Audiology Telepractice in a Clinical Environment: A Communication Perspective

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Access to adequate hearing health care is an obstacle that many individuals face worldwide. The prospect of providing audiology services via the Internet is an attractive and viable alternative to traditional face-to-face interaction between patients and audiologists, thus affording improved access to hearing health care for traditionally underserved populations. This article details our experience of using a web-based system with wireless audiometers and videoconferencing software to administer remote audiological assessments in an active medical practice. It discusses the technological infrastructure used and the pragmatic issues that arise when the Internet, Bluetooth wireless audiometers, and videoconferencing devices are converged into a clinical setting. Patients at a local office of otolaryngologists were recruited to participate in a study in which remote assessment results were compared to those collected from a traditional face-to-face assessment. Preliminary data demonstrated that the assessment results from the two sources were comparable. We conclude that remote hearing assessment over the Internet can be achieved through a distributed system synthesized with Internet, wireless communication, and videoconferencing technologies, supported by appropriate staff.

Key Words: audiology, otolaryngology, telemedicine.

INTRODUCTION

Telemedicine is a form of health care that has been in existence for decades, yielding published results in areas including, but not limited to, dermatology, radiology, and psychiatry. More recently, telepractice has been applied to the diagnosis and treatment of communication disorders. The inability to effectively communicate with one’s surroundings is a struggle that some individuals face on a daily basis simply because they have limited or no access to hearing health professionals. In audiology, as in many other health professions, there is a gap between those needing services and those providing services. According to the World Health Organization, it was “estimated that in the year 2005 there were 278 million people in the world with disabling hearing impairment” and “a further 364 million people were estimated to have a mild hearing loss.” These staggering numbers provide a catalyst for the need to develop infrastructure and plans to effectively assist these individuals with hearing needs even when hearing health professionals cannot provide services face-to-face. As stated by the American Speech-Language-Hearing Association, the opportunity that telepractice can provide to these individuals could open doors to the hearing world, as well as ensure that “the quality of services delivered via telepractice are consistent with the quality of services delivered face-to-face.” Some areas of research focusing on providing audiology services via telepractice include video-otoscopy, auditory thresholds, hearing screenings, impedance measurements, distortion product otoacoustic emissions (DPOAEs), auditory brain stem response testing (also Campbell and Hyde, unpublished observations), cochlear implant programming, and the administration of the Hearing in Noise Test (HINT).

East Carolina University (ECU) has been developing and conducting research on telepractice in the audiology field for many years and has continually worked to develop better and more accessible systems. In 2003, Givens and Elangovan introduced a system that was able to administer pure tone air and bone conduction audiometry by remotely manipulating a standard audiometer via the Internet. Elangovan described a similar study, also performed at East Carolina University, that tested the feasibility...
of assessing DPOAEs by remotely manipulating a computer that housed the required testing software. Reportedly, these researchers collected comparative data for both the pure tone audiometry results and the DPOAE results on site and from a distant location.

More recently, a web-service based system that could potentially support a subscription model was developed at ECU through a partnership between the Department of Communication Sciences and Disorders and the Department of Engineering. This web-based system was developed to serve as the medium to conduct audiological assessments via telepractice applications specifically through the use of the Internet.

AUDIOLOGY TELEPRACTICE IN CLINICAL ENVIRONMENT

At present, an effort is ongoing to identify possible networking and operational issues in implementing the web-based service system in a clinical setting, as well as documenting the feasibility and reliability of such a system.

The discussion below relates to this ongoing effort relative to technological infrastructure and pragmatic issues that were encountered with the networking system, as well as preliminary results.

