Deployed skills training for whole blood collection by a special operations expeditionary surgical team

Linda C. Benavides, MD, Iain M. Smith, MRCSEd, Jerome M. Benavides, MD, Douglas M. Bowley, Heidi A. Doughty, MB BChir, MBA, *and* **Jonathan B. Lundy, MD**, *Fort Hood, Texas*

BACKGROUND: Noncompressible hemorrhage is the leading cause of potentially preventable battlefield death. Combining casualty retrieval from the battlefield and damage control resuscitation (DCR) within the "golden hour" increases survival. However, transfusion requirements may exceed the current blood component stocks held by forward surgical teams. Warm fresh whole blood (WFWB) is an alternative. We report WFWB transfusion training developed by and delivered to a US Golden Hour Offset Surgical Treatment Team and the resulting improvement in confidence with WFWB transfusion.

METHODS: A bespoke instructional package was derived from existing operational clinical guidelines. All Golden Hour Offset Surgical Treatment Team personnel completed initial training, reinforced through ongoing casualty simulations. A record of blood types and donor eligibility was established to facilitate rapid identification of potential WFWB donors. Self-reported confidence in seven aspects of the WFWB transfusion process was assessed before and after training using a five-point Likert scale. Personnel were analyzed by groups consisting of those whose operational role includes WFWB transfusion ("transfusers"), clinical personnel without such responsibilities ("nontransfusers") and nonclinical personnel (other). Comparisons within and between groups were made using appropriate nonparametric tests.

RESULTS: Data were collected from 39 (89%) of 44 training participants: 24 (62%) transfusers, 12 (31%) nontransfusing clinicians, and 3 (8%) other personnel. Transfusers and nontransfusers reported increased comfort with all practical elements of WFWB transfusion. The confidence of other personnel also increased, but (likely due to small numbers) was not statistically significant.

CONCLUSION: WFWB transfusion is an integral part of modern deployed military remote DCR. Our in-theater training program rapidly and reproducibly enhanced the comfort in WFWB transfusion in providers from a range of backgrounds and skill-mixes. This model has the potential to improve both safety and effectiveness of WFWB remote DCR in the far-forward deployed setting. (*J Trauma Acute Care Surg.* 2017;82: S96–S102.

LEVEL OF EVIDENCE: Therapeutic/care management study, level IV.

KEY WORDS: Whole blood; blood transfusion; remote damage control resuscitation; war surgery; training.

The damage control continuum (resuscitation, surgery, evacuation) has developed dramatically during the Global War on Terror (GWOT).[1] In addition to new interventions delivered at point-of-wounding and rapid evacuation with advanced enroute care, the evolved military treatment paradigm includes the far-forward deployment of small surgical teams[2] to ensure casualties receive damage control interventions within 60 minutes of injury (the "golden hour").[3] Fluid resuscitation strategies have changed from crystalloid to hemostatic ratios of blood components[4] and use of warm fresh whole blood (WFWB).[5] Access to hemostatic resuscitation and timely definitive hemorrhage control are paramount for optimal outcomes. Since access to surgical care within the Golden Hour was mandated in 2009, the combat casualty fatality rate has decreased markedly.[3] The US Army Forward Surgical Team (FST) has been deployed widely during the GWOT and has successfully faced contingencies that led to smaller and smaller components (such as FST split operations) providing surgical care in austere settings.[2,6] The above lessons were introduced during the GWOT during extremely busy periods of military and clinical activity, typically within a mature deployed trauma system.[7] Withdrawing forces from the Iraqi operational theater posed particular challenges to the maintenance of high quality combat casualty care.[8] Withdrawal from Afghanistan presented similar challenges, with relevant lessons for the military's return to "contingency operations"— military activities whose characteristics include the rapid deployment of forces, typically without the benefit of established medical facilities.

Noncompressible hemorrhage remains the leading cause of preventable death on the battlefield.[9] Cross-coalition experience recognizes that rapid access to surgical control of hemorrhage is a key goal, and transfusion support within a coherent damage control resuscitation (DCR) strategy (consisting of early use of blood products in a balanced ratio, correction of coagulopathy, use of hemostatic adjuncts, such as tranexamic acid and minimization of crystalloid solutions) is a vital enabler of mission success and is a critical part of combat casualty care, evidenced by increasing blood product utilization. Amongst casualties

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From the Martin Army Medical Center (L.C.B., J.M.B.), Fort Benning, Georgia; Academic Department of Military Surgery & Trauma (I.M.S.), Royal Centre for Defence Medicine, Birmingham, United Kingdom; 16 Medical Regiment, 16 Air Assault Brigade (D.M.B.), Colchester, United Kingdom; Academic Department of Military Anaesthesia and Critical Care (H.A.D.), Royal Center for Defence Medicine, United Kingdom; Carl R. Darnall Army Medical Center, Department of General Surgery (J. B. L.), Fort Hood, Texas.

