Remote Hearing Screenings via Telehealth in a Rural Elementary School

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Purpose: Telehealth (telepractice) is the provision of health care services using telecommunications. Telehealth technology typically has been employed to increase the level of health care access for consumers living in rural communities. In this way, audiologists can use telehealth to provide services in the rural school systems. This is important because school hearing screening programs are the foundation of educational audiology programs. Therefore, the goal of this study was to determine the feasibility of providing hearing screening services by telehealth technology to school-age children. Method: Hearing screening services—including otoscopy, pure-tone, and immittance audiometry—were conducted on 32 children in 3rd grade attending an elementary school in rural Utah. Each child received 1 screening on-site and another through telehealth procedures. Results: Immittance and otoscopy results were identical for on-site and telehealth screening protocols. Five children responded differently to pure-tone stimuli presented by the telehealth protocol than by the on-site hearing screening services. However, no statistically significant difference was found for pure-tone screening results obtained by telehealth or on-site screening procedures (binomial test, \( p = .37 \)). Likewise, overall screening results obtained by traditional and telehealth procedures were not statistically significant (binomial test, \( p = .37 \)). Conclusion: The results of this study suggest that school hearing screenings may be provided using telehealth technology. This study did find that 5 students performed differently to pure-tone screenings administered by the telehealth protocol in contrast to on-site hearing screening services. Further research is necessary to identify factors leading to false responses to pure-tone hearing screening when telehealth technology is used. In addition, telehealth hearing screening protocols should be conducted with participants of different age groups and experiencing a wide range of hearing loss to further clarify the value of telehealth technology.

Key Words: telepractice, hearing, school-age children, screening, telehealth

Telehealth (telepractice) refers to the delivery of health care services through telecommunications technology (American Speech-Language-Hearing Association [ASHA], 2005a; Ricketts, 2000; Wootton, 2001). Telehealth is used to dispense a wide array of health care applications via dial-up, high-speed computer networks, and the Internet (Mun & Turner, 1999; Stanberry, 2000). As a result, telehealth services are provided by various professions, including cardiology, radiography, otology, pediatrics, pharmacology, psychology, psychiatry, and speech-language pathology (Blackham, Eikelboom, & Atlas, 2004; Nickelson, 1998; Perednia & Allen, 1996; Spooner, Gotlieb, & the Steering Committee on Clinical Information Technology and Committee on Medical Liability, 2004; Stamm, 1998).

Researchers have indicated that telehealth is an increasingly practical consideration for both consumers and practitioners.
because of the global expansion of Internet and network capacity (Grigsby & Sanders, 1998; Smith, 2004). Consequently, telehealth networks are used in many rural communities to provide services in medical clinics and other health care centers (Farmer, 2001; Reed, 2005; Schopp, Demiris, & Glueckouf, 2006). Given the wide application of telehealth technology by investigators, it is not surprising that telehealth is also used with children. Specifically, pediatric telehealth applications include management for cardiopulmonary disorders, psychiatry disorders, child abuse and home health care, and monitoring of vital signs during flight transport (Spooner et al., 2004). Some speech-language pathology services have also been delivered through telehealth services. For example, telehealth technology, using online specialized software programs, has been used to present children with speech stimuli, record their speech samples, elicit single word responses, measure speech intelligibility in conversation, and assess oral motor skills (Waite, Cahill, Theodoros, Busuttin, & Russell, 2006). Waite et al. (2006) further indicated online software programs could be developed for telehealth purposes to accurately diagnose speech and motor-skill disorders. In addition, speech-language pathology services have been provided to rural school districts by Integris Hospital Systems for nearly a decade (ASHA, 2005c). These services are provided utilizing webcams and videophone systems in conjunction with traditional speech-language pathology materials.

Other telehealth services have been successfully dispensed in school systems. Whitten and Cook (1999) described a study that utilized interactive video, video-otoscopy, electronic stethoscopes, and dermatology cameras to administer a variety of health care services. These devices were provided to each school in the form of a telehealth station interfaced to a personal computer for data transmission. Telehealth technology was effectively used to manage upper respiratory infections, otitis media, skin disorders, and behavioral disorders. It is noteworthy that the services described by Whitten and Cook were conducted using telephone lines rather than high-speed computer networks. Even though the use of the telephone lines limited the resolution for interactive video, these researchers indicated telehealth services were nevertheless effective and accurate. Indeed, these same telehealth services exist today still utilizing telephone lines for data transmission (Mackert & Whitten, 2007). Young and Ireson (2003) also described a telehealth study similar in scope to that of Whitten and Cook but provided a cost analysis of telehealth services. These authors concluded that telehealth services were cost-effective and further reported high acceptance of telehealth services by parents, students, and school officials.

