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Michael Kim *
Ian Torrie †
Robert Poisson ‡
Nicholas Withers ‡
Stephen Bjarnason §
Luis Teodoro DaLuz *
Dylan Pannell *‡
Andrew Beckett ‡‖
Homer C. Tien *‡

* Tory Regional Trauma Centre, Sunnybrook Health Sciences Centre, Toronto
† Embassy of Canada, 501 Pennsylvania Avenue NW, Washington, DC
‡ Canadian Forces Health Services Group, Ottawa
§ Defence Research Development Canada – Suffield Research Centre
‖ Montreal General Hospital, Montreal

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IMPORTANT INFORMATIVE STATEMENTS

The Value of Live Tissue Training for Combat Casualty Care: A Survey of Canadian Combat Medics With Battlefield Experience in Afghanistan

Michael Kim, MD MSc; LCOL Ian Torrie, RCMS†; LCOL Robert Poisson, RCMS‡; Nicholas Withers, MD‡; Stephen Bjarnason, PhD§; Luis Teodoro DaLuz, MD*; CAPT Dylan Pannell, RCMS*‡; MAJ Andrew Beckett, RCMS‡‖; COL Homer C. Tien, RCMS*‡*

ABSTRACT Introduction: The optimum method for training military personnel for combat casualty care is unknown. In particular, there is debate regarding the incremental benefit of live animal tissue training (LTT) over inanimate human patient simulators (HPSs). Although both LTT and HPS are currently used for predeployment training, the efficacy of these models has not been established. Materials and Methods: Canadian Armed Forces combat medics, deployed to Afghanistan between 2006 and 2011, were surveyed retrospectively regarding their experience with combat casualty care and predeployment training. HPSs were used to prepare these combat medics for early rotations. In later years, personnel received a combination of training modalities including HPS and LTT, using anaesthetized porcine models in accordance with appropriate animal care standards. Among those deployed on multiple rotations, there was a cohort who was prepared for deployment using only HPS training, and who later were prepared using mixed-modality training, which included LTT. We asked these medics to compare their predeployment training using HPS only versus their mixed-modality training in how each training package prepared them for battlefield trauma care. Results: Thirty-eight individuals responded, with 20 respondents deployed on multiple rotations. Respondents performed life-saving skills during 89% of the rotations. Self-perceived competence and preparedness were notably higher after incorporation of LTT than after HPS alone. Of 17 respondents deployed on both early and late rotations, the majority felt the latter training was more worthwhile. In addition, almost all individuals felt that LTT should be added to HPS training. Narrative comments described multiple benefits of adding LTT to other types of training. Conclusions: Among many experienced Canadian Armed Forces personnel, LTT is considered essential predeployment preparation. Individuals who experienced only HPS training before active duty on their first combat deployment reported feeling more competent on subsequent combat deployments after the addition of live tissue models. Impact: There has been a movement away from the use of LTT in preparing combat medics for deployment. This article suggests that we should reconsider any decision to completely exclude Live Tissue Training as part of our training plan for combat medics. Recommendations: Military medical organizations should consider judiciously incorporating LTT with human patient simulation training to prepare combat medics for treating battlefield trauma.

BACKGROUND

Tactical Combat Casualty Care (TCCC) is a paradigm for battlefield trauma care that was first introduced to U.S. special operations forces in 1996.[1] TCCC is designed to treat potentially preventable causes of death on the battlefield: exsanguination from extremity injuries, tension pneumothoraces, and acute airway obstruction. However, TCCC acknowledges that medical care may place the provider in jeopardy if performed at the wrong time, and may adversely affect the mission. As such, TCCC has 3 goals: to treat the casualty; to prevent additional casualties; and to complete the mission.[2]

