A Novel Approach to Tele-Echocardiography Across the Pacific

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Abstract

Telecardiology provides remote delayed interpretation of echocardiographic images through a store and forward program between the interpreting center, Tripler Army Medical Center, Honolulu Hawaii, and the image acquisition center, Guam Naval Hospital, Guam USA. This routine store and forward system has inherent delay, limiting application for management of acute medical conditions. In this case report we describe a novel methodology for real-time echocardiograpic interpretation methodology integrated methodology with the eICU® system (VISICU Inc., Baltimore MD). This case report demonstrates the feasibility of a clinically relevant remote real–time echocardiographic interpretation strategy, utilizing commonly available equipment.

The growth of technology and its increasing ability for high volume data transmission is leading to an expansion of medical services via telemedicine. Many centers in remote locations have access to experts through video conferencing. Telecardiology in its simplest form involves telephonic consultation with an on-site physician relaying pertinent history, physical examination, and laboratory data, along with facsimile transmission of an electrocardiogram. In recent years the technology has advanced to include transmission of digital echocardiograms to assist in diagnostic evaluation. Tripler Army Medical Center (TAMC), a 250-bed tertiary care medical center located in Honolulu, Hawaii, has established a telehealth consultation service with the U.S. Navy Hospital (USNH) in Guam. This USNH is a forward deployed 30-bed hospital with six intensive care unit beds. Daily consultation rounds are held by physicians from the two facilities over a distance of over 3,300 miles using the eICU® solution (VISICU, Inc, Baltimore, MD). Typically these consultation rounds are held between general internal medicine or family medicine specialists at USNH Guam and critical care specialists at TAMC.

The eICU® system transmits and receives high volumes of video, audio, and primary physiologic monitoring data over Terrestrial-1 (T1) lines at a rates of up to 1544 kbits/second (Figure 1). This allows for high-resolution videoconferencing with video patient assessment. Additionally, real-time physiologic data, digital radiographic images, and electronic patient records are accessed via this system. The system is FDA 510(k) approved for marketing and is Health Insurance Portability and Accountability Act (HIPAA) compliant. The connection between these two facilities in Guam and Hawaii spans over 3800 miles, the greatest distance that has been reported using this technology.

Since 2001 TAMC has utilized a "store and forward" telecardiology system with the USNH Guam. Echocardiograms performed on a routine basis in Guam are batched and transmitted to TAMC. Echocardiogram MEPG video images are forwarded over T1 lines, with transfer rates up to 1.54 Mbits/sec, and the NIPRNet (the "uNclassified but sensitive Internet Protocol Router Network" of Internet protocol routers used by the Department of Defense) for interpretation by TAMC cardiologists (Figure 2). Due to large file size (each echocardiogram is approximately 90-120 MBytes), file transfers only occur during off-duty hours, when there is reduced network traffic, to increase the efficiency of the synchronous transmission and decrease the loss of potentially vital information. Optimum transfer times occur from 00:00 to 06:00 Hawaii Standard Time and take between 10.8-14.4 minutes for complete file transfer. Given these constraints, there is an approximately 24-hour lag time for interpretation.

We report a unique application of the eICU® system, our initial attempt at a novel mode of tele-echocardiography. This telehealth consultative service link was employed in the care of a 55-year-old man with a history of prior myocardial infarction, prior percutaneous coronary intervention with unknown results, depressed left ventricular (LV) ejection fraction 25-30% in Feb 2004, hypertension, and cerebrovascular accident, who presented with chest pain. His symptoms were intermittent for 2 days, consisting of chest discomfort with a burning or tightness quality with radiation to the throat and left chest and arm, associated dyspnea, nausea, and diaphoresis. These symptoms were relieved with sublingual nitroglycerin.