Address for reprints: Jonathan B. Lundy, MD, Carl R. Darnall Army Medical Center 36065 Sante Fe Avenue Fort Hood, TX; email: Jonathan.b.lundy2.mil@mail.mil.

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treated at US military medical facilities between 2002 and 2011, crystalloid administration was almost halved to 3.2 L by the implementation of DCR, while the mean volumes of packed red blood cells (RBC) and fresh frozen plasma (FFP) increased from 8 units to 11 units and 3 units to 10 units, respectively.[10] Similarly, before 2010, 27% of all British casualties received a blood component transfusion[11] with 11% receiving at least 10 units of RBC (i.e., a massive transfusion). By 2011, 32% of coalition casualties were transfused, with 20% massively transfused.[12]

The 102nd FST deployed to Afghanistan in June 2015, tasked with providing small surgical teams—"Golden Hour Offset Surgical Trauma-Teams" (GHOST-T)—in support of US Army Special Operations Forces during Operation RESOLUTE SUPPORT. GHOST-T personnel were in a unique situation: a new rapidly deployable surgical platform with a small stock of blood components (20 units of RBC and 20 units of FFP), but neither co-located blood bank nor area support blood company. A didactic educational program comprising both lectures with a practical exercise was developed to enable delivery of WFWB. Training was provided to multiple levels of military medical personnel and certain Special Forces personnel integral to the mission, increasing the pool of individuals with the necessary knowledge and skills. The purpose of this report is to describe the educational program developed and pretraining and posttraining survey outcomes in regards to provider comfort with WFWB collection and transfusion. We hypothesized that training would improve provider comfort in the safe collection and transfusion of WFWB.

METHODS

The Fresh Whole Blood Transfusion Joint Theater Trauma System (JTTS) Clinical Practice Guideline (CPG)[13] and the U.S. Special Operations Command Tactical Trauma Protocols[14] were reviewed to familiarize staff with current guidelines regarding WFWB collection and transfusion. An instructional package, including a practical exercise, was developed and delivered to all personnel working with the GHOST-T. Training included the indications for the collection and use of WFWB.[13]

Important steps highlighted during blood collection training are outlined in Table 1. All potential donors completed a predonation screening questionnaire.[14] Point of care testing of blood donors was conducted using EldonCard, Eldon Biologicals A/S, Gentofte, Denmark) for ABO typing. Screening for blood borne viruses was performed with near-patient rapid test kits for HIV-1, HIV-2, hepatitis C (OraQuick Advance, OraQuick HCV (both OraSure Technologies, Inc, Bethlehem, PA) and hepatitis B (ATFirst HBsAg Rapid Test; FirstVue Diagnostic Corp, Lone Tree, CO). Recognition of donor-related and transfusion-related reactions was taught. However, administration of the collected unit was not included in the training package; the competence of transfusion-qualified clinicians (physicians and nurses) for this task was assumed.

TABLE 1. Steps for Performing WFWB Collection

(1) Confirm blood type with Eldon card for donor and patient
(2) Donor prescreening questionnaire complete and reviewed
(3) Vitals performed
(4) Rapid infectious disease screening exams performed (if not already performed)
(5) Donor's arm cleaned with antiseptic agent at planned venipuncture site
(6) Discussion of donor-related and transfusion-related complications
(7) Venipuncture performed and connected to single unit whole blood collection bag, avoiding overfilling by use of fixed length string around the middle of bag (required length varies depending on bag manufacturer)
(8) Place hemostat to kink tubing 15 cm from needle before removing needle to avoid air entering the line

