A Wireless Vital Signs System for Combat Casualties

CAPT Peter Rhee, MC, USN
Director, Navy Trauma Training Center
LAC+USC Medical Center
1200 North State Street
Los Angeles, California 90033

E-mail: PRhee@nshs-sd.med.navy.mil

Steve Murray, PhD & LT Walter Carr, MSC, USNR
Naval Health Research Center, San Diego
P.O. Box 85122
San Diego, CA 92186-5122

E-mail: MurrayS@nhrc.navy.mil

A WIRELESS VITAL SIGNS SYSTEM FOR COMBAT CASUALTIES

Combat casualty care can be improved if vital signs can be obtained easily. The work presented in this report describes the status of a compact and portable wireless vital signs (WVS) system that provides vital signs obtained in a traditional manner and is seamless from the field to definitive care. This system uses off-the-shelf, FDA-approved technology in a package that is lightweight, portable, and easy to use. WVS equipment is battery-powered and is comprised of a standard inflatable blood pressure cuff, a pulse oximeter, and a two-lead ECG. The information obtained from this unit is transmitted via Bluetooth® technology to a standard off-the-shelf PDA, which can track multiple patients simultaneously. Patient vital signs can be displayed on the PDA or on other devices such as a wearable 'head-up' monitor or a pre-positioned stand alone displayer. From the PDA, the information can also be transmitted via Wi-Fi to a laptop server, which then allows the information to be used in a variety of ways. This new WVS system can be deployed in the field at the point of wounding and remain on the patient through various stages of transport and through all echelons of care (e.g., helicopter, ambulance, gurney, trauma bay, surgical suite, ICU). Thus, the currently used monitoring devices will no longer have to be disconnected and reconnected through successive patient encounters and various means of transport. This capability would obviously make the handling of the patient easier and faster. Because the vital signs are obtained using standard FDA-approved devices rather than futuristic promising technology, this new WVS will soon become a reality. Support from the Office of Naval Research has allowed the Navy Trauma Training Center and the Naval Health Research Center to collaborate with NASA Ames Astrobionics and others to develop the WVS device. First-generation prototypes were delivered in 2003 and the WVS system is currently being evaluated on civilian trauma patients. Experience to date suggests that the wireless vital signs capability described here is very achievable in the near term. Prototype evaluation and the next development cycle will be reported in this symposium. The capability afforded by WVS is expected to have broad application in Emergency Medicine, beyond combat casualty care.

Paper presented at the RTO HFM Symposium on "Combat Casualty Care in Ground Based Tactical Situations: Trauma Technology and Emergency Medical Procedures", held in St. Pete Beach, USA, 16-18 August 2004, and published in RTO-MP-HFM-109.

1.0 BACKGROUND

Naval Operational Health Service Support doctrine emphasizes meeting the demands associated with Operational Maneuver From the Sea (OMFTS, 1996; endorsed under the Secretary of the Navy's, the Chief of Naval Operations', and the Commandant of the Marine Corps' Naval Transformation Roadmap, 2003) with the need for enhanced battlefield trauma management. Execution of the OMFTS concept requires a smaller medical footprint because troops are increasingly likely to be inserted into far forward ground areas by air from sea-based platforms. Future battlefronts will also have rapidly moving non-linear battlefronts. Combat casualty care and evacuation from point-of-wounding to upper echelons will be more complex and may involve great distances.

Current equipment used for combat casualty care in the battlefield is minimal. At the level of the Battalion Aid Station or Shock Trauma Platoon, the powered vital signs monitors are few and expensive. Thus casualties are triaged as to who will be monitored by the available equipment. In addition, every time casualties are moved, the equipment is not transported with them. If a casualty requires monitoring during transport, the attachments from the monitor are usually switched to the transport monitoring system. With conventional monitoring systems, valuable time is lost in set up of multiple wires, individual sensors, electrodes, etc. that need to be managed or reconnected during transport. If a casualty requires surgery, the monitoring system again needs to be changed on the patient. Every time the patient is transported, the monitoring equipment is switched from the facilities system to the transport system. This is cumbersome and causes delays. Efficient and portable vital signs systems that monitor multiple casualties and are tailored to the battlefront are needed.

