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STO TECHNICAL REPORT **TR-HFM-242**

Technology Alternatives for Medical Training: Minimizing Live Tissue Use

(Alternatives technologiques pour la formation médicale – Comment minimiser l'utilisation de tissu vivant)

Final Report of Task Group HFM-242.

Published September 2020

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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List of Acronyms

3Rs	Replacement, Reduction, and Refinement
ACME	Allied Command Medical Education Center
ATLS	Advanced Trauma Life Support
Cric	Cricothyrotomy
HPS	Human Patient Simulation
LAT	Live Agent Training
LT	Live Tissue (i.e., animals)
LTT	Live Tissue Training
NATO	Nord Atlantic Treaty Organization
OIE	World Animal Health Organisation (Office International des Epizooties)
RTG	Research Task Group
SHAPE	Supreme Headquarters Allied Powers Europe
TNA	Training Needs Analysis
USUHS	Uniformed Services University of the Health Sciences

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Technology Alternatives for Medical Training: Minimizing Live Tissue Use

(STO-TR-HFM-242)

Executive Summary

The NATO Human Factors and Medicine Research Task Group 242, Technology Alternatives for Medical Training: Minimizing Live Tissue Use, worked from September 2015 to 2018. The group was founded with the objective of evaluating simulation technologies and training to provide recommendations to minimize the use of animals without degrading readiness to care for combat casualties.

The working group had core members from Canada, France, Denmark, the United States, Germany, and Norway and was led by one of Canada's representatives. The members included surgeons, combat medics, veterinarians, and experts in training. Over the three year period, the group met face-to-face five times. During these meetings, the group evaluated and discussed current research publications related to trauma training, shared the knowledge and experiences of each member as well as their nation's experiences and practices with live tissue training and combat trauma training, and toured simulation centres for interactions with experts across a range of disciplines contributing to military medical readiness training. In each country, selected guests were invited to attend the meeting and guest lecturers contributed to the knowledge of the group.

One outcome of the working group was the rigorous analysis of the training necessary to prepare a physician or medic to perform on the battlefield and the relative value of animals and simulation in this preparation. As the group determined that animals cannot at this time be fully replaced by simulation or other techniques, another outcome was a series of recommendations related to best practices for the use of live tissue. The group discussed and evaluated the primary gaps left unfilled by alternatives to live tissue.

The work of RTG-242 reflects the efforts over the period of time from 2015 – 2018. As such, the final report is a living document that will require re-evaluation by a future RTG as training needs shift and new technologies develop. RTG-242 recommends that NATO consider another working group to evaluate the continued need for the use of animals in medical training in three to five years' time.

Alternatives technologiques pour la formation médicale – Comment minimiser l'utilisation de tissu vivant

(STO-TR-HFM-242)

Synthèse

Le groupe de recherche 242 de la Commission sur les facteurs humains et la médecine de l'OTAN, intitulé « Alternatives technologiques pour la formation médicale – Comment minimiser l'utilisation de tissu vivant » a travaillé de septembre 2015 à 2018. Il a été créé dans le but d'évaluer la formation et les technologies de simulation et de fournir des recommandations minimisant le recours à des animaux sans dégrader la préparation aux soins des blessés en zone de combat.

Les membres principaux du groupe de travail venaient du Canada, de France, du Danemark, des États-Unis, d'Allemagne et de Norvège et ont travaillé sous la direction de l'un des représentants canadiens. Les participants étaient des chirurgiens, des aides-soignants militaires, des vétérinaires et des spécialistes de la formation. Pendant les trois années de son existence, le groupe s'est réuni cinq fois en personne. Il a évalué et discuté des publications de la recherche actuelle liées à la formation en traumatologie, partagé les connaissances et expériences de chaque membre, ainsi que les expériences et les pratiques de leur pays en matière de formation sur tissu vivant et formation aux traumatismes militaires, et visité des centres de simulation pour discuter avec des experts de diverses disciplines contribuant à la formation médicale militaire. Chaque pays a invité des personnes à assister aux réunions et les conférenciers invités ont contribué aux connaissances du groupe.