Comprehensive combat casualty care rehearsals were conducted weekly and included Special Operations personnel. Each rehearsal required identification of a potential blood donor, verification of donor eligibility using the questionnaire and rapid infectious disease screening, blood type confirmation, and initiation of blood collection (approximately 100 mL during a scenario). A master rota of personnel currently colocated with the GHOST-T and their blood type was maintained and updated frequently to reflect the rapid rotation of personnel. To validate training, a performance improvement project was approved by the US Army Institute of Surgical Research, Ft Sam Houston, Texas. A pretraining and posttraining anonymous questionnaire was administered to participants (Table 2), using a five-point Likert scale (1, very uncomfortable; 3, neutral; 5, very comfortable). To attempt to mitigate respondent bias, a discussion was held before training to discuss the voluntary nature of the training and survey as well as the voluntary completion of pretraining and posttraining surveys. To mitigate acquiescence bias, possible answers to survey questions were provided in a balanced format with a neutral option so that equal numbers of affirmative or negative answers were available. For analysis, individuals were grouped as those permitted to authorize and administer a blood transfusion in an operational environment (physicians, physician's assistants, nurses, Special Operations Forces medics) ("transfusers"), personnel whose role involves aspects of transfusion but who cannot themselves authorize and administer transfusions (conventional forces medics, practical nursing specialists, laboratory technicians) ("nontransfusers"), and personnel whose background did not involve blood component transfusion (OR Technicians, SOF Weapons Specialists) ("others").

Scores are reported as median (interquartile range) and were compared within groups using the Wilcoxon signed-rank test. Comparison between professional groups was made with the Kruskal-Wallis omnibus test for mean ranks, with pairwise comparisons made using Dunn's test. The threshold for statistical significance was specified as p value less than 0.05, adjusted for multiple comparisons using the Bonferroni method. Although training would not be expected to reduce comfort, detecting such an effect would be important, thus two-tailed tests of significance were used. Statistical calculations were performed and figures produced using *RStudio: Integrated Development for R* (RStudio, Inc., Boston, MA).

RESULTS

Multiple iterations of the block of instruction and practical exercise were delivered to the 102nd FST (25 members), Special Operations Medics (15 medics), and four medics assigned to infantry units for a total of 44 personnel. Thirty-nine (89%) of 44 participants returned the questionnaires. Table 3 shows

TABLE 2. Pretraining and Posttraining Questions

How Comfortable Are You With…	
Q1	…rapid blood typing using the Eldon card typing system
Q2	…rapid infectious disease screening using test kits for HIV/HBV/HCV
Q3	…administering the field questionnaire to determine eligibility to donate WFWB
Q4	…collecting warm fresh whole blood after an appropriate donor is identified
Q5	…transfusing fresh whole blood to a casualty with supervision
Q6	…donating fresh whole blood for a casualty
Q7	…receiving fresh whole blood if you were injured/it was felt to be clinically necessary

HIV, human immunodeficiency virus; HBV, hepatitis B virus; HCV, hepatitis C virus.

the composition of training recipients. These were grouped to give 24 (62%) transfusers, 12 (31%) nontransfusers, and 3 (8%) other personnel.

Training Outcomes

Differences in self-reported confidence between professional groups were not statistically significant before training (Fig. 1A). Collectively, training increased comfort with all aspects of the WFWB screening, donation, and administration process (Fig. 2). Figure 1B compares posttraining confidence in each area of the process by professional group. In terms of statistical significance (Table 4), transfusers reported greater confidence in all aspects of the process. Predictably, those with clinical roles were more confident with some clinical components of the protocol than nonclinical personnel. The data suggest that comfort with administration of WFWB was related to clinical role, with transfusers more comfortable than nontransfusers, with other personnel being least comfortable, though statistical comparisons against the latter group are limited by its small size. Clinical staff without formal transfusion roles also improved in all aspects relating to the collecting and administering WFWB, whereas the apparent increase in confidence in providing a donor or receiving WFWB did not reach statistical significance. Other personnel reported higher scores in all aspects of the process, but statistical significance was not reached, likely because of small numbers.

Application of Training

No collection of WFWB was required during the 102nd FST's 9-month deployment. The process was activated once for a patient with a lower extremity traumatic amputation and contralateral mangled lower extremity. The only possible donor on camp was notified, brought to the medical tent, and steps 1 to 3 of the WFWB collection process were completed. Ultimately, the casualty was evacuated from point of wounding to a different facility.

DISCUSSION

Deployment of SOF in regions of the world where catastrophic blast injuries are prevalent mandates mobile, robust resuscitative and surgical support. Providing this support may require the nondoctrinal application of small surgical teams such as the US Air Force Special Operations Surgical Team, the US Army SOF Surgical Resuscitation Team[15] and the new GHOST-T. We report the development and implementation of an in-theater training program derived from existing protocols to improve safety and effectiveness of WFWB as a component of far-forward resuscitation by a GHOST-T providing surgical support to SOF during Operation Resolute Support.

