Resuscitation Plus 20 (2024) 100784

Contents lists available at ScienceDirect

Resuscitation Plus

journal homepage: www.elsevier.com/locate/resuscitation-plus

Clinical paper

Successful Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) deployment by emergency medicine physicians for refractory non-traumatic cardiac arrest

Graham Brant-Zawadzki [a,*], Guillaume L. Hoareau [a,b,c], H. Hill Stoecklein [a], Nicholas Levin [a], Craig H. Selzman [b,d], Anna Ciullo [a,d], Joseph Tonna [a,d], Christopher Kelly [a], Jamal Jones [a], Scott T. Youngquist [a], M. Austin Johnson [a]

[a] Department of Emergency Medicine, University of Utah, Salt Lake City, UT, USA
[b] Nora-Eccles Harrison Cardiovascular Research and Training Institute, University of Utah, Salt Lake City, UT, USA
[c] Biomedical Engineering Department, University of Utah, Salt Lake City, UT, USA
[d] Division of Cardiothoracic Surgery, Department of Surgery, University of Utah, Salt Lake City, UT, USA

ARTICLE INFO

Keyword:
Resuscitative Endovascular Balloon Occlusion of the Aorta
Extracorporeal cardiopulmonary resuscitation
Cardiopulmonary resuscitation

ABSTRACT

Aim: Cardiac arrest afflicts over 600,000 people annually in the United States. Rates of survival from cardiac arrest have remained stagnant for decades. Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) is most commonly used in the management of severe hemorrhagic shock, primarily for non-compressible thoracoabdominal trauma. A growing body of evidence suggests it may serve a role in augmenting cardiac and cerebral perfusion in non-traumatic, refractory cardiac arrest. Typically, REBOA is deployed by interventional radiologists under real-time fluoroscopy. Limited data exist to demonstrate the feasibility or logistics of successful REBOA deployment in emergency departments by emergency medicine physicians.

Methods: We describe an emergency medicine-driven training program and treatment protocol developed to deploy REBOA in the emergency department for patients experiencing refractory out-of-hospital cardiac arrest and deemed ineligible for ECPR. We detail the training, certification processes, and clinical outcomes from our first eight cases.

Results: Five emergency medicine physicians underwent training for REBOA placement through a didactic curriculum and hands-on training with mannequin and live tissue porcine models. Since protocol implementation, eight patients have undergone REBOA catheterization by emergency medicine physicians: 5 males and 3 females, age range 25–79. The first pass success was 8/8 (100 %), and all 3 commercially available catheters in the United States were successfully used. ROSC was achieved in 3/8 (37.5 %) patients, although no patients survived to hospital discharge. No REBOA catheter-associated complications were identified.

Conclusions: This series demonstrates feasibility of emergency physician placed REBOA for non-traumatic, refractory cardiac arrest a novel resuscitative technique. Through a combination of focused education, innovative technology use, robust large animal model-based training, and strategic procedural integration, we showcase the potential for emergency departments to spearhead the adoption of this potentially life-saving intervention.

Introduction

Cardiac arrest occurs in over 600,000 people annually in the United States, with an average survival rate of 8–12 %.[1] Despite advancements in cardiopulmonary resuscitation (CPR) and advanced cardiac life support (ACLS), prognosis remains poor.[2] Extracorporeal cardiopulmonary resuscitation (ECPR) has emerged as a novel intervention, offering survival benefits beyond standard care.[3–4] However, the high cost, technical demands, and limited availability of ECMO management teams restrict its widespread adoption.[5–7] Resuscitative endovascular balloon occlusion of the aorta (REBOA) originally emerged as a technique for managing severe hemorrhagic shock,[8] but animal data, case studies, and a recent feasibility trial suggest that REBOA may also be beneficial in managing refractory cardiac arrest by producing increased

* Corresponding author at: 6300 N Sagewood, PMB 579, USA.
E-mail address: Graham.bz@utah.edu (G. Brant-Zawadzki).

https://doi.org/10.1016/j.resplu.2024.100784
Received 8 July 2024; Received in revised form 7 September 2024; Accepted 13 September 2024

coronary and cerebral perfusion.[8–12]

REBOA is more straightforward to deploy than ECPR and appears to facilitate ROSC in approximately 50 % of refractory cardiac arrest patients.[11] Successful REBOA placement in the emergency department (ED) by emergency medicine physicians is feasible, but there is limited evidence documenting use by ED providers in the United States[13–14] and widespread use of REBOA for refractory cardiac arrest remains limited. As with other low-frequency, high-risk procedures that offer the possibility of survival in otherwise fatal situations, it is paramount for providers to maintain knowledge, proficiency, and comfort with performing REBOA given its infrequent use.[15] A 2019 literature review suggested that a lack of physicians competent in performing REBOA was a significant barrier to its implementation and indicated that comprehensive simulation-based training might help bridge the gap.[16]