Le groupe de travail a notamment produit une analyse rigoureuse de la formation nécessaire pour préparer un médecin ou un aide-soignant à intervenir sur le champ de bataille et de la valeur relative des animaux et de la simulation dans cette préparation. Le groupe ayant conclu qu'il était pour le moment impossible de remplacer totalement les animaux par la simulation ou d'autres techniques, il a également émis une série de recommandations liées aux meilleures pratiques d'utilisation du tissu vivant. Le groupe a discuté et évalué les lacunes principales que les alternatives au tissu vivant ne comblent pas.

Le travail du RTG-242 reflète les efforts déployés pendant la période comprise entre 2015 et 2018. À ce titre, le rapport final est un document évolutif qui devra être réévalué par un futur RTG, parce que les besoins de formation changent et que de nouvelles technologies se développent. Le RTG-242 recommande à l'OTAN d'envisager un autre groupe de travail d'ici trois à cinq ans, pour évaluer si l'utilisation d'animaux dans la formation médicale est encore nécessaire.

TECHNOLOGY ALTERNATIVES FOR MEDICAL TRAINING: MINIMIZING LIVE TISSUE USE

1.0 INTRODUCTION

In both military and civilian settings, medical care providers are trained to provide trauma care using a combination of approaches. Background knowledge and theory are often provided through didactic lectures, while practical and resuscitation skills are often taught on a simulation-based platform. Simulation-based platforms include computer simulation (e.g., video games), task trainers, and mannequins (Human Patient Simulation [HPS]). Live Tissue Training (LTT), the focus of this working group's efforts, is a form of simulation that may be used for teaching and practicing complex emergency and surgical procedures.

Live tissue training in medical education has been facing increasing scrutiny owing to the increased focus on animal welfare and by the rapid improvements in medical simulation technology. In the United States and Canada, the Departments of Defence have closed a number of animal laboratories, including those that were used for ballistic wound management training and in chemical weapons casualty management. In the civilian setting, the American College of Surgeons' Advanced Trauma Life Support (ATLS) course has largely moved away from LTT to simulation-based training using mostly HPS and cadavers. The ethics of balancing animal rights and welfare with preparing military medical personnel to treat combat injuries has been hotly debated. Some countries have abandoned the use of live animal models for training due to political concerns, and in several other countries the practice is under intense political scrutiny.

Alternative to LTT technologies and training techniques have been rapidly developing. Mannequins, cadavers and virtual reality, alone or in with lifelike haemorrhage have added realism to trauma training without the use of LTT. However, none of these technologies have proved superior to LTT as of yet and the high cost of some of these technologies may be probative to large scale use, as compared to LTT. Additionally, military training requires field exercises and technologies may not have the durability to permit seamless integration into training when environmental conditions vary from an indoor setting.

Currently, simulation and LTT are still both used in trauma care skills acquisition. However, it remains unclear whether simulation can completely replace LTT or whether there still remains a role for animal models in trauma education. To better explore this question, RTG-242 formed to determine the value of LTT alone and in conjunction to other simulation training models in trauma care within NATO countries as well as to provide recommendations for best practices for LTT use and strategies to reduce LTT. Recommendations for best practices for LTT use and strategies on how to reduce the use of live tissue models were discussed and included in this report.

2.0 METHODOLOGY

The working group held five in-person meetings beginning in September 2015 to May 2018 in the following locations: Paris, France, Uniformed Services University of the Health Sciences (USUHS) Washington, DC USA, Supreme Headquarters Allied Powers Europe (SHAPE), Belgium, Defence Research and Development – Toronto Research Centre, Canada and Military Hospital Berlin, Germany. The meetings began with each of the members providing an overview of the use of simulation and of live tissue training in their countries. These overviews included in-depth descriptions of how medics and physicians are prepared to meet their military operational training requirements for each of the represented countries. The panel members also provided a comprehensive review of the laws and regulations on animal use in their country, the political environment regarding the use of animals, relevant literature published either from authors within their country or in their home language, studies involving simulation, and laws or policies that had been published since the previous meeting.

During the term of this working group, the members toured the simulation centre at the Uniformed Services University of the Health Sciences (USUHS), the Allied Command Medical Education Centre (ACME) at SHAPE in Mons, Belgium, and the Toronto Research Centre. These tours facilitated interactions between working group members and subject matter experts in the areas of simulation and medical education and training in the context of military medical readiness. These tours also assisted the group in exploring virtual reality and in assessing the current state of technology. Guest lecturers who were leaders in their field were invited to brief members of the working group. These briefings led to interactive discussions on the psychological and physiological factors related to different training modalities. The technology and simulation training techniques that we explored were task trainers, manikin systems, standardized patient actors, combined actor-mannequins (such as the cut suit overlying a human actor), virtual and augmented reality as well as cadavers and perfused cadavers. Members discussed the literature from their countries as well as their own national experiences with simulation and live tissue training. Discussions among the members continued until there was consensus among the group regarding each point.