2.0 OBJECTIVE

The primary objective of this effort is to develop a system that obtains vital signs from multiple casualties on demand, using currently available technology in an efficient and portable manner. The physiologic parameters measured should be those that are currently used and accepted. This will ensure easy interpretability and acceptance by those who currently treat combat casualties.

The goal of a wearable, wireless vital signs (WVS) monitoring system is to combine medical data sensor and wireless communication technologies to enable continuous monitoring, quicker transport, and better decision making by avoiding lapses in medical data acquisition. The WVS unit is designed to integrate and wirelessly transmit multiple medical modalities from the patient to hand-held computing devices [i.e., personal digital assistant (PDA)] or pre-positioned displayers (see Figure 1 for concept illustration).

The WVS system concept is a blood pressure cuff that also has a pulse oximeter and two lead ECG. Customarily, these are the only vital signs used in trauma care today to make medical decisions. This WVS unit can be placed on the patient by the first responder near point of wounding and will remain on the patient throughout various stages of transport (e.g., helicopter, ambulance, gurney, trauma bay, surgical suite). Thus this eliminates the need to switch monitoring systems and the cumbersome wires and sensors that are integral aspects of current monitors. Patient-transmitted vital signs data will automatically be picked up and displayed for the provider (either on a handheld computing device or a display monitor). While all patients with the WVS system placed on them will be transmitting their vital signs, the monitoring systems will only display the casualty of interest. From WVS display menus, the care provider can easily choose the casualty that he or she would like to see. Because the transmitted vital signs from the patient are continually picked up by the PDA, the switch from one patient to another will be rapid. The current mode of transmission from the casualty to the PDA uses Bluetooth® technology, a low energy communications protocol capable of capturing information from a casualty up to 100 feet away. Once captured at the PDA, information can be relayed and displayed on a head-up monitoring system or on a static display monitor. This flexibility will facilitate ease of transport while using non-invasive means to continuously collect and transmit vital signs without the logistics of transporting conventional monitors.

When a server is included in the system (preferably a laptop server or other more portable model), vital signs from the PDA will be transmitted to the server via Wi-Fi so that the information can be processed and transmitted to other providers' PDAs. Therefore, all caregivers with a PDA and WVS software within a local area can have access to all patients wearing the WVS system.

A key advantage of the WVS system is the cost. In comparison to the traditional transport monitor, which can cost up to $18,000 per unit, the WVS system is relatively cheap so that many units can be acquired for the cost of one conventional monitoring system. For example, an off the shelf PDA used with WVS can be purchased for approximately $300 and flat screen displayers are approximately $250. The battery-powered WVS sensor unit, with modular blood pressure cuff, pulse oximeter, and ECG leads, is anticipated to have a cost of approximately $600 per unit.

A planned feature of the WVS system is that it can be incorporated with PDA based medical records which are currently being used in civilian trauma systems. Medical record information along with pictures and voice recordings taken with the PDA can be stored on an inexpensive memory disk and sent with patients as they are transported. Electronic medical records have advantages as they can be transmitted ahead of the casualty and data management information, including trauma registry, can be easily extracted.

A paramount feature of the WVS development effort is to yield a product that achieves the vision described here and that is deliverable in the near term (e.g., 6-month development cycles) at low per unit cost. In contrast to other ongoing efforts aimed at monitoring various physiologic parameters of non-injured combatants with futuristic modalities, the Wireless Vital Signs (WVS) system concentrates on acquiring traditional physiologic parameters with customary equipment used today. Thus the goal is merely repackaging currently available off the shelf technology to a form factor tailored to the battlefield. By leveraging currently available technology, the goal of this project is well feasible.

3.0 DEVELOPMENT AND PROGRESS

Staff from NASA Ames Astrobionics program assembled and delivered first-generation WVS prototypes within a 6-month time frame and a budget less than $100,000. Prototype WVS units performed as required and have been universally positively received, attracting various professional interests in further system development. Second-generation WVS prototypes under construction are again expected within a 6-month assembly timeframe. Delivery and initial testing of second-generation WVS prototypes are scheduled this summer, with initial testing to occur between the submission of this paper and the corresponding oral presentation and demonstration at the NATO Human Factors in Medicine symposium at the annual meeting for Advanced Technology Applications in Combat Casualty Care (2004).

