



**STRATEGY
RESEARCH
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**NEW MEDICAL TECHNOLOGY ON THE BATTLEFIELD
AND IMPLICATIONS FOR CASUALTY REDUCTION:
FACT OR FICTION?**

BY

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USAWC STRATEGY RESEARCH PROJECT

**New Medical Technology on the Battlefield and Implications for Casualty
Reduction: Fact or Fiction?**

by

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ABSTRACT

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TITLE: New Medical Technology on the Battlefield and implications for Casualty Reduction: Fact or Fiction?

FORMAT: Strategy Research Project

DATE: 11 April 2001

PAGES: 41

CLASSIFICATION: Unclassified

The Joint Vision 2020 and Army Vision 2010 are outlining the force of the future, which is calling for a smaller, lighter, more agile force, capable of rapid deployment at a moment's notice. The author surveys the current and future medical force structure designed to meet the challenge for improved soldier care. The author provides a brief overview of today's combat health system and reviews, from a historical perspective, casualty experience over a continuum of military conflicts. Assimilating casualty experience, future vision, battlefield care needs, and selected medical technologies are reviewed within categories of the soldier, communications, and evacuation to determine implications for casualty reduction. Concluding remarks summarize the discussion along with the relevancy of current technology reviewed.

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NEW MEDICAL TECHNOLOGY ON THE BATTLEFIELD AND IMPLICATIONS FOR CASUALTY REDUCTION: FACT OR FICTION?

Vision without action is a daydream. Action without vision is a nightmare

— Japanese Proverb¹

The changing strategic environment is fact; it is how the Army of today deals with this change, which is critical to the future of tomorrow's Army. The paper explores the organizational structure of science and technology, beginning with both the Joint and Army Visions and how they impact the shaping of medical support provided now and in the future. Army Transformation, along with its components, is discussed based on considerations for medical support of the future. A layout of the Combat Support System is provided followed by a review of casualty experience from previous wars and conflicts. Considering derived requirements coupled with historical casualty experiences, the author reviews selected technologies based on available information including present status, funding requirements, future availability, and impact on reducing battlefield casualties. The focus of this effort concentrates on analyzing the Combat Health System from the point of injury of the soldier to specialized care. Concluding remarks focus on future technologies, thoughts, and relevant considerations for their use.

ANALYSIS OF ROLES AND RESPONSIBILITIES

The National Security Strategy provides the overarching foundation from which visions are developed by the Joint Staff and service components. The Joint Vision 2020 (JV 2020) is the Chairman Joint Chief of Staff vision of the future battlefield, which establishes the foundation for the evolution of the joint force. JV 2020 emphasizes full-spectrum dominance of U.S. forces, including capabilities of dominant maneuver, precision engagement, focused logistics, and full-dimensional protection.² JV 2020 continues to transform technology and information systems into an effective warfighting strategy focusing on mobility, smaller battlefield footprint, and

responsiveness to the war-fighters in achieving goals. It mentions the importance of new equipment and technology; emphasizing that only with proper training and understanding can it be fully exploited to an advantage. The support role of medical services is to integrate within this process to conserve the fighting strength through utilization of new technologies across the service components.

The Force Health Protection Program (FHP), established in November 1997 under the umbrella of the Department of Defense and Veterans Affairs, represents a supporting program to JV 2020. FHP is inclusive of the entire military health system from the foxhole to medical center; from forward-deployed environmental surveillance teams to medical research centers; from operating rooms to health promotion clinics. This program reaffirms this commitment through a full array of surveillance and clinical measures needed to insure the health and safety of the fighting force. The FHP places emphasis on casualty prevention, post-casualty intervention and towards proactive, preventive services which strive to prevent casualties. The Army's counterpart to the Department of Defense sub-program of Combat Casualty Care Research resides under the U.S. Army Medical Research and Materiel Command, Fort Detrick, MD. This program is responsible for support of initiatives designed to improve casualty care on the battlefield of the future.

Evolving continuously is the Army Vision 2010 (AV 2010),³ the Army's contribution to concepts developed in JV 2020. It outlines tenets of precision engagement, full dimensional protection, focused logistics, and informational superiority for the Army of today and tomorrow.

The Army's strategic plan for new technology is formulated in the Army Science and Technology Master Plan (ASTMP), developed annually and approved by the Secretary of Army and Army Chief of Staff. This ASTMP is provided to government, industry, and academia, and conveys the priorities and strategy for the future. It represents the strategic link between Department of Defense technology planning and the plans of the Army for the warfight of the future. The Army Modernization Plan correlates directly to Chapter III of the ASMTMP and

describes how the budget supports the Army's requirements for research, development, and acquisition. This document balances the dollar requirements with the knowledge that today's modernization is tomorrow's readiness. The five major goals of Army modernization are:⁴

- Digitize the Army
- Maintain combat overmatch
- Sustain essential research and development with focus on science and technology
- Recapitalize the force
- Integrate the Active and Reserve Component.

The Army Surgeon General/Commanding General, Medical Command (MEDCOM), is the functional proponent for Combat Health Support processes and procedures. This responsibility is shared between the Army Medical Department Combat Development Directorate, Fort Sam Houston, Texas, and the U.S. Army Medical Research and Materiel Command (USAMRMC), Fort Detrick, Maryland. USAMRMC also has responsibility for all medical materiel research, development, acquisitions, testing, and experimentation requirements determination. Medical specific technologies are generally introduced through proposals submitted to U.S. Army Medical and Material Developmental Activity (USAMMDA). Sponsored annually by the Training and Doctrine Command (TRADOC), the Army Warfighting Experiments serve as a test bed for technology testing to include, but not limited to, various medical technologies. Although the details of the organization are beyond the scope of this paper, it is important to have an understanding of where requirements for new technology are generated in order to have an appreciation for the complexity of the process.