Description of Web-Based Audiology Telepractice System. A detailed description of the web-based system can be found in previous publications. In brief, the central part of the remote hearing assessment system is a web server, which hosts all application-level programs, as well as the required database (Fig 1). The web server was implemented with a three-tier architecture to improve software modularity and portability. Audiologists, who will be operating the testing application, log in to the server with web browsers through their terminal computer to operate a remote audiometer. Currently, the web server is set up as a virtual machine located in the Science and Technology Building at ECU. The server runs a virtual data-center operating system ESX with 3.5 updates from VMware Inc. The virtual machine features dual 3.4 GHz central processing units and 2 GB RAM and is set up as a Windows 2003 Pro Virtual Server. For our system, the database is implemented on the same virtual machine as the web server. For protection of the security of data exchanged between the audiologist terminal and the server, the server can only be accessed with SHTTP, the Secure Hypertext Transfer Protocol; thus, neces-
Fig 3. Remote audiologist, located at East Carolina University Telemedicine Center, has views of web-based system (far left), patient (center), and view seen by facilitator at otolaryngology office (far right).

Testing Sites and Equipment Utilized. In our current study, two sites were used to assess the web-based system. The ECU Brody School of Medicine’s Telemedicine Center served as the remote site, and a local otolaryngology office was the designated on-site location (Fig 2). By incorporating the traditional telehealth practice of interactive videoconferencing in use at the ECU Telemedicine Center, the remote audiologist in this study was able to enhance the efficacy of the web-based system addressed herein.

The remote audiologist was seated in a telemedicine room within ECU’s telemedicine suite, which was equipped with videoconferencing and Internet capabilities as illustrated in Fig 3. The Polycom videoconferencing unit (Polycom Inc, Pleasanton, California) provided encrypted audio and video transmission between the two testing sites.

A local otolaryngology office served as the on-site, or patient, location and included a facilitator (graduate student), an on-site audiologist, and a patient-participant. Equipment located at this site consisted of a Bluetooth-Ethernet gateway device (Parani 100, SENA Technologies, San Jose, California), an OTOpod audiometer (Otovation LLC, King of Prussia, Pennsylvania), and a Polycom videoconferencing unit. The Bluetooth-Ethernet gateway device and the videoconferencing system were both connected to the Internet via the otolaryngology office. This connection had no use of a server, but instead went directly to the network. The router was a Sonic Wall VPN (Virtual Private Network).

The OTOpod audiometer located on-site with the patient is an off-the-shelf product that can exchange data by use of Bluetooth telemetry, which can then be connected to the Internet through a personal computer (via EZURiO Bluetooth-USB adapter, Laird Technologies, St Louis, Missouri) or through a wireless Bluetooth-Ethernet gateway device. In both cases, the on-site facilitator is only required to power on the audiometer in order to provide remote access by the audiologist.

The videoconferencing system setup for this location was slightly different from that of a normal telemedicine encounter (Fig 4). A VSX 3000 desktop unit (Polycom, Pleasanton, California) with a video camera (Canon USA, Inc, Lake Success, New York) was connected as an alternate video source. The vid-
eo camera was mounted on a tripod located within the sound-isolated booth in which the patient-participant was seated. The remote audiologist was able to hear both the patient and the facilitator at all times. However, only one video feed could be viewed at a time. The remote audiologist was able to see the on-site facilitator or ask to be switched to the alternate camera in order for all to view the participant. Once the video source was switched, the audiologist was able to view and hear the participant during the assessment, as well as continue to privately converse with the on-site facilitator located outside the testing booth.

**Current Status.** By means of this system, participants were tested with a double-blind procedural design. All individuals were adult patients (over 17 years of age) at the otolaryngology office and voluntarily consented to participate in the research study. This study (#08-0700) was approved by the East Carolina University Medical Center Institutional Review Board. Each participant received a traditional face-to-face assessment of pure tone hearing thresholds by an audiologist at the otolaryngology office, as well as an identical assessment administered by a remote audiologist via telepractice. In this double-blind design, the testers at each site were not privy to the results collected at the other site. For example, the audiologist located at the remote site did not have prior knowledge of the thresholds determined on-site through traditional means.