Our team sought to train a cohort of emergency medicine physicians in the placement of REBOA catheters and demonstrate the feasibility of a protocol for REBOA deployment in the ED by emergency medicine physicians. We developed a comprehensive REBOA procedural training course, including a literature review, didactic lectures, hands-on simulation training, and an objective competency assessment. Initial and subsequent ongoing training and assessment were required for clinical REBOA placement certification and skill maintenance. We present a case series demonstrating our strategy for implementing an ED-driven protocol utilizing REBOA during refractory cardiac arrest. We detail our training and certification process, procedural steps, utilization of transesophageal echocardiography (TEE), and deflation strategy.

Methods

Study setting

The University of Utah, a tertiary referral academic medical center, served as the study site. It houses over 800 beds and handles approximately 50,000 ED visits annually. The Department of Emergency Medicine utilizes large animal laboratories and simulation facilities for training. Implemented as a clinical program, our initiative did not engage the university's institutional review board and data was collected retrospectively.

Personnel training and certification

Five board-certified Emergency Medicine attending physicians underwent training for the initial ED-REBOA Physician cohort. In the first stage of curriculum, trainees were provided 1 h of pre-course learning materials including a review of pertinent vascular anatomy, familiarization with different REBOA devices, placement techniques, and review of available pertinent literature. Trainees then participated in 2 h of didactic training followed by a hands-on, high-fidelity simulation on mannequins. Once completed, trainees participated in a dedicated, live-tissue porcine models laboratory session. Certification as an 'ED-REBOA' physician required achieving ≥81 % on the REBOA Rating of Skills tool (REBOA-RATE[1]) in a simulation scenario.[17] A REBOA training mannequin remained available for skills maintenance between patients and porcine laboratory days and subsequent live tissue training sessions were provided to ensure all ED-REBOA physicians met a minimum of 6 h of ongoing training during the program period to ensure routine and consistent practice with the procedure and catheter. While an on duty, trained and certified provider served as the ED-REBOA physician.

Equipment

A detailed list of specialized equipment utilized for this program including REBOA Catheters, arterial access sheaths, and bedside ultrasound probes can be found in Tables 1. We also built a specific ED-REBOA supplies pack, the contents of which are documented in Table 2. Three different REBOA catheters were utilized over the course of the program due to device availability.

ED REBOA workflow & algorithm (Fig. 1)

Patient selection

Patient selection was designed to provide an intervention to patients suffering from cardiac arrest and have not achieved sustained ROSC early during resuscitation thus most likely to benefit from an augmented resuscitation but deemed ineligible for ECPR. The ED-REBOA physician met potential patients in the ED alongside the dedicated emergency medicine resuscitation team in a standard critical care/trauma resuscitation bay. Each of these rooms were equipped with ultrasound, though none had fluoroscopy. Eligibility was validated by the ER-REBOA provider based on pre-determined inclusion and exclusion criteria (see Fig. 2).

REBOA placement and inflation

Once a patient was identified as eligible for ED-REBOA placement, the procedure commenced with the patient positioned and prepped under sterile conditions for femoral artery access. REBOA catheter deployment proceeded alongside continued ACLS. Optimal timing for needle insertion into the femoral artery was coordinated with pulse checks to increase first stick success and mitigate vascular complications. Vascular access was established in the common femoral artery

Table 1
Specialized Equipment.

Category	*Equipment*	*Details*
REBOA Catheters	COBRA-OS Catheter, 4 French	Front Line Medical Technologies, London, Ontario, Canada
	ER-REBOA-PRO Catheter, 7 French	Prytime Medical Devices, Boerne, TX
	LANDMARK REBOA Catheter, 7 French	Emergency Scientific, Salt Lake City, UT
Arterial Access Sheaths	Prelude Pro 5 French sheath	Merit Medical, South Jordan, UT; Used with the Front-Line Medical 4 French catheter (Front Line Medical Technologies, London, Ontario, Canada)
	Prelude Pro 7 French sheath	Merit Medical, South Jordan, UT; Used with the ER-REBOA-Pro catheter (Prytime Medical, Boerne, TX) and the LANDMARK catheter (Emergency Scientific, Salt Lake City, UT)
Ultrasound	Standard, high-frequency linear probe	Used to obtain vascular access under real-time guidance
	Transesophageal probe	Used to confirm REBOA catheter placement in real-time (when available)
Arterial Blood Pressure Monitoring	Bedside vital signs monitor	Measured arterial blood pressure following REBOA catheter deployment
	Blood pressure monitor (Medline Centurion Compass)	Northfield, IL; Included in the ED-REBOA kit (Table 2) for emergencies if the bedside monitor was unavailable or malfunctioned
ED-REBOA Kit	Non-electrical accessory items	See Table 2 for a complete list

[1] *A scoring tool for assessing procedural competence in REBOA based on best-available knowledge from international experts in the field.*

Table 2
ED-REBOA Pack Inventory.