4.0 APPROACH

WVS prototype development and initial evaluation in emergency room environments are ongoing. Although this technology is intended for combat casualty care in field settings, it presents opportunity for application in a range of military and non-military clinical settings. Emergency room evaluations provide vital short-term feedback, not dependent upon scheduling of field exercises. This short-term feedback provides a key resource in the "build-test-build" process endorsed by the Naval Transformation Roadmap (p. 33, Sea Trial, Spiral Development, 2003) and supplements field testing in essential ways.

Design and assembly teams for each of the two prototype development efforts have been selected according to a competitive review process. This approach has generated various ideas for achieving required capabilities and worked to control development costs. Capabilities may be adjusted as experience is gained across generations of WVS builds, but overarching requirements for each successive WVS generation adhere to key parameters of minimal weight, size, battery demand, and cost. Another overarching requirement is that WVS must be as simple as possible, operable by novice medical personnel with no access to a user manual and with less than 5 minutes of hands-on supervision.

5.0 PRODUCT COMPARISON / OTHER CAPABILITIES

The WVS system uses visual display to support the on site medical provider in delivering medical care to combat casualties, especially in trauma. A separate project, the Warfighter Physiological Status Monitoring (WPSM) component of the Objective Force Warrior (OFW), will also yield visual display to benefit medical providers, but OFW has other medical and non medical objectives, making the two projects quite distinct. The different approaches and unique capabilities of WVS and OFW are indeed separate but they complement each other well in combat casualty care. In official description of OFW and WPSM, OFW has a focus on a more global battlespace and visual display of remote information. WVS has a focus on the immediate physical vicinity of the medical provider and visual display of proximal information. The different approaches are not mutually exclusive and, in fact, when used together, yield a more robust combat casualty care capability.

A first distinguishing feature between OFW and WVS is the scope of the information network used. The network used by OFW covers a vast area and is rich with medical and non-medical information. OFW, when developed, will enable "remote triage" and processing "according to algorithms" (p. 46, Operational Requirements Document for Land Warrior, 2001). Further, in an operations requirements document, the on site support specified for the field combat medic is network-based "interface with senior medical personnel at the Battalion Aid Station to assist in the treatment of casualties" (ibid.). WVS is a local ad hoc medical network only, that provides information display and relies on the training and expertise of the on site provider.

Another distinguishing feature is the manner in which each system is applied and worn. Part of OFW's value is that, as a "unit of issue," it makes information continuously available because the WPSM is continuously worn, whereas the WVS is only applied to and worn by casualties in serious condition, on an as-needed basis. (This means that only casualties appear in the limited WVS network.)

Other distinctions can be drawn. The two described here are readily apparent examples. The two systems, OFW and WVS, used together complement each other well: WVS as a local unit that can be applied when OFW's network is not accessible or when the WPSM is non functional as a result of damage, loss, or removal for treatment; OFW as a remote sensing unit that extends information access beyond WVS' limited ad hoc network. As a dedicated medical system, WVS applied by the first responder will support continual awareness of patient conditions for the immediate emergency medical personnel who are able to respond until patients leave the emergency medical system for recovery or return to combat.

The final distinction drawn here is that the simpler, dedicated function of WVS means a simpler design and development process. Emergency room validation of already delivered first generation WVS prototypes is ongoing and experience to date is positive. For comparison, "the Army Science Board performed a study specifically focused on the Objective Force Warrior. This study identified selected technology opportunities and provided a sample roadmap for technology integration. They also found the greatest opportunities for performance gain were beyond 2012." (National Security Directorate Oak Ridge National Laboratory, 2001.) WVS can fill a role today and a limited, dedicated medical role in the future. These WVS roles are excellent and valuable complements to OFW and various other grand scale technology development efforts.

