Feasibility Study of Vascular Access and REBOA Placement in Quick Response Team Firefighters

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ABSTRACT

Background: Early hemorrhage control using resuscitative endovascular balloon occlusion of the aorta (REBOA) can save lives. This study was designed to evaluate the ability to train Quick Response Team Fire Fighters (QRT-FF) to gain percutaneous femoral artery access and place a REBOA catheter in a model, using a comprehensive theoretical and practical training program. **Methods:** Six QRT-FF participated in the training. SOF medics from a previous training served as the control group. A formalized training curriculum included basic anatomy and endovascular materials for percutaneous access and REBOA placement. Key skills included (1) preparation of an endovascular toolkit, (2) achieving vascular access in the model, and (3) placement and positioning of REBOA. **Results:** QRT-FF had significantly better scores compared with medics using endovascular materials ($P = .003$) and performing the procedure without unnecessary attempts ($P = .032$). Basic surgical anatomy scores for QRT-FF were significantly better than SOF medics ($P = .048$). QRT-FF subjects demonstrated a significantly higher overall technical skills point score than medics ($P = .030$). QRT-FF had a median total time from start of the procedure to REBOA inflation of 3:23 minutes, and medics, 5:05 minutes. All six QRT-FF subjects improved their procedure times–as did four of the five medics. **Conclusions:** Our training program using a task training model can be utilized for percutaneous femoral access and REBOA placement training of QRT-FF without prior ultrasound or endovascular experience. Training the use of advanced bleeding control options such as REBOA, as a secondary occupational task, has the potential to improve outcomes for severely bleeding casualties in the field.

Keywords: *vascular access; training; aortic balloon occlusion; firefighters; first responders*

Introduction

Controlling noncompressible truncal hemorrhage (NCTH) is the major lifesaving skill in trauma and vascular surgery. In NCTH cases, advanced options for truncal and junctional bleeding control include wound clamps, injectable hemostatic sponges, pelvic circumferential stabilizers, resuscitative thoracotomy, intra-abdominal gas insufflation, junctional and truncal tourniquets, and resuscitative endovascular balloon occlusion of the aorta (REBOA).[1] Endovascular balloon occlusion of the aorta is a rapidly emerging technique that uses a compliant balloon advanced into the aorta which is then inflated, thereby obstructing flow into the distal circulation above the region of primary hemorrhage as a temporary bleeding control measure. REBOA technology has already been successfully used in hospital settings, combat environments, and even the earliest phases of prehospital care.[2 3]

Background

In mass casualty situations or in terrorist attacks, medical support is typically limited in the immediate vicinity of the incident. Zones of care are used in the prehospital setting to define locations that are accompanied with different levels of (personal) safety and require different levels of care. These zones help delineate the personnel and equipment that can and should be used depending on the type of incident. The area of the incident can be divided into hot, warm and cold zones, based on medical care in combat situations. In the 2015 Paris Bataclan attacks, not all damage control resuscitation tools were used because of a mismatch in the number of casualties and the availability of resources (Box 1).[4,5] In the past years, several gap analyses have been published on preventable deaths in both military and civilian settings using advanced bleeding control options such as REBOA.[6–10] These studies conclude that in the military setting, high percentages of casualties are secondary to NCTH, and smaller groups of severely injured that are theoretically amenable to REBOA can be identified in civilian casualty settings. In these situations, the use of advanced bleeding control options, such as REBOA, could have saved lives. Professional first responders in the Netherlands are not commonly trained or equipped in the use of advanced bleeding control options such as REBOA. Quick Response Team Fire Fighters (QRT-FF) are part of the Fire Brigade of the greater The Hague area, the Netherlands. They are an elite group of firefighters with additional medical

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Box 1 Hot, Warm, and Cold Zones: Different Zones of Care