TRANSFORMATION: LEGACY/INTERIM FORCE (MEDICAL FORCE 2000/MRI)

The end of the Cold War precipitated a need for change from the previous Medical Force 2000 from a large, heavy, rigid, and clumsy force to a force that is responsive, agile, flexible, and able to support the demands of current missions. Lessons learned from previous conflicts

such as, Desert Shield/Storm, Just Cause, and Provide Comfort, supported this effort for change. Some important lessons learned included: medical units being unable to communicate effectively due to either obsolete, inadequate, or non-existent equipment; ground evacuation assets could not keep pace with maneuver elements; and evacuation helicopters could not support the extended battlefield. The ineffectiveness of communication was compounded by AMEDD command and control units, which were not structured to do their assigned missions. In addition, forward surgical capability was needed further forward rather than in the rear with the hospitals. Also, specific equipment sets were needed to support humanitarian efforts and disaster relief. The lessons learned fueled support for the Medical Reengineering Initiative (MRI), which describes the process to reorganize the field medical structure into Medical Force XXI. MRI is characterized as a flexible force, which is a smaller and more agile force with increased mobility, using the latest technology to conserve the fighting strength. This strategy includes a CONUS-based force which will be projected rather than being forward deployed and will include a shorter evacuation policy of 7-15 days⁵ as opposed to the older standard of 30 days. The MRI is the outcome of a process which examined functional requirements⁶ to meet Force XXI requirements, characterized by:

- Rapid deployment – The organizational structure has been simplified through elimination of the Field, General, and MASH (Mobile Army Surgical Hospital) hospitals, leaving only the Combat Support Hospital. This restructuring includes the capability of tailoring capacity to need by deploying a portion early through prepositioning or conducting split-base operations, dependent on the mission. The use of minimal care detachments further facilitates expansion by providing an additional capacity to care for patients awaiting return to duty or further evacuation.
- Provide total health care to the command – MRI includes special emphasis on preventive medicine, combat stress, and health promotion. Sanitation and entomology

teams have been combined into a single preventive medicine team, eliminating duplicative command and control while providing additional capabilities. Disease surveillance coupled with advanced communication provides commands more accurate and timely health information.

- Conduct treatment far forward at the point of injury and in a timely manner – This is a key to saving lives; reducing the lag from time of initial injury to when care is received. Technology is facilitating this process through speed and efficiency of treating injured soldiers.
- Leverage technology – Exploit the use of technology to save lives and increase the speed of treatment to those in need. This is accomplished at all levels of care, but is particularly critical during the initial period of injury. Whether it is enhanced communication (MC4) or evacuation system, the U.S. Army must continue to leverage technology.
- Utilization of seamless systems – There must be a greater interoperability between table of distribution and allowances (TDA) and the table of organization and equipment (TOE) environments. Medical personnel must be interchangeable and familiar with both modes of operation in order to function efficiently.
- Integration of all components – As stated previously, approximately seventy percent of the AMEDD force is within the reserve components (USAR/ARNG) making integration more challenging. Greater emphasis must be placed on the training and proficiency of future technology involving all components to insure interoperability.
- Command and control structure – The current structure lacks the ability to effectively conduct 24-hour continuous operations and split-based capability. MRI command and control structure has added additional personnel to account for this while providing additional staffing for deployment to immature theaters.

Although MRI tables of equipment and organization were approved 18 November 1998, there is no funding to support full implementation. Therefore, a major challenge to implementation of MRI has been striking a balance between affordability while maintaining essential treatment capability. To date, funding has been made available for Level I and II units, focusing on implementation of priority units. The AMEDD predicts a pure MRI force structure by FY09,⁷ dependent on future requirements and testing.

The funding to procure new technology in the quantities required is often not available. In some cases, this may be due to procurement dollars being used for Research and Development (R&D), which was not adequately budgeted for in the first place. Often this results in delays or, in worst cases, non-procurement of a needed technology. MRI is an example of this occurrence; initial cost projections were under budget. Once cost differences were realized, the program was reevaluated to determine what was affordable and what was not. The outcome is somewhat different in comparison to the originally planned system.

The AMEDD Modernization Plan investment strategies for the Legacy Force include improvements and fielding of communications assets within the AMEDD. This will lay the groundwork for a digital system capability. Modernization priorities for the Interim Force include support for implementation of the 91W program, which provides a better-trained medic. The design and support for lighter field equipment sets, which can be transported and set in a moments notice, are also key to future medical capability, along with improvements to evacuation and treatment platforms providing protected en route care, and the use of telemedicine.

TRANSFORMATION: OBJECTIVE FORCE

The process of change will continue in the future as portions of the medical force transition from Legacy (Medical Force 2000) and Interim (MF2K/MRI) Forces to the Objective Force. This process will require the Army to maintain two different types of medical force

structures, Legacy (MF2K) and Interim (MF2K/MRI), until the Objective Force becomes fully implemented. The Objective Force is a power projection force that is strategically responsive and dominant at every point on the spectrum of operations. The deployability requirements for troops on the ground include a brigade combat team within 96 hours after lift off, a warfighting division on the ground in 120 hours, and five divisions in 30 days. Based on Force XXI design, these requirements dictate the supporting medical force to be lighter, bringing personnel for essential care only. The training and proficiency of the forward personnel will be enhanced along with the diagnostic equipment to care for soldiers since these personnel will be operating much more independent of a specialized care setting. More treatment capability will be pushed far forward, requiring some AMEDD functions to be consolidated. For example, a single treatment and evacuation platform as opposed to separate or potential elimination of the battalion aid station in lieu of smaller mobile teams. The evacuation of patients by MEDEVAC will be non-existent during the first 96 hours, making evacuation by ground the only alternative; this will require an enhanced en route care capability. This certainly begs the question, in the absence of hospitals, where are patients evacuated? The answer is "there is no answer"; therefore, some consideration must be given to stabilization and holding patients during the first 96 hours. Other design criteria to be considered include: leveraging organic medical assets from units at risk and utilizing economy of force to support units at lower risk. Communication capability becomes critical to this design process in assuring that connectivity exists among the medical diagnostic aids projected for use by medical personnel.

