

Virtual Reality and Telepresence for Military Medicine

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Abstract

For decades, warfighters have been putting in place a sophisticated "digital battlefield", an electronic communication and information system to support advanced technology. Medicine is now in a position to leverage these technologies to produce a fundamental revolution, and the keystone is the digital physician. Today nearly all information about a patient can be acquired electronically, and with the new technologies of teleoperation and telesurgery we can provide remote treatment and even surgery through telemedicine. The following framework for military medicine will leverage upon the current electronic battlefield.

A personnel status monitor (PSM) will have a global positioning locator to tell the position of each soldier and a suite of vital signs sensors. When a soldier is wounded, the medic will instantly know the location of the soldier, and how serious is the casualty. This will permit the medic to locate the most critically wounded soldier. Once stabilised, he will be placed in a critical care pod, a fully automated intensive care unit in a stretcher, which will monitor his vital signs, administer fluids and medications and provide environmental protection. If immediate surgery is needed, a remote telepresence surgery vehicle will come to the wounded soldier, the medic will place him in the vehicle, and a surgeon will operate remotely using telepresence surgery from a distant Mobile Advance Surgical Hospital (MASH) to the combat zone. Also, the expertise from any specialist will be available from the rear echelons as far back as the home country. For education and training in combat casualty care, virtual reality simulators are being implemented.

This same scenario can be utilised in civilian health care, especially in providing care to patients in remote areas who do not currently have access to simple, let alone sophisticated, health care.

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Over the centuries, application of new principles in military medical care has decreased the total mortality of soldiers during combat; however the fact remains that, of the soldiers that were killed, 90% still occur in the far forward battle zone. The majority died from exsanguination because the medic did not arrive soon enough, or because the surgeon was not available.

The lethality of weapons, acquisition of essential military intelligence, innovations in command and control and the use of simulation (simulation network or SIMNET) have made enormous progress through the development and implementation of advanced technologies. The Gulf War epitomises the effectiveness of these new technologies, and none was more important than the "digital battlefield"; there was complete dominance of electronic warfare, especially in telecommunications. However, the medical support was using decades-old technology, with no modernisation of electronic equipment, and the mortality statistics did not change. Now, building upon the technologies already in place from Desert Storm, and implementing some of the

latest advanced technologies, we shall forever change the face of military medicine.

The three great deficiencies of combat casualty care are: 1) the inability to know when and where a soldier is wounded, 2) the lack of surgical expertise at the time and site of wounding, and 3) lack of experience in treating combat wounds (only 5% of physicians in the Gulf War had combat experience). The solution is to have every soldier wear equipment which constantly provides his location and which will alert the medic when a wounding occurs; to have a method to bring the expertise of the surgeon to the far forward battlefield; and to have the opportunity to practise battlefield casualty care. For the former, the technologies are global positioning satellite (GPS) location, identification of friend or foe (IFF), and remote vital signs sensing; for the surgeon, it is remote telepresence surgery and teleconsultation; and for training, it is virtual reality simulation.

With these new technologies available, a new framework for the modern medical battlefield can be constructed, all enabled by the digital communication

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infrastructure.^{1,2} The combat surgeon, as well as his civilian counterpart, will be a “digital physician”. Today, almost any information we need about a patient can be acquired electronically, for example, video images for laparoscopic surgery or endoscopy, vital signs from ICU monitors, electronic patient record, digital X-rays including computed tomographic and magnetic resonance imaging scans, and computer-based anatomy and the new virtual reality surgical simulators. Thus, anything a physician needs to know about a wounded soldier or patient can be acquired in electronic form and transmitted to a physician at a computer workstation. With the new technologies of teleoperation, telemanipulation and even telesurgery, the physician can bring expertise to the place where the soldier is wounded or the patient is sick.^{3,4} In addition, the same computer workstation for surgery can import a “virtual” cadaver to practise before an operation on a combat injury and with a flip of the switch, begin surgery on a real patient using the same workstation. This telecommunication revolution is the essence of the fundamental change in medicine, and the cornerstone is the digital physician.

A possible scenario for the battlefield of the future is described, based upon the Advanced Warfighting Demonstration field exercise conducted on 28 June, 1994 at Fort Gordon, Georgia. All demonstrated technologies were prototypes, not completed products but highlighted those technologies which can change the future of combat casualty care.

Every soldier will wear a Personnel Status Monitor, (PSM) that provides location as well as a suite of vital signs to tell “alive versus dead” and if wounded, how severe the wounding. This allows the medic to locate the casualty precisely, to determine which soldier is most seriously wounded, and to provide immediate medical assistance. If the soldier is only slightly wounded, the medic will evacuate him to the rear hospital. If there is severe injury, a Remote Telepresence Surgery vehicle will drive to the soldier, where a surgeon back in the Mobile Advance Surgical Hospital (MASH) will immediately perform remote surgery with the telepresence surgery system. Once stabilised, the soldier will be evacuated rearward. In addition, any necessary specialty consultation to the theatre of war will be available worldwide from both military hospitals such as Walter Reed Army Medical Center as well as civilian hospitals. In addition, the ability to train for these casualties will also be available using virtual reality.