Category	Item
Sterility	Hat Mask Gown Gloves: 7 × 2, 7.5 × 2, 8 × 2 Small drape ×2 Chlorhexidine large ×2 Ultrasound probe cover
Catheter Placement	18-guage echogenic needle Micropuncture set 7 French arterial sheath 5 French arterial sheath Femoral arterial line kit and blood pressure monitor Sterile flushes in sterile syringes Suture Needle Driver Tegaderm

under ultrasound guidance and an introducer sheath inserted over the guidewire. The REBOA catheter was prepared, with attention to creating a vacuum in the balloon port, and advanced to a predetermined depth gauged by placing the catheter the patient's chest to align the catheter tip with the sternal notch; this location approximaes the supra-coeliac region of the aorta (Zone 1). The balloon was then inflated with 10 ml of normal saline, or until resistance was felt in order to achieve aortic occlusion. The entire assembly was then secured with sutures and an adhesive dressing. REBOA catheter placement was confirmed in real-time by TEE with or without subsequent x-ray or computed tomography (CT) scan of the chest.

Realtime ultrasound use for REBOA placement and confirmation

Ultrasound played a crucial role in both placement and confirmation of REBOA catheters during this study. Two types of ultrasound were employed: linear ultrasound and TEE.

The linear ultrasound probe was primarily used to facilitate vascular access. Under real-time ultrasound guidance, the femoral artery was identified, and a needle was inserted to achieve access. This technique ensured accurate and safe placement of the introducer sheath, minimizing the risk of vascular complications. Once access was secured, the REBOA catheter was advanced to the desired position using anatomical landmarks for initial guidance.

When available, TEE was used to confirm the precise placement of the REBOA catheter and the balloon within the aorta. TEE availability was dependent on the presence of a TEE trained emergency medicine physician as part of ED resuscitation team. After the catheter was advanced to the estimated position, the TEE probe was inserted by that provider to visualize the aortic anatomy. Real-time TEE allowed for the verification of the catheter tip location in the supra-coeliac region (Zone 1) and provided immediate feedback during balloon inflation to ensure effective aortic occlusion. This method of confirmation was particularly valuable in the absence of fluoroscopy, as it offered a reliable means to assess the adequacy of the procedure in real-time. In cases where TEE was not available, and where appropriate, subsequent imaging, such as chest X-ray or computed tomography (CT), was used to confirm catheter placement. However, TEE provided the advantage of immediate intra-procedural feedback, reducing the reliance on post-procedural imaging.

Post-ROSC management in the ED

If ROSC was obtained, the balloon was gradually deflated over one minute. This approach was selected due to concerns that extended inflation after ROSC result in rapid and potentially harmful rise in afterload..[14] All patients with ROSC were assessed for ECPR cannulation based on initial ABG results. Should patients manifest unfavorable indicators, they were transitioned onto a "resuscitation Pathway" defined