TCCC was first introduced to Canadian Special Operations Forces in 1999.[3] However, since then, TCCC has been widely adopted by Canadian Conventional and Special Operations Forces. During Canada's combat mission in Afghanistan (2006–2011), Canadian Forces Health Services (CFHS) medical technicians (medics) were trained to provide TCCC care to wounded soldiers. Medics were taught to treat acute airway obstruction with either a nasopharyngeal airway or a cricothyrotomy; they were trained to decompress tension pneumothoraces, and they were taught to apply tourniquets for bleeding extremity injuries. In addition, they were taught to achieve vascular access through either an intravenous or intraosseous approach, and they were taught to pack bleeding wounds at junctional locations (axillary/inguinal).[4]

*Tory Regional Trauma Centre, Sunnybrook Health Sciences Centre, 2075 Bayview Avenue, Toronto, Ontario M4N 3M5, Canada.

†Embassy of Canada, 501 Pennsylvania Avenue NW, Washington, DC, 20001-2111.

‡Canadian Forces Health Services Group, 1745 Alta Vista Drive, Ottawa, Ontario K1A 0K6, Canada.

§Defence Research Development Canada, Suffield Research Centre, Medicine Hat, Alberta T1A 8K6, Canada.

‖Montreal General Hospital, Suite L9 411, 1650 Cedar Avenue, Montreal, Quebec H3G 1A4, Canada.

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Military medics need to be trained to perform these critical TCCC skills before deploying on combat missions. A review of 318 severely injured patients who presented to a U.S. medical treatment facility in Iraq with vital signs revealed that airway control, needle thoracostomy, and tourniquet application were the most frequently administered life-saving interventions to survivors of this cohort of patients.[5] TCCC interventions, particularly tourniquet application, have been shown to improve survival on the battlefield, when used by properly trained personnel.[6–9] However, other studies have reinforced the importance of proper training for medics in performing these procedures. Audits have shown that medics sometimes perform these procedures improperly on the battlefield, particularly airway and thoracic procedures.[10–12]

There is currently no consensus on the optimal method for training combat medics to perform TCCC interventions on the battlefield. Anecdotally, military medics and senior military leaders believe that the use of animals for combat trauma training best simulates the challenges and stress inherent in stopping actual bleeding on the battlefield.[13] However, the American College of Surgeons (ACS) has adopted human patient simulators (HPSs) as an alternative to live tissue training (LTT) to train civilian physicians to perform trauma procedures as part of its ATLS curriculum.[14,15] Furthermore, a 2010 survey of NATO countries also suggests that the many national military medical organizations are phasing out live animal tissue training.[16] A recent systematic review of the literature on LTT versus HPSs reported that there is no conclusive evidence supporting one form of training over another for emergency trauma procedures.[17]

The goal of this study is to assess the perceived value of LTT versus HPS training for preparing combat medics for battlefield trauma care. We surveyed medics who had provided battlefield trauma care in Afghanistan, and who had been trained using both LTT and HPS. Our hypothesis is that medics valued the realism of LTT, in addition to training with HPS.

METHODS

From 2006 to 2011, the Canadian Armed Forces participated in combat operations in the Kandahar Province of Afghanistan as part of the International Security Assistance Force. During this time, TCCC interventions were taught to combat medics who were deploying "outside the wire," to provide medical support to combat soldiers on operations. Before January 2007, medics were trained only on HPS. A variety of simulators were used.

After January 2007, all CFHS medics deployed "outside the wire" in Afghanistan were trained on the TACMED (Tactical Medicine) course. This predeployment training course brought medical technicians to Canadian Forces Base Suffield, in Alberta, for a 10-day course on how to deliver effective combat casualty care in a simulated combat environment. Contracted to a civilian agency, the CFHS had oversight of curriculum development and mode of instruction. Although it culminated in the utilization of the anesthetized porcine model, the medics were taught using a "walk-jog-run" paradigm. For example, using surgical airway as an example, students were first provided lectures on advanced airway management and indications for cricothyrotomy. They were then shown instructional videos, and the procedure was demonstrated on a "ribbed water bottle" with opportunities for repetition over the subsequent days. The students then performed the procedure in a "pluck lab": on tracheas removed from dead animals. Finally, the procedure was then performed by students on live porcine models in the operating room setting. In week 2, students were expected to perform the procedure on the anesthetized porcine models while in simulated combat conditions. Other interventions such as management of hemorrhage and tourniquet use followed a similar training progression.