The AMEDD Modernization Plan investment strategies for the Objective Force for casualty care focus on modernization of forward resuscitation and stabilization treatment. This includes control of hemorrhage and resuscitation guidelines while improving diagnostics and monitoring of the injured. The reduction in time allotted for troops to deploy necessitates equipment that is lighter and smaller in order to meet movement requirements. Tactical mobility for medical support must be at the same level as the supported warfighter if care is going to be

provided in a timely manner. In addition, unit functions will become modularized while storage of supporting equipment will be containerized for rapid deployment. Evacuation systems are a priority, considering the extended battlespace, thus new and improved platforms will be given priority for future development.

COMBAT HEALTH SUPPORT

Medical personnel are the U.S. Army's first line of defense in the race against time and often are the determinant of whether a patient lives or dies on the battlefield. The term "The Golden Hour,"⁸ originally coined by Dr. R. Adams Cowley, is often used to describe this critical

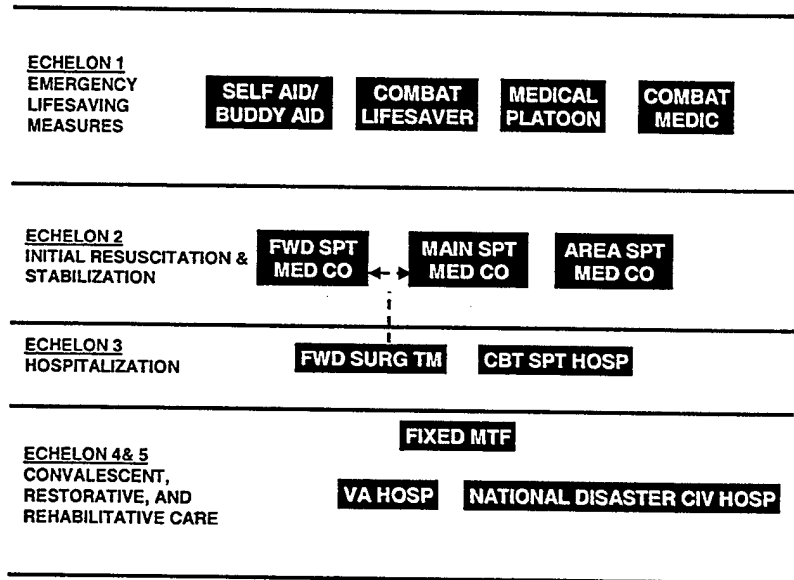


FIGURE 1 - ECHELONS OF CARE

time between the point of injury and the inevitable end of life.

Crowley advocated that most trauma patients die of shock, and believed that most trauma

patients could be saved if the bleeding could be stopped and blood pressure restored within

one hour.⁹ It is this time period

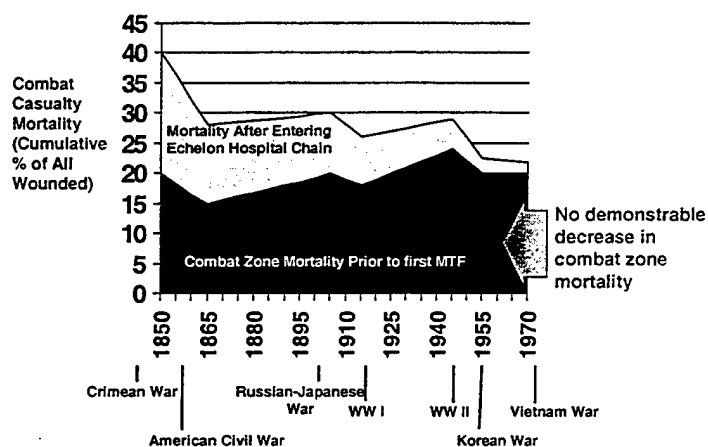
that is critical to saving the life of a soldier and represents the

entry point into the Army's Combat Health Support system, which is defined as, "a single, integrated system that reaches from the combat zone in the theater to CONUS".¹⁰ The system is a continuum of care in which an injured soldier will be provided a full range of services, from simple first aid in theater to more definitive care at a fixed facility.¹¹

Figure 1 illustrates the levels or echelons of care and the treatment capabilities of each, beginning with Level I care (point of entry) through Level 5 (the most sophisticated care). It is important to note that patient triage is the process that determines the level of care required by the patient; therefore, no patient is evacuated farther to the rear than his medical condition or the tactical situation dictate. The purpose of this system is to provide a continuum of care within an organized structure, and across strategic, operational, and tactical levels.

CASUALTY EXPERIENCE

When discussing casualties, it is important to be sensitive to differences in definitions, reporting capabilities, and operational situations when making comparisons. This becomes



*Slide from Dr. Jane Alexander. DARPA

FIGURE 2 - IN-THEATER COMBAT MORTALITY

increasingly difficult when evaluating data over a number of different time periods as noted in Figure 2. Bellamy¹² describes important considerations when evaluating casualty data. First, give primary considerations to the historical period and medical expertise available. Casualty data

is a snap-shot in time; left to the investigator to examine the historical significance in deriving a meaningful conclusion. Second, one must pay careful attention to classifications [i.e., Killed in action (KIA) vs. Died of Wounds (DOW)] utilized and understand what they mean. A soldier could die immediately of a gunshot to the leg while another soldier could experience the same injury only to expire 10 weeks later due to complications; however, both injuries would be reported the same. Third, casualty figures lack a definitive control group from which to judge the efficacy of treatment. In other

words, what is the equivalent to an untreated population, and how do you judge if the treatment provided was successful? The disparity of figures varies a great deal in viewing statistics collected from World War II in comparison to more recent conflicts. Zajtchuk¹³ reports that

