did not have the compatible arterial line tubing and transducer cables to monitor arterial pressures. None of the sites maintained a supply of disposable vascular pressure devices as the Centurion Compass devices (Medline, Northfield, IL) or femoral arterial line kits.

All four locations were inside a hardened military structure converted to an MTF. Each site had a resuscitation bay or an operating theater where an endovascular balloon can be placed in a sterile or semi-sterile environment.

REBOA-Capable Provider

Each location had a physician who had completed the BEST course. This was the emergency medicine physician at one location and general surgeons at the other three. One Regional Role 3 had two providers found by consensus agreement of the investigators to have familiarization training. One of the locations had this provider incidentally present as a medical asset at the location, but they were not formally part of the surgical team. This location was staffed by a German surgical team. At the time of this project, this team reported not using or supporting use of the REBOA device in Germany, and therefore not having formal training on it prior to deployment.

Support Staff (Medics and Nurses)

Out of the 81 medic and nurse participants, one had experience and proficiency in ER-REBOA indications and post—balloon deployment monitoring. This corresponds to one individual (nurse) who had received training at a civilian institution (part of a REBOA training study). Additionally, most of the support staff had never set up an arterial line prior to the subsequent training event. Only 17 out of 81 (20.7%) felt comfortable setting up the arterial pressure line system to monitor the balloon. Nursing staff also reported predeployment unit-based training did not include arterial line management. Of nurses surveyed, critical care nurses who initially trained in the intensive care unit were not comfortable with arterial line set-up or management.

Discussion

While none of the sites had the complete complement of manufacturer-recommended equipment, they had the basic, necessary equipment of the ER-REBOA and introducer catheters. Three of the four sites were capable of deploying an ER-REBOA catheter with the incapable site having trained staff but nonfunctional equipment (i.e., expired ER-REBOA catheter and introducer kits). Arterial pressure monitoring was not available at a location because of incompatible cables. While invasive arterial monitoring in placement of REBOA is helpful, it is not an absolute necessity. The purpose for arterial monitoring is to 1) help confirm ER-REBOA balloon deployment and 2) measure blood pressure proximal to balloon occlusion. These goals can be achieved with other means, as with a Compass device and/or

TABLE 3 *Results of Site Survey, Focus Group Discussion, and Survey*

Survey item	Site #1 (Regional Role 3)	Site #2 (Regional Role 3)	Site #3 (Regional FRST/Role 2)	Site #4 (Regional FRST/Role 2)
Minimum equipment required (catheter and introducer)	Yes	Yes	Yes	Yes
Manufacturer-recommended equipment (all items below)	No	No	No	No
ER-REBOA™ catheter (no. available)	Yes (11)	Yes (6)	Yes (3)†	Yes (5)
Compatible introducer kit	Yes	Yes	Yes†	Yes
Arterial pressure monitoring capability*	Yes	Yes	Yes	No
Femoral arterial lines for early placement	No	No	No	No
No. of physicians capable of ER-REBOA placement / total no. of physicians (%)	Yes 3/10 (30)	Yes 1/11 (9.1)	Yes 1/5 (20)	Yes 1/6 (16.6)
Support staff training/familiarity, no. familiar/total no. (%)				
ER-REBOA placement	0/20	0/8	1/25	0/28
Arterial pressure monitoring‡	10/20 (50)	3/8 (37.5)	2/25 (8)	2/28 (7.1)
Additional survey data (scale 1–4)				
Useful course?	N/A	N/A	3.75§	3.28¶
In situ damage control resuscitation training useful?	N/A	N/A	3.9§	3.5¶

*Defined as having pressure tubing/pressure bag/monitor and/or readily available Compass device.
†Expired ER-REBOA and Compatible Introducer Kit.
‡Defined as self-reported ability to set up arterial line pressure tubing/monitoring system.
§30 respondents.
¶29 respondents.
FRST = forward resuscitative surgical team; N/A = not applicable.

noninvasive blood pressure monitoring and checking for loss of contralateral distal pulse. While all sites did not have femoral arterial line kits, they are not a necessary component for REBOA placement. Instead, they allow early common femoral arterial access in anticipation of a possible REBOA.

