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Randomized Objective Comparison of Live Tissue Training versus Simulators for Emergency Procedures

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There is a lack of objective analysis comparing live tissue and simulator training. This article aims to objectively determine the difference in outcomes. Twenty-four Air Force volunteers without prior experience performing emergency procedures were randomly assigned to receive training in tube thoracostomy (chest tube) and cricothyroidotomy training on either a pig model (*Sus scrofa domestica*) or on the TraumaMan simulator. One week posttraining, students were tested on human cadavers with objective and subjective results recorded. Average completion time for tube thoracostomy in the animal model group was 2 minutes 4 seconds and 1 minute 51 seconds in the simulator group with a mean difference of 12 seconds ($P = 0.74$). Average completion time for cricothyroidotomy in the animal model group was 2 minutes 35 seconds and 3 minutes 29 seconds in the simulator group with a mean difference of 53 seconds ($P = 0.32$). Overall confidence was 9 per cent higher in the animal trained group ($P = 0.42$). Success rate of cricothyroidotomy was 75 per cent in the animal model group and 58 per cent in the simulator-trained group ($P = 0.67$). Success rate of chest tube placement was 92 per cent in the animal group and 83 per cent in the simulator group ($P = 1.00$). There was no statistically significant difference in chest tube and cricothyroidotomy outcomes or confidence in the groups trained with live animal models or simulators at the 95 per cent confidence interval. Trends suggest a possible difference, but the number of cadavers required to reach greater than 95 per cent statistical confidence prohibited continuation of the study.

ACCURATE AND EFFECTIVE simulation to maintain and develop skills offers the possibility of low stress, less expense, and more accessible training. In comparison to on-the-job training on human patients or training on animal models, simulated training eliminates the risk to humans and preserves animal life. Unfortunately, as a result of a lack of objective data, there remains a question as to the continued need for animal training. In both the military and civilian emergency environment, young medics will be expected to perform life-saving procedures in potentially austere and stressful conditions. It is important that medics are given the best training possible to reduce hesitation and anxiety when only minutes or seconds matter in terms of saving a life. This article, therefore, aims to answer the following questions: does the current generation of simulation give equivalent or even superior training to animal models and, if not, is the difference significant enough to change use practices of one or the other?

Materials and Methods

After Institutional Review Board and Institutional Animal Care and Use Committee approval, volunteer Airmen of the 81st TRW assigned to Phase II training at Keesler Medical Center were randomly assigned to receive training in cricothyroidotomy and chest tube placement on either the Simulab TraumaMan™ (Simulab, Seattle, WA) simulator or a pig model (*Sus scrofa domestica*). All subjects were screened for prior medical training and those with prior procedure training were excluded. Subjects were given a standardized lecture including indications, relevant anatomy, and technique, which was designed based on Advanced Trauma and Life Support (ATLS) principles and with the consultation of ATLS instructors and board-certified general and trauma surgeons. Eight research subjects at a time were evaluated over a 2-month period were evaluated.

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All subjects were given a basic suturing course on commercial pig feet to familiarize them with medical instrument handling. After a joint lecture, the eight subjects were then trained in separate four-member groups on the simulator or live tissue model over the course of the same day. Subjects in groups of four were, in turn, required to properly place chest and cricothyroidotomy tubes into their training modality without assistance while observed by the other group members. All subjects had the same instructor and lecturer.

One week posttraining, subjects were taken to perform chest tube placement and cricothyroidotomy on human cadavers. Throughout testing, subjects were segregated between those who and had and had not been evaluated. All subjects were given identical instructions and equipment, including fresh scalpel blades. Upper torsos of cadavers separated above the pelvis were used with the area of the incision line and lower half draped to prevent observation by the research subject. Cadavers, with a predivision weight of 130 to 160 lbs., were thawed, unpreserved specimens and included both female and male specimens. Unbiased expert evaluators, not involved in procedure training, monitored performance and took objective measurements of the time of performance, incision size, and correct location of placement. A subject was deemed to have successfully completed a cricothyroidotomy if the catheter was placed initially through the cricothyroid membrane into the trachea. Subjects successfully completed placement of a chest tube if it was placed over the rib and between the posterior and anterior axillary lines and between the nipple and inframammary crease and placed with all distal tube holes within the thoracic cavity. Timing began after telling the volunteer which procedure to perform and saying the word "start." Time ended after all instruments were removed from the cadaver and the volunteer signaled complete by removing their hands from either tube. A small break between procedures was given to volunteers to reorganize instruments. Volunteers were not permitted to identify landmarks by palpation before signaling the start of evaluation.