For the literature review, the group conducted a descriptive review searching PubMed (http://www.ncbi.nlm.nih.gov/pubmed) which is an open access online database that contains over 25 million citations on biomedical literature including also MEDLINE, life science journals and online books.

The search was conducted in English from 1946 to present using these key words:

- Simulation;
- Training;
- Medical;
- Education;
- Live tissue;
- Animals;
- Trauma; and
- Replacement.

3.0 RESULTS

Sample of results from PubMed search:

- Using all terms in combination: 0
- Simulation and Training: 31610
- Simulation and Training and Medical: 13316
- Simulation and Training and Animal: 753
- Simulation and Training and Animal and Replacement: < 10

The results of the PubMed search using Simulation and Training and Animal and Replacement were primarily of veterinary medical interest. Articles in PubMed relevant to the subject were already familiar to members of RTG-242. The literature supported the fact that medical training programs use animals and there is a common interest in replacing animals. This effort to replace animals with simulation or other technologies was common to emergency/trauma medicine, surgery, and veterinary medicine. Common replacements were identified as ‘nonanimal-based methods’ and primarily included simulators and cadavers. These systems were already familiar to the working group. No new systems were revealed in the literature.

Many of the articles compared simulation to LTT and did not establish whether simulation or live tissue was superior to prepare practitioners for the performance of the required task. The challenge was in clearly establishing effectiveness of the training modality.

Through review of the literature and through conversations among the group members and with subject matter experts, the members of RTG-242 became familiar with the topic of assessment of training effectiveness. The Kirkpatrick model identified four levels of effectiveness – L1: subjective preference – L2: measures of skill/knowledge acquisition within the training context – L3: transfer of training to a target (operational or job) context – L4: impact on organizational effectiveness. There have been many studies comparing LTT to simulation that examine subjective preference for one modality over another. Similarly, many studies have also sought to measure the knowledge and the skills acquired within the context of the training. For military medical training, the most difficult yet important aspects to assess with the selected training modality are transfer of training to the target environment (i.e., operational environment) and impact on organizational effectiveness (i.e., completion of the mission). To our knowledge, there have been no studies assessing the transfer of military medical skills in garrison to performance in wartime mission. Such a comparison would be both unsafe and potentially unethical given the nature of delivering medical care in an unpredictable, hostile environment. Given these limitations on arranging a direct comparison of LTT to simulation and the associated impact of each on the transfer of training to the target environment and the impact on organizational effectiveness, there may always remain a lack of evidence for the value of one training modality over another when it comes to the delivery of military medical care in the operational environment.

In personal communications with military medics, the prototypical experience involves trying to save the life of a living patient when the stakes are high (e.g., hostile, austere environment, sole medically-trained individual on site, personal connection to the injured). Factors such as empathy for and camaraderie with the patient as well as the environment may impact transfer of training and organizational effectiveness in ways that are unique to the military. Such factors may also affect learning through other variables, e.g., motivation, self-concept. The working group found no published literature addressing these potential factors on the selected training modality. In personal communications, the realism and stress of caring for a live, anesthetised patient in a military-relevant environment as occurs with LTT most closely simulated the prototypical military medic experience. LTT is noted for its realism of haemorrhage and associated physiological responses to trauma, but it remains unclear how the animal itself, perhaps through the trainee's attachment to a "living patient", contributes to this preferred training experience.

4.0 DISCUSSION

The use of animals to model combat casualty care is one component of training military medics, medical teams, and surgeons to perform in high stress operational environments resulting in the lowest recorded case fatality rates in spite of increased injury severity [1].While LTT is still a part of pre-deployment training and assessment, its continued use is being questioned by those who believe that simulation technologies have advanced to the point where they are "at least equivalent to, if not superior to, animal models" [2], [3], [4]. The objective of this working group was to examine the issue of technological alternatives for military medical training and find ways to minimize the use live animals. In reviewing the current simulator technologies, the working group found that to date, there are no simulation tools or technologies that can replace the live animal model. The working group then discussed ways in order to reduce and refine the use of this training model and provided some general recommendations for the use of this model in military medical training.