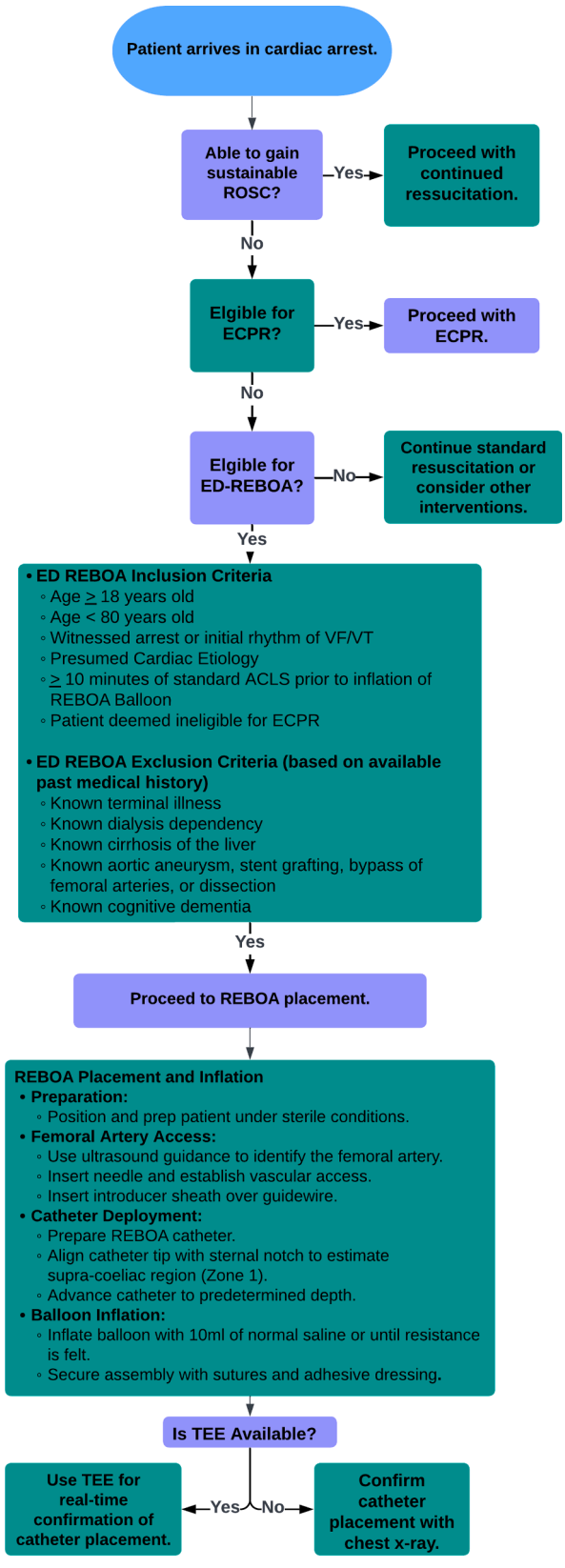

Fig. 1. ED-REBOA Workflow Algorithm.

by our institution's ECPR team. (Fig. 3). Those still unstable despite vasopressors (defined as persistent hypotension requiring increasing pressor support or ongoing REBOA support with partial inflation) were reconsidered for potential ECMO initiation in the ED. Regardless of