We discovered several promising areas for improvement. These include device-specific training for support personnel (medics and nurses), a codified REBOA equipment list and tracking system, and stocking of femoral arterial line kits, Compass transducer kits, pressure tubing, and transducer cables. We also recommend ad hoc in-theater training, especially in regional Role 3 facilities in order to maximize operator familiarization and success for advanced trauma care for noncompressible torso hemorrhage.

Our training curriculum was implemented to briefly introduce the ER-REBOA device and its placement to partners in our area of responsibility. The intent was in-service training for physician and nursing staff, while reviewing clinical practice guidelines.

A major challenge identified in this quality improvement project was the number of trained staff—physicians, nurses, and medics—with little to no REBOA and arterial line monitoring competency. With 6 out of 32 physicians capable of placing REBOA across four different locations, there is little personnel redundancy. Similarly, support staff with knowledge of invasive arterial monitoring was as low as 2 out of 28 personnel, but, as mentioned previously, this is not an absolute prerequisite to REBOA placement.

While our survey demonstrated there was at least one REBOA-capable provider at each site, it is doubtful that every candidate that could benefit from REBOA at these sites would receive it. REBOA training is not standardized or required across military medical personnel, and thus medical personnel may not be trained to place or support a REBOA. There are formal courses to teach REBOA placement and arterial line management, such as the BEST and the American Association of Critical Care Nurses' Essentials of Critical Care Orientation, respectively. The BEST Course has both didactic and practical sessions involving a perfused cadaver, which allows participants to have direct hands-on training in accessing and placing ER-REBOA via the common femoral artery, with additional emphasis on ultrasound-guided and open exposure techniques. The Essentials of Critical Care Orientation is a nursing-specific course covering arterial access set-up, arterial wave form identification, and arterial line management. However, tradeoffs of appropriateness of REBOA, time commitment, logistical feasibility, and monetary costs of these courses must be considered. Another option given logistical and monetary constraints are less formalized avenues of training to obtain the technical and cognitive skills involved in REBOA. Technical aspects of REBOA are achievable, even without the BEST course. In a prospective trial involving novices, anesthesiologists, and endovascular experts, novices performed just as well as experienced anesthesiologists 8–12 weeks after a 2.5-hour simulation training on REBOA Seldinger technique.[12] In addition, a systematic review of REBOA training revealed that conceived didactics with simulation was effective in increasing procedural competence for REBOA deployment.[13]

A review by Thrailkill and colleagues found there were around 600 cases of REBOA per year, with decreasing use since 2019.[2] From this review, it appears REBOA is a relatively uncommon procedure with specific and circumstantial applications. Thus, REBOA and its support should not be included in training for all military medical personnel, but rather taught to those most likely to use it—personnel working in resource-constrained environments where there may be delays in damage control surgery.[8,11,14] For example, the U.S. Army's Forward Resuscitative Surgical Detachments (FRSDS; formerly FRSTs) are suitable teams that may encounter a need for REBOA placement given their finite surgical capacity and potential austere deployments with limited resupply.[15–17] FRSDs have predeployment training platforms as the Army Trauma Training Center (ATTC) and Strategic Trauma Readiness Center (STaRC), which are ripe avenues for formal courses as BEST or REBOA familiarization with arterial line set-up.[18,19] Additionally, there needs to be the ability to sustain this perishable skillset through didactic "refresher" training and/or obtaining a STAAR or similar trainer available at predeployment locations for austere units. Successful REBOA capabilities in deployment settings require predeployment and sustainment training for select individuals and teams.

Medical equipment sets for deploying units can be standardized to include femoral arterial line kits, along with arterial line monitoring cables through the Defense Medical Materiel Standardization Program (DMMSP).