Animal rights activists continue to focus their efforts on eliminating the use of LT for medical training and claimed these activities often subjects the animals to invasive procedures causing great bodily harm and suffering [2]. These activists insist that the use of animals for military medical training is not necessary and that other tools and technologies exist that are just as effective. The concern of animal use has not been restricted to military or civilian medical training, but all industrial purposes where animals are sacrificed for the sake of human use (for instance in the cosmetic or pharmaceutical industry). This has led to the creation of animal ethics committees in most NATO membership countries. Since the 1950s, the principles of the 3Rs – Replacement, Reduction and Refinement [5] are "a widely accepted cornerstone of policies on animal-based science around the world" [6], [7]. These principles represent a humane treatment of animals in research and education and focuses on using alternatives wherever possible (i.e., any methods or approach that avoids or minimizes the use of animals).

In some countries there is no other subject that may cause such concern as the use of live animals for the purpose of research and education and a topic that has great potential for evoking emotions in humans. The most profound concern is that the animals may suffer pain and discomfort, as well as being subjected to cruel actions. One reason being that people (as both consumers and observers) have become more aware of how animals are being kept. This is not only in regard to how animals are kept for agricultural reasons and as pets, but in particular how animals are being held and used for research and education. Most countries have legislative bodies that govern the use of animals and their welfare and are in general meant to ensure that they will not suffer unnecessary stress and pain [7]. The decision on what is unnecessary stress and strain would of course be left for us humans to decide. In keeping and holding the animals, we, as a society, take on a huge responsibility.

The principle of ethical and moral conduct is not only applicable to the relationship between people, but should also be applied to the way humans act and behave when they are in contact with animals and in particular when humans keep and use animals for their own benefit, this includes the use of live tissue for medical training purposes. In order to determine what is right or wrong, we must consider both the regulatory affairs and the opinion of society in general. Cruelty to animals will provoke emotions in humans; thus, the use of live animals for research and education should be a subject for discussion, in particular, activities involving invasive procedures that could be considered unethical and immoral. Society may come to accept the use of live animals for research and educational purposes if the procedures are carried out in a way that is not affecting the animal's welfare and they are not experiencing any unnecessary pain and stress.

In terminal non-recovery trials, where the animals will not regain consciousness, a balanced anaesthetic protocol will ensure they will not experience pain throughout the procedures. Therefore, all invasive procedures must be carried out under continued and full anaesthesia. There have been claims that the animals used in medical training show signs of movement that could be interpreted as an insufficient level of anaesthesia [8]. Anaesthetic protocols in both human and veterinary practices are based on scientific studies and experience. Even though it is adjusted to the species, age and weight of the individual, responses may vary. For example, one animal may be very deeply anaesthetized while another may maintain their reflexes and require additional doses of the anaesthetic. These variations in responses can result in misinterpretations regarding animal welfare, but variability in response to anaesthetics are the norm and will not always be a sign of insufficient levels of anaesthesia [8]. As noted above, the animal's wellbeing is being cared for during terminal and non-recovery exercises under continuous anaesthesia and analgesia, protecting them from unnecessary stress and pain. In addition, there are concerns regarding animal welfare when conducting activities during management and handling (including transport) prior to and during induction of anaesthesia. Care should be taken that the animals do not undergo unnecessary stress during these activities. Another aspect of the animal's welfare that should be considered is how they are housed and maintained [7]. This should be done under conditions appropriate to their species and environment. Opportunities for refinement should be considered during the animals' lifetime such as enriching the housing environment to achieve appropriate species' behaviours and avoid or minimize stress-induced behaviours [7]. The care and handling of animals should be carried out only by trained and experience personnel.

In discussing the ethics and morals of using live animals for medical training we also have to take into consideration the ethics and morals of not using them as models of human patients. This report examined the pros and cons of simulators and simulation technologies currently available for medical training with the end goal for such training being proper treatment and care for human patients. The discussion concerning the ethical and moral issues should therefore also consider how treatment of patients would be performed without proper (and the best!) training available, including the ethical aspects of not providing the appropriate treatment to a patient or even losing them. Will the patient (survivor), the next of kin or the society accept this? Until we are certain that there are simulator technologies that can ensure a better or equivalent outcome, it is believed there can be an ethical and moral acceptance amongst society for the continued use of live animal models for training on life-saving techniques.