Damage control surgery (DCS) has continued to evolve since its inception in the 1980s.[15] The more recently described concept of DCR was first described during the GWOT. DCR includes provision of minimal crystalloid, balanced ratio blood component transfusion, hemostatic adjuncts, such as the antifibrinolytic tranexamic acid and the use of WFWB when clinically indicated. Military surgical teams have demonstrated their ability to provide lifesaving DCS maneuvers in many austere settings and in some situations, despite use of established hemorrhage control techniques, such as tourniquet application and junctional hemorrhage control with prolonged tactical combat casualty care provided by SOF medics, WFWB transfusion has been necessary to resuscitate and maintain perfusion in patients without rapid access to a surgical team.[16] The provision of DCR in austere environments by small and mobile surgical teams is likely to become increasingly prevalent in the current global environment.

This extension of DCR into the prehospital environment has recently been termed "remote DCR" (RDCR).[17] Various blood product combinations have been deployed for military RDCR, with RBC and thawed plasma carried for en-route resuscitation during retrieval missions[18,19] and on land-based patrols.[20] The UK Defence Medical Services have recently reported use of lyophilized plasma (LP) for RDCR.[21,22] In the civilian setting, resuscitation with RBC and LP is employed routinely by Norwegian prehospital retrieval services,[23] one of which has also introduced prehospital whole blood transfusion (G. Strandenes, personal communication). However, limitations to entirely component-based RDCR include the lack of current options to provide stored platelets forward of a medical facility

TABLE 3. Personnel Trained

Transfusing Clinicians (MOS, Role)	n	Nontransfusing Clinicians	n
61J (general surgeon)	8	68W (combat [conventional] medic)	7
61M (orthopedic surgeon)	1	68C (practical nurse specialist)	3
66F (certified registered nurse anesthetist)	3	8506 (US Navy adv. lab. technician)	2
66T (registered nurse)	3	**Nontransfusing personnel, other**	**n**
65D (physician's assistant)	1	18B (SOF weapons specialist)	2
18D (SOF medic)	8	68D (operating room technician)	1

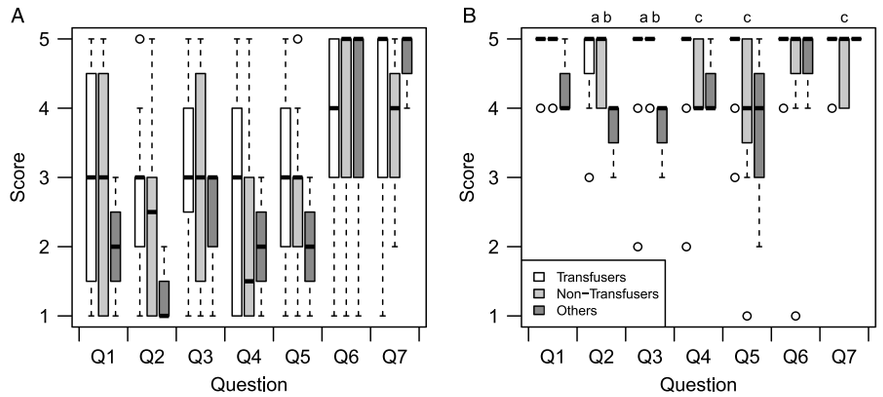

Figure 1. Self-reported confidence (*A*) before training and (*B*) after training. $p < 0.05$ for comparisons a: Transfusers and Other, b: Nontransfusers and Other, c: Transfusers and Nontransfusers.

and the logistic burden incurred by all available products, both in terms of physical space and (other than LP) strictly thermally controlled storage conditions. Even where an initial supply of immediately available thawed plasma is maintained, the rate of blood product administration required to maintain 1:1 resuscitation for severe combat trauma may outstrip not only the rate at which the blood bank in a forward facility could defrost FFP or reconstitute lyophilised plasma but also the available component stock of the blood bank. In the setting of massive component transfusion, ongoing coagulopathic bleeding, and a need to maintain balanced transfusion ratios, WFWB is also indicated for the hemostatic effect of platelets; limited in the current combat environment due to storage limitations.

