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Using Augmented Reality as a Clinical Support Tool to Assist Combat Medics in the Treatment of Tension Pneumothoraces

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ABSTRACT This study was to extrapolate potential roles of augmented reality goggles as a clinical support tool assisting in the reduction of preventable causes of death on the battlefield. Our pilot study was designed to improve medic performance in accurately placing a large bore catheter to release tension pneumothorax (prehospital setting) while using augmented reality goggles. Thirty-four preclinical medical students recruited from Morehouse School of Medicine performed needle decompressions on human cadaver models after hearing a brief training lecture on tension pneumothorax management. Clinical vignettes identifying cadavers as having life-threatening tension pneumothoraces as a consequence of improvised explosive device attacks were used. Study group ($n = 13$) performed needle decompression using augmented reality goggles whereas the control group ($n = 21$) relied solely on memory from the lecture. The two groups were compared according to their ability to accurately complete the steps required to decompress a tension pneumothorax. The medical students using augmented reality goggle support were able to treat the tension pneumothorax on the human cadaver models more accurately than the students relying on their memory ($p < 0.008$). Although the augmented reality group required more time to complete the needle decompression intervention ($p = 0.0684$), this did not reach statistical significance.

INTRODUCTION

The second most common injury sustained from an improvised explosive device (IED) is an untreated tension pneumothorax. The current U.S. conflicts in both Afghanistan and Iraq are highlighted by the unilateral deployment of IEDs used by enemy combatants with traumatic limb amputations followed by tension pneumothoraces. Approximately 90% of combat deaths occur forward of any medical station, and frontline prehospital care is delivered by combat medics under conditions profoundly different than in civilian emergency medical systems.[1–3] Scenario-based management of IED injuries is an essential part of predeployment Tactical Combat Casualty Care (TCCC) training for combat medics. The combat medic maximizes the probability of mission success by relying on predeployment training to deliver the war fighter to a Forward Surgical Team or a Combat Support Hospital for initial damage control surgery. However, the transport of an alive soldier is jeopardized when perishable emergency medical skills are not properly learned, or are forgotten. The heavily relied on use of mannequins for TCCC training is not sufficient in preparing combat medics for IED injuries including the management of tension pneumothoraces.

A recent study published in the journal *Military Medicine* evaluated the skill sets of young medics participating in a Semi-Annual Combat Medic Skills-Validation Test (SACMS-VT).[1] In the study, the participants were combat medics scheduled to deploy to Iraq or Afghanistan within a year. Each scenario required the combat medics to think on their feet and seek the best combination of good medicine and good tactics. The medics needed a score of 70% or better on the test, and could not miss any performance steps designated as critical to pass the SACMS-VT. The average SACMS-VT score obtained was 58% with 66 critical steps missed. The trauma scores received were the lowest of any of the scenarios that were evaluated. Specifically, these lower scores were found in the areas of trauma assessment, combitube placement, and needle decompressions for the management of tension pneumothoraces.[1]

The study highlights the fact that teaching novices unfamiliar procedures without an adequate pedagogical method leads to the disintegration of critical skills. This study also posits that it is unlikely that a novice medic without adequate field experience will perform effectively on the battlefield. The study in this article presents a perspective that instructional and assistant intervention is required to train and assist combat medics with correct life-saving procedure skills when the fully trained surgical personnel is unavailable. The authors of this article hypothesize that augmented reality (AR) can fill the void between insufficient training and a lack of experience by delivering auditory, visual, or tactile cues for combat medics during not only training, but also in real-time battlefield resuscitations.

We evaluated AR as a clinical support tool to assist in the reduction of preventable causes of death on the battlefield. Our pilot study was designed to ascertain whether AR could be used to improve task completion in the treatment of a tension pneumothorax with the performance of a needle decompression. A tension pneumothorax still remains as the

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second most preventable cause of death from an IED injury, behind a traumatic limb amputation, in both Afghanistan and Iraq. On the basis of the Army's SACMS-VT study, where the correct release of a tension pneumothorax was completed only with 50% accuracy, a dramatic improvement in the successful treatment of tension pneumothoraces is needed by medics training to mobilize to frontline positions where evacuation to definitive medical care by trained personnel may be delayed.