On completion of the evaluation, subjects were given a subjective questionnaire. Questions were based on a 1 to 10 scale and included self-review, training modality review, and self-confidence if required to perform the procedures on a living patient. Feedback on performance was delayed until after completion of the questionnaire.

Results

The *t* test for independent samples was used to evaluate the objective differences in outcomes in the 24 volunteers. Average time to tube thoracostomy placement in the animal model group was 2 minutes 4 seconds and 1 minute 51 seconds in the simulator group with a mean difference of 12 s ($P = 0.744$) (Fig. 1). Average time to cricothyroidotomy placement in the animal model group was 2 minutes 35 seconds and 3 minutes 29 seconds in the simulator group with a mean difference of 53 seconds ($P = 0.320$). Mean incision size in the animal-trained group was 4.3 cm for chest tubes and 5 cm for cricothyroidotomies and 4.5 and 6.5 for the simulator-trained group with a mean difference of 0.21 cm ($P = 0.767$) and 1.16 cm ($P = 0.149$), respectively (Fig. 2).

The *t* test for independent samples was used to evaluate the difference between the answers to subjective questions. The animal model consistently resulted in subjectively better evaluation results posttesting on the 10-point scale but no difference at or beyond the 95 per cent confidence level was found (Fig. 3). Subjective adequacy of the animal model and simulator in preparing for human procedures showed a 20 per cent higher evaluation ($P = 0.111$) of the animal model for cricothyroidotomy and 8 per cent

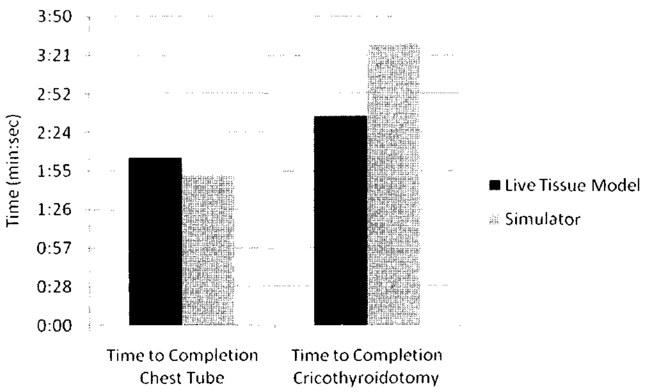

FIG. 1. Time to completion of cricothyroidotomy and tube thoracostomy (chest tube).

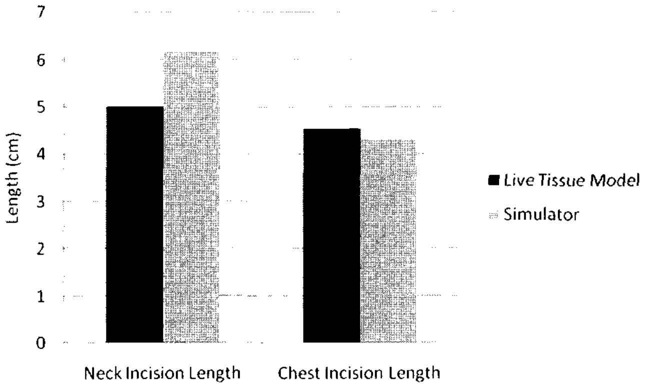

FIG. 2. Comparison of neck (cricothyroidotomy and chest tube thoracostomy) incision lengths.