It must be acknowledged that the benefit of prehospital transfusion has not been definitively established when rapid evacuation from point of injury (by air or ground) to definitive care (role III NATO facility or robust tertiary trauma center) is possible. A recent systematic review found extremely limited evidence to support this practice.[24] A subsequent assessment of the impact of the Golden Hour mandate associated both reduced transport times and prehospital transfusion with reduced prehospital death.[3] However, prehospital transfusion was associated with a statistically nonsignificant increase in subsequent mortality and significantly increased morbidity (likely reflecting the greater trauma burden experienced by prehospital transfusion recipients). With 62% of potentially relevant cases excluded due to incomplete data, this retrospective, observational study (which including only 132 prehospital transfusion recipients [3% of the study population]) suffered from many of the same limitations as those considered in the systematic review. Definitive answers to the role of civilian RDCR are being sought in a number of ongoing randomized controlled trials highlighted in that review. However, recent military experience has also been of predominantly short transfer times—exploiting uncontested air supremacy to operate helicopter-based advanced medical retrieval platforms within a mature trauma system. Such fortuitous circumstances may not exist in future conflicts, whose operational context may not permit the delivery of the current Golden Hour mandate. Consequently, the available clinical data and current civilian trials (which investigate only blood component therapy, not WFWB) will be unable to provide robust evidence regarding austere RDCR—far-forward military environments in which *delayed* (>60 min) and potentially *prolonged* (>6 hrs) evacuation from point of wounding to DCS can be anticipated.[17]

Current resources carried by a GHOST-T include 20 units of RBC and 20 units of FFP for a mission capacity of five surgical cases in 72 hours. However, US data from the latter part of operations in Iraq and Afghanistan showed that transfusion recipients receive average "RBC" transfusions (including both RBC and WFWB) of 17.5 U,[25] whereas the median transfusion received by coalition casualties with major injuries (ISS > 15) treated at the UK facility in Camp Bastion was 16 U RBC and 14.5 U plasma.[12] Transfusion requirements of this magnitude will see even a single severely injured casualty rapidly deplete the blood component stock available to a GHOST-T, especially

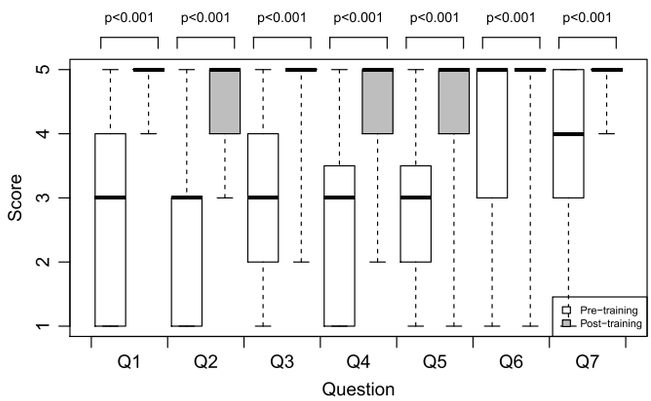

Figure 2. Comparison of overall self-reported pretraining and posttraining scores (*boxes* show median and interquartile range; *whiskers* show range).

TABLE 4. Improvement in Self-Reported Confidence by Transfuser Status

Question	1	2	3	4	5	6	7
Transfusers	+	+	+	+	+	+	+
Nontransfusers	+	+	+	+	+		
Other							

+$p < 0.05$.

in the far-forward environment from which a delay in further evacuation (and thus a need for ongoing transfusion support) might be anticipated. Although various approaches to the delivery of component-based RDCR have recently been discussed,[26] WFWB—as espoused by the Norwegian Naval Special Operations Commando's "Blood Far Forward" programme[27,28]—could significantly ease the associated logistic burden. A recent case report demonstrates that a practiced, rehearsed team can supply WFWB within 30 minutes of process activation, producing 24 units of WFWB over the next two hours[29] but relies on a sufficiently large pool of suitable donors.

WFWB has been used in resource-limited military settings.[30,31] US Army Rangers and SOF personnel are trained in WFWB transfusion, all providers deployed to role I and II facilities receive didactic and hands-on training that mirrors our training platform, and role III facilities are equipped with robust blood bank capabilities including training and resources for WFWB use.[32,33] The 102nd FST faced a unique mission: deployment in support of Operation RESOLUTE SUPPORT (withdrawal operations in Afghanistan) to provide far-forward surgical support to US Army Special Forces. This required extremely mobile, small, light surgical teams to areas without blood bank capabilities. In addition, only four transfusion-trained clinicians (three general surgeons and a SOF medic) had prior experience with WFWB transfusion during previous deployments. Other than the SOF medic, the previous deployed experience of the three general surgeons was of WFWB collection by a colocated blood detachment or troop medical clinic tasked and trained to provide this service; a luxury not available to our GHOST-T. In-theater training of the entire GHOST-T in accordance with existing SOF CPGs[14] increased the pool of personnel able to collect and transfuse WFWB, providing greater resilience and flexibility for both concentrated and split-team missions, ultimately closing any potential gaps in providing robust RCDR capabilities.