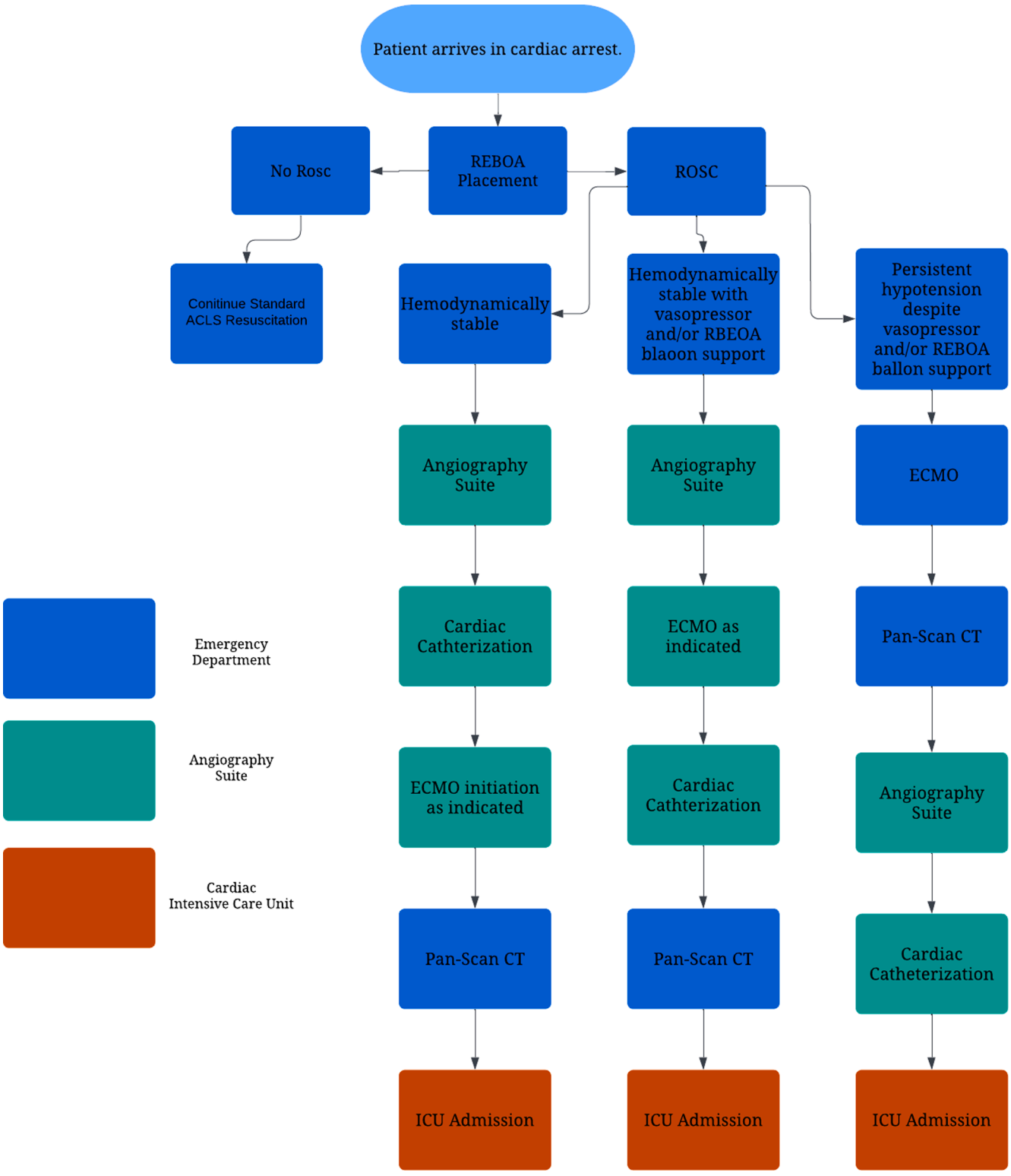

Fig. 2. Post-ROSC Management Pathway.

pathway, following stabilization from catheterization or ECMO cannulation, all patients underwent CT of the head, chest, abdomen, and pelvis before being admitted. Should ROSC not be achieved within 15 min of aortic occlusion and the patient remained ineligible for ECPR, the REBOA catheter was deflated and withdrawn. ACLS efforts persisted under standard practices, which included the potential discontinuation of resuscitative efforts.

Results

Eight patients, 5 males and 3 females (age range 25–79) underwent REBOA placement. The first-pass success was 8/8 (100 %), and all 3 commercially available catheters in the United States were successfully used. ROSC was achieved in 3/8 (37.5 %) patients, all of whom were admitted to the hospital. All three admitted patients died during hospital admission. No REBOA catheter-associated complications were identified

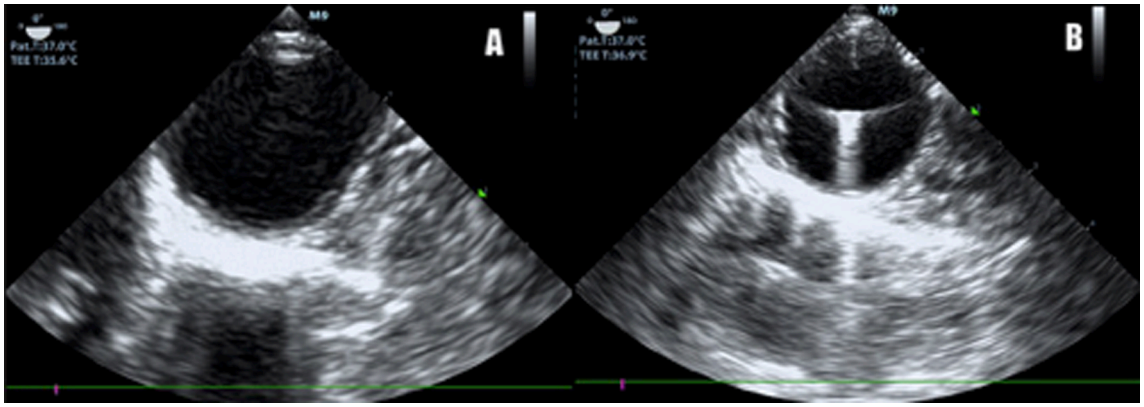

Fig. 3. REBOA placement confirmation by ED physician resuscitative transesophageal echocardiography views of the descending aorta in short access. [A] prior to catheter placement. [B] Following REBOA catheter balloon inflation. .

on imaging or autopsy reports. See Table 3 for case details.

Discussion

The cases presented here demonstrate the successful deployment of REBOA in non-traumatic cardiac arrest (NTCA) by emergency medicine physicians following a comprehensive emergency department driven training and certification program. Our results demonstrated a 37.5 % (3/8) rate of ROSC, though there were no neurologically intact survivors.

The 37.5 % ROSC rate reflects a positive initial effect of REBOA in augmenting perfusion to vital organs. While the lack of neurologically intact survivors may raise concerns about the overall utility of REBOA in NTCA, this should be considered within the context of the challenging nature of these cases. Our patient cohort consisted of individuals who were ineligible for ECPR, and thus had an inherently low likelihood of survival at the outset. This selection bias may have let to an underrepresentation of the broader effectiveness of REBOA in a more diverse population of cardiac arrest patients. Future research is needed to determine if refinements in patient selection or earlier intervention might improve neurologic outcome.