Results collected at each testing site were compared for accuracy, and the test administration completion time for the telepractice portion was also reported. We are optimistic regarding the preliminary results garnered thus far (see Table). This Table displays the mean difference (in decibels), as well as the standard deviation, between the traditional and telepractice assessments for all participants at each accessed frequency. The mean differences between the two assessments were all less than or equal to 10 dB hearing level, which is considered to be clinically acceptable. The average amount of time required to complete a hearing test via telepractice was approximately 7 minutes per test administration, consistent with the time required for a traditional face-to-face assessment. Participants are still being recruited to determine any concerns, as well as to gather additional data from a larger sample.

### DISCUSSION

This novel web-based audiology telepractice system integrated web services with Bluetooth wireless telemetry and videoconferencing equipment. Although the Bluetooth-Ethernet gateway and the server have previously been studied, two additional issues were investigated when the web-based system was integrated into a clinical environment: 1) the simultaneous presence of the Bluetooth device used in the audiology telepractice system with the hearing aid programmers used in the otolaryngology office; and 2) the bandwidth demands among the web-based system, the videoconferencing traffic, and the otolaryngology office's regular Internet data transmission. This section discusses these issues and points out the necessities of a facilitator at the patient site.

**Co-presence of Bluetooth Devices.** One problem that was encountered during testing was interference of the Bluetooth-Ethernet gateway device used to connect the audiometer to the Internet with the otolaryngology office's Bluetooth hearing aid programmers. Most audiologists use wireless devices to program hearing aids, which are an integral part of many audiology practices. Ensuring no interference was crucial to the feasibility of incorporating this system. The Bluetooth-Ethernet gateway device was reprogrammed to allow connections only to those Bluetooth addresses owned by the OTOpod audiometer. Even though this solution resolved the predicament, we were forced to sacrifice system flexibility. Before an audiometer could be connected to the Internet during the initial setup, its Bluetooth address had to be preprogrammed in the Bluetooth-Ethernet gateway device.

**Video Communication.** The current study described herein utilized a Polycom VSX3000 desktop videoconferencing unit that was readily available to the ECU researchers. All of the videoconferencing units used were encrypted to maintain compliance with the Health Insurance Portability and Accountability Act. These units are also UL 60601-compliant for use in patient care environments. Site connectivity for the videoconferencing unit was obtained through ECU's network to the public Internet and then routed through the otolaryngology office's local network. The bandwidth for the videoconferencing system was set at a minimum rate of 384 ki-
lobits per second and required an Internet connection separate from the web-based testing application. This provided the remote audiologist with a smoother, more natural view of the participant’s facial and body movements.

The use of a hard–end point videoconferencing system — the described Polycom unit or one similar — is popular among many telemedicine operations, because these systems are equipped with encryption for the interactive video and audio transmissions. The systems are also scalable to the infrastructure available, but do require sufficient bandwidth to provide clear audio and video transmissions. It is suggested that if one is to consider providing audiology telepractice services, investing in a hard–end point or freestanding video conferencing system would be beneficial. On the other hand, there are further options available, including free video and/or audio conferencing software programs (soft end points) and inexpensive computer cameras, “webcams,” that can be used to provide visual and audio contact. Further research needs to be conducted regarding the reliability and feasibility of these options. Nevertheless, one must make certain that no matter the videoconferencing system and/or network connectivity chosen, it must provide sufficient encryption and/or network safeguards to ensure satisfactory privacy and confidentiality of patient information and resulting outcomes.

Internet Infrastructure. This study was conducted at a well-established university telemedicine suite and with a well-connected otolaryngology office. Although we did experience some instances in which the video and/or audio feed was affected by slow transmission and breaks in audio communication, this hindrance was transitory and resolved quickly, thus not affecting our ability to test. To further examine possible issues due to the introduction of the videoconferencing traffic, an experiment was conducted whose results showed that the audiology telepractice testing caused no concerns to regular Internet usage in the otolaryngology office for completion of typical office duties (eg, uploading and downloading images, e-mail, etc).

