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Remote, Synchronous, Hands-On Ultrasound Education

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Abstract

Background: Ultrasound has become a major diagnostic tool in many parts of the world, with broad clinical applications. Ultrasound provides a noninvasive, painless mode of diagnostics that produces instant results. Disseminating ultrasound skills to remote and rural communities has become a challenge for many medical schools, particularly those where distances are great and the density of population is low. Materials and Methods: The University of California, Irvine School of Medicine and the University of New England School of Rural Medicine in Australia piloted the use of dual video feeds in two scenarios: (1) to display the instructor's ultrasound feed and the instructor's transducer placement to provide guidance for remote students; and (2) to display side-by-side views of the instructor's and the remote student's ultrasound feeds to allow the instructor to guide the remote student in his or her transducer placement. Results and Conclusions: Using high-speed broadband connections, the two schools demonstrated the feasibility of remote, synchronous, practical, and hands-on ultrasound training and instruction over international distances. This opens up a broad range of possibilities for future remote ultrasound education.

Key words: telementoring, ultrasound, remote, medical education

Introduction

Ultrasonography is an important diagnostic modality that is now an integral part of many, if not most, clinical specialties and subspecialties. It is recognized that ultrasound provides a noninvasive, painless mode of diagnostics that provides instant results. Ultrasound has particular applications in rural and remote environments[1] where access to hospitals and clinicians is often limited. Although the feasibility of remote diagnostic applications of ultrasound has been well demonstrated,[2–4] including relay of images from the International Space Station,[5] the practicality of remote hands-on instruction and teaching has not been reliably established; however, it has been successful in addressing some of the unmet educational needs of rural and remote Australian doctors.[1]

Disseminating ultrasound skills to remote and rural communities has become a challenge for many medical schools, particularly for those where distances are great and density of population is low. This challenge can be attributed in part to two underlying issues that have been identified as barriers to remote ultrasound instruction. The first issue is the wide variability in the delivery of ultrasound education in general.[6] For example, although comprehensive guidelines for ultrasound education in emergency medicine have been established by the American College of Emergency Physicians, Ahern et al.[6] found that many programs fell short of the required 150 ultrasound exams, and only 54% of programs "felt they were meeting all their goals for resident [Emergency Ultrasound] education."

The second barrier to remote ultrasound education is that ultrasound education requires not only a didactic component, but as well a complementary hands-on instruction in the practical skills of ultrasonography. It is not possible to learn ultrasound through didactic measures alone. The art of placing a transducer on a patient and generating a perfect image can only be learned through a rigorous hands-on curriculum that involves expert instruction in how to manipulate the transducer. However, achieving active, hands-on experiences can be ambitious in remote and distance-learning environments. This is because of a variety of reasons, including technical, infrastructure, and financial limitations. Furthermore, although remote videoconferencing and remote instruction by lecture format have been well established,[7] the pedagogical training needed to promote the effective use of synchronous videoconferencing has been inadequate, with institutions relying on faculty to be self-taught. Accordingly, integrating a hands-on aspect to remote instruction creates further technical and pedagogical complexity that often goes unaddressed.

To address these barriers to remote ultrasound instruction, the University of California, Irvine School of Medicine (UC Irvine) and the University of New England School of Rural Medicine in Australia (UNE) have collaborated in a pilot program investigating the use of high-speed broadband connections, validated pedagogical lessons and remote hands-on ultrasound experience.

UC IRVINE

UC Irvine is located in suburban Orange County, California, the sixth most populous county in the United States.[8] The Medical School is an Liaison Committee on Medical Education–accredited institution that educates more than 400 students and trains more than 600 residents annually.

In August 2010, UC Irvine became one of the first medical schools to launch an iPad® (Apple, Cupertino, CA)-based curriculum through the iMedEd initiative, the goal of which is to transform learning with a digital, interactive environment.[9] UC Irvine was also one of the first to create a 4-year integrated ultrasound curriculum. Publicly available lectures and online podcasts (in iTunesU[10]) form the basis of this curriculum, supplemented by an extensive hands-on skills lab, a critical component of the program. First- and second-year medical students receive weekly hands-on training with expert ultrasound instructors during a longitudinal clinical foundations course. Students continue their ultrasound training during third-year clerkships and are offered a fourth-year ultrasound elective.

UNE

Remote and distance teaching have been hallmarks of the UNE, located in Armidale (population of 25,000[11]) in rural Australia, halfway between Sydney and Brisbane. The nearest major metropolitan center to Armidale is Newcastle, which is 241 miles (388 km) by road, but there are no regular flights between these two cities. Of note is that UNE is isolated, with more than an 8-h train service available once a day from Sydney to Armidale, no train service to Brisbane, and only five flights a day during weekdays available between Armidale and Sydney.