Despite these challenges, the repeated successful placement of REBOA catheters by emergency medicine physicians without the use of fluoroscopy marks a significant achievement. Comparative data from other REBOA programs, such as those from Yale and European centers, report similar or better ROSC rates to ours (30–50 %), though also with limited survival to hospital discharge.[12,13,18] These programs have shown variability based on factors such as patient selection, timing of REBOA deployment, and integration with other advanced resuscitative techniques like ECPR. Our program's 100 % success rate with first-pass REBOA placement stands out, highlighting the proficiency of our emergency medicine physicians in performing this procedure. The training, which included a literature review, didactic lectures, hands-on simulation, and live tissue practice, ensured that physicians performed the procedure with persistent success. We recognize that our series represents a small number of cases and that the overall survival rate is poor. However, as we refine the intervention with more streamlined processes, obtain earlier vascular access, apply quicker interventions, and increase provider skill and experience, we believe there is potential to enhance patient outcomes.

We advocate that similar training programs and REBOA deployment protocols presented here can and should be replicated in other centers across the country. However, several factors must be considered for successful implementation, including access to appropriate training resources, the ability to ensure skill maintenance over time, institutional support for integrating REBOA into existing resuscitation protocols, and the availability of further patient assessment and management capabilities, such as in house cardiac angiography and ECMO.

Following an accessible training and credentialing process tailored for emergency medicine providers, the successful implementation of our ED-REBOA program particularly demonstrates the feasibility of making advanced resuscitative techniques available to ED clinicians within the

Table 3
Case Details:

Case	*Age*	*Witnessed Arrest?*	*Bystander CPR?*	*Initial Cardiac Rhythm*	*Down Time*[*]	*REBOA Catheter*	*ROSC?*[**]	*Placement Confirmed on Imaging*	*Survived to Hospital Admission*	*Outcome*
1	44	Unwitnessed	No	PEA	10 min	ER-REBOA-PRO	Y	CT	Yes	Death inpatient day 7
2	40	Witnessed	Yes	PEA	82 min	COBRA-OS	Y	TEE & CT	Yes	Brain death
3	55	Unwitnessed	Yes	VT	50 + min	COBRA-OS	N	TEE	No	Death
4	79	Witnessed	Yes	PEA	120 min	ER-REBOA-PRO	N	Chest XR	No	Death
5	25	Witnessed	Yes	VF	60 min	ER-REBOA-PRO	N	Linear US probe	No	Death
6	52	Unwitnessed	Yes	VF	48 min	COBRA-OS	N	Linear US probe	No	Death
7	54	Witnessed	No	VF	15 min	LANDMARK REBOA	Y	TEE	Yes	Death
8	44	Witnessed	Yes	PEA	60 min	LANDMARK REBOA	N	TEE	No	Death

[*] Prior to balloon inflation.
[**] Following REBOA Balloon inflation.

crucial time windows dictated by cardiac emergencies. Unlike protocols that necessitate a hybrid room or fluoroscopy, our landmark and measurement-based catheter placement method allows the procedure to be performed within the ED without reliance on advanced imaging technologies. This approach preserves the procedural integrity and safety of REBOA insertion while aligning with the logistical realities and resource constraints of emergency medicine environments.

While we advocate that arterial access and REBOA catheter placement be performed by the most capable available provider, there is no reason why resident physicians who receive the same standardized training, certification, and ongoing skills maintenance program as our attending physicians should not be capable of deploying this intervention. Relative to ECPR, REBOA is a more straightforward and resource-efficient procedure. With minimal training, any provider can place a 4- or 6-French catheter with relatively low risk of adverse effects. By contrast, ECMO is significantly more resource-intensive, requiring specialized training, larger access catheters, and a higher degree of expertise, all of which lend to greater opportunities for complications. The ability to deploy REBOA quickly and effectively, particularly in resource-limited settings, positions it as an accessible intervention that could fill a critical gap in resuscitative care, especially in settings where ECMO is not readily available.

Barriers to adoption

Despite its potential benefits, the adoption of REBOA for NTCA faces several barriers. These include the complexity and resource-intensive nature of the training required to achieve and maintain proficiency. Additionally, the perceived risks associated with REBOA, such as vascular complications and the potential for iatrogenic injury, combined with the lack of robust, large-scale data demonstrating clear survival benefits may contribute to hesitation among clinicians and deter its wider use. Addressing these barriers will require more extensive research as well as efforts to standardize training and certification processes.