A variety of simulation tools exist, and they should be used in the context of a given curriculum [9]. A comprehensive curriculum should be carried out in a stepwise fashion from didactic instructions to description and demonstration of the procedure to be trained followed by simulator-based instruction. All relevant training modalities are to be used before considering the use of the LT model and then only if the procedure or training level warrants the use of the LT model should this training tool be used. If LT models are to be used for medical training, then it is essential that the training protocol strictly adheres to the ethics and legislation on the use of animals. In addition, teachers/trainers should be familiar with animal ethics and possess the relevant level of knowledge and experience to conduct the training courses. A review of the training procedures is essential to ensure the use of LT models in the exercises conforms to high ethical and humane standards and the 3Rs are being followed. In countries where there are no military hospitals, similar training requirements are often met in civilian hospitals, with the general public also benefiting from this training. The use of simulators to educate healthcare personnel has shown to be effective [10]; however, training in civilian sectors does not necessarily translate to the ability to adequately treat battlefield injuries. The types and severity of injuries sustained during combat are rarely seen in civilian settings which make the combat casualty care training unique and important for saving lives [11]. Most commercially available medical simulation technologies need to be redesign in order to fit the requirements of military medical training [12]. Future developments in simulator technologies to support military medical training may allow replacing training with live animals [13].

As mentioned previously, there are many different medical training models and in choosing which one(s) to use, the following questions should be addressed: Who is being trained? What are the training objectives? And what resources are available? It is important to provide training to those personnel required to perform targeted medical procedures often in a hostile environment on the front lines or in a Role 1 hospital and are not clinically active on a daily basis. The medical training is only a small part of their overall military training. Therefore, the medic's ability to interpret clinical signs is highly dependent on the medical training courses provided to them. These trainees are usually not familiar with procedures such as cutting into live tissue and do not know what to expect in the form of tissue contraction, bleeding, etc. The training objectives should be clearly identified prior to the training exercise as this will determine the most appropriate training model(s) to be used. The fidelity of the simulator is also important and should meet the training objectives. For example, a task trainer or a simple mannequin may be sufficient to teach a given skill whereas a high-fidelity patient simulator may be required for teaching more complex procedures [9], [10]. Whatever resources are available, it is important that the training modalities are used appropriately to meet the training objectives. The cost of simulators is often very high and there is a need for dedicate personnel for maintenance and daily use of these training models. In addition, simulators are effective only in replicating specific procedures that require targeted technical skills. Simulators and cadavers (including perfused cadavers) are useful in certain applications however, neither responds authentically to medical interventions in the same manner that live tissue does, which is required for more advanced technical skills. Moreover, these simulators do not function properly under extreme weather conditions or in certain simulated battlefield scenarios. While simulators (such as high fidelity patient simulators) are useful in targeted simple procedures and can easily be placed in a combat-like environment that can stress decision-making, due to the delayed feedback (often prompted by the instructor or by the individual directing the simulator) it fails to produce a physiologic response. This response is essential in reflecting the technical ability of the trainee as well as mentally stressing them, as he or she is dealing with a "live patient" [14]. While live animals have certain advantages such as having live tissue allowing for bleeding and coagulation, urgency for treating a "live patient" and standardized injuries, there are a number of disadvantages as well. The disadvantages include lack of similar anatomy, the requirement for veterinary support as well as dedicated staff and facilities for housing the animals (see Table A-1 in Appendix 1).

Figure 1 depicts the relationship between the different training models, different hospital Roles and the type of training relevant for individuals and troops. The figure also illustrates the stepwise approach to the complexity of the procedures combined with the personnel needed to train and includes if the training is targeted towards an individual or a team. Simple procedures like bandaging and placing a tourniquet that all troops are required to learn, can be trained on buddies, simple mannequins or a task trainer. More advanced procedures undertaken by specialised personnel needs to be practised using a variety of simulators (including LT models) which will allow these medics to "practice their combat trauma skills in addition to team work, managing their resources, communication and overall performance" [9]. In Role 2-4 hospitals, the environment where surgeons and anesthetists would be working, the use of LT models is preferable for training advanced surgical skills.