UNE maintains a focus on distance education, although some courses are exclusively delivered on-campus, including the undergraduate entry medical degree, a joint program between UNE and the University of Newcastle. The first intake of students of this joint medical program began in 2008. The students enrolled in the School are based in Armidale for the first 3 years. In the fourth and fifth years, students are on clinical placements, often in Newcastle or larger costal centers. The availability of clinicians for instruction is limited given the rural location and isolation of Armidale. The collaboration between UNE and UC Irvine, which launched in 2011, has enabled synchronous links for clinical instruction to be a regular feature of the UNE medical program.

THE UC IRVINE–UNE COLLABORATION

The UC Irvine–UNE collaboration, initially undertaken as a joint university project between the medical schools, has now developed into an international affiliation that involves synchronous virtual engagement and physical on-site visits, enabling UNE to become an international medical school in a rural setting. Specific features of the UNE educational program and initiatives include the adoption of UC Irvine initiatives, specifically, use of iPads for delivery of the medical curriculum and implementation of ultrasound broadly across the educational strata.

Although UC Irvine faculty and students have visited UNE and held on-site courses on ultrasound and simulation, initial links were made using the Australian Academic and Research network (AARnet),[12] demonstrating ease of access, quality of call, and interoperability via a public Internet protocol (IP) address. A pilot study was launched to investigate the efficacy of remote hands-on ultrasound instruction using this established videoconferencing link. The

hypothesis for this research was that a dual video stream approach with a telementoring pedagogical protocol for ultrasound instruction could effectively address the barriers to remote ultrasound instruction described above.

Materials and Methods
PARTICIPANTS

Participants in this pilot study were eight second-year medical students from UNE and faculty from both UNE and UC Irvine. The UNE students had studied anatomy, physiology, and pathology and an introduction to ultrasonography. The UC Irvine clinical faculty member who served as the instructor was a highly skilled ultrasonographer with extensive experience in ultrasound training and use.

MATERIALS

The use of dual video streams was central to the design of the remote ultrasound teaching experience. A form of expert visual guidance[13] was used to educate the UNE students. Expert visual guidance is the use of computer assistance to display to an ultrasound examiner "how the image plane moves towards (or away from) a desired anatomical location as the ultrasound probe is manipulated over the patient's body."[13,p.77] Although Sheehan et al.[13] investigated the use of expert visual guidance on a computer in a simulated tele-ultrasound session, our pilot study planned to take advantage of the ability to conduct a true tele-ultrasound session with live video capabilities from the instructor and the remote students.

Interoperable high-speed, high-definition videoconference connections between the UC Irvine and UNE sites were made possible by a multipoint control unit that allows multiple sites to connect into a single conference channel (in this case, a Codian bridge) and the video management server. The videoconference format was International Telecommunication Union (ITU)[14] standards using H.323 protocols with a videoconference server. This format is an open platform that makes it easier to add functionality to the system such as increased or external storage, firewalls, virus protection, and video algorithms and is easier to integrate with other systems. The system is fully scalable, enabling any number of network video products to be added to the system as needed.

Both the UC Irvine and UNE networks run a video subnet enabling open videoconference access between any registered port on either network or registered portable devices. Unlike other universities with a culture of risk aversion, the capability to make and receive videoconference calls is neither limited nor controlled between the two sites. The key foci are interoperability, portability, and mobility along with the pedagogical components of the sessions.

Connections between UC Irvine and UNE included multipoint connections on various devices using ITU standards-based platforms with relatively high-speed (10–100 megabits/s [Mbps] download and 2–20 Mbps upload speed). The consistent component in all connections was the standards-based codecs used by both sites and participants. A codec, derived from the words "coder" and "decoder," is hardware or software that is capable of encoding or decoding a stream of digital data. Faculty used the soft codec application Cisco

(San Jose, CA) Jabber Video (CJV) for TelePresence (Movi)[15] on devices, including PCs and Macs (Apple). The need for a standards-based connectivity that can include multipoint connections and data sharing was critical for the geographically dispersed faculty. Internet connectivity was established by local area network connection via an IP address as well as 3G wireless connectivity registered to the Gatekeeper at UNE.

Audio is also a key component of any videoconferencing connection, particularly the issue of minimizing latency (the delay in the audio signal), packet loss (the loss of some data during the connection resulting in garbled or dropped connections), and synchronization between the video and audio signal. The H.323 protocols include both audio and video standards. During this pilot study, the audio connection benefited from the high-speed, standards-based connections such that latency was minimal, as was video and audio jitter, with very little packet loss throughout the connections.

