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Military Influence and Novel Utilization Strategies of Ultrasound Technology

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Abstract

Ultrasound (U/S) technology has advanced from large, wall-mounted systems to pocket-sized devices that provide high-quality image resolution. Through several innovations, u/s systems were optimized for military medical use in the 1980s. Due to utility in point-of-care, lack of ionizing radiation, and expansion of computer technology, point-of-care u/s (POCUS) was rapidly introduced in trauma, emergency department, and out-of-hospital settings. Military deployment environments are one of these out-of-hospitals settings, and other imaging modalities are not feasible in these conditions. In this article, how the military has influenced and utilized u/s technology will be discussed.

Keywords: Military; Portable ultrasound; FAST; Medical evacuations; Mass casualty events; Teleradiology

Introduction

Sonar was first implemented during World War I; however, static medical u/s was not available until the 1960s. Active scanning was introduced in the late 1970s, but machine size limited its deployment utility. In 1996, the Defense Advanced Research Project Administration awarded a grant for development of a portable u/s device for battlefield use [1]. By the late 1990s, commercial companies began manufacturing portable u/s machines for civilians. Today's devices are lightweight, heavy-duty, and offer multiple imaging modalities, including vascular, echocardiography, color Doppler, and endovaginal exams. Commercial market and military demand for durable and portable u/s units have contributed significantly to their evolution at vastly reduced costs [2].

Equipment

The first portable, battery-operated u/s weighed approximately 5 pounds and could withstand unpredictable deployment environments. Equipment design and environment-specific advances have permitted successful use of u/s in unforgiving conditions.1 Widespread use of u/s devices is possible due to technological advances such as multicore processors, liquid crystal display, high-capacity small size battery units, probe miniaturization, and wireless data transfer. Due to these advancements, u/s has shown to be useful in environments where other imaging options are not feasible, such as the International Space Station, medical transport, mass casualty incidents, and front-line combat surgical teams [3].

U/s machines tend to undergo rigorous wear during deployment. Highly fluctuating temperatures and sandy landscapes such as Afghanistan and Iraq can cause battery degradation and overheating. Despite these issues, u/s technology can function in tropical, frozen, high-altitude, and other extreme environments where other imaging modalities cannot. Also, u/s is much faster compared to CT or MRI, decreasing exposure time to severe weather. To meet the harsh demands of deployment, the military helped develop u/s units that were handheld, maneuverable, had cooling fans and high-capacity batteries, and improved patient access [1].

Fast

Most battlefield deaths are due to hypovolemic shock; therefore, the most common u/s use in the field is the focused assessment with sonography in trauma (FAST) exam. Other imaging studies are not always available, and deployed physicians found u/s to be a valuable tool in triage. Data from the Iraq conflict demonstrated u/s can identify trauma injuries with high sensitivity/specificity, confirmed later by CT scans.1 U/s is also helpful in identifying internal injuries in young, highly conditioned military personnel who have a high physiologic reserve, resulting in compensatory mechanisms that undermine vital signs until the late stages of hemorrhagic shock. The FAST exam can identify occult blood loss in these patients before their condition deteriorates to late-stage shock, allowing for early life-saving interventions [3]. Also, the handheld FAST exam can supplement rapid, accurate diagnosis of abdominal or thoracic bleeding in casualty events during operational deployment [4].

The FAST exam is an effective method of patient assessment to aid in decision-making and optimize patient outcomes. However, a change in the National Institute for Health and Care Excellence guidance has increased CT availability. Therefore, civilian centers may begin to rely more heavily on the increasingly available CT scan [5]. Although this may be true in private operations, the military often operates in environments with limited CT access. Because of this, portable u/s will continue to be a valuable mission tool during deployments [5].

Medical Evacuations

There are several emergency POCUS applications in deployment settings, including fracture assessment/reduction, high-altitude pulmonary and cerebral edema, pneumonia, pneumothoraces/hemothoraces, hydration status, inferior vena cava collapsibility, and

optic nerve sheath diameter. POCUS can also be used for procedural guidance for venous access, regional anesthesia, pericardiocentesis, cricothyrotomy, and foreign body identification/removal. With these diagnostic capabilities, u/s can be used to avoid unnecessary procedures and evacuations to higher-level facilities, resulting in saved time, resources, and reduced patient harm.