MATERIALS AND METHODS

Preclinical medical students from Morehouse School of Medicine were recruited to perform AR-needle decompressions for the emergency release of tension pneumothoraces. We selected medical students in the first- and second-year classes, before any clinical exposure. Similar to young combat medics deploying to Afghanistan and Iraq, these students have negligible experience with invasive medical procedures. The only information disseminated to the students before the initiation of the study was that their participation was needed to help improve medical care delivered in combat zones. Thirty-four medical students consented to participate in the study (12 men, 22 women). Of this group, there were no students with previous emergency medical technician or medic training. The students were randomly assigned into two groups, an experimental AR group and a control group that would not have the usage of AR. A greater number of students were assigned to the latter group because of the limited numbers of AR devices available for the study.

The morning of the study, the students were still unaware of the nature of the study, other than the fact that they would have the gratification of assisting in a study that may save lives on the battlefield. All of the preclinical medical students in the study participated in a PowerPoint presentation about the prehospital management of thoracic emergencies. The lecture stressed the topical landmarks of the thoracic cavity and the pleural anatomy. The pathophysiology of a tension pneumothorax was discussed in the lecture, and repeated emphasis was placed on the placement of a 14-gauge angiocatheter in the midclavicular line, in the second intercostal space to evacuate the accumulation of air in the pleural space as the correct procedure to release a tension pneumothorax. The students were allowed to ask questions about what they had learned earlier in the presentation to the initiation of the study. At the conclusion of the lecture, we confirmed again that there were no students with prehospital training as an emergency medical technician, and that none of the students had deployments as members of the armed forces. The students were taken to a classroom outside the anatomy lab and monitored by surgical residents where they were unable to review textbooks or electronically educate themselves further about the treatment of a tension pneumothorax. The design of the study allowed some of the students to wear AR goggles to assist with performing AR-needle decompressions, whereas the others relied on what was taught in the lecture. Sixteen adult cadavers were used for the study, and both sides of the thoracic cavities were exposed. Each of the 16 tanks was aligned with angiocatheters and needles of different sizes to test the students' ability to recall what the correct decompressing instrument that was taught in the lecture. There were 4 predetermined critical steps that were to be measured as being crucial for task completion during the study (Fig. 1). Competency shown by the students was agreed on to be if 3 out of the 4 steps could be completed without assistance from the surgical staff and residents proctoring the students' performance. Therefore, a score of 75% was needed to prove competency in needle decompressions, which approaches the score of 70% that the combat medics needed to prove competency while participating in the SACMS-VT.

Context-Aware Mobile Mix Reality Assistive Device headsets manufactured by Juxtopia (Baltimore, Maryland) were used for this study. Information chronicling the steps necessary to perform a needle decompression was programmed into the wearable (AR) goggles. The AR goggles would provide the students with the capability to interoperate with data stored in the computer's memory while treating the pneumothorax. A mini-microphone, accepting hands-free voice prompts would allow the students wearing the AR goggles to initiate the sequence of steps needed to perform a needle decompression for a tension pneumothorax. A minicamera, facilitating object recognition, allowed the stored information of how to treat a tension pneumothorax to project onto the thoracic cavity of the cadavers. In addition, a minispeaker, so that the student could receive computer-synthesized voice responses, was embedded in the AR goggles to aid in treating the tension pneumothoraces effectively.

The students were brought into the cadaver lab four at a time, and were shielded by drapes, thus not allowing them to see the performance of other students. Each student was read

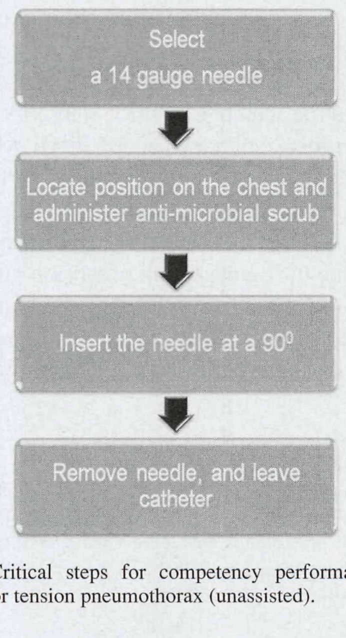

FIGURE 1. Critical steps for competency performance with needle decompression for tension pneumothorax (unassisted).

a clinical vignette about a thoracic emergency that his/her cadaver had allegedly suffered from an IED attack requiring the placement of a large angiocatheter needle to release a tension pneumothorax. The experimental group ($n = 13$) performed the needle decompression using AR goggles whereas the control group ($n = 21$) relied solely on their recollections from the lecture.