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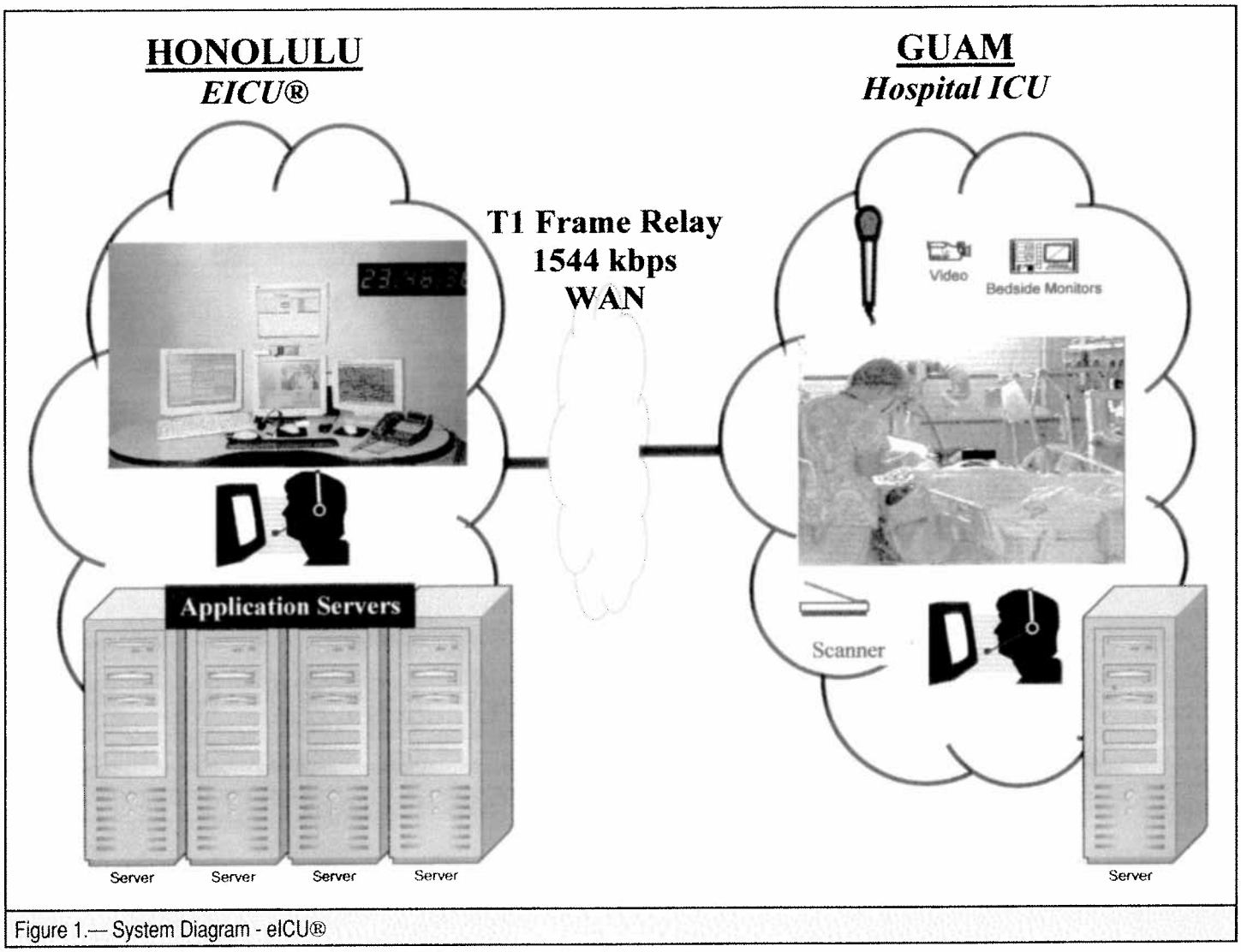

Figure 1.— System Diagram - eICU®

Upon evaluation in the emergency department, he was hypertensive to the 180s-190s/100s-110s, ECG without ischemic changes, showing normal sinus rhythm with 1st degree AV Block, and left ventricular hypertrophy. There was mild troponin I elevation to 0.68 ng/ml. During his hospital admission he had recurrent chest pain and was treated with intravenous nitroglycerin and morphine. Blood pressure and heart rate were controlled. The clinical presentation was consistent with demand related ischemia and due to his prior diagnosis of depressed LV function urgent cardiology consultation with echocardiogram was requested to evaluate current LV function and potential wall motion abnormalities to diagnose active myocardial ischemia.