The animals used for LTT were York-Landrace cross pigs (20–25 kg). The animals were cared for in accordance with published standards in "Guide to the Care and Use of Experimental Animals" and "The Ethics of Animal Experimentation" published by the Canadian Council on Animal Care (CCAC).[18] Animals were allowed to acclimatize before use on the course. The animals were anaesthetized and given analgesics at least 1 hour before the start of the training/assessment scenarios. At all times, a trained animal care technician accompanied each animal to monitor the level of anesthesia in order to minimize any pain and/or discomfort during the scenarios. Each of the animal care technicians involved in the courses had extensive experience with this animal model and was responsible for carrying out all surgical wounding. At the end of each training/assessment scenario, the animals were humanely euthanized. All aspects of animal care and treatment, including surgical wounding, were approved by the Defence Research and Development Canada Animal Care Committee which is a member of the CCAC.

Operating Room Setting

During TACMED, procedures were first taught in an operating room environment before conducted in simulated battlefield conditions. This surgical suite was a clean, temperature-controlled, standard operating room used for conducting large animal research and training. This operating room had two heated surgical tables.

Simulated Combat Scenario: This took place in large outdoor field area with a "village" constructed of sea cans. In this setting, the course participants wore full military tactical clothing, protective equipment, and carried their personal weapons.

Battlefield conditions were simulated using pyrotechnics, smoke, and firing blank ammunition.

Medics were instructed and trained on the indications and techniques for performing 5 TCCC interventions: (i) open

TABLE I. Baseline Demographics

Characteristic	Value
Age	27
Rank	
Pte	3
Cpl	21
MCpl	15
Sgt or above	4
Number of Deployments	
1	23
2	19
3 or More	1

cricothyrotomy; (ii) needle decompression of a tension pneumothorax; (iii) packing of a junctional, exsanguinating wound; (iv) tourniquet application on an injured extremity; (v) sternal intraosseous insertion.

Survey Development

Canada's combat mission to Afghanistan ended in 2011. In July 2012, as part of a "Lessons Learned" effort, the CFHS team (TCCC Committee), responsible for organizing and conducting trauma training, sought to determine if TACMED and LTT provided any incremental benefit to medics before combat deployment. Using a consensus methodology, the team developed a 9-item survey questionnaire in order to determine if medics with combat experience perceived any incremental benefit with the addition of LTT to their predeployment training.

All CFHS medics who deployed to Afghanistan in an "outside the wire" position, in support of a combat unit between 2006 and 2011 were identified using official tasking messages (Canadian Forces Taskings, Plans and Operations messages). Using a military human resources database (Human Resources Management System, PeopleSoft Inc.), we then identified those medics who were still part of the Canadian Armed Forces as of early 2012. The questionnaire was distributed electronically to all the medics, as part of a quality improvement project.

This questionnaire was meant to assess the combat medical training received before deployments, and the perceived incremental value (if any) that LTT added. As some personnel were known to have deployed multiple times, they were also asked regarding the number and timing of these deployments and how TACMED and LTT prepared them for combat trauma care compared to HPSs only.

For this research study, we received Surgeon General's approval to analyze these data retrospectively. As well, we obtained and received institutional ethics approval to conduct this retrospective analysis of survey data. Before any analysis, questionnaires were deidentified so that individual personnel could not be linked to responses. Descriptive Likert-scale items were converted to numerical values for the sake of analysis. For example, in the item regarding perceived competence, a rating of "Poor" received a score of 1, whereas "Excellent" was assigned a score of 5. Similarly, questions regarding the value of training were assigned a score of 1 for "no value," and a score of 5 for "essential."