The experimental group, wearing the AR goggles, used the mini-microphone for voice-recognition initiation after a clinical vignette was read (Fig. 2). Once the goggles were activated, the steps to treat a tension pneumothorax were projected across the thorax of the cadaver, thus allowing the student to simultaneously view the thorax of the cadaver and the stored treatment steps programmed into the goggles. After each student attempted a needle decompression, a scorecard was kept. Each of the individual 4 steps had three possible scores that the subjects could achieve: "Completed without assistance; completed with assistance; or unable to complete." Once the student completed the steps, discussions were held for inter-rater agreement by the proctors to determine whether or not each critical step was completed correctly or incorrectly.

RESULTS

The medical students wearing AR goggles were able to treat tension pneumothoraces using the human cadaver models more accurately than the students relying solely on recall from the lecture. The odds ratio comparing the AR goggle group versus the group receiving only the lecture revealed that the AR group had a higher degree of competency in performing needle decompressions for tension pneumothoraces (odds ratio, 3.46 vs. 2.62) (Fig. 3). Participants who received ratings of either "completion with assistance" or "unable to complete" were highest in the lecture-only control group

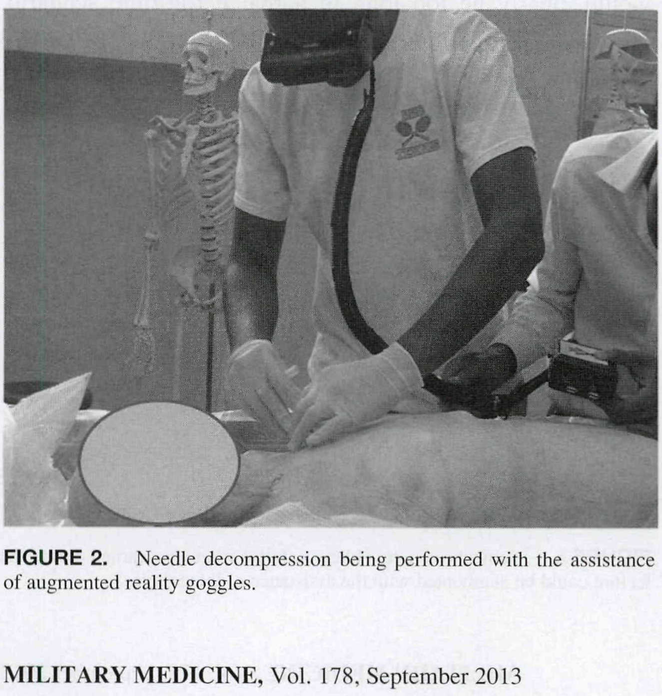

FIGURE 2. Needle decompression being performed with the assistance of augmented reality goggles.

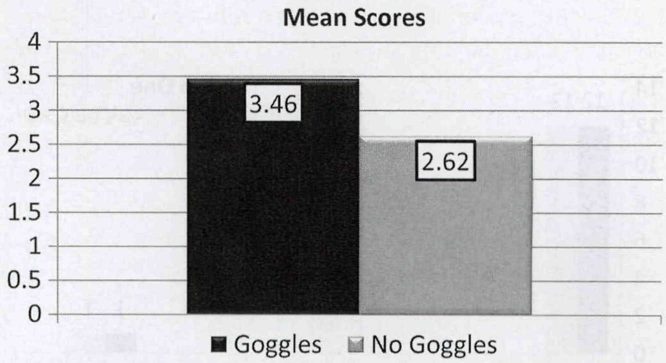

FIGURE 3. Medical students using augmented reality vision support were able to treat the tension pneumothorax on the human cadaver models more accurately than the students relying solely upon their memory.