	World War II	Korea	Vietnam
Killed in action: wounded In action	1:3.1	1:4.1	1:5.0
Ratio of Troops Killed in Action to Those Wounded in Action			

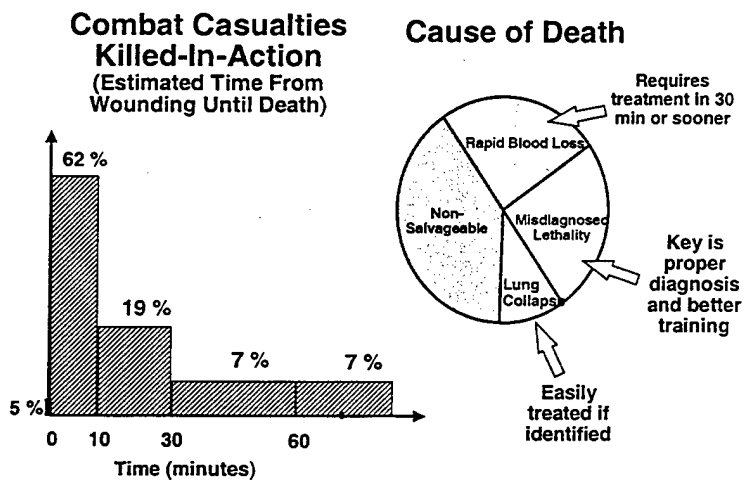
American analysts report combat mortality by percentage killed in action (those who die before they reach a medical treatment facility) and the percentage that die of wounds (those who die while receiving medical care). The author's interest is not to belabor

TABLE 1 - RATIO OF TROOP KIA TO WIA

the point of definitions, but rather to point out some potential reporting

differences which exist. Figure 2 shows combat casualty mortality data from seven wars occurring between 1854 and 1973. These particular wars were selected due to the Army's state-of-the-art-medical care available at that point in time. Data for the Crimean War pertain to the British Army; American Civil War data represent the Union Army only; Russo-Japanese War, Japanese Army only; World War I, U.S. Army only (excluding gas casualties); World War II, U.S. Army ground forces; and for the Korean and Vietnam conflicts, U.S. Army only. Of particular interest are the KIA rates that have remained about 20% over this duration of time, while the DOW rates have steadily decreased.¹⁴ Table 1 shows ratios of troops killed in action to those wounded in action, which suggests a similar trend.¹⁵ This decrease in casualties is attributed to greater organization of the military medical care system, dispersion of troops, improved protective equipment, improved medical procedures of those caring for the injured, and increasingly rapid and safe evacuations using improved techniques.¹⁶ This suggests that

great improvements have been made in decreasing mortality once the injured soldier receives medical care; however, there is an ongoing need to improve far-forward resuscitative procedures on the battlefield, at the aid station, and during transport. The bottom line is, mortality rates still remain at approximately 20% (considered KIA over total percent of those wounded) - there's been no demonstrable decrease. The Wound Data Munitions Effectiveness Teams from the Uniformed Services University of the Health Sciences (USUHS), have collected extensive data on the casualties of U.S. Army and U.S. Marine forces from 1967 to 1969 in Vietnam.¹⁷ Figure 3 shows that battlefield deaths occur rapidly; 67 percent occurring within the first 10 minutes of wounding. Of the



*Slide from Dr. Jane Alexander, DARPA

FIGURE 3 - COMBAT CASUALTIES KIA

along with sepsis (overwhelming bacterial infection).¹⁹ Additionally, 10 percent of the fatally wounded died from tension pneumothorax (lung collapse).²⁰ Two conclusions can be derived from this data. First, some of these deaths could have been prevented had they received medical treatment within a short time after injury. Second, medical personnel were sometimes unable to locate injured soldiers due to terrain/confusion,

remaining 33 percent, most die within the next 50 minutes.

Approximately 50% of soldiers killed in action die from hemorrhagic shock resulting from blood loss on the battlefield.¹⁸ Trauma to the central nervous system is among one-third of all deaths

reported within the definitive care setting

causing life-saving treatment not to be available. The estimated time between wounding and death is critical to survival and places a great deal of emphasis on the rapid initiation of medical treatment. Certainly other factors contribute to these life-saving measures, such as training of treating personnel, availability of medical supplies, and equipment used in treatment. The reduction of time required to evacuate the wounded from the battlefield is critical to affecting the percentage of deaths on the battlefield. Realistically, medical personnel will never be able to save 100 percent of those injured; however, time and care administered still remain critical factors in improving chances for survival.

CASUALTY EXPERIENCE: URBAN WARFARE

The previous discussion did not differentiate between types of environments where casualties occurred. Urban warfare provides unique challenges to the survival rate of the soldier. The urban setting is envisioned as the battlefield of the future; a place where demographers predict 50 percent of the world's population will live by 2005.²¹ Bowden²² provided a chilling account of the special operations mission in Mogadishu, Somalia, that resulted in a force sustaining 125 casualties within a 15-hour period.²³ This account represents a recent conflict within an urban environment. Some lessons learned from this experience include:

- Combat trauma evacuation must be planned in advance and include contingencies for delays. The system for evacuating patients from Mogadishu was ineffective, resulting in delays (15 hours) in receiving medical treatment.
- There was a lack of effective tourniquets to stop bleeding resulting from superficial wounds. It was noted that one-handed tourniquets, if available, would have allowed injured soldiers' to apply it to themselves.
- Hespan, a resuscitation fluid, is preferred to lactated Ringer's solution for the treatment of shock resulting from hemorrhage.