Almost all of the returned questionnaires had copious narrative comments. For the purpose of qualitative analysis, study investigators read through each of the comments and identified thematic categories. The comments were then re-reviewed in order to see if any new themes were identified. At the completion of this iterative process, investigators then selected representative text describing each of the thematic categories.

RESULTS

We sent surveys to 75 medics, who were identified as having deployed "outside the wire" in Afghanistan from 2006 to 2011 and who were still in the CFHS as of August 1, 2012. We received 43 surveys from these medics. See Table I for demographics. Rank presented is the last rank achieved, as of the beginning of their last deployment to Afghanistan. Thirty-eight of 43 surveys were returned completed. The remaining 5 uncompleted forms had only comments that the individuals either did not participate in any predeployment training or that they had not been deployed at all.

Of those who completed surveys ($n = 38$), 20 respondents reported multiple deployments. This resulted in a total of 62 deployments among the respondents to the survey. Regarding the type of training received relative to the study period, only one respondent from earlier deployments (Roto 1-3) received LTT (4%) as part of their predeployment training. As part of the pre-deployment training for latter deployments (Roto 4-8), 97% participated in LTT or both HPS and LTT.

When asked whether they actually utilized their combat casualty training, respondents reported that they performed life-saving skills during 89% of the deployments. In 58% of

TABLE II. Medic Perception of LTT Versus Simulation

	N	Range (5 = Highest Score)	Mean	±SD	Median	Mode
Perceived competence after simulation	38	1–5	3.28	0.99	3	3
Perceived competence after addition of LTT	31	4–5	4.92	0.28	5	5
Preparedness to save lives after addition of LTT	28	3–5	4.64	0.56	5	5
Should LTT continue to be part of predeployment training?	37	3–5	4.76	0.60	5	5

deployments, respondents reported performing life-saving procedures more than 5 times. Ratings of self-perceived competence and preparedness after each training modality are reported in Table II. With regard to whether TACMED should continue as part of predeployment training, 70% of respondents (30/38) rated it as "essential" and only two rated it as "neutral" for a mean rating of 4.76 ± 0.60 (highest possible score = 5). None of the responses to this item were negative. Of respondents who were involved in both early and late deployments, 88% (15/17) felt the latter training was more worthwhile. In addition, 94% of individuals (16/17) felt that LTT training should be added to HPS.

Narrative comments reiterated the benefits of adding LTT to other training. Of the 27 respondents who wrote additional comments, all were strongly in favor of TACMED and the use of LTT. Thematic categories as well as representative quotations from the comments are shown in Table III. There were a total of 13 of these descriptive categories.

DISCUSSION

In 2002, a study was performed where physicians taking the ACS ATLS course performed their surgical training on both live animal models and on HPSs. These students were then