(Fig. 4). Overall, participants were less likely to fail if what was learned during the lecture could be augmented with the assistance of the AR goggles, which would serve to prompt them when recall from the lecture could not be summoned, $p < 0.008$ (Fig. 5). The time to task completion was recorded with stopwatches beginning at the conclusion of the reading of the clinical vignette, and concluded when the fourth step was successfully or unsuccessfully completed. Comparing completion time for the AR goggle group to that of the lecture-only group, showed mean completion times of 4.29 and 3.08 minutes, respectively (NS).

DISCUSSION

The results of this study suggest that AR can improve task completion while educating medical novices as to how to treat trauma emergencies. This study also shows that AR could also be implemented in the treatment of battle injuries in real time by providing inexperienced combat medics with quickly accessible information while treating tension pneumothoraces in austere environments, such as Afghanistan and Iraq.

It was not until after Operation Desert Storm and Desert Shield that it became visibly evident that initial combat medic training was not at the level required for first responder combat causalty care.[4] Numerous studies have shown that even with frequent use, up to 50% of a medic's core skills can be lost within the first 6 months and continuing education does little to slow down the process unless the training is followed with repetitive performance of the learned procedure.[1,5–7] AR can provide contextual information and situational awareness by augmenting real-world scenarios, thus filling the gap for failed recall and incomplete training. Simultaneous AR with the integration of human cadaver models can aid in decreasing the learning curve to learn complex invasive procedures.[8] The goal of the researchers for this project is not to replace TCCC moulage for medic training in preparation for wartime, but to increase proficiency in performing lifesaving procedures by providing

