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Demonstration of novel, secure, real-time, portable ultrasound transmission from an austere international location

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Abstract

There is not sufficient access to medical care or medical expertise in many parts of the world. An innovative telemedicine system has been developed to provide expert medical guidance to field caregivers [who have less medical expertise but can reach the patient population in need]. Real-time ultrasound video images have been securely transmitted from the Dominican Republic to Hackensack University Medical Center, Hackensack NJ (HackensackUMC), while the expert physician at HackensackUMC maintained direct voice communication with the field caregiver. Utilizing a portable ultrasound machine (Sonosite) integrated with portable broadcasting device (LiveU), extended Focused Assessment Sonography in Trauma (e-FAST) examinations were performed on healthy volunteers and transmitted via the local cellular network. Additionally, two e-FAST examinations were conducted from a remote location without cellular coverage and transmitted via broad ground area network (BGAN) satellites. The demonstration took the technology "out of the lab" and into a real life, austere environment. The conditions of the Dominican Republic ultrasound mission provided experience on how to manage and utilize this innovative technology in areas where reliable communications and medical coverage are not readily available. The resilient transmission capabilities coupled with the security features deem this portable Telesonography (TS) equipment highly useful in the telemedicine forefront by offering healthcare in underdeveloped areas as well as potentially enhancing throughput in disaster situations.

Introduction

As part of a larger study, this arm demonstrated transmission and communication success from a remote, international location. The austere environment of the Dominican Republic simulated a mass casualty environment as well as represented the lack of resources available in an under developed nation. Due to the remoteness of many under developed areas, it is difficult for doctors to provide the necessary medical attention. The telesonography equipment bridges the distance in healthcare by interfacing a mobile ultrasound machine with transmission technologies to provide real-time ultrasound examinations.

Similar to areas with minimal healthcare access, disaster situations often have a high demand for portable, on-scene care. Acute trauma, which is one of the leading causes of morbidity and mortality in the United States, requires immediate attention, diagnosis and care.[i] Most importantly, the first hour, often termed the "golden hour" is crucial in terms of survival for those suffering from acute trauma.[ii] The Focused Assessment with Sonography in Trauma (FAST) has been shown to save time during the golden hour by helping physicians accurately diagnose acute abdominal trauma.[iii]

The quality, live ultrasound transmissions offered by this technology provides immediate patient care to those with acute trauma as well as medical care in isolated areas. The transmitted images, whether by cellular or satellite networks, are securely delivered, in real-time to the physicians who have the expertise to best determine patient care.

Methods

Overview of Study Design

The design of this study is patterned after the work of Sibert et al.[iv] Real-time ultrasound images were securely transmitted from the austere scene to a specialist or additional doctors at a base location.

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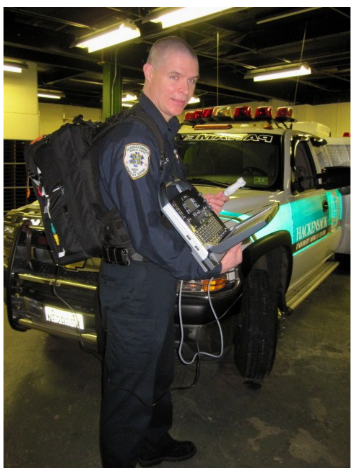
Throughout the entire e-FAST exam, two way voice communications allowed the doctors in both locations to communicate. The on- scene e-FAST exams were performed by an ultrasound trained physician (UTP). A UTP has received additional training in emergency ultrasound. Additional UTPs acted as evaluators using the validated Questionnaire for User Interaction Satisfaction (QUIS), which evaluates the images based on their quality, resolution, and detail.[v]

The size and mobility of the ultrasound machine along with transmission equipment can be seen in Figure 1.

Figure 1- *The portable system consists of a LiveU Transmission equipment backpack with Sonosite portable ultrasound machine.*



Study Setting and Participants

This demonstration was conducted in two locations; near Dabajon, Dominican Republic and HackensackUMC. The study participants included six healthy subjects of varying height, weight, age and gender. The ten UTPs who evaluated the images included Emergency Department Physicians, Radiologists and Trauma Surgeons.

Recruitment and Informed Consent

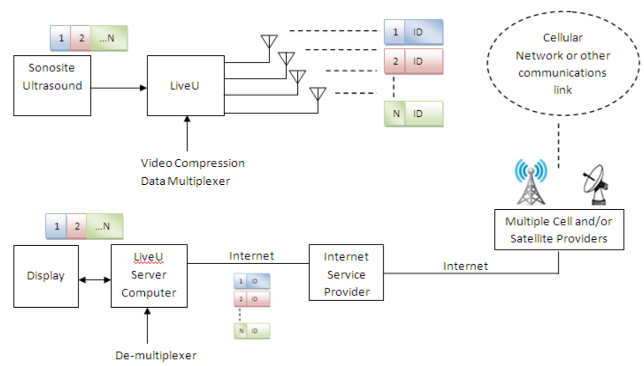
This study was approved by the HackensackUMC Institutional Review Board. All participants in the demonstration have been familiarized with the protocol and have provided written informed consent.

