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Original Research

Live Tissue Training on Anesthetized Pigs for Air Ambulance Crews

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A B S T R A C T

Objective: Patients with life- or limb-threatening severe injuries pose a challenge to prehospital services. Time-critical decision making and treatment are challenging because of occasional incomplete information, limited resources, adverse environments, and a range of basic and advanced technical skills available. To prepare for these infrequent critical situations, medical personnel from the helicopter emergency medical service at Oslo University Hospital developed a 1-day advanced trauma training course focusing on individual skills and teamwork during resuscitative procedures.
Methods: Participants were trained under supervision in teams on an established live tissue model with anesthetized pigs. A questionnaire-based evaluation was conducted before and after training to measure the feasibility of covering the allocated learning objectives in the time allotted and participants' perception of any change in their skills as a result of the course.
Results: The self-reported skill level in all learning objectives improved significantly. Combining all learning objectives, the median self-reported skill level was significantly increased from 4 to 6 points ($P < .001$).
Conclusion: Experienced prehospital physicians and other health staff reported an increased level of skill and competence in lifesaving and limb-saving procedures after completing a brief, intense 1-day course using living anesthetized pigs and cadaver models.

Major physical injury often necessitates advanced emergency care. In Norway, injuries account for about 10% of life years lost.[1] Each year, 4% of the Norwegian population receives treatment for traumatic injuries by specialized health services.[2] Approximately one third of all helicopter emergency medical service (HEMS) missions in Norway are trauma related.[3]

For providers of advanced prehospital care, this group of patients poses particular challenges because of austere environments, limited on-scene resources, and a need for time-critical decision making. Some injuries require advanced lifesaving or limb-saving procedures that cannot await referral and transfer to specialist hospital services. Relative to the total number of trauma cases, procedures such as decompression of a pneumothorax, emergency surgical airway, advanced hemorrhage control, and resuscitative thoracotomy are rarely performed in the prehospital setting.[4] However, the lifesaving benefit of these procedures is well established.[5] Therefore, preparing for these situations is challenging and essential. Mental rehearsal, stress inoculation training, and other techniques have been adopted in some centers.[6,7] Simulation training is widely implemented and can bridge the gap between theory and practice,[8] in particular with regard to decision making and some practical skills. However, traditional simulation training is not ideal for improving procedural skills that require tactile sensation and sensory feedback to the performer as well as an adequate physiological response.[9] Although new technology better approximates the anatomic, physical, and physiological properties of live tissue, there is evidence that these models still have major shortcomings.[10,11]

Opportunity-based training on patients in an apprentice-tutor model has been the mainstay of surgical training for decades.[12] Although this principle is suitable for procedures performed predictably or frequently in which a tutor is readily available and time is not a critical factor, it is unlikely to be feasible for training for infrequently performed emergency procedures in the prehospital setting. The integrated crew approach, which is relied on in Norwegian

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HEMS, further challenges the concept of training in elective hospital patient settings because the majority of the crew manning the helicopters only occasionally work in the hospital.

A number of training programs have been developed to standardize in-hospital trauma management and reinforce relevant procedural skills.[13,14] However, to our knowledge, there is a lack of courses specifically focusing on training lifesaving and limb-saving procedures for prehospital care providers in the civilian setting using an adequate training model.

Therefore, Oslo University Hospital HEMS has developed a 1-day advanced prehospital live tissue training (PLTT) course that focuses on individual procedural skills and teamwork. Over a 2-year period, the course has been refined to meet the participants' needs. For ethical and financial reasons, the course aims to use the model animal as effectively as possible as described later.

The purpose of this study was to evaluate the feasibility of the 1-day live tissue model course to achieve a predefined set of learning objectives and to report any change in participants' self-assessment of their skills.

Methods

The PLTT course takes place 4 to 6 times per year at Oslo University Hospital. Prehospital physicians, paramedics (PMs), and HEMS crewmembers (HCMs) employed in the advanced prehospital emergency services may attend. In our emergency medical system, most of the prehospital physicians are consultant anesthesiologists, whereas HCMs are nurses, specialist nurses, or PMs. The study was conducted during a 1-year period from October 2014 to October 2015, which included 8 PLTT courses.