PROCEDURES

Two pilot sessions for synchronous hands-on ultrasound instruction were undertaken between UC Irvine and UNE in July and August 2012. On the first occasion, the multipoint link included a wireless 3G connection in Brisbane, Australia using CJV and a wireless connection in Sydney as part of the Remote Medical Education Conference.[16] Sites were linked to the UNE bridge and UC Irvine via an optic fiber connection. During this session, four second-year UNE students were given brief instruction on several ultrasound windows by a UC Irvine instructor using a dual video stream to enable ultrasound images to be visible to the UNE students and clinician (the UC Irvine instructor) and remote observation by the academic director. Streaming ultrasound video taken from a standardized patient via the transducer of the UC Irvine instructor was shared in the first video stream. In the second video stream, the handling of the ultrasound transducer on the standardized patient's skin by the UC Irvine instructor was visible to the UNE students (*Fig. 1*).

After receiving instruction from the UC Irvine instructor, the UNE students asynchronously demonstrated their ultrasound competency on a local standardized patient. UNE students used a dual video stream to transmit a video stream from their ultrasound feed and a video stream transmitting their transducer placement on the body. This resulted in the UC Irvine instructor being able to give real-time feedback on the image quality and probe mechanics for each sonographic window. UNE students rotated on using the transducer with the standardized patient so that each student received one-on-one telementoring and feedback throughout the process from the UC Irvine instructor. The latency in the connection was minimal, although there were issues with the dual video feeds for each ultrasound device, particularly with a public IP connection that was not at guaranteed rates of connection speed.

On the second occasion, connectivity was accomplished via AARnet rather than a public IP connection. More significant is that the pedagogical protocol was extended to include synchronous side-by-side expert and novice ultrasound images to the instruction, again taking advantage of dual video streams. Prior to this second session, the UNE students were instructed to watch video podcasts on iTunesU[10] created by the UC Irvine instructor on a range of ultrasound scenarios, including cardiac, renal, and liver windows. During the session, four second-year UNE students received instruction remotely from a UC Irvine instructor while contemporaneously using the ultrasound transducer on a standardized patient in Armidale. The protocol was conducted in a stepwise fashion, where the UC Irvine instructor demonstrated the various ultrasound windows covered in the podcasts on a standardized patient. The first video stream from the UC Irvine instructor showed a real-time ultrasound video of an organ that was simultaneously viewed at both locations. The UNE student was then instructed to produce an ultrasound video stream matching that of the instructor's ultrasound video. This synchrony between the two locations provided the UNE student a side-by-side comparison so that the UC Irvine instructor could offer specific, real-time, and relevant feedback to the remote student such as how to adjust the angle or position of the transducer to capture a matching image (*Fig. 2*). UNE students rotated through the scenarios and received one-on-one telementoring and feedback from the UC Irvine instructor. Briefing and debriefing sessions were held with the
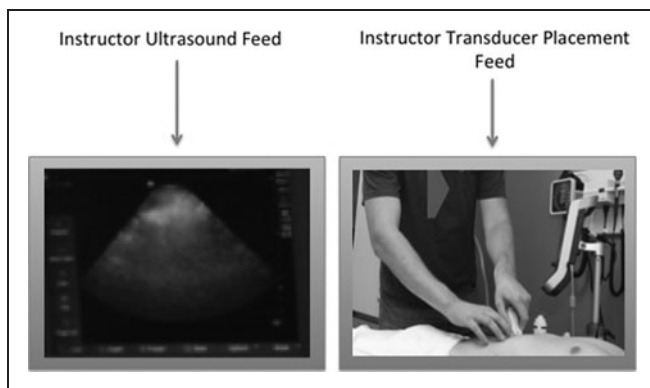
Fig. 1. Dual-feed expert visual guidance using tele-ultrasound.
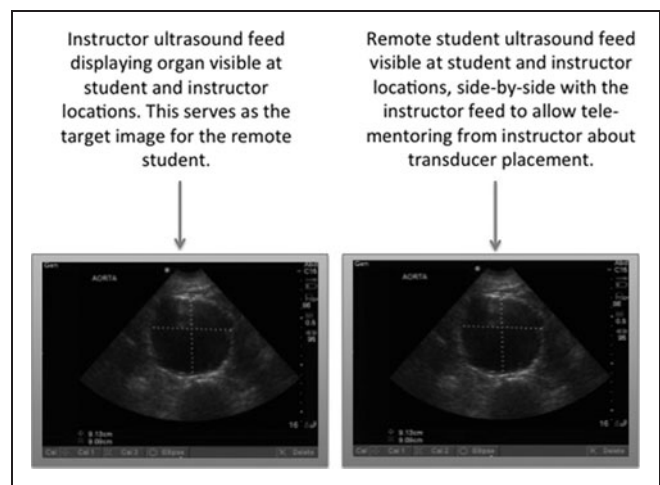
Fig. 2. Dual-feed synchronous ultrasound telementoring.

students and UNE faculty in conjunction with the UC Irvine ultrasound instructor.