Telemedicine Equipment

A Sonosite M- Turbo portable ultrasound system by (Sonosite Inc.) was equipped with a C 15/4-2 m Hz transducer for e-FAST abdominal exams.

The Sonosite medical ultrasound unit supplied analog video to the LiveU unit where it is converted to a digital video stream. The stream of digital words representing the video is then compressed and multiplexed to multiple communications pathways; the number of pathways varies depending on availability. Pathways can consist of cellular data channels, WiFi, Ethernet/LAN, satellite data links, etc. This multiplexing multiplies available bandwidth and is accomplished by tagging digital data with identifiers for re-assembly at the receiving station.

Figure 2- *Illustrates a top-level block diagram of the overall system.*



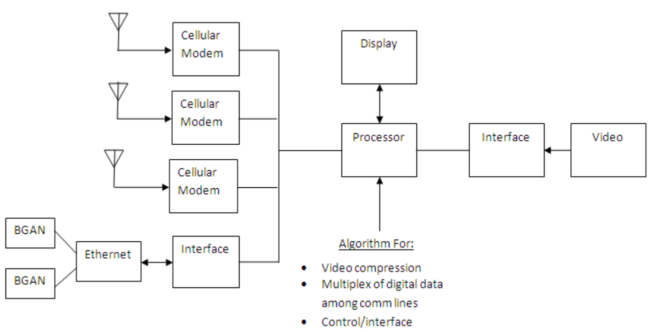
The telesonography system utilizes proprietary technology by LiveU Corporation (Hackensack, New Jersey), developed for high quality remote video transmission in the broadcast industry. This technology integrates multiple broadband channels to ensure exceptional, continuous high quality transmissions in almost all environments. Additionally, the transmissions are secure because of the advanced algorithms used in the transmission technology. The real time ultrasound image is divided, parceled, and transmitted over multiple channels, and recompiled at the base location where a server equipped with advanced digital signal processing capabilities recompiles the signal to produce a quality ultrasound image. The image is then displayed on a monitor at the hospital for a UTP or specialist to review in real time while they are in voice communication with the ultrasound operator in the field. If necessary, an HD video camera can also be interfaced to provide the base location with video of the scene.

The unit contains interface devices for multiple communications pathways including cellular, Wi-Fi, Ethernet, BGAN satellite, etc.

A processor in the unit coordinates operations including analog to digital conversion, video compression, multiplexing digital video to multiple communications channels, and management of the communications channels. The LiveU unit is now in use in over 60 countries across five continents and is used in covering major news and sports events.

In addition to the ability to transmit via multiple cellular networks, the transmission technology can interface with BGAN satellite terminals. Multiple BGAN satellite terminals (Hughes 9201), which are the size of an average laptop and each weighing 6.2, can be integrated to provide transmission connection in the most austere environments. When cellular service is not available – whether it is due to a disaster or remoteness of location—dual BGAN terminals provide the connection to transmit live ultrasound images as well as satellite voice communication. An overview of the transmission system can be seen in Figure 3.