Ethical Considerations and Consent to Participate

Participation in the study, by responding to the questionnaire, was voluntary and anonymous. Individuals could withdraw their responses at any time. The Regional Committee for Medical Research waived the need for ethical approval (Regional Ethics Committee Helse Sør-Øst, Oslo, Norway). The Norwegian Social Science Data Services approved the recording of data related to the study.

The animal model used in this study has been developed in accordance with "Regulations on Animal Welfare" under the Norwegian Animal Welfare Act and approved by the Norwegian Animal Research Authority (FOTS ID 5800, dated 08/11/2013). In order to comply with the reduction principle,[15] we have reduced the number of animals needed by using each animal as much as possible. In accordance with the refinement principle, the animals were placed under general anesthesia with adequate monitoring. Because of the lack of anatomical similarities in other species, we considered pigs as the only suitable replacement for humans for training the majority of procedures. Some technical skills were trained in cadaver models based on the replacement principle.

The Animal Model

For the purpose of the PLTT course, we used an animal model previously described in detail.[16] Domestic swine of either sex, 10 to 12 weeks of age and weighing approximately 30 kg, were used. The animals were sedated with an injection of ketamine. Anesthesia was maintained throughout the course with continuous intravenous propofol and fentanyl infusions. Animals were orally intubated and ventilated. Throughout the course, clinical, respiratory, and hemodynamic monitoring ensured an adequate level of anesthesia. Participants were instructed to immediately alert training staff if they suspected that the pig might be experiencing any discomfort. At the end of the course, the pigs were euthanized with an overdose of propofol and 30 mL 1 M KCl solution intravenously. Individual practical training in emergency surgical airways was performed in a cadaver model using animal larynxes (from pigs).

Course Content and Layout

The course was designed to teach a specific set of advanced prehospital procedural skills and to discuss the underlying theory.[17] The skills and learning objectives are summarized in Table 1.

Before the training, all participants were briefed by a senior member of the laboratory facility about the ethical standards relating to the use of anesthetized living animals. Each training group consisted of 4 physicians and 2 paramedics or HEMS crewmembers. The groups were constructed to include participants from a variety of workplaces, to improve dialogue, and to exchange experiences between participants. Each group trained on 1 animal, and a named instructor stayed with each group throughout the day. An extra "floating" instructor was available to assist the 2 groups as needed and to ensure standardization of the procedural techniques, as outlined in the written course materials. After completing each skill, the group debriefed the procedure. This was moderated by the instructor, who facilitated input from all participants. To maximize learning outcomes for the participants, we used several debriefing methods.

Table 1
Topics and Learning Objectives for the Prehospital-Oriented Live Tissue Training

Sequence	Topic	Learning Objectives
1	Pulmonary ultrasound	To use ultrasonography to identify pneumo- and hemothorax
2	Intravascular access	To use ultrasound to establish intravascular access, including understanding differences in compressibility of veins and arteries To correctly place and remove an intraosseous vascular access using an EZ-IO (Arrow, Teleflex, Morrisville, NC, USA)
3	Management of external hemorrhage	To effectively control external hemorrhage using direct manual compression and packing of deeper wound tracts and cavities To actively reduce the risk of rebleeding through the management of risk factors
4	Use of tourniquet	To correctly use and remove EMT (Delfi Medical, BC, Canada) and SOF-T (Tactical Medical, Anderson, NC, USA) Wide tourniquets to control life-threatening extremity hemorrhage
5	Proximal bleeding control	To use proximal vascular compression for hemorrhage control
6	Emergency surgical airway	To establish an emergency airway using cricothyroidotomy using a 4 step approach (scalpel-hook-bougie-tube technique)
7	Management of open fractures	To manage an open compound extremity fracture with concomitant vascular injury and hemorrhage
8	Pulmonary decompression	To perform a needle decompression of tension pneumothorax To understand the role and limitations of the procedure and the observed physiological effects To perform a finger thoracostomy for pneumothorax during positive-pressure ventilation To establish prehospital chest drainage using a dedicated Portex (Smiths Medical, Dublin, Ohio, USA) kit
9	Resuscitative thoracotomy	To perform a thoracotomy To understand the role of prehospital resuscitative thoracotomy as described in the international guidelines for traumatic cardiac arrest

Promoting Excellence and Reflective Learning in Simulation (PEARLS) was used as an overall principle.[18] For specific tasks, we used rapid cycle deliberate practice, which offers the opportunity for participants to repeat a procedure after feedback.[19] Debrief on demand was used when technical procedures needed immediate correction and feedback.[20] Because the groups consisted of experienced providers, peer-led debriefing could be used when appropriate.[21] During debriefs, both the technical aspects of the procedure and its application in prehospital care were discussed.