- Considering the delays in evacuation, consideration must be given to administering antibiotics as soon as possible.
- The use of a fibrin-impregnated bandage, as opposed to the application of a tourniquet, would have had a more significant impact on the control of hemorrhage.²⁴

This is not an all-inclusive list of recommendations, but rather touches on some basic soldier care/technology issues. In addition, it is important to note the Somalia operation began as a humanitarian/civic action mission, which subsequently escalated into a combat action. This may explain the comments on evacuation delays and low medical supply stockage levels. An urban environment is one in which soldiers become more difficult to locate, treat, and evacuate, due to the numerous obstacles. The types of injuries in comparison to those found on the conventional battlefield may include a greater number of crush injuries from collapsing buildings, burns, and multiple injuries from flying debris.²⁵

Reiterating the key findings presented: combat mortality remains at about 20% over previous major conflicts;²⁶ blood loss is the principle injury causing death;²⁷ and rapid treatment and evacuation to definitive care is paramount to life saving measures.

MODERNIZATION INITIATIVES

The remaining discussion will focus on issues and technology central to three broad categories impacting the soldier medic, organization concepts/equipment, and future concepts. The author has limited the scope of this paper to include only those technologies routinely found within echelons I and II. The discussion will include information on costs, projected availability, and other issues pertinent to the acquisition process.

MODERNIZATION INITIATIVES: SOLDIER (MEDIC)

The critical link to providing care to the soldier in immediate need is the medic. Next to the Physician and Physician Assistant, the medic is considered a first line of defense in

providing critical care to the injured soldier; therefore, having a highly trained medic is critical to the soldier's survival.²⁸ As stated previously, a majority of medical personnel are located within the reserve component and in most cases do not occupy medical positions which provide regular training as part of their civilian employment. Ben-Abraham²⁹ pointed out a similar circumstance in which a sample survey of reserve combat medics revealed that few medics were exposed to the types of trauma they are likely to encounter in combat. This reinforces the importance of the training process. In addition, his survey noted that learned skills degrade over time,³⁰ reinforcing a need for sustainment training. The implementation of the 91W program, scheduled to begin 1 October 2001,³¹ will enhance the U.S. Army's forward medical capability through improved initial and sustainment training of medics. LTG James Peake, The U.S. Army Surgeon General, has indicated, "We are enroute to a better trained medic, and the new MOS 91W will not only come out of the school house better trained, but will have a sustainment package that will help you support those enhanced skills."³² Training will focus on improving trauma treatment and stabilization skills through national certification as an Emergency Medical Technician (EMT) prior to graduation. In addition, certification will formalize the sustainment training process through requirements to maintain licensure.³³ This reclassification and specialized training is necessary to support a potential patient population, which is located within a dispersed battlefield (non-linear), subject to delayed evacuation, and requirements for better treatment capability through enhanced technology.

COMBAT MEDIC VEST SYSTEM (CMVS)

Former medics understand the importance of the aid bag. Although difficult and cumbersome to carry, it transports those supplies necessary to save lives and take care of soldiers. In an effort to improve on the design, the U.S. Army Natick Soldier Center conducted market surveys to develop prototypes in hopes of designing a model that could withstand the rigors of field duty. The CMVS was developed by Natick under the auspices of the Program

Manager Soldier for Clothing and Individual Equipment (PM-CIE) Soldier Enhancement Program (SEP). The vest itself is designed to carry 40 percent of the medic's load with a resupply bag carrying the remaining 60 percent. The vest itself has four large removable pockets, two on each side of the vest panels. It is constructed of 1000-denier textured nylon (woodland camouflage color) that integrates with the standard U.S. Army equipment belt.³⁴ This equipment began initial fielding in January 2000³⁵ and is ongoing. Although this has no direct impact on casualty reduction, indirectly it allows the medic to operate more efficiently to apply lifesaving supplies as required to save lives.

DRY FIBRIN SEALANT BANDAGE

One of the technologies carried within the CMVS system, may include bandages that have the capability of controlling severe, life threatening hemorrhage. Of the 14.3 percent KIA and 0.3 percent DOW due to hemorrhage in the Viet Nam conflict, more than 5000 soldiers could have been saved had a hemostatic dressing been available.³⁶ The U.S. Army Medical Research and Materiel Command and the American Red Cross have teamed up on the development of the dry fibrin sealant bandage that could potentially reduce blood loss by 50-85 percent.³⁷ The bandage utilizes two coagulation proteins that are freeze-dried and applied to an absorbent backing. When combined with short duration, direct pressure, this dressing develops a clot at the bleeding site within two minutes.³⁸ The fibrin material used to saturate the absorbent bandage has been shown to be effective in animal studies when applied directly to the point of injury.³⁹ The developmental stages of this product continue despite absence of funding for an acquisition plan for costs associated to meet the Food and Drug Administration (FDA) regulatory requirements. The current projected cost of this dressing is between \$300-\$1000 per unit,^{40,41} with the high price associated with production costs. Provided an acquisition plan is approved and implemented, this product could be available for fielding as early as fiscal year 2004.⁴²

Since this product uses naturally occurring blood components, it takes approximately 40 units of blood to produce one dressing. Medical technologies dealing with drugs, immunizations, or patient contact monitoring devices must meet additional requirements before the acquisition process can occur. Although designated for use in the U.S. Army, these products are subject to FDA regulations governing drugs and medical devices. FDA requires that all drugs, vaccines, diagnostic kits, and medical devices be approved and licensed prior to use, which requires 3 phases of clinical trials.⁴³ The clinical trials have posed some difficulties in the testing and acquisition of the fibrin bandage and associated products based on United States Code section 980 which requires:

Funds appropriated to the Department of Defense may not be used for research involving a human as an experimental subject unless – (1) the informed consent of the subject is obtained in advance; or (2) in the case of research intended to be beneficial to the subject, the informed consent of the subject or a legal representative of the subject, is obtained in advance.⁴⁴

The individual consent authority required prior to clinical testing makes it nearly impossible to test, given the nature of the product to stop hemorrhaging. This issue is currently being worked on to establish a compromise to the requirement, replacing “individual” with “community” consent, which is currently accepted by FDA and utilized by the pharmaceutical industry.