To do medical forces planning and training, individual medics will use sophisticated tracking devices so their graphic representations can be inserted as individual soldiers into the virtual simulated battlefield of SIMNET. Thus, as soldiers are wounded, the medics

can practise casualty location, *en route* triage, advanced trauma and life saving, and evacuation. Also using individual simulators of a “virtual cadaver” with battle wounds, medics and physicians can practice control of haemorrhage, wound debridement, and even surgical procedures.

The status of these technologies is changing exponentially and the time for a major advance, a full order of magnitude of improvement, is about 18 to 24 months. The following are a few of the key technologies playing a role in creating the future.

The PSM is being initially developed as a wrist worn device (referred to as a “Dick Tracy watch”) by many different groups, including Motorola, Sarcos Inc and Sandia National Labs. The prototype includes non-invasive vital signs sensors with the following parameters: heart rate, blood pressure, electrocardiogram, temperature, and oxygen saturation. The next generation sensors will noninvasively measure blood electrolytes and metabolites, respiration, and levels of consciousness. In addition, the capability to detect friend from foe (IFF) will be integrated in order to help reduce the 15% to 20% fratricide rate in conflicts. Even though all soldiers will be wearing a PSM, the same devices are applicable for law enforcement, hospital patients, and even for nursing homes.

The Green Telepresence Surgery System⁵ being developed by Dr Phil Green of SRI, International is a prototype system that permits precise, accurate surgery remotely with all the illusion of being at the forward battlefield. Similar systems are also being constructed by Dr Steven Charles of Microdexterity Systems and by Dr Ian Hunter of Massachusetts Institute of Technology. These systems have a remote work site, and a surgeon’s console similar to a computer workstation. Begun as an improvement on laparoscopic or ophthalmologic surgery, the systems bring three-dimensional vision, enhanced dexterity, and the sense of touch. These components provide the realism (telepresence) of actually operating at the remote site.

For training in virtual reality, there are four major efforts which have individual simulators. Two laparoscopic surgery simulators have mannequins with ports for the surgical instruments that provide force reflection feedback. A virtual abdomen with simple organs for gallbladder surgery is projected on the laparoscopic video monitor, providing real-time interaction for practising surgery. The systems are “The Preceptor”, produced by Dr David Hon of Ixion Corporation and “The Virtual Clinic” by Kevin McGovern of Ciné-Med Corporation. There is also a simulator for prostate and genito-urologic surgery by Jonathan Merrill of High Techsplanations, Inc. For battlefield medicine, Dr Scott Delp is taking a lower limb simulator, which has been used for tendon transplant and knee reconstruc-

tion surgery, and will be adding a library of battlefield injuries. The purpose is to permit combat medics and physicians to practise battlefield medicine on a simulator rather than the wounding goats as an animal model.

Today, soldiers train in a virtual battlefield over a simulation network (called SIMNET), but are limited to simulators that are like flight simulators (which have 4 to 6-man crews) which only portray vehicles such as tanks, Bradley Fighting Vehicles (BFW), helicopters or aircraft. Dr Stephen Jacobsen of Sarcos Inc is building a simulator for individual soldiers, called I-Port, for individual portal into the virtual environment. This consists of an exo-skeleton worn on the upper body which tracks hand, arm and head motion, and an exercycle-like stand upon which the soldier sits. Peddling the cycle makes the soldier run in the virtual battlefield, and moving the arms and head makes the virtual soldier perform actions. What the soldier can see is cartoon level figure of himself and other members of the platoon, in addition to any of the tanks, BFW or aircraft. For the virtual medic, when a soldier is wounded the medic can practise location, triage and eventually emergency first aid.

In order to have all the components of the virtual battlefield be interoperable, Professor Ken Kaplan of Harvard and the Massachusetts Institute of Technology is creating the Operating Environment of the Future. The first phase will be completely creating a virtual surgical room, based upon next generation technologies like wireless networking, smart materials, noninvasive sensors and dynamic design tools. Once the surgical

room is created, battlefield instruments and equipment, such as the PSM, a next generation intelligent stretcher, telepresence surgery system and telemedicine vehicle will be modelled in order to insure total battlefield compatibility. The ability to virtually prototype all these various components will permit testing and evaluation during the design phase, before costly prototypes are built, thus insuring maximum system design and integration.

Medical care for the future requires technologies for the future. We must leverage the enormous resources of the information age to step beyond traditional thinking in medicine and implement the power of telemedicine and the digital physician. Described herein are some of the possible pioneers that will redefine medicine in the 21st century.

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