"Zones of care" is the term used in the prehospital setting to delineate locations that require different levels of care and/or safety. These zones help delineate the personnel and equipment that can and should be used depending on the type of incident.[1] The definition of different zones can be applied in both military and civilian settings, for instance in a mass shooting or other mass casualty incidents. The most dangerous zone of care within tactical medicine is care under fire, also known as a hot zone or red zone. This zone poses the highest risk to life, and therefore limited care should be provided. The only medical treatment in this zone should be essential hemorrhage control, for example, pressure or tourniquet use. The second zone of care is tactical field care (TFC) also known as a yellow zone or warm zone.[1] This is generally where Emergency medical Services (EMS) and tactical support personnel will work.[2] When the TFC phase is entered, more medical interventions are possible. These include airway control and for instance the treatment of tension pneumothorax and application of a vented chest seal to open entry and exit chest wounds. Bleeding control with tourniquets, hemostatic gauzes or junctional tourniquets should be continued. Resuscitation with hypovolemic fluid resuscitation through intravenous (IV) access or intraosseous (IO) access is recommended for rapid fluid delivery and resuscitation.[3] The third zone is the Tactical Evacuation zone (TACEVAC), also known as the green zone or cold zone where basic emergency management services can be performed. Incident command posts, triage areas and ambulance staging areas are located in this zone. This is the zone outside of immediate danger and transportation to definitive care is usually available. In this zone, continued care and reassessment are the keys to ensure patient safety.[1] In the 2015 Paris Bataclan attack three tactical physicians were in the hot zone performing triage and applying tourniquets and hemostatic dressings. They were on the scene 11 minutes after the attack started. A dressing zone was established in the warm zone to perform damage control resuscitation (DCR). Two other tactical physicians joined the team in the dressing zone. This involved the application of tourniquets, dressings and the use of tranexaminic acid and the administration of fluids. Not all of the DCR recources were used because of a mismatch between the number of casualties and the insufficient amount of equipment. The five tactical physicians were the first and only responders in position to treat the victims inside the Bataclan. The conventional rescue teams were situated in the cold zone and when these teams received clearance to enter the warm zone, all living casualties had already been extracted. The final evacuation was performed 4.5 hours after the start of the attack.[4,5] In civilian setting, Emergency medical Services, more commonly known as EMS, can be based in a fire department, a hospital, an independent government agency (i.e., public health agency), a non-profit corporation (e.g., Rescue Squad) or be provided for by commercial for-profit companies.[6] These are examples of professional first responders. The hot zone is dynamic in nature and dependent on the location of the threat, the mobility of the threat, and the mobility of the patient. The hot and the warm zone can, at different times, be the same location. The warm zone is where most of the care of the sick and injured is accomplished, in respect to tactical medicine. Care can be varied depending on the equipment available, the location of local hospitals, and expertise of personnel. Introducing advanced bleeding control options into the warm zone could improve outcomes.

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and tactical training for complex situations. They can be deployed in mass casualty events or terrorist attacks. Medical support for the casualties is a secondary task in addition to their primary task. At times, however, first responders are the only professionals initially at the scene of the incident, and improving their ability to control hemorrhage is a logical way to improve outcomes when advanced medical providers are not immediately available. Before considering making these advanced skills available to first responders, the ability to train them must first be assessed.

There are a few formal training curricula designed to train the skills necessary to perform REBOA: the Basic Endovascular Skills for Trauma™ (BEST) and the Endovascular Skills for Trauma and Resuscitation™ (ESTARS) and Endovascular Resuscitation and Trauma Management (EVTM) courses. Our Advanced Bleeding Control study group recently published two papers on vascular access and REBOA training. These studies showed that a comprehensive theoretical and practical training program can be used for effective introduction of the skills necessary for percutaneous femoral access and REBOA placement in personnel without prior ultrasound or endovascular experience.[4,5] The aim of this current feasibility study was to determine whether QRT-FF with no prior endovascular or ultrasound experience could be trained to acquire the skills to adequately place an endovascular sheath in a femoral artery flow model and subsequently place a REBOA catheter in aortic zone I, using our previously published microteaching curriculum on a task training model.[5]

Methods

This study was conducted under a protocol reviewed and approved by the Dutch Ministry of Defense (MoD) and both the Institutional Review Board and medical Ethical Committee of Alrijne Hospital, the Netherlands (NWMO 17-15, 17.409rt.tk). All participants completed an informed consent to participate in this effort, including permission for video recording.