As technology improves, items once reserved for care at a higher echelon are becoming potentially available at a lower care level. Ultrasound technology, although effective, has not been practical for rapid deployment due to equipment size and weight. Advance Technologies Laboratories, Inc. (ATL), with funding from the Office of Naval Research and the Defense Advanced Research Projects Agency (DARPA), has developed a handheld ultrasound scanner capable of providing images of internal organs and indicating sites of internal bleeding.⁴⁵ Other projects being developed include development of an electrically powered device which would produce pure oxygen and development of a lower cost hemostatic bandage similar to the fibrin bandage.⁴⁶ The miniaturization of medical equipment such as the digital x-ray system, vital

sign monitor, and lab test devices, in the future may be responsible for changing the type of care provided within the forward area. Development of more durable and smaller equipment, once designed for the hospital only, is now becoming available to the field. This could potentially cause the echelons of care described earlier to change or, in some cases, be eliminated as equipment becomes available to the soldier closer to point of injury.

Hemoglobin Based Oxygen Carriers (HBOC)⁴⁷ or blood substitutes research is ongoing and shows promise for future resuscitation treatment of hemorrhagic shock trauma patients; however, the use of substitutes far forward in combat may be many years away.

MODERNIZATION INITIATIVES: COMMUNICATIONS

The important transition of improved training for medical personnel and availability of life saving supplies discussed earlier cannot be overemphasized. However, communication and synchronization of these resources is critical to the survival of the injured soldier. Unlike the previous discussions, a majority of the equipment items are still in the developmental stages and will not be available for at least five years, if available at all. As with all programs, technology being no different, funding is a necessity for acquisition. Medical communications are critical to the technologies being developed for echelons I and II, since they provide the backbone for future care technologies.

MEDICAL COMMUNICATION FOR COMBAT CASUALTY CARE (MC4)

MC4 is the Army's medical communication architecture that is fully integrated into all echelons of medical care. It provides the linkage establishing connectivity to databases, administrative procedures, medical diagnostic equipment, monitoring systems, treatment systems, and evacuation platforms. Combat health support personnel at all echelons of care will have the capability to exchange information via digital, audio, video, and electronic media. It should be noted this system would establish a worldwide capability giving caregivers a reach

back capability to the United States for expert medical consultation, diagnostic capability, and improved treatment regimens. This integration of medical information across echelons of care would facilitate world-class service to the individual soldier. Since this system would have connectivity with some non-medical type systems, such as the Land Warrior Information Network, it would have a significant impact on improving combat casualty care through improved communication.⁴⁸ Although this will improve the connectivity within the Army, it will not necessarily alleviate the difficulty in transferring vital medical information on soldiers deployed between the services.⁴⁹ Currently, theater CINCs manage a variety of their command and control information systems, to include medical information, through the Global Command and Control System (GCCS), in order to achieve a seamless Joint operational environment. The newly created Theater Medical Information Program (TMIP) will assist in maximizing the transfer of tri-service medical information, while integrating the Army component MC4 into the system. TMIP will migrate existing legacy information systems to about 15 base systems that will provide medical data across the battlefield.⁵⁰ The Assistant Secretary of Defense, Health Affairs ASD(HA), will fund approximately \$130 Million for the initial start up involving the integration and standardization architecture, with the services' picking up their portion (Army cost is approximately \$104 Million).⁵¹

Many of the high technology applications discussed are operationally dependent on the MC4 backbone, which is already overburdened. The compatibility of systems being developed will be paramount to efficient operation. The MC4 is critical to the integration of care throughout the battlefield; something the medical community has not experienced, and focuses on reduction of the time period between injury and when the soldier first receives care.

PERSONAL INFORMATION CARRIER (PIC)

The Personal Information Carrier (PIC) is a transportable medical record stored electronically on a microchip retained by the soldier. Prototypes tested are the size of the

soldier's identification tag (dog tag) and provide comprehensive personal readiness data in addition to critical medical data. The initial design criteria includes: the capability of being worn, having a read/write capability so information can be readily updated through a special reader, and having a memory capability to store a specified amount of information (32K).⁵² The PIC represents a sub-component of MC4. The current prototype eliminates the need for a separate card reader (hardware) but instead utilizes a PCMCIA port card (available on laptop computer) to transfer and edit data. The PIC has been tested extensively in a number of different environments, including temperature extremes, vibration, shock, and electromagnetic interference. In addition, it has been subjected to fresh and salt water, insecticides, as well as nuclear, biological and chemical decontamination substances. All have proven not to degrade performance.⁵³ In order to prevent unauthorized use, the data is encrypted, allowing medical information to remain secure. It is anticipated the PIC will replace the paper casualty tag used by medical personnel for evacuation.⁵⁴ When and if this program is approved, a full Pentagon buy would include more than two million PICs and thousands of adaptors to fully implement the program. Although testing of this system continues, implementation is not scheduled for at least several years.⁵⁵

WARFIGHTER PHYSIOLOGIC STATUS MONITOR (WPSM)

In contrast to the PIC, WPSM is an active status monitor utilizing biosensors placed directly on the soldier, or indirectly on the uniform, providing the capability to monitor the status of a soldier in "real" time. Sensor technology would not only generate vital signs data (heart rate, blood pressure, respiration rate, body temperature), but also monitor sleep/alert status, energy balance, psychological status, workload capacity, and stress. The U.S. Army Research Institute of Environmental Medicine worked with FitSense Technology on use of this technology and tested it during a U.S. Marine Corps training exercise.⁵⁶ Using a low-power wireless digital network, the company was able to simultaneously monitor body parameters including heart rate,

caloric burn, sleep time, location (via GPS), and temperature on fifteen individuals for ten days.⁵⁷ This wearable wireless system was able to log sensor information and transmit to a centralized data center. Similar sensor technology will be a key to these advanced systems and it is not new to the technology world.⁵⁸