Instructors

All instructors were experienced senior prehospital flight physicians from the HEMS service at Oslo University Hospital with extensive teaching experience. They were all instructed in the use of living animals in training by a senior member of the laboratory staff (M.E.) at Oslo University Hospital (formerly Ullevaal Hospital). During the first 10 PLTT courses and before initiating this study, the instructors had developed a comprehensive training manual for the PLTT. All instructors were required to follow the manual.

Data Collection and Analyses

The key outcome with regard to the feasibility of the course was whether all learning objectives were covered as per the course manual within the time available. With regard to the use of a live animal model, any difficulties with the animal model negatively affecting the learning objectives were noted.

In the beginning of the day, participants completed an anonymized questionnaire of 15 questions to be answered on a 7-point Likert scale. Demographic data about the participants regarding clinical experience, prehospital experience, and experience with the specific procedures taught in the PLTT course were collected. Participants were asked to evaluate their procedural skill level and theoretical knowledge of these procedures before and after the course.

The questionnaire was drafted by 3 of the authors (P.B., G.F., and H.S.T.). To ensure that it was unambiguous, it was tested on 2 independent HEMS physicians; their input was used to modify the questionnaire. The improved questionnaire was rewritten and presented to the participants in English (Appendix 1). No further validation of the questionnaire was performed. Data analyses were performed using R (R Foundation for Statistical Computing, Vienna, Austria). For comparative analysis, the Wilcoxon signed rank test was used. Numbers are given as medians with interquartile range (IQR).

Results

Training was conducted over 8 days. All topics in the training manual were covered in all sessions. There were a total of 83 participants, 17 (20.5%) women and 66 (79.5%) men. Fifty-six (67.5%) were medical doctors with completed specialist training in anesthesiology and 25 (30.1%) PMs or HCMs. Two participants did not specify their profession. Among doctors, the median number of years working as a specialist was 7 (IQR, 2.25-12). The median number of years working in prehospital critical care was 6 (IQR, 2-12) for doctors and 12 (IQR, 5-15) for PMs/HCMs.

We observed a statistically significant improvement in self-reported skill level in all learning objectives after the course as shown in Figure 1 ($P < .01$). Combining all learning objectives, the median score increased significantly from 4 to 6 points ($P < .001$). The largest improvement was observed in resuscitative thoracotomy skills with a median improvement of 4 points. The smallest improvement was noted in ultrasound-guided vascular access, fracture handling, and surgical airway, each with a median improvement of 1 point.

The self-reported theoretical knowledge level improved significantly in 4 of 5 topics. The median improvement for these 4 topics was 1 (IQR, 1-1; $P < .01$). The median knowledge score on the difficult airway algorithm remained unchanged at 6 points out of 7. Ultrasound-guided vascular access, fracture handling, and surgical airway each showed a median improvement of 1 point.

Discussion

This study describes a feasible model for live tissue training with optimal use of animals and significant improvements in self-reported skills and knowledge. Importantly, it shows improvements in