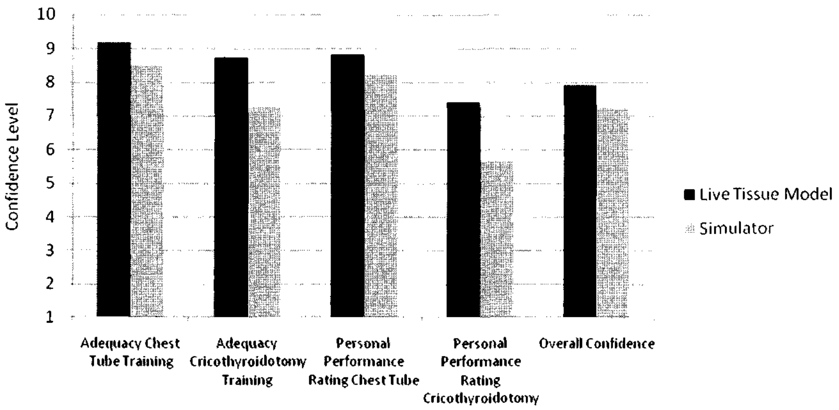

FIG. 3. Mean results of subjective analysis of volunteers post training. Volunteers rated adequacy of training, personal performance, and overall confidence on a 10-point scale with 1 being the lowest and 10 the highest.

higher evaluation ($P = 0.415$) of the animal model for chest tube training. Subjective evaluation of the volunteers' own personal performance resulted in a 31 per cent higher self-evaluation after cricothyroidotomy ($P = 0.158$) and 7 per cent higher evaluation after chest tube placement ($P = 0.262$) in the animal-trained group. Overall confidence in ability to perform the procedures on a human if required was 9 per cent higher in the animal-trained group ($P = 0.415$).

Fisher exact test was used to evaluate the differences in success rate. Success rate of cricothyroidotomy was 75 per cent in the animal model group and 58 per cent in the simulator-trained group ($P = 0.667$) (Fig. 4). Success rate of chest tube placement was 92 per cent in the animal group and 83 per cent in the simulator group ($P = 1.000$).

Discussion

Medical simulators offer the possibility of skills training almost anywhere and almost any time without the need for the infrastructure and trained staff required to support animal-based training. Without question, training leads to enhanced performance, but what training regimen is better has not been well answered.[1, 2] Previous analyses looking at outcomes exist but are frequently based on observational assessments and surveys with little objective outcome measurement done to date.[3–8]

The determination of success in this study was based on proper performance of the life-saving step only. In the case of chest tube insertion, simple placement of the tube into the thoracic cavity beyond the terminal holes was deemed successful. When performing cricothyroidotomy, placement of the catheter in the trachea through the cricothyroid membrane was deemed successful. Additional procedures such as securing and correct suture technique are subject to opinion and are not critical steps so were disregarded when evaluating success and time. The elimination of extra steps was designed to remove as many variables as possible and to determine how fast the volunteers could potentially save a life.

Failure tended to vary dramatically for both procedures when looking at very specific location of placement, but general trends for each training group were noticed in the cricothyroidotomy procedure. The few that failed chest tube placement either placed it through the anterior chest wall or at or below the diaphragm. Notably neither group had a volunteer that placed the tube directly beneath a rib damaging the neurovascular bundle. Cricothyroidotomy placement

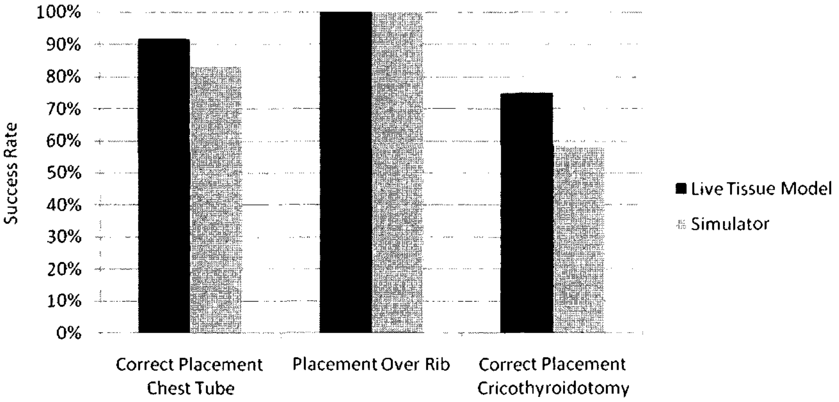

FIG. 4. Rate of successful performance of cricothyroidotomy and tube thoracostomy (chest tube).