Reliance on WFWB as a primary or additional source of blood components has two important limitations. First, the blood group mix in the available donor pool may not include all blood groups.[34] Possible strategies to mitigate this include use of group O RBC where available,[35] transfusion of group A WFWB to group A recipients with group O WFWB reserved for non-A recipients[28,36] or prematched "blood buddies,"[28,36,37] the latter being especially relevant to small unit missions. However, this approach requires predeployment screening and testing. In our study, the identification of donors was also only able to be performed in-theater. Second, after donation, whole blood donors are normally excluded from further donations for 8 to 12 weeks after donations.[36]

Nonetheless, retrospective military hospital-based studies suggest that WFWB confers survival benefits over component-based resuscitation.[5,38] In combat-injured patients with comparable injury burdens and physiologic disturbance, supplementary WFWB has been associated with greater survival despite lower transfusions of other blood components, lower total transfusion volumes and lower platelet/RBC ratios amongst WFWB recipients.[5] In a more recent report of 488 battlefield casualties, of whom 94 had received WFWB, unadjusted mortality was similar between groups, despite WFWB recipients being more seriously injured and more physiologically compromised. This apparent protective benefit remained in multivariate analysis in which WFWB was associated with greater survival.[38]

With ongoing deployment of surgical assets into the far-forward area in support of expeditionary missions, WFWB capability is recognized as an essential component of transfusion support to operations.[26] Our experience highlights that formal training of the entire expeditionary surgical team in austere RDCR techniques, including the use of WFWB, increases confidence in all aspects of this process. Through the process of this performance improvement project and dissemination of lessons learned during our unique experience to subject matter experts in medical planning, the Army Trauma Training Center, Ryder Trauma Center, Miami, Florida training platform now includes a specific didactic and hands-on experience to teach deploying FSTs safe collection and transfusion of WFWB. (J. Seery 2016, personal communication, 25 June).

The UK Defence Medical Services deliver Blood Donation, Storage and Supply training (including collection of WFWB from Emergency Donor Panels) to a wide range of personnel.[36] In addition, current guidance is that personnel held at high readiness for deployment and potential donors should be prescreened and trained in these techniques. Through the process of wide dissemination of lessons learned during the GWOT, US military medical forces are able to provide DCR capabilities including collection and transfusion of WFWB to all deploying medical treatment facility, from role I through III. This is ensured by providing predeployment WFWB training to physician assistants, general duty medical officers, physicians providing resuscitation capabilities at or near the point of injury, and surgical teams such as the 102nd FST and throughout the Special Operations community using the well-established protocols that guided our experience. The training is reproducible, and units are highly encouraged to conduct multiple iterations of training as outlined here at theater unit reception sites and throughout the deployment. Although our team was not capable of storage of whole blood, Strandenes and colleagues[39] have demonstrated feasibility of cold storage of crew-donated whole blood during antipiracy operations. Although not currently part of US policy, cold storage of whole blood is an alternative that would greatly increase the RDCR capabilities of a small surgical team.

This study is limited to a demonstration of subjective knowledge transfer and self-reported confidence in the delivery of WFWB for military RCDR. It is unable to demonstrate clinical benefit from this strategy; however, we believe that provider confidence should translate to enhanced safety and effectiveness. Other limitations to this study include the low number of participants and potential for various forms of bias in a survey study. This article adds to the literature demonstrating the viability of in-theater training for future operations.

CONCLUSION

This report describes a performance improvement project that successfully increased RDCR capabilities during withdrawal operations in Afghanistan by delivering training on the safe collection of WFWB to clinical and nonclinical members of an expeditionary surgical team attached to US Army Special Forces. This training was reproducible, rapidly taught, and can be used during predeployment training or in the operational

setting, and ensures seamless support to RDCR capabilities in the most austere of environments by all levels of medical personnel. The training generated resilience and provided flexibility to the medical mission commander. Training in all aspects of RDCR, including WFWB use, is essential for all teams providing surgical support to Special Operations personnel and other operations in austere environments; such missions are likely to only increase in the current global environment.

AUTHORSHIP

L.B., J.M.B., and J.B.L. designed the study, obtained institutional review board approval and collected data. I.M.S. analyzed and interpreted the data. All authors contributed to drafting and critical revision of the article.

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