Next Generation Stress Inoculation Training for Life Saving Skills Using Prosthetics

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Abstract. By integrating medical science with cutting edge simulation and training technologies, realistic prosthetic tissue, wounds, and part task trainers have been developed for the training of trauma care clinicians. The next generation of Stress Inoculation Training (SIT) includes the use of prosthetics developed based on human anatomy and physiology, material science, and nanotechnology. Testing has revealed that these products are highly useful and reliable.

Keywords. stress inoculation training, injury simulation, trauma care training, prosthetic tissue, medical skills training.

Introduction

Medical simulation training currently relies mainly on plastic forms, computerized mannequins, animals, and cadavers. All of these have significant drawbacks, such as incorrect anatomy (animals), lack of realism (plastic forms and mannequins), limited use (cadavers), and expense. Additionally, they do not replicate the majority of injuries encountered on the battlefield. Severe medical trauma creates major challenges for front line medics. Although the military is investing millions of dollars in training for soldiers, current training methods for combat medics need to be improved. Many scenarios designed for training medics employ simulation of some type, however, their limited realism calls into question their ability to fully immerse the trainee into combat medical situations. This is exactly the kind of experience that will properly prepare medics for actual battlefield injuries including broken bones, lacerations, severe bleeding and tissue damage. Many civilian-trained medical personnel are not psychologically prepared to face severe wartime traumatic injuries. ICS’s Stress Inoculation Training addresses the need for realism to optimize trainees’ performance under fire and other stressful conditions.

To supply more realistic military medical training, the U.S. Army Research and Engineering Command – Simulation and Technology Training Center (RDECOM – STTC) partnered with the Medical Research Materiel Command (MRMC) to research innovative technologies to simulate the look, feel, and smell of severe trauma. As part of this effort, RDECOM-STTC is managing a three year Severe Trauma Army
Technology Objective (ATO) to develop simulation technologies to prepare Soldiers to deal with the injuries encountered on the battlefield. The Virtual Reality Medical Center (VRMC) conceptualized and developed a unique injury simulator under the Severe Trauma ATO initiative as an adjunct to current combat medic training. The Injury Creation Science (ICS) technology represents an injury simulation capability that includes the prosthetics required to train medical professionals in procedures such as bypassing a compromised airway, inserting an intravenous port, preventing blood loss as a result of arterial and venous wounds, dressing burns, and expanding a collapsed lung. Initial ICS technology very realistically simulated a number of battlefield injuries such as amputations, eviscerations, blast injuries, punctures, and burns. Since the initial prototypes, VRMC has developed this technology into wearable “part-task trainers” that simulate injuries as well as allow combat medics to practice actual medical procedures common to the battlefield.

1. Review of Literature

Simulation for the development and refinement of surgical skills has come to the forefront in recent years [1]. Reznick & MacRae [2] note that the earlier stages of teaching technical skills should take place outside the operating room (i.e., on surgical simulators) with practice being the rule until automaticity in basic skills is achieved. ICS is based on surgical procedures and techniques to enhance medical training. Most of the technology funded by the Department of Defense in recent years falls into four categories:

1. PC-based decision teaching tools (e.g., STATCare)
2. Digitally enhanced mannequins (e.g., Combat Trauma Patient Simulator)
3. Virtual workbench technology (e.g., HT Medical Systems)
4. Total immersion virtual reality (e.g., Center for Integration of Medicine and Innovative Technology).

The computer and mannequin-based models listed above can be useful, yet they present technical challenges and compromised realism. The design of computerized surgical simulators must overcome the obstacles of choosing the appropriate soft tissue models and solving the underlying differential equations or algorithms [3]. Mannequins do not bleed convincingly during simulation, and different mannequins are necessary to represent patients with different injuries, body types, and age groups [4]. ICS seeks to overcome the realism problem by basing the trainer on a visually realistic simulation.

Wound simulation, or “moulage,” began in 1834 with military mass casualty exercises in which artists painted injuries on the body. Hollywood makeup and theatre techniques followed, providing elements of realism such as blood and open fractures to the training simulation. In general, however, some of the more advanced Hollywood techniques have not been used in military simulation training. A number of companies offer casualty simulation kits online for trauma training. These kits are generally comprised of “stick-on” wounds with a limited subgroup of “bleeding moulage,” but these do not claim to be medically realistic (only visually so). Forensic science currently employs simulated tissue and bone to test the effect of ballistics. Synthetic body parts are also used for performance testing of helmet and body armor. These simulations or recreations focus more closely on scientific realism than either moulage or Hollywood special effects.
Simulated skin has been studied much less than simulated tissue, although animal skin has been used for injury simulation studies. Jussila notes that the significance of simulated skin has been overlooked, even though its use increases the fidelity of experiments involving low-velocity projectile injuries or effects such as ricochets. Thali, Kneubuehl, Zollinger & Dirnhofer [5] created an artificial head they call the “skin-skull-brain model” which uses a silicon cap with synthetic fibers on a polyurethane skull to simulate skin. The silicon cap is artificial leather and prevents the bone fragments from scattering after the model has been struck by gunfire.

The bone simulant literature is also found in forensic science as well as in biomaterials research. Bone engineering in the biomaterials field, however, concentrates on grafts and resorbable biomaterials as temporary scaffolds [6-9] and therefore does not lend itself well to injury simulation.