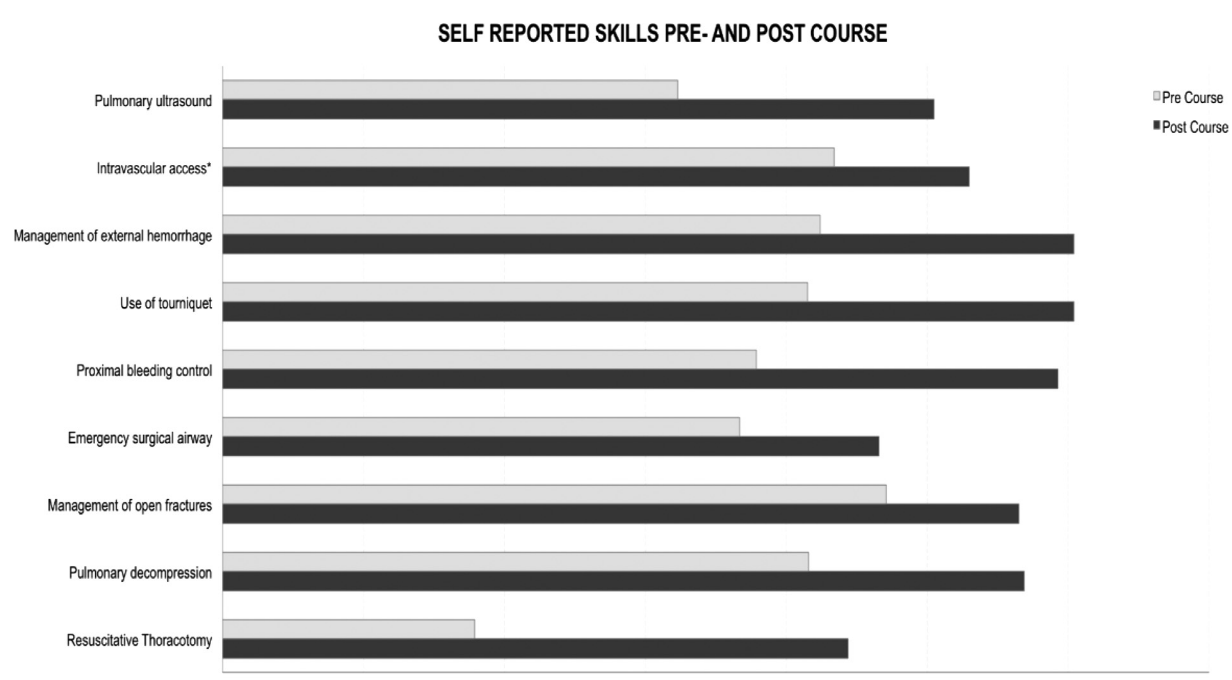

Figure 1. The self-reported skill level in all learning objectives in the course on a Likert scale where 1 = completely unconfident and 7 = completely confident (N = 83). A significant overall improvement in all topics is demonstrated ($P < .01$).

knowledge and skills even though the participants were experienced in their specialty and in prehospital work. Our measured improvements may be a result of the high experience level of the participants, as shown by their high initial skill level; guided vascular access and surgical airway are both key anesthetic skills. Fracture handling is a minor part of the course and therefore may not significantly develop participants' skills. Despite this high level of prior experience and training, an improvement was reported in all other learning procedures, reflecting the utility of practicing these rare but critical skills.

Sohn et al[22] describe a combat casualty training course for physicians that is similar to our strictly civilian PLTT course. They found similar self-reported improvements in confidence levels in handling battlefield casualties.

Simulation is a well-accepted and widely used method for both the acquisition of new skills and maintaining skills in prehospital care.[23,24] However, there is little consensus regarding which modality of simulation is superior. In their review of simulation in prehospital care, Abelsson et al[23] found heterogeneity related to methods of simulation. Many of the procedures needed for prehospital care can be learned in either ex vivo models or mannequins. Our experience indicates that some animal-based training, especially simulation of bleeding and practice achieving bleeding control, is difficult to replace with nonanimal models.

The target group for this 1-day course is anesthesiologists and prehospital personnel who rarely perform surgical procedures but who need to attain and maintain their skills in a range of critical resuscitative procedures. Sultan et al[9] describe features for an ideal simulator, which includes, but is not limited to, the texture and resistance of human tissue. Our belief, based on our experience, is that tissue sensation and surgical skills should be practiced on bleeding tissue. We believe that anesthetized animals are superior to artificial models for this purpose.[25] The benefits of animal tissue are also described by Forbes et al[11] and Hocking et al.[26] Like senior trauma surgeon colleagues, we believe that this tissue feeling and tactile sensation cannot be properly practiced without hands-on practical in vivo training.[10] This is especially true for staff without a background in surgery.[27] Live tissue training has previously been proven useful.[27] There is an ongoing debate whether other forms of training can replace live tissue training. Most studies find no differences in learning outcomes.[10,28] At the same time, several authors are reluctant to, or opposed to, abandoning live tissue training.[10,27]

After the initiation of the live tissue course, we have become aware of other training courses for critical surgical interventions, some that use human cadavers and others simulation techniques with animal tissue.[25,29]

The use of living anesthetized animals is well recognized but demands a high level of ethical consideration.[27] This course aims to comply with the same principles of reduction, replacement, and refinement as for animal research.[15,30]

We focused on the reduction of the number of animals to an absolute minimum, first through careful selection of the participants; the course was only offered to active prehospital physicians, HCMs, and PMs working in the doctor-paramedic team. This is in contrast to some courses using cadaver models, which are open to a wider range of participants.[25] Second, the number of animals was reduced by systematically performing noninvasive and minor procedures before the complex procedures. Through this sequential approach, the physiology was virtually unaffected even after a number of procedures had been performed, leaving the animal suitable for practicing more complex invasive procedures.