Participants

Participants were members of a Quick Response Team of the Haaglanden Fire Brigade, The Hague, the Netherlands. In this study we included the six members of this QRT-FF team. These QRT-FF performed the identical procedure a second time as a posttest after 2 hours of additional endovascular training during this EVTM workshop in Leiderdorp, the Netherlands. Eleven Special Operations Forces (SOF) medics from a previous EVTM training functioned as control group for technical skills and the first attempt for vascular access and REBOA placement, with five medics performing the posttest.

Curriculum

A formalized microteaching curriculum consisted of instruction in the basic anatomy of the femoral region and knowledge of the access materials required, including a guide wire and introducer sheath and ultrasound utilization (30 minutes). The details and instructions for use of the ER-REBOA® balloon were explained and demonstrated via an animation video covering the steps necessary for achieving vascular access and deployment of the balloon in zone I (15 minutes).[13] Ultrasound and percutaneous access skills were practiced on moulage flow models. Ultrasound imaging of the femoral artery and vein was practiced on a buddy trainee.

The task training model used for this study was the REBOA Access Task Trainer (RATT; Prytime Medical Devices™). Trainees were introduced to the RATT and were then individually instructed by a vascular surgeon (Dr Borger van der Burg) to identify anatomical landmarks and to verbalize each step required for adequate achievement of vascular access and REBOA positioning in zone 1. Key skills were as follows: (1) preparation of the endovascular tool kit, (2) achieving vascular access in the model, and, finally, (3) bleeding control with REBOA. Scoring ranged from 0 to 5 for nonanatomical skills. Identification of anatomical structures was either su0-pfficient (score = 1), or insufficient (score = 0).

A point-of-view GoPro® camera was used in all participants (via a point-of-view camera), as well as one additional GoPro® camera that was positioned to achieve a full view of the model and participant. After verbalizing every step of the procedure, video recording was commenced and the actual test was started with registration of procedure time.

Scoring System

Participants were evaluated using a modified checklist that was developed as part of a validation study for the Advanced Surgical Skills Exposures for Trauma (ASSET).[14,15] This included the individual procedure scores (IPS), outcomes of these scores on five components of technical and nontechnical skills, Global Rating Scale scores, errors, and time to complete the procedure of achieving vascular access and balloon placement. Two evaluators (Drs Borger van der Burg, van Dongen, and/or Hoencamp) located in the same laboratory evaluated performance with a standardized script for data collection.

Statistical Analysis

Statistical analyses were performed in collaboration with the help of a statistician expert (TD), using the Statistical Package for the Social Sciences (SPSS®, Version 24; IBM Corporation, Armonk, NY). All baseline information of the subjects and subsequent follow up data were registered in an electronic data file (Microsoft Excel® and SPSS®). The *t* test was used to analyze the test scores and procedure times. For all statistical analyses, a *P* value ≤.05 was considered significant.

Results

Six QRT-FF participated in this study were assessed and 11 previously trained medics functioned as a control group. The differences of technical skills between the six QRT-FF and 11 medics are presented in Table 1. Evaluators were in agreement of all scoring results. The QRT-FF had significantly better scores on using the endovascular material properly (n = 0.003), communicating clearly and consistently (n = 0.038), performing the procedure without unnecessary attempts (n = 0.032), and following a logical sequence for the procedure (n = 0.006). The baseline knowledge of surgical anatomy for QRT-FF was significantly better than that of the medics, *P* = .048. The QRT-FF had a significantly higher overall technical skills point score than the medics: 51.0 (44.8–52.3) vs 44.0 (41.0–46.0), *P* = .030. The QRT-FF had a median time of 2:04 minutes compared with 3:59 minutes for the medics to insert the sheath. Although the QRT-FF were faster than the medics, this was not significant, as presented in Table 2. Regarding the total time from start to REBOA inflation, QRT-FF had a median time of 3:23 minutes and medics 5:05 minutes. Again, QRT-FF were faster than medics, though not to a statistically significant degree.