One of the most significant advantages of u/s is it does not require a physician for proper execution, decreasing physician referrals. Concerning military applications, primary care physicians often care for patients in battalion aid stations with no diagnostic testing available. With POCUS, physicians in war zones could decrease the number of service members evacuated for diagnostic testing. Medical evacuations are time-consuming and often require movement through unsecured areas, posing danger to the patient and transporters. U/s could decrease unnecessary, resource-consuming evacuations, and the patient may quickly return to duty [6].

Aeromedical evacuations are frequent. Due to noise and space limitations, POCUS has become a valuable tool for medical evacuations. Patients may deteriorate during aeromedical removal due to physiologic stressors, including hypobaria, hypoxia, extreme pressure changes, constant noise, and movement, and pneumothoraces. The extended FAST exam (eFAST) is useful in pneumothorax assessment and prophylactic thoracostomy to prevent in-flight decompensation. To be applicable in flight, u/s equipment was designed to be small, lightweight, and tolerate vibrations, turbulence, and significant fluctuations in temperature and pressure for military use [1].

Mass Casualty Events (MCI)

During MCIs, the overwhelming volume of casualties often surpasses the resources of the response effort [1]. Patient survival depends on the responders' ability to accurately and rapidly triage patients. FAST can be performed repeatedly without exhausting resources in an already resource-constrained situation [3]. Also, POCUS is often the only functional imaging modality during an MCI due to operation remoteness, lack of organized infrastructure, destruction of equipment, or lack of electricity.1 Interestingly, one case report described the use of u/s-guided nerve blocks in disaster settings, demonstrating portable u/s may have more uses as medical technology advances [7].

In humanitarian efforts, the military needs to quickly triage patients and make crucial decisions regarding patient management, including patients that require immediate surgical intervention. In natural and human-made disasters, several studies concluded POCUS and eFAST are invaluable tools to determine patient management and prognosis [1]. Positive FAST images can be recognized promptly, and negative FAST exams can be completed in an average of 2.5 minutes [3]. After the 2010 Haitian earthquake, portable u/s influenced care in 70% of patients, helping solidify its use in disaster efforts [8].

Training

One concern is the ability of military medics to use and interpret u/s imaging. However, studies have shown that with minimal training, martial practitioners can effectively and efficiently use portable u/s equipment. Previous research has demonstrated the ability of trained personnel to interpret FAST imaging obtained during aeromedical transport correctly. Moreover, medics did not experience significant technical issues, and pilots did not experience avionic interference [3]. Special Forces Medical Sergeants were able to detect a simulated long bone fracture in combat theater with high sensitivity/specificity, [9,10] suggesting mobile u/s could possess several advantages in the Special Operations Forces [10]. Non-physician healthcare providers can accurately detect tension pneumothoraces after minimal training using portable u/s [11]. Army medics with minimal u/s training can identify foreign bodies larger than 2mm in hand models with similar accuracies to trained physicians [12]. Novice ultrasonographers can accurately measure optic nerve sheath diameter after brief training, suggesting new ways for qualified personnel to measure intracranial pressure [13]. These studies combined suggest trained, non-physician personnel can use portable u/s equipment in several scenarios.

Teleradiology

Another appealing use of u/s technology is its ability to share images in real-time remotely. U/s image transmission is possible using satellite and low bandwidth internet connections. One simulated disaster scene demonstrated that video data of FAST exams could be sent through commercial cellular telephones >150 miles away in <90 seconds, [14] suggesting trained interpreters can be reached from remote locations. Also, as technology allows for reliable imaging transmission to receiving hospitals, specialized u/s training can be given to prehospital providers, allowing receiving hospitals to remain fully staffed to be better prepared for MCIs [3].

With the increased utility of u/s, teleconsultation through image transmission will likely possess future implications in humanitarian and combat casualty scenarios. Teleconsultation modalities include a vest with wireless live-video communication, global satellite systems, and ambulances with local area networks [15]. Several transmission modalities exist, each with their unique advantages and disadvantages. Factors such as weight, portability, clarity, accuracy, power source, cost, and bandwidth must be considered when choosing a modality for the mission [15].

Conclusion

U/s systems have come a long way from bulky machines that were glued to the radiology department. To meet military demands, u/s devices have evolved to be handheld, battery-operated, and capable of withstanding extreme temperatures and altitudes. POCUS is a reliable tool to assist in triage, screening, and management of patients with medical issues common in deployment.1 As medical technology improves, u/s will continue to be an invaluable tool for quick, reliable patient care during military deployments. Because of military needs, u/s has grown to be a valuable piece of imaging technology in deployment settings.

Conflict of Interest

The authors disclose no conflicts of interest.

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