Even though middle and outer ear disease has been effectively managed through the use of video-otoscopy (Whitten & Cook, 1999; Young & Ireson, 2003), telehealth is comparatively new to audiology and will require a greater research base to gain acceptance (ASHA, 2005b). Audiology telehealth services appear feasible, as modern day audiomotoric equipment is often computerized and may be interfaced to telehealth computer networks. Equipment used in this fashion may include audiometers, video-otoscopes, otoacoustic emissions systems, hearing aid programming modules, and auditory brainstem-evoked response units. When supplemented with interactive video, it is possible that these systems could be employed via telehealth technology to provide services comparable with those found in on-site settings.

An essential factor for providing telehealth services is the method by which information is transferred between the locations of the clinician and the client. Historically, both synchronous and asynchronous information transfer have been effective methods used to dispense telehealth services (Bashshur, Reardon, & Shannon, 2000; Mun & Turner, 1999; Ricketts, 2000). Synchronous services are provided when the clinician administers services to the client in real time (Perednia & Allen, 1996; Wootton, 2001). Alternately, asynchronous (or “store and forward”) services are normally provided by saving patient information on a computer at the patient location. These patient files are then typically sent electronically to a clinician at another location for later interpretation (Fitch, Briggs, & Beresford, 2000; Grigsby & Sanders, 1998). Common methods of asynchronous data transfer include sending text files, scanned records, and video images by means of e-mail, file transfer protocol, or fax (Mun & Turner, 1999; Ricketts, 2000). By definition, asynchronous technology is employed when audiologists send audiometric data, video-otoscopy images, and patient files via e-mail or fax. Although not extensively studied, researchers have developed asynchronous services for tinnitus treatment and video-otoscopy with desirable outcomes (Birkmire-Peters, Peters, & Whitaker, 1999; Goldenberg & Wenig, 2002; Kaldo-Sandström, Larsen, & Andersson, 2004).

At present, two models seem feasible for synchronous delivery of services from a distant clinical site (ASHA, 2005b). The first model requires the clinician to utilize interactive video to supervise patient services provided by a technician at the distant clinical site. Such services may include hearing aid fittings, pure-tone audiometry, immittance, and otoacoustic emissions technology by investigators, it is not surprising that

telehealth applications include management for cardiopulmonary disorders, psychiatry disorders, child abuse and home health care, and monitoring of vital signs during flight transport (Spooner et al., 2004). Some speech-language pathology services have also been delivered through telehealth services. For example, telehealth technology, using online specialized software programs, has been used to present children with speech stimuli, record their speech samples, elicit single word responses, measure speech intelligibility in conversation, and assess oral motor skills (Waite, Cahill, Theodoros, Busuttin, & Russell, 2006). Waite et al. (2006) further indicated online software programs could be developed for telehealth purposes to accurately diagnose speech and motor-skill disorders. In addition, speech-language pathology services have been provided to rural school districts by Integris Hospital Systems for nearly a decade (ASHA, 2005c). These services are provided utilizing webcams and videophone systems in conjunction with traditional speech-language pathology materials.

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A second model of synchronous audiology services incorporates remote computing technology that enables a clinician in one location to directly test the patient at a distant site. In this circumstance, a clinician using a computer at one location can control an audiometer at the client’s location for hearing assessment. The advantage of this synchronous “remote computing” is that clinicians test patients directly with minimal reliance on a technician. In this model, the technician would largely be limited to headphone or immittance probe placement, video-otoscopy (as directed by the clinician), basic computer support, and some patient instructions. The clinician, not the technician, would actually present audiometric stimuli and interpret client responses. Therefore, remote computing technology provides potential to offer the on-site or “face-to-face” environment mandated by ASHA in a recent position statement on telehealth (ASHA, 2005a).