Limitations

There were limitations to this study, most notably that all data were obtained from individuals who sought out the training and on a volunteer basis. Volunteer bias may confound results to a population less likely to have REBOA familiarization. The number of sites and teams was low, they were only in one area of operation, and all were conducted during a 3-month period. We did try to account for inaccurate personnel turnout through discussions with on-site leadership teams, but we may have missed additional providers/support staff who may have had formal training. A major limitation is the fact that having a "REBOA-capable" provider does not ensure proficiency of placement of REBOA. The latitude of definition of "REBOA-capable" could mean a provider took a BEST course many years prior without sustainment training. Furthermore, "familiarization training" was based on expert assessment, which has marked subjectivity and is not necessarily equivalent to the BEST course. While there is evidence that different modalities of didactics and simulation other than BEST can provide REBOA-improving skills, they have not been compared head-to-head.[13] A better assessment of providers would be testing REBOA proficiency on a perfused cadaver, but this was not possible within the confines of this project. In addition, the levels of support staff familiarization with ER-REBOA and arterial line set-up varied and was determined by self-report. The findings of this study are not necessarily generalizable to all deployed environments given the ever-changing personnel, missions, and medical capabilities. Specifically, this quality improvement project occurred in 2019, after which significant changes to medical and operational environments have occurred.

Conclusion

This deployed site survey demonstrates that the minimal requirements and personnel for ER-REBOA placement were met at most studied locations in 2019. However, improvements in

predeployment training of select medical personnel in REBOA and arterial blood pressure monitoring are recommended to ensure adequate resourcing and redundancy in training.

Acknowledgments

The authors would like to express our gratitude to Oanh Tran, JSOM staff, Madigan's Department of Clinical Investigation, Public Affairs Office, and Department of Emergency Medicine for their review of the manuscript.

Author Contributions

KC, JE, TK, and KR participated in study design and execution. AK, KC, and KR participated in study analysis. AK and JH participated in manuscript writing and all authors participated in manuscript review.

Disclaimer

The views expressed are those of the author(s) and do not reflect the official policy of the Department of the Army, the Department of Defense, or the U.S. Government.

Disclosures

No competing interests are held by any authors in the design, writing, or review of this publication.

Funding

No funding was provided for the design, execution, review, or writing of this publication.