TABLE III. Themes From Narrative Comments

Theme	Representative Comment
(1) Actual use of skills trained on LTT while deployed in Afghanistan	On roto 8 I did a cric [cricothyroidotomy] on a casualty with massive facial trauma and choking. If not for my training on the pig I would never have had the confidence to do it on a human.
(2) Reiterating that LTT (not just inanimate models) should be used pre-deployment	The level of confidence the individual Med Techs gained from both, I say again, both forms of training was immeasurable . . . They benefit from the simulation aspect, but without the live tissue training they are left questioning their (training).
(3) Self-confidence in technical skills after experience with LTT	However, for my second tour on roto 8 I had done the TACMED course as part of the work up training and I felt 10x more prepared and comfortable with my skills and ability and again they were put to the test. I was more prepared to deal with combat related trauma after the TACMED course.
(4) Self-confidence dealing with the stress of saving lives in combat situation after LTT	You do not sense the urgency of someone's life slipping away without seeing the amount of blood that can be lost and how quickly it happens without TACMED.
	Live tissue issues a high stress level to members and it gives them the opportunity to overcome that if possible.
(5) (Realism is irreplaceable) actual bleeding during LTT prepares you for real patients with severe bleeding	I preferred live tissue training over any simulation training. . . I had never seen what a gun-shot wound on a person looks like, with simulations they would tell me to imagine. Whereas with the live tissue training they actually showed you what it would look like.
	Simulation training is an important part of the training; it provides a good foundation for further training. However, simulation training lacks the realism that can only be achieved with live tissue.
	As well, the training provides a desensitized to the injuries they will see as well as let them understand how much destruction a body can take and how little they need to do to sustain a life.
(6) Combat medical training should be used even when not deploying	I feel that combat casualty care should be an ongoing part of training for all soldiers, not just those deploying.
(7) Wish that he/she had TACMED before earlier deployments	I had the full TACMED course for ROTO 6 and I wish I had the training for ROTO 2.
(8) Can help to select out those who cannot deal with actual severely injured patients (cannot handle stress)	This course builds confidence in Medics to know they can do it or on the other hand that this is not the job for them.
	The Live Tissue training also identified the medical technicians that had the greatest deficiencies and were the least suited for continuing in the trade.
(9) Techs should run training	I would like to see a cadre of Med Techs and PA's run this.
(10) It should be added to earlier level training	Live Tissue training should be applied to the QL3 training of Med Techs. It not only is great training but also allows a junior Med Tech to gain confidence in their skills.
(11) TACMED is the best training course I've taken	I personally would trade any and all of my MCSP experiences to go on TACMED again.
	In my career and with all of the medical courses that I have done between my QL3's and my QL6A's, the TACMED course is the best medical course that I have ever done. It's the only course that I'd love to do again.
	This course (TACMED) is probably the best and the most efficient I have had in the CF.
	The TACMED course was by far the best medical course I have taken in the CF.
(12) First sight of real blood should not be in battle	The first time a medic gets blood on their hands and tries a life-saving procedure should not be on a fellow solider with their friends looking on.

surveyed regarding their preferences for training modalities. In many of the students' opinions, the HPS was superior to the animal model for many skills.[19] As a result, the HPS used in that study is now considered an acceptable alternative to LTT for teaching surgical skills in the ATLS course.

In this study, we surveyed CFHS medics who had deployed on combat deployments in Afghanistan regarding their preferences of training modalities (LTT or HPS) for preparing them for combat trauma. The respondents felt that the addition of LTT specifically helped them feel much more confident to handle battlefield casualties than after training with HPSs alone (median score of 5 after LTT compared to 3 after simulation alone).

The difference in our findings compared to Block's study on ATLS physicians may be explained when one considers that our study focused only on medics with combat experience, instead of a mixed group consisting of physician, nurses, and medics. For medics who may not have cared for many (any) trauma patients before deployment, the feel of live tissue and experiencing the stress of actual bleeding may not be captured well in synthetic models or cadavers. This concept is described in one of the comments from this survey: "You do not sense the urgency of someone's life slipping away without seeing the amount of blood that can be lost and how quickly it happens without TACMED." Although it is true that civilian health-care providers do not practice every procedure on live tissue before real patients, physicians and nurses have a considerable amount of "hands-on" clinical training during their education, with hundreds of hours of mentored training experience with real patients where they have a graduated level of clinical responsibility, supervised by more experienced clinicians. Many combat medics do not have such an apprenticeship experience, nor do they even have extensive patient contact before performing procedures on their own during a deployment. Hence, the first sight of blood for many medics may be during a real combat situation.

Of particular note is that this study has a subgroup of personnel who were deployed before the incorporation of LTT into their predeployment training, but subsequently received LTT and were deployed again. Of these personnel who trained using different methodology (HPS only versus TACMED LTT]), 94% felt that LTT should be included with human patient simulation as part of future predeployment training. These experienced combat medics felt strongly that the addition of LTT brought incremental value to predeployment training.