In accordance with the replacement principle, procedures that can be taught as well on mannequin models were not performed in this live tissue training course. We limited the course content to procedures in which we are convinced that the live tissue animal model is superior to artificial models, with the exception of the surgical airway procedure, which was replaced with a cadaver model. Because of the unique anatomic similarities between pigs and humans, we believe replacing pigs with other less sentient species would be inadequate for the purpose of practicing emergency surgical procedures.

Several aspects of animal welfare were considered in order to comply with the principle of refinement. The courses were held in a well-established animal laboratory with species-appropriate stabling facilities and feeding opportunities. In addition to the fact that the majority of participants were experienced anesthesiologists, experienced laboratory personnel supervised the induction and maintenance of anesthesia throughout the course until euthanasia. In the precourse briefing, participants were instructed to do repeated clinical observations during the course to ensure adequate anesthetic depth. No muscle relaxant that may have masked signs of pain was used.

Training models and methods are being developed rapidly. When more suitable models for training these procedures become available, we look forward to implementing them into our training. If these newer training models are sufficiently effective, we would prefer them over the use of an animal model. However, until these are available, we believe our model is ethically justifiable because it ensures that prehospital teams are confident in their ability to perform rare, lifesaving interventions when needed.

Limitations

This is a self-reporting study in which only immediate experiences were recorded. There has been no validation of skills for the long-term or short-term after the course. The study design evaluated participants' perceptions of their own skills in the live tissue model, which might be different from their perception of their skills in a clinical context. However, we have often received informal feedback months or years after a course indicating that participants have applied a skill learned on the course in a clinical context and that they felt the course had positively impacted their abilities.

Conclusion

We conclude that our live tissue training concept designed to ensure the effective use of animals in an ethical and responsible manner was feasible. Experienced prehospital physicians and their team members reported an increased level of skill and competence in lifesaving and limb-saving procedures after completing this 1-day course.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amj.2020.10.003.

References

1. Tollånes MC, Knudsen AK, Vollset SE, Kinge JM, Skirbekk V, Øverland S. Disease burden in Norway in 2016. Tidsskr Nor Laegeforen. 2018;138(15). English, Norwegian. https://doi.org/10.4045/tidsskr.18.0274. PMID: 30277038.
2. Grøholt E, Bøhler L, Hånes H. *Folkehelserapporten—helsetilstanden i Norge i 2018*. Oslo, Norway: Folkehelseinstituttet; 2018.