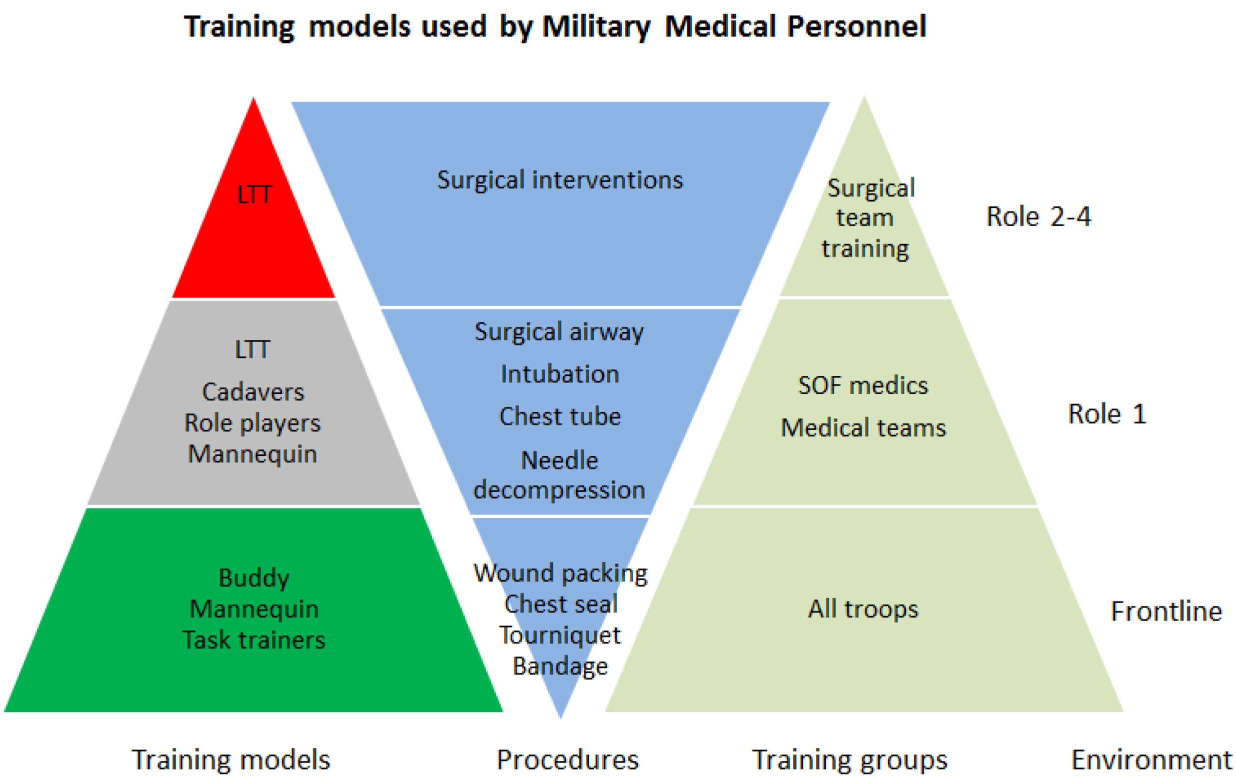

Figure 1: Illustration of the Different Training Models Used to Prepare Military Medical Personnel to Treat Battlefield Injuries. The combined training methodology uses all available training models ensuring that the right tools are being used for the right training, at the right time for the appropriate level of care provider to be able to perform in operational environments.

Uncontrolled haemorrhage is the leading cause of preventable death for soldiers wounded on the battlefield and trauma in general [1], [15], [16], [17]. The problems associated with massive haemorrhage in trauma can be avoided by controlling the bleeding and limiting the blood loss. Human cadavers do not bleed, and dead tissue does not respond to surgical procedures in the same manner that living trauma patients would. While some simulators are capable of bleeding, they do not respond in the same biological manner that a patient does, making it difficult to teach bleeding and haemorrhage control methods using these training modalities. Simulators cannot adequately mimic bodily functions and therefore cannot recreate the reality of a wounded human patient. The change in the physiology of the patient and the response to treatment is an important part of the medics' training. If the goal is to reduce pre-hospital deaths, then optimal training should be provided to medical personnel to ensure they are capable and confident in performing these life-saving techniques on the battlefield or in the emergency room. At this time, that training involves the use of all available training tools including the use of the LT models. After examining the issue of technological alternatives for medical training, the working group concludes that instead of replacing LT models, the focus should be on refining the use of LT in military medical training which could lead to a reduction in LT use. It is important to also continue to explore, assess and validate developing technologies as alternatives to the LT model for use in training as this is in keeping with most countries' animal care guidelines.