A critical area requiring further investigation is the optimal timing of REBOA deployment. In our program, REBOA was applied late in the resuscitation process, but earlier placement could potentially improve outcomes by augmenting coronary and cerebral perfusion earlier during the course of resuscitation. Future studies should explore whether earlier intervention, possibly even before conventional measures have been exhausted, could yield better results.

Finally, the question of whether REBOA should be limited to large academic centers with ECMO capabilities is an important one. While these centers are well-suited to integrating REBOA into a broader resuscitation strategy, including as a bridge to ECMO, we argue that there is also a role for REBOA in non-ECMO centers. In these settings, REBOA could serve as a standalone intervention for NTCA or as a bridge to more widespread available treatment pathways such as cardiac angiography, operative repair of traumatic injuries, transfer to an ECMO capable center, or organ donation. However, careful consideration must be given to the infrastructure, training, and support required to implement and sustain such a program in non-academic or resource-limited environments. Finally, critical to the realization of this program was the strategic recruitment of a physician basic scientist with an extensive background in REBOA. These roles proved fundamental in crafting a specialized training regimen to ensure our clinicians possess the necessary proficiency for the technical aspects of REBOA and the complex decision-making required for its deployment. This highlights the importance of backing clinical expertise with a robust institutional framework in advancing medical intervention. Further enhancing our program's foundation is our robust use of large animal models and infrastructure for live tissue and simulated use placement and training. This unique advantage has allowed for a comprehensive understanding of the procedure's intricacies in a controlled environment, closely mimicking real-life scenarios.

Limitations

Several limitations of our study should be acknowledged. First, this study was conducted at a single academic medical center with specialized training programs including large animal models and simulation facilities. While these training sessions were effective, they took place in controlled environments that may not fully replicate the complexities of a real-world emergency department (ED). Further, access to these resources and the support of physicians specifically recruited for their prior and comprehensive background in REBOA raises questions regarding the feasibility of implementing this training and REBOA deployment protocol in other settings, particularly in non-academic or resource-limited environments.

Additionally, our case series involved only eight patients. This small sample size, combined with the specific resources available at our institution, limits the generalizability of our findings. Given that REBOA is a low-frequency, high-risk procedure, maintaining proficiency over time is inherently challenging. Despite regular skill maintenance opportunities, it remains uncertain how well these skills are retained and transferred to actual patient care settings over extended periods, especially in high-pressure situations where cognitive overload can be significant.

Moreover, the study utilized three different commercially available REBOA catheters, each with unique characteristics. While the inclusion of multiple devices demonstrates the versatility of REBOA deployment in the ED, it also introduces variability that could affect the consistency of our results. Although our findings provide valuable insights into the feasibility and potential of REBOA deployment in refractory cardiac arrest, larger studies are needed to validate these results and to establish more robust outcome data.

Conclusion

In conclusion, our study demonstrated the feasibility of REBOA deployment by emergency physicians in the ED for non-traumatic refractory cardiac arrest. While there are significant challenges and limitations to the successful implementation of such a program, we believe that with proper training and institutional support, REBOA has the potential to become a valuable tool in the resuscitation of patients experiencing refractory cardiac arrest, in academic centers and beyond. Future research should explore the optimal timing of deployment, training and skills maintenance strategies, and settings for REBOA deployment to maximize its potential.

Contribution statement

MAJ and GH conceived and designed the protocol and training program. SY, CS, AC, and JT consulted on the design of the program and developed integration between departments and other institutional practices and protocols. GBZ, HHS, NL, CK, JJ, SY, AC, JT, and MAJ were each certified as REBOA physicians and performed catheterization. GBZ drafted the manuscript and all authors contributed to its revision. MAJ is responsible for the paper as a whole.

Funding source

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethical approval statement

All procedures were performed in compliance with relevant laws and institutional guidelines and were approved by the appropriate institutional committees.

This study was a retrospective review of cases and did not involve new data collection from human or animal subjects. The privacy rights

of patients have been observed.

CRediT authorship contribution statement

Graham Brant-Zawadzki: Writing – review & editing, Writing – original draft, Investigation. **Guillaume L. Hoareau:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Conceptualization. **H. Hill Stoecklein:** Writing – review & editing, Investigation, Conceptualization. **Nicholas Levin:** Writing – review & editing, Investigation. **Craig H. Selzman:** Writing – review & editing, Investigation. **Anna Ciullo:** Writing – review & editing, Formal analysis, Conceptualization. **Joseph Tonna:** Writing – review & editing, Investigation, Conceptualization. **Christopher Kelly:** Writing – review & editing, Investigation. **Jamal Jones:** Writing – review & editing, Investigation. **Scott T. Youngquist:** Writing – review & editing, Investigation. **M. Austin Johnson:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Dr. Austin Johnson is a co-founder, board member, consultant, and stockholder in Certus Critical Care. Dr. Austin Johnson is a board member of TitinKM Biomedical.