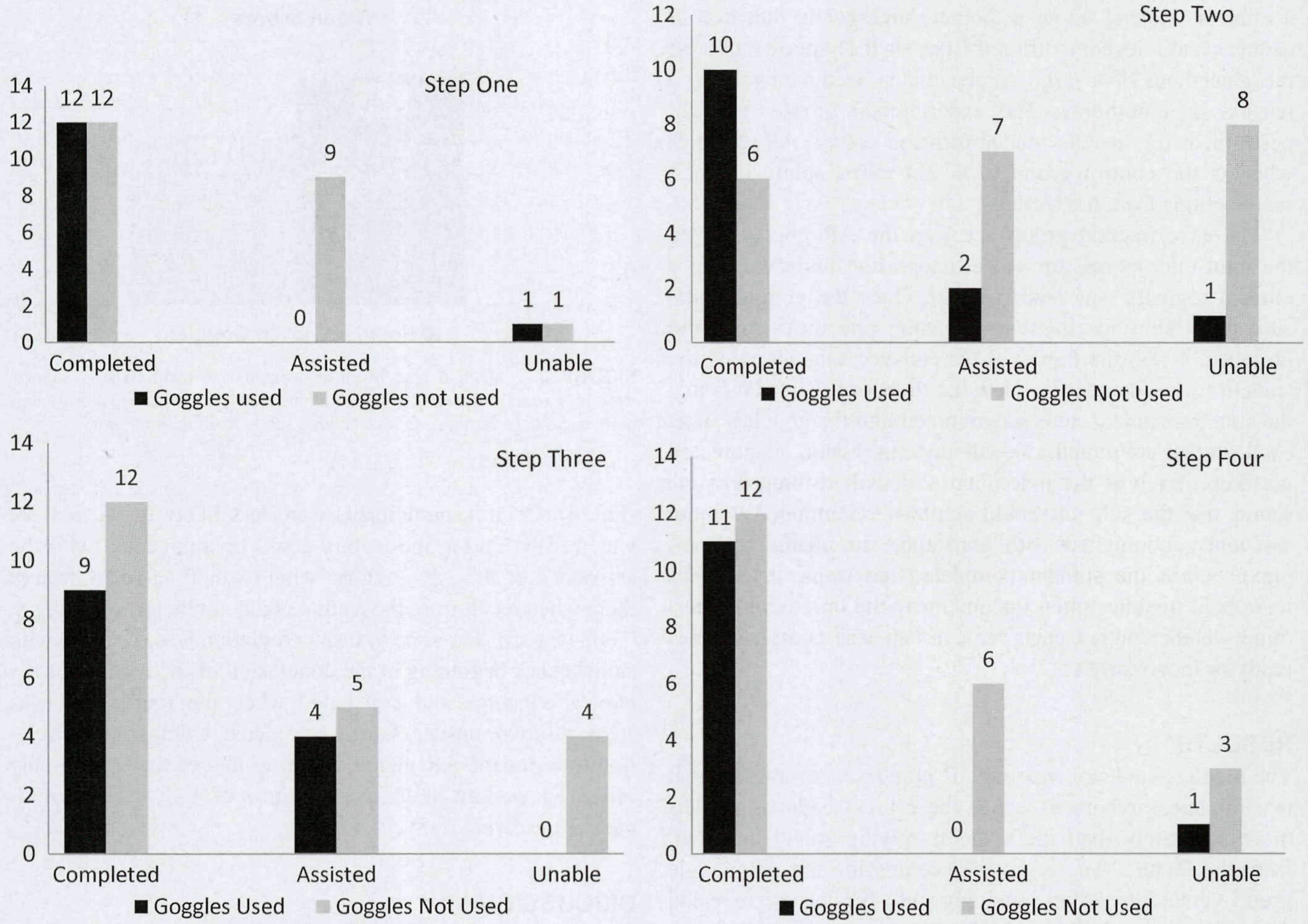

FIGURE 4. Completion with assistance and unable to vomplete steps were higher in the control group.

alternative media for facilitating instruction. The programmable images that can be projected into the "real-world" environment also do not blind the combat medic to the battlefield, thus allowing him to deliver TCCC to a wounded soldier while surveying and neutralizing hostile threats.

Completing the task with a passing score was greater in the AR goggle group versus the lecture-only group. The AR goggles enabled the medical students to replay each step before proceeding, which was not available to the lecture-only group. The visual projection by the AR goggles onto the thoracic cavities of the human cadavers allowed the AR group the opportunity to simultaneously compare to the exact physical location for the placement of the decompressing needle while being able to move the programmed information for the treatment of a tension pneumothorax forward/backwards before performing a needle decompression. The lecture group had difficulty with performance more than likely as a consequence of failed recall and unfamiliarity similar to combat medics that showed poor performances with needle decompressions. The programmed voice-on-demand information allowed successful advancement through the steps by augmenting the medical students' cursory familiarity with the treatment of tension pneumothoraces when they were unsure of themselves. The time needed to complete the treatment of tension pneumothoraces, once recognized, would clearly be too long in a real battle-time scenario. However, the study shows a clear advantage in teaching an

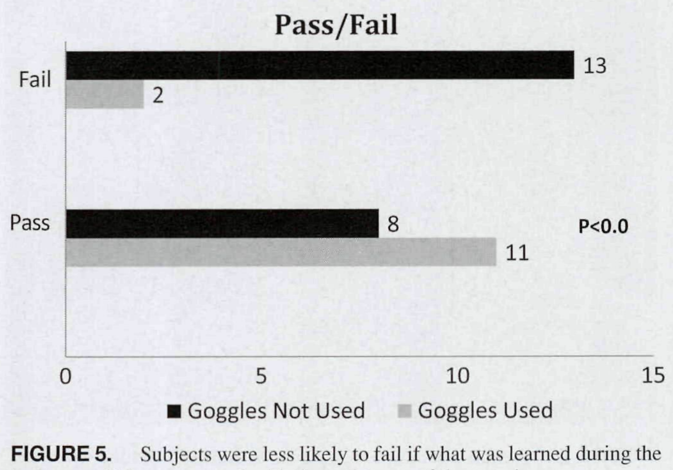

FIGURE 5. Subjects were less likely to fail if what was learned during the lecture could be augmented with the assistance of the goggles.

invasive procedure, with an AR interface to enhance the performance of the combat medic when recall fails or training is incomplete.

CONCLUSION

AR increases the likelihood of completing invasive procedures when the performer has only cursory familiarity about the procedure. Relying solely on memory allows for the dissipation of critical information, which can lead to performance errors. In the case of combat medics, failed recall and performance errors can increase the death signature on the battlefield. AR was shown in our study to have increased accuracy in the performance of medical students treating pneumothoraces. The reason for the treatment advantage was that the information was readily retrievable. The retrieved information was projected into a "real environment (the cadavers' thoracic cage)," and could be manipulated by the students, and any step that was forgotten or unclear could be reviewed before performing a needle decompression. AR as wearable goggles will allow the inexperienced combat medic a TCCC advantage increasing casualty survival while allowing him to view the battlefield.

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