TABLE 1 *Technical Skills of Firefighters and Medics*

Technical Skill	Firefighters (n = 6), Median [IQR]	Medics (n = 11), Median [IQR]	*P* Value*
01. Identifies optimal introduction site CFA	4.0 [4.0–4.3]	4.0 [4.0–5.0]	NS
02. Identifies introduction site skin	4.0 [3.8–5.0]	4.0 [4.0–5.0]	NS
03. Uses endovascular material properly	5.0 [4.8–5.0]	4.0 [4.0–4.0]	.003
04. Appropriate pace with economy of movement	4.5 [3.8–5.0]	4.0 [3.0–4.0]	NS
05. Effectively obtains necessary US exposure	4.5 [4.0–5.0]	4.0 [4.0–5.0]	NS
06. Communicates clearly and consistently	5.0 [3.8–5.0]	4.0 [4.0–4.0]	.038
07. Performs procedure without unnecessary attempts	5.0 [3.8–5.0]	3.0 [3.0–4.0]	.032
08. Follows a logical sequence for the procedure	5.0 [5.0–5.0]	4.0 [4.0–5.0]	.006
09. Correctly identifies CFA sagittal†	1.0 [1.0–1.0]	1.0 [1.0–1.0]	NS
10. Correctly identifies CFV sagittal†	1.0 [1.0–1.0]	1.0 [1.0–1.0]	NS
11. Technical skills for imaging femoral artery	4.0 [3.0–4.0]	4.0 [3.0–4.0]	NS
12. Overall understanding of the surgical anatomy	3.5 [3.0–4.0]	3.0 [2.0–3.0]	.048
13. Ready to achieve percutaneous access to the CFA	4.0 [3.8–4.3]	3.0 [3.0–4.0]	.024
Overall: technical skills total points	51.0 [44.8–52.3]	44.0 [41.0–46.0]	.030

Abbreviations: CFA, common femoral artery; CFV, common femoral vein; IQR, interquartile range; NS, not significant; PFA, profundal femoral artery; SFA, superficial femoral artery; US, ultrasound.
*Mann-Whitney *U* test.
†Score ranging from 0 to 1.

All six QRT-FF performed a second attempt of gaining vascular access and REBOA placement. These results are compared with the posttest of the medics in Table 3. Five medics performed a second attempt at gaining vascular access and REBOA placement and were compared with the QRT-FF. All QRT-FF improved their procedure time, as were four of the five medics (Table 4).

TABLE 2 *Procedure Time (Needle in Hand to Balloon Insufflation) at First Test*

Expert Level	Firefighters (n = 6)	SOF Medics (n = 11)	*P* Value*
Time sheath, median [IQR] (min:sec)	2:04 [1:54–2:12]	3:59 [1:55–4:21]	NS
Time total, median [IQR] (min:sec)	3:23 [2:59–4:13]	5:05 [3:07–5:38]	NS

Abbreviations: IQR, interquartile range; min:sec, minutes:seconds; SOF, Special Operations Forces.
*Mann-Whitney *U* test.