Also unique to this survey is the qualitative data describing the reasons why these individuals favor LTT so strongly. Witnessing bleeding and injuries in live tissue appears to convey a level of stress and urgency to trainees that is not as present with HPSs. Although synthetic models can mimic anatomy and function as excellent training platforms for practicing specific techniques, experiencing the stress of real bleeding seems to add an extra level of self-perceived confidence and preparedness. The issue of stress was noted repeatedly in the narrative comments. Several comments also suggested that the inability to handle this stress during LTT could be used as a potential screening mechanism for determining which personnel could reliably perform lifesaving techniques in combat situations. As one respondent noted, "without LTT: The issue was nobody had any idea how individual Med Techs would respond to seeing trauma/uncontrolled bleeding from multiple penetrating injuries for the first time (particularly in combat conditions)".

Uncontrolled hemorrhage is the most common preventable cause of death for soldiers wounded in combat.[20,21] In LTT, animals (mostly goats and pigs) are used to train physicians and combat medics in how to treat severe traumatic injuries, particularly those associated with severe blood loss. Military personnel insist that such realistic training is necessary to properly prepare medics for the battlefield. Animal rights groups, however, argue that the practice is inhumane and should be replaced with alternative methods.[22] As well, animal rights groups also now quote studies that show medical care providers who learn trauma treatment using simulators are better prepared to treat injured patients than those who are trained using animals.[23]

In a frequently quoted study, Bowyer and colleagues conducted a study on learning diagnostic peritoneal lavage by randomizing medical students to either training on an HPS or to anesthetized swine. Subsequently, both groups were assessed in their ability to perform diagnostic peritoneal lavage on an HPS. There was a significant improvement from baseline knowledge in both groups; however, there was more improvement in the HPS group in terms of site selection ($p < 0.001$) and technique ($p < 0.002$) than those who trained on a swine.[24] However, there was a measurement bias in this study. The testing scenario took place on the same HPS that half of the trainees were taught on, thereby likely favoring HPS over LTT.

In contrast, Hall trained Air Force volunteers to perform cricothyroidotomy and tube thoracostomy. Participants were randomized to LTT (anesthetized swine) or HPSs. In sequence, the 2 groups performed both procedures in human cadavers—a completely separate validation model. Confidence was overall higher in the LTT group, but this was not statistically significant difference ($p = 0.42$). Success rate of cricothyroidotomy and tube thoracostomy placement was higher in the group with LTT, but again, these differences were not statistically different.[25]

In a recent symposium on combat casualty care, Gambhir and colleagues observed that worldwide trauma training still incorporates live animal models, HPSs, and human cadavers.[26] Many countries now use simulation to teach trauma resuscitation.[27] However, many organizations still use LTT to teach advanced surgical skills. Although the ACS is moving away from LTT in its ATLS course, the ACS still incorporates LTT in its Advanced Trauma Operative Management course, which consists of didactic lectures and LTT. Participants (surgeons and surgeons-in-training) have reported that the course improves knowledge and operative confidence.[28–32] Trauma educators, however, recognized the need for different models for trauma training. The ACS, e.g., has also recently incorporated cadaver-based training to address limited experience of residents and practicing surgeons in rapid exposure of major blood vessels for trauma. The Advanced Surgical Skills for Exposure in Trauma course was well received and significantly improved self-reported confidence in the exposures needed to care for trauma in both surgical trainees and practicing surgeons.[33,34]

Probably, the best method for training health care providers for trauma care is a hybrid model. On the basis of the current state of technology of HPSs, there is likely still a role for all modalities for trauma training. Each model has advantages and disadvantages. Hybrid models for trauma training—including TACMED—are common, and well received.[35–37] Because LTT sacrifices animals, military medical and educational organizations exercise due diligence in minimizing LTT courses, and should justify the specific educational need that requires LTT over HPSs. However, eliminating all LTT may leave a gap in medic trauma training.