References

1. **Petrone P, Pérez-Jiménez A, Rodríguez-Perdomo M, Brathwaite CEM, Joseph DK.** Resuscitative endovascular balloon occlusion of the aorta (REBOA) in the management of trauma patients: a systemic literature review. *Am Surg*. 2019;85(6): 654–662.
2. **Thrailkill MA, Gladin KH, Thorpe CR, et al.** Resuscitative endovascular balloon occlusion of the aorta (REBOA): update and insights into current practices and future directions for research and implementation. *Scand J Trauma Resusc Emerg Med*. 2021;29(1):8. doi:10.1186/s13049-020-00807-9
3. **Moore L, Brenner M, Kozar RA, et al.** Implementation of resuscitative endovascular balloon occlusion of the aorta as an alternative to resuscitative thoracotomy for non-compressible truncal hemorrhage. *J Trauma Acute Care Surg*. 2015;79(4):523-530; discussion 530–532. doi:10.1097/TA.0000000000000809
4. **Long B, Hafen L, Koyfman A, Gottlieb M.** Resuscitative endovascular balloon occlusion of the aorta: a review for emergency clinicians. *J Emerg Med*. 2019;56(6):687–697. doi:10.1016/j.jemermed.2019.03.030
5. **Pieper A, Thony F, Brun J, et al.** Resuscitative endovascular balloon occlusion of the aorta for pelvic blunt trauma and life-threatening hemorrhage: a 20-year experience in a Level I trauma center. *J Trauma Acute Care Surg*. 2018;84(3):449–453. doi:10.1097/TA.0000000000001794
6. **Glaser J, Stigall K, Cannon J, et al.** "Clinical Practice Guidelines for Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) for Hemorrhagic Shock." Joint Trauma System. Published March 31, 2020. Accessed November 9, 2020. https://jts.health.mil/assets/docs/cpgs/resuscitative_endovascular_balloon_occlusion_of_the_aorta_(reboa)_for_hemorrhagic_shock_31_mar_2020_id38_v1.1.pdf
7. **Stannard A, Morrison JJ, Scott DJ, Ivatury RA, Ross JD, Rasmussen TE.** The epidemiology of noncompressible torso hemorrhage in the wars in Iraq and Afghanistan. *J Trauma Acute Care Surg*. 2013;74(3):830–834. doi:10.1097/TA.0b013e31827a3704
8. **Adams D, McDonald PL, Holland S, et al.** Management of noncompressible torso hemorrhage of the abdomen in civilian and military austere environments: a scoping review. *Trauma Surg Acute Care Open*. 2024;9(1):e001189. doi:10.1136/tsaco-2023-001189
9. **Davidson AJ, Russo RM, Reva VA, et al.** The pitfalls of resuscitative endovascular balloon occlusion of the aorta: risk factors and mitigation strategies. *J Trauma Acute Care Surg*. 2018;84(1):192–202. doi:10.1097/TA.0000000000001711
10. **Ribeiro Junior MAF, Feng CYD, Nguyen ATM, et al.** The complications associated with resuscitative endovascular balloon occlusion of the aorta (REBOA). *World J Emerg Surg*. 2018;13:20. doi:10.1186/s13017-018-0181-6
11. **Saito N, Matsumoto H, Yagi T, et al.** Evaluation of the safety and feasibility of resuscitative endovascular balloon occlusion of the aorta. *J Trauma Acute Care Surg*. 2015;78(5):897–903; discussion 904. doi:10.1097/TA.0000000000000614
12. **Engberg M, Mikkelsen S, Hörer T, et al.** Learning insertion of a resuscitative endovascular balloon occlusion of the aorta (REBOA) catheter: is clinical experience necessary? A prospective trial. *Injury*. 2023;54(5):1321–1329. doi:10.1016/j.injury.2023.02.048
13. **Engberg M, Taudorf M, Rasmussen NK, Russell L, Lönn L, Konge L.** Training and assessment of competence in resuscitative endovascular balloon occlusion of the aorta (REBOA) – a systematic review. *Injury*. 2020;51(2):147–156. doi:10.1016/j.injury.2019.11.036
14. **Stokes SC, Theodorou CM, Zakaluzny SA, DuBose JJ, Russo RM.** Resuscitative endovascular balloon occlusion of the aorta in combat casualties: the past, present, and future. *J Trauma Acute Care Surg*. 2021;91(2S Suppl 2):S56–S64. doi:10.1097/TA.0000000000003166
15. **Rees P.** Response to: 'REBOA at Role 2 Afloat: resuscitative endovascular balloon occlusion of the aorta as a bridge to damage control surgery in the military maritime setting' by Rees et al. *J R Army Med Corps*. 2019;165(3):213–214. doi:10.1136/jramc-2018-001016
16. **Teeter WA, Romagnoli AN, Glaser J, et al.** Resuscitative endovascular balloon occlusion of the aorta: pushing care forward. *J Spec Oper Med*. 2017;17(1):17–21. doi:10.55460/BQOR-ZQYJ
17. **Manley JD, Mitchell BJ, DuBose JJ, Rasmussen TE.** A modern case series of resuscitative endovascular balloon occlusion of the aorta (REBOA) in an out-of-hospital, Combat Casualty Care setting. *J Spec Oper Med*. 2017;17(1):1–8. doi:10.55460/9H3H-5GPS
18. **Vicente DA, Ugochukwu O, Johnston MG, Craft C, Damin V, Tadlock MD.** Preparing Austere Maritime Surgical Teams for deployment during the COVID-19 global pandemic: is it time to change the training pipeline? *Mil Med*. 2021;186(9-10):e873–e878. doi:10.1093/milmed/usaa574
19. **Allen CJ, Straker RJ, Murray CR, et al.** Recent advances in Forward Surgical Team training at the U.S. Army Trauma Training Department. *Mil Med*. 2016;181(6):553–559. doi:10.7205/MILMED-D-15-00084