3. Luftambulansetjenesten. Helseforetakenes nasjonale luftambulansetjeneste ANS Årsrapport 2012. Årsrapport 2012. Available at: www.luftambulansetjenesten.no2013. Accessed January 7, 2020.
4. Sollid SJ, Bredmose PP, Nakstad AR, Sandberg M. A prospective survey of critical care procedures performed by physicians in helicopter emergency medical service: is clinical exposure enough to stay proficient? *Scand J Trauma Resusc Emerg Med*. 2015;23:45.
5. Wilson MH, Habig K, Wright C, Hughes A, Davies G, Imray CH. Pre-hospital emergency medicine. *Lancet*. 2015;386:2526–2534.
6. Siriratsivawong K, Kang J, Riffenburgh R, Hoang TN. Immersion team training in a realistic environment improves team performance in trauma resuscitation. *Surgery*. 2016;160:586–590.
7. Lauria MJ, Rush S, Weingart SD, Brooks J, Gallo IA. Potential role for psychological skills training in emergency medicine: part 1 - introduction and background. *Emerg Med Australas*. 2016;28:607–610.
8. Weller JM. Simulation in undergraduate medical education: bridging the gap between theory and practice. *Med Educ*. 2004;38:32–38.
9. Farjad Sultan S, Shorten G, Iohom G. Simulators for training in ultrasound guided procedures. *Med Ultrason*. 2013;15:125–131.
10. Barnes SL, Bukoski A, Kerby JD, Llerena L, Armstrong JH, Strayhorn C. Live tissue versus simulation training for emergency procedures: is simulation ready to replace live tissue? *Surgery*. 2016;160:997–1007.
11. Hocking G, Hebard S, Mitchell CH. A review of the benefits and pitfalls of phantoms in ultrasound-guided regional anesthesia. *Reg Anesth Pain Med*. 2011;36:162–170.
12. Franzese CB, Stringer SP. The evolution of surgical training: perspectives on educational models from the past to the future. *Otolaryngol Clin North Am*. 2007;40:1227–1235. vii.
13. ATLS Subcommitee; American College of Surgeons' Committee on Trauma; International ATLS Working Group. Advanced trauma life support (ATLS®): the ninth edition. *J Trauma Acute Care Surg*. 2013;74:1363.
14. Boffard KD. *Manual of Definitive Surgical Trauma Care 3E*. Boca Raton, FL: CRC Press; 2011.
15. Kirk RGW. Recovering the principles of humane experimental technique: the 3Rs and the human essence of animal research. *Sci Technol Human Values*. 2018;43:622–648.
16. Steinberg MT, Olsen JA, Eriksen M, et al. Haemodynamic outcomes during piston-based mechanical CPR with or without active decompression in a porcine model of cardiac arrest. *Scand J Trauma Resusc Emerg Med*. 2018;26:31.
17. Reid C, Clancy M. Life, limb and sight-saving procedures—the challenge of competence in the face of rarity. *Emerg Med J*. 2013;30:89–90.
18. Eppich W, Cheng A. Promoting Excellence and Reflective Learning in Simulation (PEARLS): development and rationale for a blended approach to health care simulation debriefing. *Simul Healthc*. 2015;10:106–115.
19. Cory MJ, Colman N, McCracken CE, Hebbar KB. Rapid cycle deliberate practice versus reflective debriefing for pediatric septic shock training. *Pediatr Crit Care Med*. 2019;20:481–489.
20. McMullen M, Wilson R, Fleming M, et al. "Debriefing-on-demand": a pilot assessment of using a "pause button" in medical simulation. *Simul Healthc*. 2016;11:157–163.
21. Kim SS, De Gagne JC. Instructor-led vs. peer-led debriefing in preoperative care simulation using standardized patients. *Nurse Educ Today*. 2018;71:34–39.
22. Sohn VY, Runser LA, Puntel RA, et al. Training physicians for combat casualty care on the modern battlefield. *J Surg Educ*. 2007;64:199–203.
23. Abelsson A, Rystedt I, Suserud BO, Lindwall L. Learning by simulation in prehospital emergency care - an integrative literature review. *Scand J Caring Sci*. 2016;30:234–240.
24. Abelsson A, Lundberg L. Trauma simulation in prehospital emergency care. *J Trauma Nurs*. 2018;25:201–204.
25. *The Sydney Trauma and Resuscitative Emergency Surgical Skills Course, Training Non-Surgical Physicians in Life- and Sight-Saving Procedures, Stress Course*. https://stresscourse.me/. Accessed June 15, 2020.
26. Forbes RB, Murray DJ, Albanese MA. Evaluation of an animal model for teaching fibreoptic tracheal intubation. *Can J Anaesth*. 1989;36:141–144.
27. Kim M, Torrie I, Poisson R, et al. The value of live tissue training for combat casualty care: a survey of Canadian combat medics with battlefield experience in Afghanistan. *Mil Med*. 2017;182:e1834–e1840.
28. Izawa Y, Hishikawa S, Muronoi T, Yamashita K, Maruyama H, Suzukawa M, et al. Ex-vivo and live animal models are equally effective training for the management of a penetrating cardiac injury. *World J Emerg Surg*. 2016;11:45.
29. The Royal College of Surgeons of England. *Pre-hospital and Emergency Department Resuscitative Thoracotomy*. London, UK: The Royal College of Surgeons of England; 2020.
30. Russell W, Burch R. *The Principles of Humane Experimental Technique*. London, UK: Methuen; 1959.