5.0 CONCLUSION

In reviewing the current training models and technologies, RTG-242 has concluded that the use of the live tissue model for training medical personnel should not be replaced, but rather the use of this model should be reduced and the techniques refined. Going forward, the working group recommends a Training Needs Analysis (TNA) for pre-hospital/combat casualty care be done at the level of each NATO country. Once completed, a TNA across NATO members would assist in forming a more systematic review of outcomes desired at each particular stage of pre-hospital/combat casualty care training and for each type of provider. Figure 1 provides this working group's initial assessment upon which future working groups can build. Overall, the working group provides the following general recommendations for all NATO members regarding the continued use of live tissue.

5.1 General Recommendations for the use of Live Tissue Models in Military Medical Training

5.1.1 Governing Regulations

- Recommend compliance with home nation laws and regulations on animal care; in instances where there are no national laws or regulations addressing animal welfare.
- At a minimum, a written document (protocol) describing the procedures to be carried out using the animal should be written and an ethical review should be conducted.
- The animal use protocol should be reviewed at regular intervals (e.g., a minimum of every 3 years) to ensure new developments in technology and/or new training needs are addressed.

5.1.2 Planning

- Alternatives to LTT should be considered for every planned exercise (ask why LTT) and consider a reduction in animal use for each training iteration.
- Remain committed to the training objectives as required by military medical personnel who know and understand what is required to succeed medically, do not alter the training to meet what a simulator such as mannequin, cadaver, etc. can do.
- A combination of LTT and simulation systems (manikin, standardized patient, virtual reality) should be considered to meet the training requirements. LTT should only be carried out after developing proficiency in other relevant, available training systems.

5.1.3 Prerequisite Training and Competence

- Personnel attending must be first be trained and proficient in the life-saving techniques prior to the use of LT in training
- Consider trainees' and the trainers' scope of practice, and their current and required skill sets before using LTT
- Instructors should be highly proficient before they are permitted to use the LT model for training
- Management of profuse bleeding is of a primary concern on the battlefield; therefore, realistic training to prepare medical personnel to manage these types of injuries is critical.

5.1.4 Animals

- Minimize the number of animals and maximise the procedures with standardized plans for training
- Use healthy animals to minimize risks of zoonotic diseases
- Immediately following training and without recovering from anaesthesia, live animal models will be terminated using methods that are acceptable for humane euthanasia

5.1.5 Training with Live Tissue Models

- Animals must be anesthetised, have appropriate analgesia and be continuously monitored throughout the training period.
- A veterinarian should be on site during the training exercises to ensure the humane care of the animals and to make certain appropriate anaesthesia and analgesia are administered.
- The use of live animals for training is a privilege and as such, the training models must be treated with the same respect granted human patients when performing the various life-saving techniques and throughout the training exercises.
- The principles of the 3 Rs – Refinement, Replacement, and Reduction – should always be considered when using this training model.
- Maximise the use of the live tissue model by performing as many of the training procedures as indicated in the approved training protocol.
- Training should be conducted using internal military assets and unless highly supervised, avoid the use of external (i.e., contract) providers of training.

5.1.6 Public Relations and Media

- Unless there are strict exceptions and processes to grant these exceptions, no video recordings should be made, or photographs taken during the training activities while using the animal model. These recordings and photographs can be taken out of the context of the training intent and used to manipulate public trust in the assurance of animal welfare.
- Consider communication with the public on the importance of live tissue training.
- Ensure transparency about the principle goal of animal use and appropriate ethical reviews when combining research to study training effectiveness as compared to pure training efforts.

5.1.7 Way Ahead

- Continue effort and investments to develop and improve technologies that will be suitable alternatives to LTT.
- NATO endorse a standard set of minimum requirements for mannequins (e.g., tourniquet application, chest tube) so that member countries can use this as a guide and not perform these procedures on animals unless part of other, more complex training plans).
- Consider collecting data on the skill level of the trainees, ratio of trainees to each animal, the types of procedures conducted on each animal to determine the effectiveness of this type of training.
- Consider investigating the type of training medical providers received to patient outcomes (consider this for future conflict how to capture this data in advance such as on a NATO combat casualty card).