At the USNH Guam in an eICU® monitored critical care bed, an echocardiogram was performed by an experienced technician, with the video camera (resolution 768 x 492 pixels) focused on the echocardiogram screen. There was real-time interpretation by a cardiologist in the TAMC e-ICU®, demonstrating preserved left ventricular systolic function with an ejection fraction of 50%, mild left ventricular hypertrophy, and an inferior and inferoseptal wall motion abnormality. Prior to the real-time bedside echo, physicians were hesitant to use negative inotropic agents due to the prior diagnosis of depressed LV function with EF of 25-30%. The echocardiographic interpretation facilitated tailored medical management of hypertension. His symptoms improved with better blood pressure control and he was later risk stratified with a myocardial perfusion study, which showed a moderate-sized fixed transmural inferior wall defect compatible with prior infarction and consistent with the wall motion abnormality identified by our real-time echo. The same echocardiogram was then stored in the usual fashion and forwarded to TAMC for official interpretation. The final report of the echo was consistent with that of the initial live interpretation.

The e-ICU® has not been used for "real-time" echocardiogram interpretation previously. Although there was "real-time" interpretation of this echocardiogram, the equipment used has not been validated for use with tele-echocardiography. We acknowledge there are potential limitations with our current system. The capture rate of the camera, 32 frames/second (fps), is less than our current frames rates used to store and forward. Second, the gain required to make the image interpretable for live interpretation was significantly higher than our usual settings. In this case there was no appreciable difference in the interpretation of the live vs. store and forward echocardiogram; however, a subtle wall motion abnormality may have