Results

The instructor and student feedback from the pilot sessions demonstrates that the use of dual video feeds present a viable approach to remote hands-on ultrasound training and instruction over international distances. The UC Irvine instructor reported that setting up the dual-feed system was relatively easy: the video output of the ultrasound machine was connected to the codec for one video feed, and a video camera (which was directed on the instructor's transducer placement) was also connected to the codec to provide the second video feed. Videoconference connections were tested days prior to the scheduled teaching session and again immediately before the scheduled teaching session.

The instructor also found that teaching with the dual video feed system was similar to the experience of teaching hands-on ultrasound skills in front of a normal classroom:

> One needs to ensure that the camera can capture the probe movements and angling across the body. During the teaching process, it is necessary to wait for the receiving audience to attempt the ultrasound window on their own for up to 15 seconds. If unsuccessful then I can draw their attention to my probe hand explaining how I think they should move their transducer. This is essentially the same as teaching at the front of a classroom.

The instruction was further enhanced by the use of standardized patients at both sites, giving the students additional feedback and a comparative image to guide and promote the learning objectives. Students subsequently involved in remote hands-on instruction responded positively in an informal survey:

> It was great to do the scan practically rather than having the method just mentioned…helps consolidate book learning when you see it for yourself and do it myself. (UNE Student 1)
> It was great to be able to compound learning by hands on practical session!! (UNE Student 2)
> Great to have some hands on practice—especially with 2 different [patients] because their organs look really different so it helps to build your skills. (UNE Student 3)

Discussion

This research attempts to address two of the barriers to remote ultrasound education: (1) inconsistent ultrasound instructional objectives and (2) the difficulty of achieving a hands-on ultrasonography skills learning component. The first barrier can be addressed as pedagogically sound ultrasound scenarios and assessment methods mature. The use of video podcasts to share ultrasound didactics is one effort toward this end. However, limited thought is being given to the barrier of hands-on learning and virtual delivery mechanisms, even though the emphasis on telemedicine, telepsychiatry, and telesurgery

continues to increase.[17,18] Minh et al.[19] highlighted not only the growing use of telemedicine, but also the portability and mobility of devices and soft codec applications that include Vidyo™ (Vidyo, Hackensack, NJ) and other proprietary products. Consistent, however, is the push for use of standards-based applications, which in some universities had been lacking, as video components were purchased for learning management systems that are not interoperable or ITU standards-based, leading to islands of connectivity. If medical educators can positively engage with the opportunities that telemedicine can provide and institutional infrastructure is made available to support standards-based remote learning, the benefits of this pilot study can be better realized.

LIMITATIONS

An obvious limitation of this remote instruction is that it does require significant technical support in the initial phases of set-up and stable high-speed links. For example, after establishing successful multisite connectivity on the first occasion of this pilot, the video link to the Sydney convention hotel dropped out after some video streaming was started in an adjacent conference hall. Fortunately, the links between UC Irvine and UNE were not lost. This demonstrates the fragile nature of wireless connectivity, particularly in public or commercial spaces, and the need for networks managers to ensure that any wireless connectivity includes increased density of use.

Another technical limitation is that setting up the dual video feed scanning stations can only be replicated if the proper equipment is obtained. This includes a scanning table, videocameras capable of panning, zooming, and tilting (preferably at least two), and an ultrasound machine with video output capability at each site if showing side-by-side instructor and student images is desired.

Furthermore, multiple picture-in-picture viewing on large screens is especially effective for the pedagogical protocol. Although it is essential to have the ultrasound images from the two sites displayed side-by-side, it is also important to have camera views of the participants at both sites. A student can quickly and effectively adjust the probe if he or she can see both ultrasound images and how the instructor is manipulating the probe. Similarly, it is important for the instructor to have these same views to provide appropriate guidance to students.

Conclusions

Remote reading of ultrasound images for diagnostic purposes has been well documented. This study, however, has also demonstrated the potential for remote synchronous hands-on skills development in ultrasound and helped to understand the technical and pedagogical methods to approach this type of instruction. Future research on the dual video feed approach that includes outcome measures such as the System Usability Scale[20] from a larger sample of medical students is planned and will better inform educators on the feasibility of remote ultrasound instruction.

Disclosure Statement

No competing financial interests exist.

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