The development of algorithms, however, is imperative to the proposed use of sensor technology. More research needs to be conducted on development and measurement of key indicators that accurately report the status of an individual. They must clearly define data parameters required which truly define a health condition or status. Sensors, particularly those planned for use within this device, do present some difficulty with the soldiers. The willingness of soldiers to utilize sensor technology has yet to be determined. Many sensors could become invasive (i.e., sticky tape affixed to skin, wires rubbing against skin causing discomfort) to the soldiers, causing them not to use them in given situations. The system must use the "plug in and forget" mode (automatically connected) if it is going to achieve consistent use. Other concerns of battlefield sensors are performance and reliability. Will they remain operational in the heat of battle or during an extended road march? Not only must sensors function properly, further study is necessary to develop the metrics to be measured. A great deal of research is necessary in defining what algorithms may be used and what the medic may interpret from them. Probably the most difficult dilemma is the false positives reported by the sensors. For example, sensors may report a need for assistance or death, but in reality the report may only be a result of a network communication error or the soldier temporarily removing the sensor. If successful, this system affords the medic the capability to conduct remote triage, to detect trauma, and vital signs, which will significantly improve efficiency in providing care to those in need. This system is a sub-component of MC4 and is tied into the Land Warrior Network. WPSM operational requirements have been inputted, yet a number of questions still need to be answered. WPSM is currently in the developmental stages and cost or projection data is not currently available.

Dependent on the technical gadgetry developed, power requirements for the digital battlespace are critical to the survival of the products created. The soldier of tomorrow will not necessarily be able to carry more than the soldier of today. Systems such as the Warfighter Physiological Status Monitor and Electronic Field Medical Card will require man-portable power which increases not only the weight of the product, but power source as well. Improved batteries and chargers are being developed, but further research is required to oversee whether or not the products themselves are power efficient. Interestingly enough, an initiative is being reviewed to reduce power consumption via the software operating system as well as the system's application software.⁵⁹

WARRIOR MEDIC

Warrior Medic, like the PIC and WPSM, are subcomponents of MC4. Warrior Medic is an integrated system under the Land Warrior tactical network and has been dubbed the soldier's "911" system.⁶⁰ Capabilities include alerting the medic/commander of an existing casualty, emergency call for help, and a capability for identifying and locating casualties on the battlefield. In addition, as an information system, it would allow the medic to record initial treatment, transmit request further assistance, and provide reference guides for the purpose of treatment assessment.⁶¹ This system is considered an enhancement to the Soldier Biological Chemical Command's (SBCCOM) Land Warrior System which is currently in the development stage and could be available as soon as the third quarter of FY03.⁶²

TELEMEDICINE

Telemedicine is defined as "the use of information in conjunction with communications systems to provide health care remotely".⁶³ It is another component/customer of the MC4 communication architecture. The term "telemedicine", unlike "telepresence", usually refers to utilization of conferencing (video/audio) to exchange information or remotely consult with a patient. It has been touted as the solution to providing critical forward surgical capability to the

far-forward battle zone.⁶⁴ Telemedicine has been used successfully in treating patients for whom specialized medical consultation was required, such as during Desert Storm, or in Somalia and Kosovo. Telepresence refers to the performance of surgery through the use of robotic manipulators electronically controlled through a wireless network from one point to a remote site. Although still within the developmental stages, it has shown promise in proof-of-concept tests conducted by SRI International within controlled settings.⁶⁵ The general consensus of the U.S. Army is that both systems show promise within given applications and continuing evolution; however, several barriers must be overcome for either to be effective for sustainment of casualty care on the battlefield. Currently, the availability of bandwidth and power requirements coupled with durability of equipment make these systems less desirable for far forward wartime applications.

MODERNIZATION INITIATIVES: EVACUATION

Evacuation equipment discussed in this section involves large end-items designed to move patients across the theatre continuum to higher echelons of medical care. The evacuation platform provides the balance of en route treatment coupled with speed of movement to get the wounded to critical care treatment facilities.

CRITICAL CARE SYSTEM FOR TRAUMA AND TRANSPORT (CSTAT)

The CSTAT is an individualized portable intensive care system and surgical platform which provides resuscitation and stabilization capability through an integrated suite of state-of-the-art medical devices. An example of a system comparable to CSTAT is the Life Support for Trauma and Transport (LSTAT) produced by Integrated Medical Systems, Inc.⁶⁶ This system is designed for evacuating trauma patients to specialized care, while providing en route care during evacuation. As a self-contained system, it provides a ventilator with on-board oxygen; fluid/drug infusion; suction, defibrillator; blood chemistry analysis; patient physiological

monitoring; data logging with MC4 compatibility; and power and system data management.⁶⁷

The entire platform with equipment is the size of a standard NATO liter. This system is of immense importance in dealing with the stabilization of the severely wounded soldier for transfer to more definitive care. As with many of these systems, there are some drawbacks, it is bulky, heavy to maneuver, and expensive. Despite these shortfalls, the LSATS may prove to be a very effective tool for patient stabilization during transit. This product does not meet initial operational requirements based on weight, O₂ cylinder supportability, and evacuation vehicle compatibility. Pending revisions and subsequent approval of this product, it could be available for use as early as the first quarter of FY02.⁶⁸

ARMORED MEDICAL TREATMENT VEHICLE (AMTV)

The M577A2 has been the Army's Battalion Aid Station since the 1960's. However, it lacks the maneuverability, speed, and survivability required to support mechanized and heavy forces. The Armored Medical Treatment Vehicle (AMTV), a variant of the Bradley C2V/MLRS chassis, was designed as a replacement. Unlike the M577A2 which utilizes tentage set up on the outside of the vehicle, the AMTV has sufficient space (compartment room for a minimum of four litter patients) within the vehicle to provide a protected treatment environment for casualty care in support of heavy forces. It utilizes existing armor and tracked technology to provide mobility, survivability, navigational, and communication capability to keep pace with supported forces. The AMEDD requires 70 AMTVs at a cost of \$240.6 million to support Force Package 1.⁶⁹ As of 22 June 2000, this program was officially terminated with stipulation the remaining 11 AMTVs on contract be converted, pending funding from FORSCOM, to support operational and sustainment costs.⁷⁰

It is important to note that termination of this program may have a significant impact on evacuation of patients from forward combat areas. As forces modernize, it is critical that consideration be given to transportation requirements to get patients to treatment. Evacuation

platforms must have the same or greater capability than the troops they support if lives are to be saved.