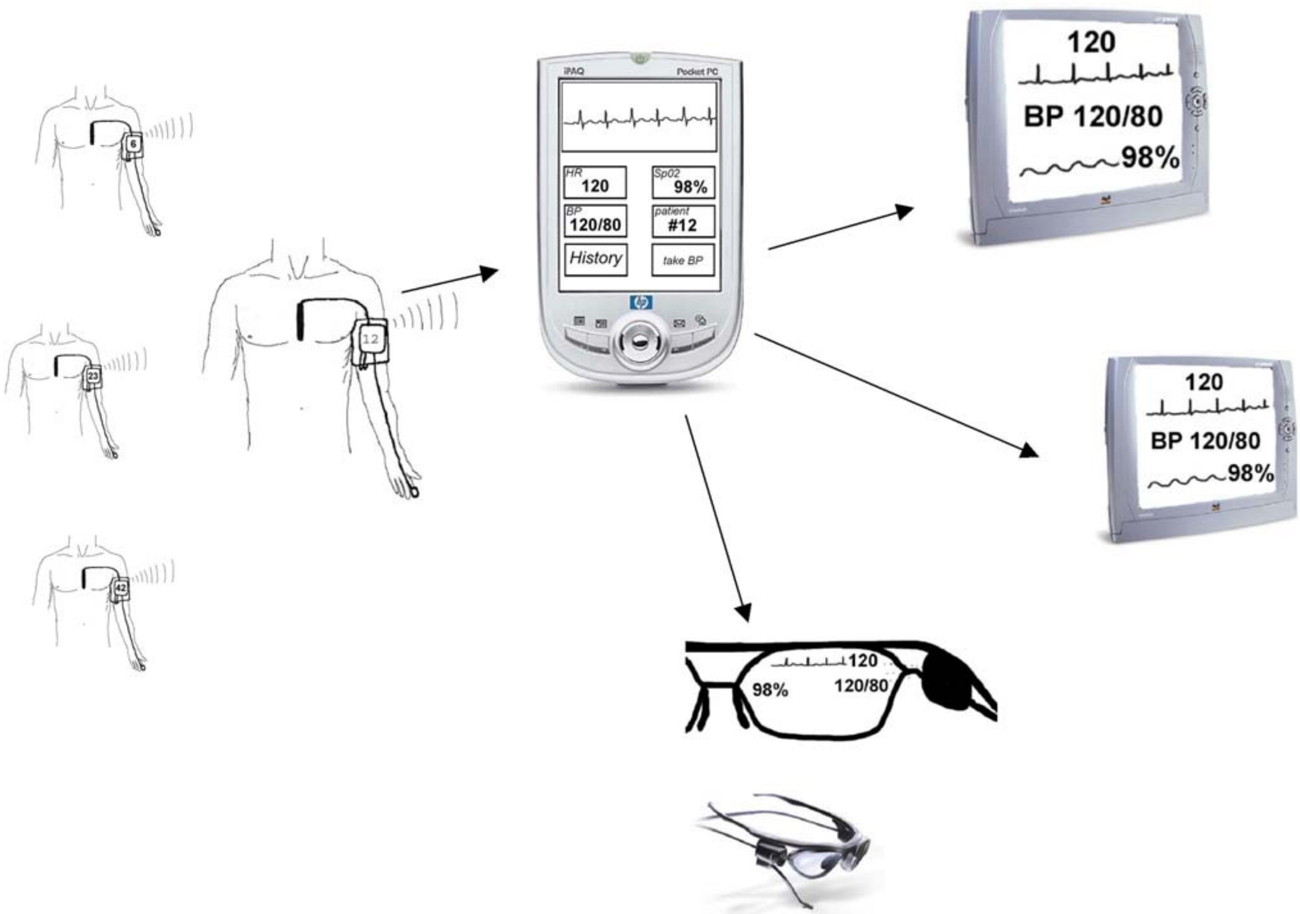

Figure 1. WVS System Concept

REFERENCES

[1] Headquarters Marine Corps. 1996. *Operational Maneuver From the Sea: A Concept for Projection of Naval Power Ashore*. Washington, DC.

[2] Department of the Navy. 2003. *Naval Transformation Roadmap: Power and Access…From the Sea.* Washington, DC.

[3] Department of the Army. 2001. *Operational Requirements Document for Land Warrior.* Washington, DC.

[4] National Security Directorate Oak Ridge National Laboratory. 2001. *Objective Force Warrior: "Another Look."* Oak Ridge, TN.