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Appendix 1: COMPARISON OF MEDICAL TRAINING MODELS

Table A-1: Comparison of Medical Training Models.

Medical Training Model	Pros	Cons
Mannequins/Computerised Mannequins (High-Fidelity)	• Anatomy is generally representative of human. • Can be used repeatedly to perfect techniques. • Acceptable by society.	• Poor tissue fidelity. • Cannot simulate the feeling of real tissue, blood or bone. • Cric is too easy. • No feedback as to how well the technique is performed even with computerised mannequins. • Can be difficult to make a mistake, i.e., too easy to get things right (limited negative outcome potential). • No sense of urgency – does not duplicate the “stress of saving an actual life”. • Cost – consumables. • Can be very expensive to maintain and requires operator training.
Cadaver/Perfused Cadaver	• Perfused cadavers – artificial bleeding for haemorrhage control. • Can practise incisions and sutures. • Good for surgical skills acquisition. • Real anatomical landmarks. • Acceptable by society for general medical training.	• Time of death and the fresh/frozen state – storage of cadaver, consent to use cadaver (donated). • Unrealistic smell. • Age of the individual and physical condition may not model military population. • Tissue fidelity. • No physiological feedback. • Not a true “standardized” model – different size/weight of cadavers. • High cost and scarcity. • Lack of evidence that model translates to performance on a live patient. • Single use – fresh/cryopreserved. • Use in trauma training may not be acceptable by society.

Medical Training Model	Pros	Cons
Virtual Reality	• Can be a stand-alone device with built-in scenarios, multiple patients to increase variation. • Enables trainees to practise and perfect life-saving procedures. • An **additional** training aid only (at this time, doesn't replace modalities). • Acceptable by society.	• Cost – can be very expensive. • Infrastructure is required. • Tissue fidelity and bleeding are not realistic, lack haptic sensation. • Can "reset" the scenario so mistakes are not realistic.
Task Trainers	• Can be cost effective. • Easily maintained. • Can be used repeatedly to perfect techniques (build muscle memory). • Acceptable by society.	• Focus is only on a single task to be trained on. • Limited negative outcome potential. • Lack realism/physiological response.
Live Tissue	• Anatomy – vital organs are essentially in the same place. • Realism of procedures (e.g., pressure you exert is extremely different than when you use a manikin). • Physiology similar to humans – reaction to treatment both short and long term. • Wounding – with multiple wounds the physiology of the LT changes – not seen in simulators. • Haemorrhage/Wound packing. • A sense of urgency not felt with simulators – performing techniques correctly and timely. • Haemorrhage control and airway intubation-provides immediate feedback about quality of care.	• Requires Veterinarian and trained technician to monitor anaesthesia. • Anaesthetized. • Anatomy (landmarks are slightly different). • Size – not as large as humans. • Cost and infrastructure to house. • Ethical questions /concerns about proper use and care of animals. • Simulation limited by maintenance of anaesthesia (e.g., staff must be nearby monitoring).

Medical Training Model	Pros	Cons
Role Players (Moulage / Cut Suit)	• Feedback from casualty. • Realistic anatomy. • Add realism to trauma training. • Cut Suit – can quickly repair the damage "skin" for repeated use, unlike manikins. • Cut Suit – provides sensation of working on live tissue/ performing procedures on a conscious "casualty". • May allow practice of multiple skills in conjunction with patient communication. • Acceptable by society.	• Wounds are not fully realistic. • Simulated blood – texture, clotting, coagulation, smell not fully representative. • Tissue fidelity. • Require trained individual to "act" out symptoms of the wounds. • No invasive procedures can be conducted (Role player). • Requires application of moulage/overlay suits by skilled individuals.

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14. Abstract

The use of animals to model combat casualty care, also called Live Tissue Training (LTT), is one component of training military medics, medical teams, and surgeons to perform in high stress operational environments. LTT has been an important contribution to combat casualty care. Combat casualty care now has the lowest recorded case fatality rates in spite of increased injury severity. LTT has come under increased scrutiny in many countries. Educational, scientific, and technological advances may provide opportunities to reduce reliance on LTT. NATO nations wish to ensure the best training for military medical personnel while minimizing LTT. Therefore, the objective of this working group was to provide recommendations to reduce and refine LTT use without compromising the readiness of military medical personnel.

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