TABLE 3 *Difference in Procedure Time Between First and Second Attempts*

Procedure Time	First Attempt	Second Attempt	Difference	*P* Value*
Firefighters (n = 6)				
Time sheath, mean [SD] (min:sec)	2:04 [0:18]	1:48 [0:39]	–0:16	NS
Time total, mean [SD] (min:sec)	3:32 [0:40]	3:07 [0:57]	–0:25	NS
Medics (n = 5)				
Time sheath, mean [SD] (min:sec)	2:32 [1:04]	2:38 [2:33]	+0:06	NS
Time total, mean [SD] (min:sec)	3:54 [1:04]	3:27 [2:42]	–0:27	NS

Abbreviations: min:sec, minutes:seconds; SD, standard deviation.
*Paired *t* test.

TABLE 4 *Procedure Time (Needle in Hand to Balloon Insufflation) Retest for Firefighters Versus Medics*

Expert Level	Firemen (n = 6)	SOF Medics (n = 4)	*P* Value*
Time sheath, median [IQR] (mm:sec)	1:38 [1:18–2:12]	1:19 [1:09–2:04]	NS
Time total, median [IQR] (mm:sec)	2:44 [2:25–3:54]	2:07 [1:46–2:53]	NS

Abbreviations: IQR, interquartile range; mm:sec, minutes:seconds; SOF, Special Operations Forces.
*Mann-Whitney *U* test.

Discussion

This feasibility study provides evidence that vascular access training and REBOA placement of QRT-FF with no endovascular experience is possible via a formalized and comprehensive curriculum using a task training model. Our results show that QRT-FF were able to perform REBOA placement on a task training model with similar and acceptable procedure times compared with medics.

All six participating QRT-FFs were able to improve their procedure times in the posttest, indicating that this training program delivers consistent results and improvements in procedure times are to be expected with more exposure to training.

This is an important finding considering that QRT-FF and medics only have a 4-month medical training program that currently does not cover these topics. Although insertion is relatively straightforward, achieving percutaneously arterial access in unstable patients in austere environments is challenging for providers without a surgical skillset and should be the focus of further training.

Teeter et al.[16] described US Army Special Operations Command medical personnel without prior endovascular experience who were included in the BEST™ course, with findings similar to our own—that procedure time after basic training of medical personnel of various backgrounds and limited prior endovascular experience can be improved. In another study on the subject, Pasley et al.[17] concluded that independent duty military medical technicians can be effectively trained to perform the procedure for REBOA placement accurately and rapidly. In a similar fashion, we confirm in our study that personnel with no prior endovascular training can be trained in performing this procedure in a task training model. Similarly, in case of extracorporeal membrane oxygenation cannulation is not only performed by vascular surgeons but also by trained nonphysicians such as perfusionists. Recent programs on remote cannulation and transport have also shown good patient outcomes. [18] A recent Delphi consensus paper stated that REBOA can be safely and effectively performed in a variety of settings and by providers of various clinical background, provided that they have appropriate training and local protocols for use. [19]

Prompt bleeding control and advanced resuscitation in a prehospital environment are essential to improve outcome of trauma victims with major hemorrhage. Although medical treatment is not the primary skillset for QRT-FF, providing them with effective training and tools for early hemorrhage control has apparent potential advantages. Currently, however, these critical first responders have limited options in their toolkit in this regard. Depending on the zone they are operating in, presently available hemorrhage control adjuncts include only the use of pressure bandages, hemostatic dressings, and tourniquets.[20] Availability of additional treatment options for advanced bleeding control in the warm zone, as commonly used by QRT-FF, could improve outcome in trauma patients because extraction times can be longer than formally accepted timeframes for medical care. Analysis of the Bataclan attack showed that when the conventional rescue teams received clearance to enter the warm zone, all living casualties had already been extracted. The final evacuation was performed 4.5 hours after the start of the attack.[4,5] One could argue that only victims with deemed survivable injuries were extracted before conventional teams were allowed in. When advanced bleeding control options are implemented in the hot/warm zone, more injuries could be triaged as survivable and therefor extracted sooner. Properly trained and equipped, these first responders could bring advanced bleeding control kits into the warm zone and at least assist forward surgical teams and other medical professionals in performing advanced bleeding control procedures including REBOA when legislation does not permit these professional first responders to perform these acute care measures. Several gap analyses have revealed groups of casualties with NCTH that could have benefitted from advanced bleeding control options, such as REBOA, both in military and in civilian settings. Obviously, the number of amendable casualties in civilian settings is lower than in the military settings.