In a 2004 study, Kneubuehl and Thali developed an artificial bone using polyurethane to compare gunshot wounds to swine bones. The design was patterned after human bone structure, with a compact outer layer covering a porous inner layer. Ordnance gelatin was injected into the bone’s hollow core to simulate marrow. To simulate the periosteum, the bone was covered with a layer of latex. The comparison between the biological swine bones and the non-biological model in regard to loss of velocity and energy after striking bone, bone fragmentation, bullet deformation, and penetrating wound channel were absolutely equal. Other studies leave some doubt about similarity in terms of longitudinal fractures but still give good, consistent results [10]. A Swiss company, Synbone AG, manufactures artificial bones designed for teaching orthopedic techniques in fracture repair. This type of product may prove useful in the development of ICS.

2. Methods

The ICS prosthetics were designed to train and prepare military medics to accurately stabilize fallen warriors during combat while specifically addressing four practical needs: enhance realism to ensure an immersive training experience for medical professionals, minimize application/removal time, increase prosthetic durability and reusability, and comfort. The prosthetics are packaged in self-contained kits that include prosthetic wounds and the supplies required to provide an immersive training experience. Existing injury simulations require specialized skill, significant application time, and the prosthetic is neither reusable nor durable in most cases. An ICS prosthetic wound is physiologically accurate, highly durable, very comfortable to wear, and most importantly, ready-made, which minimizes the skill and time required for application.

The ICS technology is focused on research and development in support of the tactical combat casualty care (TC3) training mission, which includes Basic Life Support, Patient Assessment, Hemorrhage Control, Fracture Management, and Shock Prevention & Treatment. By merging the latest special effects technology with material science research, the ICS team is developing prosthetic human tissue and wounds for realistic trauma care training. The research conducted revealed some important information that may be useful in the development of simulated skin and tissue for the advanced trauma-training program. In particular, we have found information that reveals both biochemical and structural clues as to how to begin to quantify the physiochemical properties of skin and tissue. For example, skin water content and elastic properties are important contributors to the look, feel, and texture of skin. In
addition, some of the most important connective tissue components that have been identified provide a basis to begin modification of existing artificial substances to improve the level of realism in artificial tissue. A number of non-invasive and minimally invasive technologies have been identified that will assist in the creation of new synthetic materials that reproduce the critical aspects of tissue. We will continue development of artificial tissue based on this finding, and will search for polymers that can have a graded hydration component.

VRMC and RDECOM-STTC worked together to significantly increase the medical realism of prosthetic injury simulation appliances. The collaboration offered the opportunities for further laboratory research and to develop improved materials that simulate the smell and feel of human tissue and fluids. The VRMC/RDECOM-STTC Integrated Product Team (IPT) refined the simulated skin and tissue of the earlier prototypes and built upon it to better replicate wounds for medical training. The skin was engineered based upon the configuration of the actual layers present in skin. Candidate silicone formulas were matched to the skin’s layers through spectral analysis and nanotechnology applications. Studying human tissue using spectroscopy was critical to further developing the ICS technology. We used spectral analysis to evaluate the early ICS prototypes, and explored ways to improve them based on the quantitative data acquired during testing. With this data, we compared ICS prototypes to the properties of human skin. Additional work remains in this area and possible outcomes include identifying existing materials for simulation effects, developing hybrids, and developing completely new materials and methodologies.

Initial research indicated that although transparent silicone appliances would be favorable in terms of flexibility and packaging in the kits, these would require specialized expertise or training. The prosthetic appliances were then colored inherently to minimize application steps and to maximize ease of use, three shades of skin tone were developed to be used in the prototype kits. The prosthetic appliances were designed to affix to a human actor or mannequin as a patch, and consist of simulated skin, underlying tissue, representations of organs or structures, and a protective layer next to the wearer’s skin.

3. User Test Results

Whether they were new or previously used, preliminary testing showed that stretching made little difference to the prosthetic appliances. Friction from tighter pants made edges start to peel after several hours, but pieces still would not come off the human skin. Even after showering, no difference was noticed in the prosthetic appliances. Wearing socks and shoes all day did not affect the edges of appliances adhered to ankles; the edges of the prosthetic appliances did not lift when adhered at the ankle, whether on the top of the foot or on the crease. During testing, the strength, realism, and ease of use of the prosthetic appliances were demonstrated.

During a trial usability test at the Field Medical Training Battalion (FMTB) in Camp Johnson, near Camp Lejeune, nine USN Corpsman squads were trained in 4.5 hours less than it would normally require because the ICS injury simulation products were used instead of the existing products. The application of the ICS prosthetics only took 1 hour on all patient actors and the prosthetics remained intact during the 6 hours of training, not requiring reapplication in between scenarios. The prosthetics are durable, where as existing products require re-application after dressings are applied.
and removed by trainees during the scenarios. Patient-actors reported higher levels of comfort. Trainees reported higher levels of immersion during the training scenario.

4. Discussion

The ICS prosthetics have proven to be useful and reliable and provide a realistic training experience for health care professionals. After evaluating data from the U.S. Army Institute for Surgical Research, it is clear that a need exists for part task trainers to prepare military trauma care professionals for life saving procedures necessary to preserve the life of wounded war fighters. Many of these same procedures are done in civilian hospitals. Identifying common needs between field medicine and civilian hospitals can help reduce the estimated 98,000 people that die each year as a result of medical errors. It is imperative that we continue to train medical personnel by employing the highest level of fidelity and realism and leveraging the lessons learned from military training to civilian medicine.

5. Conclusions

Moving forward, VRMC and RDECOM-STTC are employing state of the art techniques and materials in the development of physiologically accurate synthetic tissue, a critical technology in the development of dynamic wound and medical procedure kits. In addition to the work cited in this paper, current research and development is focused on creating the next generation of kits, which include the materials required to train emergency medical personnel in performing a cricothyrotomy and chest tube insertion. We are refining prosthetic tissue technology and transitioning this capability to medical training applications.

References