Few published studies in the field of audiology telepractice have been conducted in areas with potentially less-than-ideal infrastructure. Successful examples include isolated communities in Alaska, including the use of satellite transmission to conduct teleconferencing sessions. Unfortunately, satellite transmission was not deemed ideal, because it resulted in “real-time delay, audio problems, and networking problems.” A dedicated landline is presumed to provide better communication functionality.

Additional research pertaining to infrastructure requirements for the provision of audiology telepractice is needed for many settings, including but not limited to military bases and/or hospitals, Veterans Health Administration clinics and/or hospitals, residential facilities, and prisons.

Facilitator. Our current study protocol made use of an on-site facilitator. This individual, who in our case was an audiology graduate student, was responsible for obtaining participant consent, equipment setup, providing instructions, and participant management. The facilitator was also responsible for collecting the results from the participant’s traditional audiological assessment.

Even though audiological services are being provided from a distant location through technological applications, it is still advisable that a facilitator be on-site with the patient. The exact role and training level of the facilitator is an area of continuing study, but having trained personnel at the patient site is recommended, particularly for patient management and placement of diagnostic equipment, ie, correct headphone placement. Krumm et al also stated caution regarding the need for knowledgeable technical support personnel.

Economic Considerations. As with any new modifications to patient-directed care, economic considerations are paramount. There are concerns whether adopting a system like that described in this article will monetarily benefit a clinical practice. Many of the costs incurred with the proposed remote hearing assessment will be no different from those of a standard audiometric setup. Our study indicates that the Internet transmission required by this system is no more than what currently exists in most office locations, especially if digital transmission of patient data is already in use. The required facilitator can be an existing staff member or a nursing professional with certain training. These costs are minimal compared to those of a licensed audiologist spending crucial patient contact hours traveling to remote clinical locations. Instead, these trained professionals can spend this time at the primary office seeing more patients via telemedicine techniques. This system can also be economically beneficial for satellite offices of medical practitioners as a triage initiative, in that audiologists may see patients in remote loca-
tions via telemedicine and then make an educated determination as to whether these patients would be candidates for hearing aids, cochlear implants, or assistive listening devices and make the recommendation for further follow-up by patients at the audiologist's home office. This system will also reduce travel time for the audiologist and potentially reduce the need for transportation of individuals in remote locations if no follow-up audiological care is currently needed. Thus, the audiologist's time and efforts are more efficiently utilized in providing care. In addition, although the current model discussed herein is not available on the market, communications with the company who holds the license for this technology indicate that their plan is to charge a minimal monthly subscription for this service.

Another economic benefit is patient transportation. Many patients in our communities are unable to be transported to audiology centers because of medical conditions or current economic status. By use of telemedicine, the costs incurred by patients can be minimized when initial care and follow-up care can be provided in closer locations. This is particularly important for traditionally underserved rural regions in which hearing services might be obtained only after hundreds of miles of travel.

CONCLUSIONS

This report describes an ongoing effort to provide remote hearing assessment in a clinical setting. Issues encountered and addressed in this effort may occur when similar systems are implemented. These include the following.

1. Depending on the current Internet infrastructure of the potential sites, additional bandwidth and/or services might be required to provide optimal audiology telepractice services.

2. Since some devices commonly used in medical practices utilize the same wireless protocol (eg, Bluetooth connection), co-presence of wireless devices should be closely examined. It is crucial for a wireless system to automatically identify the devices with which it should be associated to ensure that no other devices are causing or being affected by interference.

3. In a converged network environment, despite the highly advanced technology, a facilitator can aid in providing optimal services and make audiology telepractice more efficient.

The implementation of telepractice applications in audiology is a promising field, as demonstrated by previous research and the study described herein. However, studies heretofore have only examined successes and issues when the local and remote sites were located within close proximity. Future research requires determination of the reliability and feasibility of assessments when this web-based system is utilized in worldwide locations with varying amounts of infrastructure and support.

REFERENCES