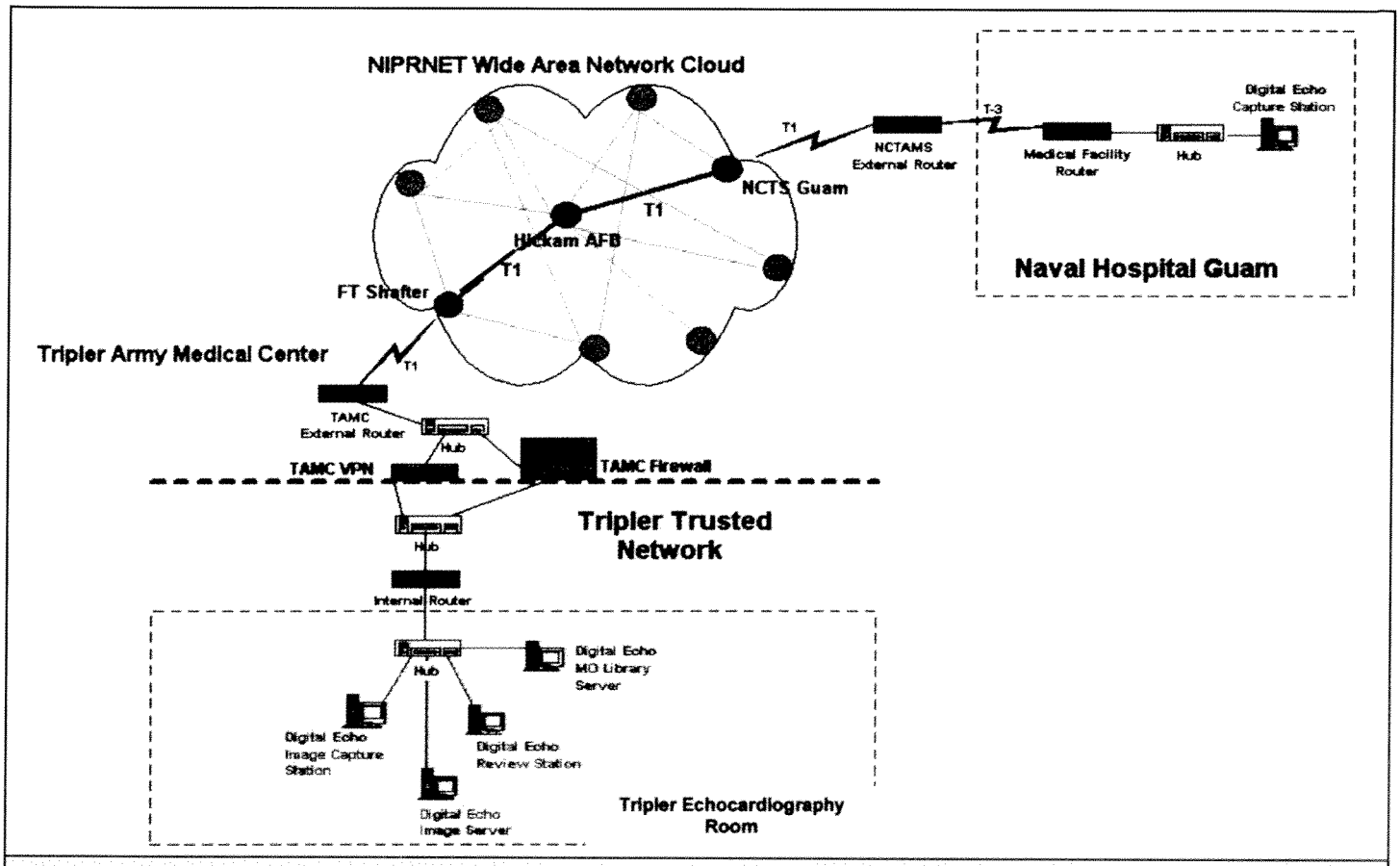

Figure 2.— Digital Echo-Cardiography-Tripler to Guam

been missed at this frame rate. While stationary structures such as pericardial effusions could be identified with our current real-time settings; the evaluation of mobile structures such as vegetations or contrast studies using agitated saline would require high resolution images with at least 60 fps for the most accurate evaluation.

Digital streaming video at the highest resolution and frame rate is not feasible at this time. Our current store and forward system uses MPEG-2 (Motion Pictures Expert Group) compression technology for a ratio of up to 50:1. Higher compression rates would decrease the file size and allow faster transfers, but may lead to further degradation in image quality that we have not explored. While the data lost may not be critical, this nonetheless remains an identified limitation. Another possibility is a directed echocardiogram, with short segments batched and then forwarded for interpretation. With these limitations stated we still remain optimistic about offering real-time echo for critically ill patients and hope to expand our services.

The potential applications for telecardiolgy is expansive. Adults and children with suspected or known heart disease are frequently cared for in remote intensive care units, emergency rooms and newborn nurseries, without immediate availability of cardiologists or other specialty trained providers. Essential information can be obtained via echocardiography including determination of congenital heart disease in neonates, pericardial effusions, severe valvular disease, wall motion abnormalities, and overall cardiac function[1]. In 1996, Trippi et al[2] investigated the clinical utility of interpreting after-hours urgent adult echocardiograms by an experienced technician through a telemedicine connection to on-call cardiologists. This study used standard telephone lines (14.4 Kbps) transmitting images to home laptop computers, and found 96-99% correlation in interpretation. There also was a decreased time for interpretation from the average 11.7 hours with the traditional method, to 2.1 hours with telemedicine. A Norwegian study evaluated remote echocardiography performed by an inexperienced technician or physician under the tele-guidance of specialist and found similar results between the remote exam and any repeat exam under normal circumstances[3]. This reliability will allow smaller hospitals to have access to specialist diagnostic capability.

In remote regions with widely dispersed populations networks of telemedicine have become essential to providing access to specialist care. These practices have been evaluated and found to be cost effective due to decreased hospital time and avoided transport costs. To a large health care system, these practices save money and time as well as extend care. The military and NASA are interested in using telemedicine to provide better care to their members and are in a unique position to do so because they already have many remote facilities that have excellent communications equipment but are limited in medical personnel. These techniques will allow specialist guidance and interpretation from the Space Station, the Antarctic base, or from forward deployed military units. As technology continues to improve and costs fall, expansion of these services and methodologies to additional applications of medical care seems inevitable. The specific technology is only important as far as questions of image and transmission quality, compatibility,

and reliability are concerned. These telemedicine services are provided using internet lines, ISDN lines, dedicated cables, and even with satellite phones[4]. Obstacles remain, however, with different formats, different standards, and many questions about legal and regulatory issues. As our initial attempt at real-time tele-echocardiography we acknowledge the potential technical and regulatory limitations of our approach, and are optimistic about improving the system and continuing to offer these servicies to patients across the Pacific Ocean.

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