PMID: 40952910; DOI: 10.55460/VOEM-ODN1

APPENDIX 1: REBOA PRE-SURVEY

Please indicate your level of training									
Medic	**Nurse**	**MD (Surgeon)**	**PA**	**Other:**					
Please indicate your current awareness of REBOA placement/management: *(1) None (10) I could teach this course*									
1	2	3	4	5	6	7	8	9	10
Please indicate your comfort placing (Provider) or assisting in placement (Nursing/Medic) of a REBOA Catheter: *(1) Very little confidence (10) Very Confident*									
1	2	3	4	5	6	7	8	9	10
Confidence using ultrasound for procedures in general *"(1) none, no past experience (10) extensive, I use ultrasound for procedures regularly"*									
1	2	3	4	5	6	7	8	9	10
Theater REBOA Course Post-Survey									
Please indicate your current awareness of REBOA placement/management: *(1) None (10) I could teach this course*									
1	2	3	4	5	6	7	8	9	10
Please indicate your comfort placing (Provider) or assisting in placement (Nursing/Medic) of a REBOA Catheter: *(1) Very little confidence (10) Very Confident*									
1	2	3	4	5	6	7	8	9	10
Please indicate agreement/disagreement with the following statement "I feel incorporation of the simulation model (RATTS) trainer was beneficial to understanding this procedure" *(1)* (*strongly disagree*) *(10)* (*strongly agree*)									
1	2	3	4	5	6	7	8	9	10
Did you find this course useful?									
☐ Not at All	☐ Somewhat	☐ Useful	☐ Very Useful						
Do you feel training on damage control techniques is useful in the deployed environment?									
☐ Not at All	☐ Somewhat	☐ Useful	☐ Very Useful						
Any suggestions for course improvement? Any suggestions for future deployed training in general?									
Suggestions for improved instructor performance? (Please state instructors name) feedback is appreciated – it is the only way we improve!									

APPENDIX 2: REBOA POST-TRAINING TEST

Thank you for what you do!

REBOA Theater Post-Test

1. Where is the correct location to place a femoral arterial sheath that could be used for REBOA placement?
   A) Common femoral artery, 2 cm below the inguinal ligament
   B) Confluence of superficial femoral and profunda arteries
   C) Superficial femoral artery
   D) Profunda femoral artery
   E) Common femoral vein, 2 cm below the inguinal ligament
2. You are evaluating an unstable blunt trauma patient with a negative FAST and normal chest x-ray in a pelvic binder who meets clinical criteria for REBOA placement for an open book pelvic fracture. A femoral arterial line is upsized to a 7 French sheath without difficulty. While inserting the REBOA catheter you feel resistance. All of the following are acceptable management options EXCEPT:
   A) Retract the catheter several inches and try again, advancing slowly
   B) Retract and advance under fluoroscopic guidance
   C) Keep advancing the catheter despite resistance
   D) Abort the procedure and proceed to the OR
3. What is the maximum diameter of the ER-REBOA™ balloon?
   A) 3 cm
   B) 3.2 cm
   C) 4 cm
   D) 4.2 cm
4. Zone 1 for REBOA placement is defined as the segment of aorta between the:
   A) Left subclavian and celiac arteries
   B) Innominate and celiac arteries
   C) Celiac and renal arteries
   D) Innominate and left subclavian arteries
5. Zone 3 for REBOA placement is defined as the segment of aorta between the:
   A) Lowest renal artery to the highest hypogastric artery
   B) Aortic bifurcation and the common femoral arteries
   C) Celiac and lowest renal artery
   D) Lowest renal artery to the aortic bifurcation
6. Which of the following is the smallest sheath size that will accommodate the ER-REBOA™ catheter?
   A) 2 mm
   B) 7 French
   C) 12 French
   D) 18 French
7. A 30 year old female presents with a penetrating left upper quadrant abdominal injury. The chest x-ray is normal but the patient is profoundly hypotensive and does not respond to resuscitation with blood products. Because an OR was not immediately available, an ER-REBOA™ catheter is being placed. Which zone of the aorta should be targeted for balloon inflation in this case?
   A) Zone 1
   B) Zone 2
   C) Zone 3
   D) Zone 4
8. A 35 year old male status post dismounted IED blast presents with a severe pelvic fracture and a left lower extremity traumatic amputation with a tourniquet in place without any active extremity bleeding. His chest x-ray is normal and his FAST is negative, but he remains hypotensive and does not respond to resuscitation with blood products. A ER-REBOA™ catheter is inserted without complication. Which zone of the aorta should be targeted for balloon inflation in this case?
   A) Zone 1
   B) Zone 2
   C) Zone 3
   D) Zone 4
9. Insertion of an arterial access sheath which can be used to place a REBOA catheter can be accomplished by which of the following techniques?
   A) "Up-sizing" a femoral arterial line to a larger (i.e. 7Fr) access sheath
   B) Direct insertion of 14 French access sheath
   C) Use of an Amplatz SuperStiff guide wire and serial dilators to achieve appropriate arteriotomy for sheath insertion.
   D) REBOA does not require an access sheath for insertion.
10. After successful placement and inflation of a REBOA catheter in the emergency department for hemorrhage control in severe hemorrhagic shock, what is the most appropriate next step in the management of this patient?
    A) Continue blood product resuscitation in the ED with a 1:1:1 ratio and re-assess response
    B) Continue resuscitation while proceeding immediately to the OR/IR for definitive hemorrhage control
    C) Transient deflation of the REBOA balloon to test for hemodynamic stability; continue this maneuver in the ED until the patient's blood pressure normalizes
    D) Resuscitative thoracotomy to define the injury
    E) Admission to the ICU for warming and resuscitation
11. The ideal duration of aortic balloon occlusion in the unstable trauma patient is:
    A) Maintain occlusion until major truncal hemorrhage is controlled, and then deflate the balloon
    B) Maintain occlusion until all injuries are identified and repairs are completed, and then deflate the balloon
    C) Maintain occlusion during initial resuscitation, and then deflate the balloon on arrival to the operating room
    D) Maintain occlusion until systolic blood pressure > 90 mmHg achieved, and then deflate the balloon
12. Which of the following should be assessed after femoral sheath removal to aid in the early identification of a common serious complication?
    A) Pulse distal to the access site
    B) Lactate level
    C) D-dimer level