ARMORED MEDICAL EVACUATION VEHICLE (AMEV)

The Armored Medical Evacuation Vehicle (AMEV) was designed to replace the M113A2/A3 Armored Ambulance as the medical evacuation platform for the Army's heavy force. The AMEV addresses shortfalls identified in Desert Storm with the M113A/2A3 such as limited patient holding, no en route care capability, lack of storage space, and no environmental control. Similar to the AMTV, it will utilize a variant of the Bradley Fighting Vehicle chassis which will enable it to sustain the mobility, survivability, and maintainability equivalent to the supported force. In addition, it provides enhanced navigational and communication capability. The medical capacity includes on-board oxygen, suction, storage for medical items and equipment, and space for eight patients (4 ambulatory/4 litter) and a crew of three.⁷¹ The vehicle provides armor protection for forward deployed medical personnel while providing en route patient monitoring capability through utilization of an additional crewmember (1 driver, 2 medics). The AMEV provides close combat medical treatment on the battlefield and has the capability for rapid collection and treatment of casualties. The total Army requirement is for 1,491 vehicles to fill all required force packages at an estimated cost of a little less than \$1million each. There is currently no funding to support this project. Another issue of concern is the weight and speed of the vehicle, which is in direct conflict with the vision of a medium interim force. As of 17 January 2001, this project is on hold with decision to continue due out in March 2001.⁷²

MEDICAL EVACUATION HELICOPTER (UH-60Q)

This UH-60Q replaces the UH-1V and upgrades the UH-60A with an additional material upgrade, optimizing the aircraft for medical evacuation missions. This aircraft provides capability to evacuate casualties as far forward as the situation permits; conduct combat search and rescue; perform shore-to-ship evacuation; and move medical equipment and personnel in

emergency situations. The medical capabilities include an equipment storage area, onboard oxygen and suction, electric power for equipment, combat litter system, and hoist. The navigational system includes a global positioning system, forward looking infrared system, and tactical air navigation. Communication capabilities support all functions of MC4 for command and control and telemedicine, data port, and high frequency multiband radio.⁷³ The development of the UH-60Q is based on experiences identified from Operation Just Cause, which indicated a need for a medical version of the UH-60⁷⁴.

The total objective force requirement for this is 386 MEDEVAC aircraft, which includes 356 for the warfighter and 29 for the operational readiness float account. Of the 356 aircraft, 191 are scheduled to go to the active component and 165 to the reserve component. The current modernization funding projections are for 132 aircraft for Force Package One to be completed by 2010 and the 150 aircraft in Force Package Two by 2020.⁷⁵

From all projections, the battlefield of the future will become dependent on air evacuation. But will it be available when needed? Increasing costs of production, coupled with the aging of the existing fleet, are not positive projections for the future. With a decreased footprint of specialized care (hospitals), will technology be able to overcome the delta for the necessity of evacuation? Will ground and air evacuation platforms be available in the quantities needed?

FUTURE SUPPORT FOR 2020 AND BEYOND

What the future holds is up to those willing to think outside the box because the future has no limits. What is known is that conflicts will produce casualties which will require care in order to save lives. Metabolic engineering⁷⁶ is an interesting concept being looked at by researchers of the Defense Advanced Research Projects Agency (DARPA). With increasing demands on movement of soldiers to treatment, scientists are studying animal hibernation in learning how metabolic systems reduce activity while still maintaining life. The research

objective is to determine if the Army can suspend an injured soldier in time until specialized care becomes available.

The potential of evacuation platforms is one of debate. Does the Army continue with the UH-60Q or diversify and look at other platforms, which may meet mission requirements and be less costly to produce. Certainly the V-22 Osprey⁷⁷ or the Moller SkyCar⁷⁸ may be supplemental platforms of the future at costs more affordable.

The future battlefield is no longer a linear model, but rather an urban environment with no boundaries. The levels of care will become less structured as movement of care is pushed closer to the point of injury coupled with newly advancing technology.

CONCLUSION

The Army Science and Technology Master Plan and the Army Modernization Plan are key elements to defining strategy and priorities for future technology. Presented herein is an overview of technology development from the top down along with brief descriptions of the combat health support system and a few of the organizational challenges it faces moving towards Army Transformation.

Historical battlefield casualty experience attempts to determine baseline trends of types and kinds of injuries resulting in death occurring on the battlefield. Battlefield mortality factors show approximately 50 percent of battlefield deaths are the result of hemorrhage, with remaining deaths split between central nervous system injuries and bacterial infection. Although the number of injured soldiers who receive hospital care has declined steadily over time, mortality from battlefield injuries remains at 20 percent with no demonstrable decline and is becoming the focus of advanced technology development. Experience has shown, the more rapidly medical treatment is available to injured soldiers, the greater the chance for survival.

Although limited to technologies utilized at echelon I and II, included initiatives impact a broad spectrum of casualty care from the soldier medic to medical communications and evacuation. All selected technologies fit the historical parameters for the potential to reduce battlefield deaths. The miniaturization of medical equipment coupled with better-trained medical personnel is providing better care to the injured soldier. The enhanced communication products will provide greater battlefield awareness, whether it is providing immunization information for deployment or as complicated as a telemedicine consult for specialized treatment, while increasing the survival rate of the soldier. The evacuation platforms provide the en route care and speed to specialized care, remain critical to the injured soldiers survival.

The emphasis of new medical technology on the battlefield focuses on saving lives and therefore will have a significant impact in decreasing battlefield mortality.

WORD COUNT = 7,976

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