errors tended to be dependent on type of training received. The majority of errors after pig training involved placement of the cricothyroidotomy tube below the cricoid cartilage and through tracheal rings, whereas the majority of the erring was that simulator-trained volunteers attempted to place the tube above the thyroid cartilage. Patients who would have been treated by the live tissue model group would still have been saved and had a tracheostomy, whereas the simulator-trained group, although saved, would have significant morbidity after damage to the pharynx and larynx. Observations during testing and on posttest questioning revealed that the reason for the superiorly placed cricothyroidotomy tube was often the result of confusion with the hyoid bone. The hyoid bone was not present on the simulator and, with their unfamiliarity with real tissues and anatomy, the volunteers assumed the two largest hard prominences on palpation corresponded with the TraumaMan's two hard prominences in the neck. Better design of the TraumaMan or similar simulators to include a hyoid bone may be a significant improvement.

Although no statistically significant differences were obtained with $P < 0.05$, apparent trends were evident (Figs. 1–4), most notably in results concerning cricothyroidotomy placement. The differences in the aforementioned failures as well as better neck incision lengths, time to completion, and personal performance rating after live animal training suggest better results compared with simulator training. Observations during testing and training as well as posttest conversations with the volunteers suggest that the more difficult nature of the dissection in the pig resulted in the difference. A pig neck tends to be far thicker with abundant subcutaneous fat and thick strap muscles. Students training on a pig had to continuously palpate their landmarks as well as manipulate much more tissue. This is in contrast to the TraumaMan, which has essentially one layer of synthetic tissue overlaying the simulated larynx. This thin overlying tissue layer accurately reflects the small separation between skin and cricothyroidotomy in a human but does not prepare the volunteers for any anatomic deviation, bleeding, give basic hands-on experience of the anatomical intricacies of the neck, nor give preparation in manipulating real tissues. The difficulty of the pig neck prepared the volunteers better for the simpler human neck than did the more spatially accurate TraumaMan.

Differences in chest tube placement were negligible across all measurements with better time results after simulator training. Subjective trends (Fig. 4) indicate more confidence with animal models, but improved confidence is not reflected in actual results. The observed difference was that it was more difficult for the simulator-trained volunteers to perform the chest tube procedure. In the TraumaMan mannequin, there are two distinct layers of tissue the students had to penetrate: a single piece of artificial skin, which they incised, and a black rubbery layer (representing the intercostals muscles/tendon) through which they bluntly placed a tract over the rib. Often there was difficulty in opening the black rubbery layer wide enough for the tube unless the clamp was carefully placed to allow for maximum separation. The learned skill of having to accurately place a clamp to effectively widen the intercostal tract likely allowed the simulator group to quickly establish a sufficiently large tract for the chest tube. As seen in cricothyroidotomy, a more difficult simulated experience resulted in better outcomes on a human.

The low statistical difference between the two groups suggests that modern simulation is reaching parity with live animal training models. The study does have weaknesses, however, including nonstandardized human cadavers, unblinded subjects, and it lacks detailed psychological assessment of the subjective portion of the study. The study only looks at one live tissue model and only the TraumaMan simulator. The low power is the greatest weakness but could be overcome with similar studies done at multiple institutions. At our institution, we could not commit the calculated 100+ cadavers necessary to continue the investigation to 95 per cent statistical significance given their limited availability and need elsewhere.

Conclusion

This study shows no statistically significant difference in the results obtained from training on live animal models and the TraumaMan to train cricothyroidotomy and tube thoracostomy. Trends were apparent, but to reach the greater than 95 per cent confidence level, the calculated number of cadavers required would have been unattainable. The lack of statistical difference helps argue that modern simulators are reaching parity with, but are not surpassing, live tissue models.

Although there was no statistically significant difference between live tissue models and the simulator, if trends are an indication of potential difference, especially in cricothyroidotomy placement, then there remains a matter of ethical debate. Is the removal of a few seconds of additional hypoxia and potential brain damage a soldier or civilian patient experiences worth an animal's life? There is also a potential difference in confidence. Will this difference affect performance in the heat of battle? For future combat medics and their civilian counterparts, the possible delay in action resulting from psychological insecurity, although not seen in this study, may become apparent in real-world scenarios. Additional research, debate, and experience will be required to answer those questions. At this time, an ideal training regimen could ideally be seen to include at least some animal models in addition to routine simulated exercises to prepare emergency responders and physicians.

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