References

1. Mozaffarian D, et al. Heart disease and stroke statistics—2016 update. *Circulation*. 2016;133(4):e38–e360.
2. Yan S, et al., *The global survival rate among adult out-of-hospital cardiac arrest patients who received cardiopulmonary resuscitation: a systematic review and meta-analysis.* Critical Care, 2020. **24**.
3. Yannopoulos D, et al. Advanced reperfusion strategies for patients with out-of-hospital cardiac arrest and refractory ventricular fibrillation (ARREST): a phase 2, single centre, open-label, randomised controlled trial. *Lancet*. 2020;396(10265):1807–1816.
4. Belohlavek J, et al. Effect of intra-arrest transport, extracorporeal cardiopulmonary resuscitation, and immediate invasive assessment and treatment on functional neurologic outcome in refractory out-of-hospital cardiac arrest: a randomized clinical trial. *JAMA*. 2022;327(8):737–747.
5. Hutin A, et al. Early ECPR for out-of-hospital cardiac arrest: Best practice in 2018. *Resuscitation*. 2018;130:44–48.
6. Marinaro J, et al. Out-of-hospital extracorporeal membrane oxygenation cannulation for refractory ventricular fibrillation: a case report. *J Am Coll Emerg Physicians Open*. 2020;1(3):153–157.
7. Youngquist ST, et al. Current work in extracorporeal cardiopulmonary resuscitation. *Crit Care Clin*. 2020;36(4):723–735.
8. Bekdache O, et al. Resuscitative endovascular balloon occlusion of the aorta (REBOA): indications: advantages and challenges of implementation in traumatic non-compressible torso hemorrhage. *Trauma Surg Acute Care Open*. 2019;4(1).
9. Tiba MH, et al. Use of resuscitative balloon occlusion of the aorta in a swine model of prolonged cardiac arrest. *Resuscitation*. 2019;140:106–112.
10. Aslanger E, et al. Intraaortic balloon occlusion during refractory cardiac arrest. A case report. *Resuscitation*. 2009;80(2):281–283.
11. Brede JR, et al. Feasibility of pre-hospital resuscitative endovascular balloon occlusion of the aorta in non-traumatic out-of-hospital cardiac arrest. *J Am Heart Assoc*. 2019;8(22).
12. Levis A, et al. Resuscitative endovascular balloon occlusion of the aorta (REBOA) during cardiopulmonary resuscitation: a pilot study. *Resuscitation*. 2020;156:27–34.
13. Daley J, Buckley R, Kisken KC, et al. Emergency department-initiated resuscitative endovascular balloon occlusion of the aorta (REBOA) for out-of-hospital cardiac arrest is feasible and associated with improvements in end-tidal carbon dioxide. *J Am Coll Emerg Physicians Open.* 2022;3(5). https://doi.org/10.1002/emp2.12791.
14. Kelly C, Stoecklein HH, Brant-Zawadzki G, et al. TEE guided REBOA deflation following ROSC for non-traumatic cardiac arrest. *Am J Emerg Med*. 2023;63:182.e5–182.e7. https://doi.org/10.1016/j.ajem.2022.10.013.
15. Neumar RW, et al., *Post-cardiac arrest syndrome: epidemiology, pathophysiology, treatment, and prognostication. A consensus statement from the International Liaison Committee on Resuscitation (American Heart Association, Australian and New Zealand Council on Resuscitation, European Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Asia, and the Resuscitation Council of Southern Africa); the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; and the Stroke Council.* Circulation, 2008. **118**(23): p. 2452-83.
16. Hoareau GL, et al. Esmolol reduces myocardial injury induced by resuscitative endovascular balloon occlusion of the aorta (REBOA) in a porcine model of hemorrhagic shock. *Injury*. 2020;51(10):2165–2171.
17. Engberg M, Hörer T, Rasmussen TE, et al. Developing a tool to assess competence in resuscitative endovascular balloon occlusion of the aorta: an international Delphi consensus study. *J Trauma Acute Care Surg*. 2021;91(2):310–317. https://doi.org/10.1097/TA.0000000000003191.
18. Brede JR, Lafrenz T, Klepstad P, et al. Feasibility of pre-hospital resuscitative endovascular balloon occlusion of the aorta in non-traumatic out-of-hospital cardiac arrest. *J Am Heart Assoc*. 2019;8(22):e014394.