Figure 3- *Illustrates a top-level diagram of the LiveU unit*



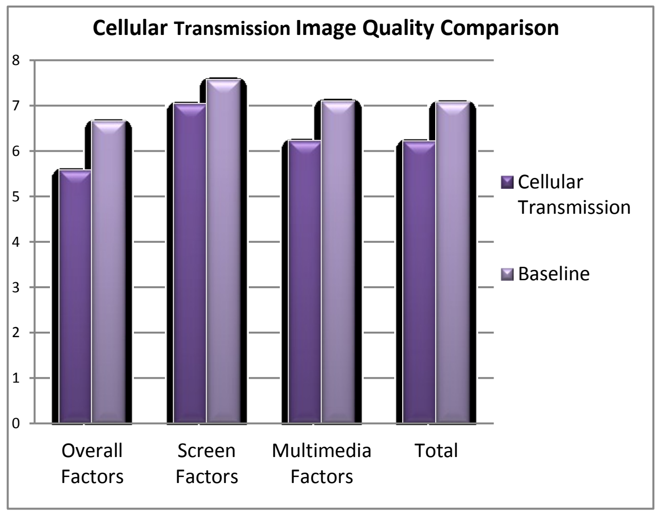
Data Collection and Demographic Data

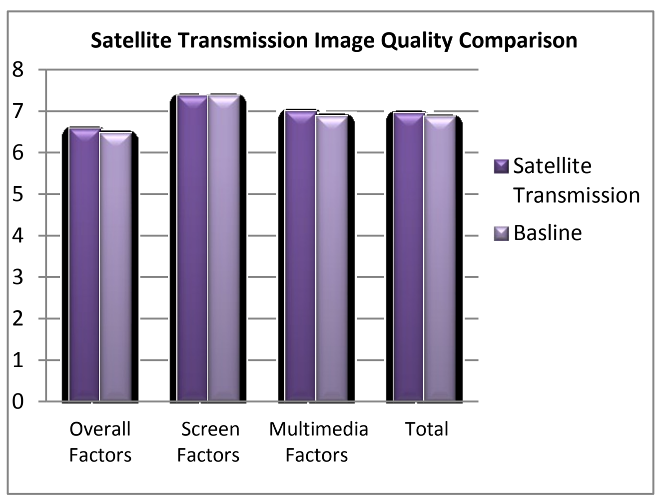
At the time of entry into the study, volunteers completed a demographic questionnaire that provides information including their age, gender, and exact height and weight. This information did not include any patient identifiers and was used to determine Body Mass Index (BMI).

Sonographic Data and Evaluation

Six pre-determined e-FAST images of different regions of the body (left and right chest, hepatorenal, splenorenal, suprapubic, cardiac—parasternal long axis or subxiphoid) were obtained, and transmitted via the telesonography system to the hospital for storage in the hospital servers. A second set of e-FAST images were obtained and recorded on the ultrasound machine at the base location to serve as a controlled comparison. The usability of these images will be evaluated by UTP evaluators using the validated QUIS questionnaire. The evaluators will be blinded and will be rating the two sets of images based on quality, resolution, and detail.

Results





Figures 4 and 5- *Descriptive statistics are reported as means with standard deviations for items and QUIS scale scores. Paired samples t-tests determined if ratings differed between the baseline and transmitted conditions. The same raters were used in all conditions. All raters were trained in* *the e-FAST exam. Mean years of rater medical experience of 19.2 and a standard deviation of 10.3. Internal consistency of our QUIS questionnaire subscales by the evaluators was high and therefore reliable.*

Coefficient Alpha

Scale	Condition		
	Subject	Transmitted	Base
Overall Factors	Cellular	0.943	0.959
	Satellite	0.986	0.983
Screen Factors	Cellular	0.620	0.529
	Satellite	0.773	0.878
Multimedia Factors	Cellular	0.948	0.938
	Satellite	0.973	0.985
Total Scale	Cellular	0.949	0.945
	Satellite	0.975	0.984

Discussion

The Telesonography System successfully transmitted real-time, secure ultrasound images across multiple cellular and satellite networks from an austere environment. The successful integration of the BGAN satellites provided image transmission and voice communication in a simulated national disaster model. With regard to the clinical diagnostic ability, this system will allow real time, secure Telesonography to aid in the emergency evaluation of victims of blunt trauma, orthopedic extremity injuries, or anyone who is suspect of having certain conditions or illnesses that require urgent attention, such as those involving: cardiac, gallbladder, gyn and other abdominal/ chest areas. Likewise, x-ray images may be transmitted securely and in real time so that they may be viewed, and discussed with radiologists, orthopedists and other medical experts who are located remotely from the rescue scene.

Its unique transmission technology will provide for secure cellular communication. It will provide cellular service across several carriers (instead of one carrier), allowing for broader bandwidth, which reduces the risk of dropped or weak signals, as well as permits the sending of more detailed, higher quality pictures. This system will also enable ready connection to any other available internet modalities such as LAN/WAN, cable/optical fibers, and Wi-Fi.

The HackensackUMC Emergency Trauma Department Research Team has developed the use of LiveU—cutting edge technology that was originally developed for the broadcast industry—and has adapted it for medical rescue. This greatly advances the diagnostic capabilities of a medical team, while saving design and development costs. Today, for a reasonable cost, this system could substantially augment medical care in remote locations and mass casualty incidents.

Future Outlook

This system can include the addition of a high definition (HD) video camera—specifically designed for dermatological use—which can be used to evaluate a patient who presents with an unusual rash or burn. In addition, other diagnostic devices such as an otoscope, ophthalmoscope, portable radiologic imaging devices, general use HD video, etc. can be added in the future. Other clinical applications would include remote expert consultation in evaluation of conditions such as Traumatic Brain Injury (TBI).

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