D) aPTT/INR level
E) X-ray of the extremity distal to the access site

13. Which is the best method to rapidly obtain arterial access of the common femoral artery?
    A) Fluoroscopic guidance of a hollow-tip needle
    B) Ultrasound guidance of a hollow-tip needle
    C) Puncture with a hollow-tip needle above the inguinal canal
    D) Open groin cut-down
    E) Both B and D
14. A trauma patient with pelvic crush injury is hypotensive and a non-responder to fluid and blood product resuscitation. A pelvic binder is placed with no improvement in blood pressure despite ongoing resuscitation. No other injuries are present. You decide to place an ER-REBOA™ catheter, but the pelvic binder appropriately obscures the arterial access site. What is the best option to facilitate obtaining arterial access in this patient?
    A) Remove the pelvic binder to improve exposure
    B) Brachial artery access
    C) Open cut-down on the superficial femoral artery
    D) Ultrasound guided access of the superficial femoral artery with a hollow-tip needle
    E) Cut a window in the pelvic binder to access the common femoral artery
15. In which of the following would REBOA have a role in hemorrhage control?
    A) Penetrating cardiac trauma
    B) Exsanguinating upper extremity injury
    C) Penetrating neck trauma with uncontrolled bleeding
    D) Penetrating right upper quadrant wound with hypotension
16. In placing an ER-REBOA™ catheter, what is the external landmark that should be used for placement of the p-tip to approximate Zone 1 aortic balloon position?
    A) Tip of the xiphoid process
    B) Umbilicus
    C) Mid-sternum
    D) Sternal notch
17. What is the best external anatomic landmark to locate the common femoral artery for insertion of a femoral arterial line or arterial sheath?
    A) Arterial pulse immediately caudal to the inguinal skin crease
    B) Palpable pulse in proximal thigh
    C) Arterial pulse immediately caudal to an imaginary line connecting the anterior superior iliac spine and pubic tubercle
    D) Immediately medial to the site where venous blood was aspirated caudal to the level of the inguinal ligament
18. A patient with an open pelvic fracture had a REBOA catheter placed and inflated in Zone 3. He was then brought to the operating room and had preperitoneal packing performed. He was resuscitated with blood products and is now normotensive. All of the following are appropriate considerations regarding balloon deflation EXCEPT:
    A) Pre-notification of anesthesia
    B) Pre-emptive administration of bicarbonate and calcium
    C) Minimize ischemia time by rapid balloon deflation
    D) Use of partial balloon deflation with progression guided by hemodynamic parameters
    E) Pre-emptive administration of pressors prior to balloon deflation
19. The phrase "3 and 8, don't overinflate" refers to:
    A) The expected external diameter (in cm) of the inflated ER-REBOA™ balloon in aortic Zones 3 and 1, respectively
    B) The expected volume of fluid injected (in mL) into the ER-REBOA™ balloon typically required to achieve aortic occlusion in aortic Zones 3 and 1, respectively
    C) The maximal aortic occlusion time (in hours) for Zones 1 and 3, respectively
    D) The two recommended sheath sizes for ER-REBOA™ and Coda™ balloon placement
20. In placing an ER-REBOA™ catheter, what is the external landmark that should be used for placement of the p-tip to approximate Zone 3 aortic balloon position?
    A) Tip of the xiphoid
    B) Umbilicus
    C) Mid-sternum
    D) Suprasternal notch
21. A soldier has a REBOA placed by an austere surgical team for exsanguinating hemorrhage following an IED blast. He undergoes damage control laparotomy with packing of a major liver injury. Following this procedure there are no signs of ongoing bleeding, but the patient is acidotic and has an INR of 2. He is now being prepared for helicopter transport to a Forward Surgical Team that is 20 minutes away. The optimal management for the REBOA catheter and sheath will be which of the following:
    A) Transport with femoral sheath in place and REBOA in place and inflated
    B) Remove REBOA catheter and remove the femoral sheath prior to transport
    C) Transport with femoral sheath in place and REBOA in place but deflated
    D) Remove REBOA catheter and leave the femoral sheath in place
22. A patient arrives at your Forward Surgical Team with penetrating wounds to the abdomen and an initial SBP of 60 mmHg. He has a positive FAST and a normal CXR, but then progresses to PEA arrest 10 minutes after arrival. Which of the following statements is correct regarding the role for REBOA in traumatic arrest?
    A) REBOA is associated with similar time to achieve aortic occlusion compared to ER thoracotomy
    B) REBOA is contra-indicated in traumatic arrest due to penetrating mechanisms
    C) Placement of the 7 French sheath is best performed using palpation and landmarks in this scenario
    D) Blood product resuscitation should not be initiated until the REBOA is in place and inflated

The Special Operations Medical Association's Official Journal

JSOM

JOURNAL *of* SPECIAL OPERATIONS MEDICINE™

Fall 2025
Volume 25, Edition 3

THE JOURNAL FOR OPERATIONAL MEDICINE AND TACTICAL CASUALTY CARE

Inside this Issue:

- FEATURE ARTICLES: Four Ukrainian-Manufactured Tourniquets
- Mitigating FWB Heat Loss During Austere Transfusions
- In-Theater Assessment of REBOA Capabilities and Training
- Novel Hand-Held Device for Chest Tube Insertion
- Tourniquet First-Use Learning
- Accuracy of Whole Blood Collection Techniques for Target Volume
- Antibiotic Concentrations after Massive Transfusion
- CASE REPORTS: Esophageal Perforation After Explosive Injury
- Axilla Injuries and Ceramic Plate Coverage
- Optic Nerve Sheath Diameter Reduction with TBI
- A Back-to-Basics Approach for Resuscitation
- EDITORIALS: Feasibility of Vascular Ultrasonography by SOF Medics
- Prehospital Administration of Low-Titer O+ Whole Blood
- ONGOING SERIES: Human Performance Optimization, Infectious Diseases, Prolonged Casualty Care, Unconventional Medicine, TCCC Updates, 2025 SOMSA Abstracts, *and more!*

Dedicated to the Indomitable Spirit, Lessons Learned & Sacrifices of the SOF Medic

A Peer Reviewed Journal That Brings Together The Global Interests of Special Operations' First Responders