In civilian public mass shootings (CPMS), the probability of death is based on the firearm type used, with handguns associated with a higher percentage killed compared with when a rifle is used. Wounding with a handgun was significantly associated with brain and cardiac injuries. Urban fire arm related violence and CPMS have little difference in wounding patterns. The percentage of potentially preventable deaths (PPD) is reported to be 15–16%. The most commonly injured organs in those with PPD were the lung (59%) and spinal cord (24%). The PPD rate after CPMS is high and is due mostly to nonhemorrhaging chest wounds. These injury types are not typically amendable with REBOA. [21,22,23]

In civilian settings, this provides challenges in training of larger volumes of providers and sustaining their training levels. Monitoring degradation of skills over time should be part of any program.

The evidence base for the use of REBOA is growing; nevertheless, more robust data must become available. We have published several feasibility studies on training of vascular access and REBOA placement.[11,12] We also published a consensus paper on the use of REBOA.[18] These articles contribute to the discussion on when, where, and in which patients this procedure is indicated and who should perform REBOA. When percutaneous access fails, open surgical access is a bailout. This report shows that QRT-FF are able to acquire basic skills for vascular access and REBOA placement. We do not state that QRT-FF should perform these procedures or that this training is sufficient to perform these complex tasks in real-life, austere situations.

Our present feasibility study has some important limitations that must be acknowledged. Although the task training model used for vascular access training does provide standardization, the biomechanical limitations of this training adjunct clearly do not represent perfectly realistic conditions and haptics. Ideally, percutaneous access of the femoral artery would be trained on a human (cadaver) model. In addition, the QRT-FF group was smaller than the medic cohort. Although the identical training was provided and skills were scored by the same observers (Drs Borger van der Burg and van Dongen), group size may have influenced the results of the training. Furthermore, although the RATT is a flow model, the model is not representative for a hemodynamically unstable patient. Austere training and test environments should also be part of subsequent research as laboratory conditions are not realistic proxies for the chaos of actual major casualty events. Further training to facilitate true expertise in the examined skills would also likely require using ultrasound in combination with a realistic moulage model and cadaver flow model. Such a setup is needed for percutaneous and open access training with achieving access in a hypotensive model with collapsed vessels. Before the implementation of these advanced bleeding control options in QRT-FF, more training in real-world scenarios would be essential. Furthermore, this would only be the case in which medicolegal matters would be addressed and policies altered.

Conclusions

This study shows that our comprehensive theoretical and practical training program using a task training model can be used for percutaneous femoral access and REBOA placement training of professional first responders without prior ultrasound or endovascular experience. Training in the use of advanced bleeding control options, such as REBOA, as a secondary task, could improve outcomes of bleeding casualties in the warm zone. Higher levels of training reduce procedure times. The training method proved useful and can be used in a multistep program, in combination with a realistic task training model and perfused cadaver model, for percutaneous and open access training.

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Disclaimer

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the Dutch or US Department of Defense, or the Dutch or US governments. Several authors are employees of the Dutch government.

Conflictss of Interest

The authors declare that there are no conflicts of interest that could inappropriately influence (bias) their work.

Author Contributions

BLSBvdB and RH prepared the study setup. BLSBvdB, SMV, TTCFvD and RH included participants and performed the study during the EVTM workshop in Leiderdorp and collected the data. TTCFvD performed the statistical analyses. BLSBvdB, SMV, TTCFvD, and RH prepared the manuscript, and TTCFvD prepared the tables and figures. BLSBvdB, SMV, TTCFvD, JJD, MWB, and RH contributed to the final version of the manuscript.

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