LIMITATIONS

The major limitation to this study is that the medics who deployed on earlier rotations and then redeployed on later deployments received more training than those who deployed only once, and on an early rotation. As such, these medics who deployed on multiple rotations and who received LTT on later rotations, received at least twice the training for the second rotation, than they did for their first rotation, and so would be expected to be more confident. We tried to quantify the magnitude of this bias. A total of only 7 individuals (18.4%) completed HPS training only on an earlier deployment before later undergoing LTT as part of a later deployment. The signal suggesting improved confidence appears across more than just these few respondents, and therefore, we believe that this bias does not account for the entire signal of increased confidence among medics who received LTT.

Another limitation to this study includes the relatively small sample of respondents. As well, because predeployment training was more ad hoc during earlier deployments, medics may be responding more favorably to the comprehensive nature of predeployment medical training package, as presented by TACMED. However, medics still identified an incremental benefit to LTT versus HPS in their questionnaires. Finally, as the survey was administered after respondents had returned from deployment, there was a considerable gap in time between when some of the medics trained and when they completed the survey. This may add an element of recall bias in their responses.

The primary strength of this study is the focus on the value of LTT as perceived by medics who actually had to use that training in real combat. To the best of our knowledge, no other published study addresses this question so specifically. In addition, the qualitative data from the abundant narrative comments shed light on why military medical personnel value the use of LTT for predeployment preparedness.

CONCLUSIONS

Although there remains controversy regarding the best way to offer trauma training to medics to prepare them for the battlefield, CFHS medics valued the continued use of LTT in addition to other methods of simulation for preparing them to save lives on the battlefield.

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Kim, M.; Torrie, I.; Poisson, R.; Withers, N.; Bjarnason, S.; DaLuz, L.T.; Pannell, D.; Beckett, A.; Tien, H.C.

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ABSTRACT Introduction: The optimum method for training military personnel for combat casualty care is unknown. In particular, there is debate regarding the incremental benefit of live animal tissue training (LTT) over inanimate human patient simulators (HPSs). Although both LTT and HPS are currently used for predeployment training, the efficacy of these models has not been established. Materials and Methods: Canadian Armed Forces combat medics, deployed to Afghanistan between 2006 and 2011, were surveyed retrospectively regarding their experience with combat casualty care and predeployment training. HPSs were used to prepare these combat medics for early rotations. In later years, personnel received a combination of training modalities including HPS and LTT, using anaesthetized porcine models in accordance with appropriate animal care standards. Among those deployed on multiple rotations, there was a cohort who was prepared for deployment using only HPS training, and who later were prepared using mixed-modality training, which included LTT. We asked these medics to compare their predeployment training using HPS only versus their mixed-modality training in how each training package prepared them for battlefield trauma care. Results: Thirty-eight individuals responded, with 20 respondents deployed on multiple rotations. Respondents performed life-saving skills during 89% of the rotations. Self-perceived competence and preparedness were notably higher after incorporation of LTT than after HPS alone. Of 17 respondents deployed on both early and late rotations, the majority felt the latter training was more worthwhile. In addition, almost all individuals felt that LTT should be added to HPS training. Narrative comments described multiple benefits of adding LTT to other types of training. Conclusions: Among many experienced Canadian Armed Forces personnel, LTT is considered essential predeployment preparation. Individuals who experienced only HPS training before active duty on their first combat deployment reported feeling more competent on subsequent combat deployments after the addition of live tissue models. Impact: There has been a movement away from the use of LTT in preparing combat medics for deployment. This article suggests that we should reconsider any decision to completely exclude Live Tissue Training as part of our training plan for combat medics. Recommendations: Military medical organizations should consider judiciously incorporating LTT with human patient simulation training to prepare combat medics for treating battlefield trauma.

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