One study describing synchronous audiology telehealth services was published by Givens and Elangovan (2003).
They assessed 45 participants’ pure-tone thresholds using both an audiometer and software adapted for telehealth applications. Specifically, these researchers interfaced a computer network card to a portable MA 40 digital audiometer (Maico Diagnostics) and configured this system to be controlled through remote computing technology. Modifications described by Givens and Elangovan included interfacing a controller to the MA 40 audiometer and adding a micro Web server to the MA 40 audiometer to regulate information flow between the audiometer and the remote user (audiology examiner). The remote computing software used with the MA 40 audiometer was developed at East Carolina University and is capable of operating on a Windows-based personal computer or on a Palm Pilot. This program also includes pure-tone audiometry software enabling clinicians at one location to connect with an MA 40 audiometer at a different clinic location to administer patient hearing tests. Using this system, Givens and Elangovan found that thresholds obtained face-to-face and by telehealth technology were essentially equal. However, Givens and Elangovan indicated that further validation of telehealth services was necessary in a wider range of environments, including rural and remote areas requiring audiology services.

Audiology telehealth services may be useful for school systems implementing school hearing screening programs. Blair (1991) found that hearing screenings in schools were often administered at improper intensity levels, with non-calibrated equipment, at noisy locations, or by poorly trained individuals. Although little contemporary research is available on the adequacy of hearing screenings, it is clear that school hearing conservation programs should include comprehensive plans concerning screening protocols, referral, follow-up, student education, calibration, and record keeping. Implementing these plans can be complex, and therefore ASHA and the Educational Audiology Association mandate that audiologists supervise school screening programs (ASHA, 2002; Educational Audiology Association, 1997). Unfortunately, high student caseloads may minimize the impact of educational audiologists. Specifically, Blair (1991) has reported that educational audiology caseloads were extreme and in some cases reached 100,000 students per audiologist. Similarly, Johnson, Benson, and Seaton (1997) indicated that the average audiologist-to-student ratio was 1:68,804. Clearly the number of students served by audiologists far exceeded ASHA’s (2002) recommended ratio of 1 audiologist per every 10,000 students. In addition, ASHA recommends this ratio be decreased when audiologists are itinerant or when other factors increase workloads, including unusually complex student services and administrative demands.

Although telehealth technology will not completely resolve the high caseloads managed by educational audiologists, providing hearing screenings through a variety of synchronous and asynchronous procedures could help overcome the barrier of distance and increase the productivity of audiologists. In particular, audiologists could reduce travel time to rural locations when providing hearing screening services. As a result, schools could utilize telehealth to support district-wide hearing conservation programs with the benefits of time and cost savings to district personnel. Furthermore, compliance with the practice guidelines of the Educational Audiology Association and ASHA could ensure quality hearing conservation programs.

Modern computer connectivity and the emergence of remote service delivery indicate that telehealth technology can be used to provide hearing screening services to school-age students in rural locations. However, no systematic investigations have been conducted to assess the feasibility of delivering audiology screening services via telehealth to rural school districts. Therefore, the purpose of this study was to assess the feasibility of delivering hearing screening services by telehealth technology. Specifically, this study compared otoscopy, immittance, and pure-tone audiometry results obtained by telehealth technology to otoscopy, immittance, and pure-tone results obtained on-site with the same children. Using this design, the screening results by remote computing could be compared directly with the results found through on-site school hearing screening methods to determine the feasibility of telehealth screening protocols.

Method
Participants

Parental consent forms were sent to all 43 third-grade students at the Fielding Elementary School in Fielding, UT. Thirty-two third graders (17 boys, 15 girls) ranging from 8 to 9 years of age returned signed consent forms in volunteering to participate in this study. Third-grade students were chosen for this study, as this grade level is recommended by ASHA for pure-tone hearing screenings. The investigators reasoned that third graders were much more likely to tolerate the longer test protocol required to complete this study. In addition, the investigators believed that more accurate pure-tone hearing screening results would be elicited from third-grade participants in contrast to younger participants in lower grade levels. The hearing sensitivity of the students was not known prior to beginning the study.

Setting

Fielding Elementary School is located in the north-central Utah community of Fielding, a farming community of approximately 450 people. Although within 90 miles of Salt Lake City and other metropolitan cities, Fielding is somewhat isolated from other communities by a sizable mountain range that periodically creates hazardous travel conditions during winter weather. Fielding Elementary School has a very progressive educational atmosphere and was chosen for this study because it represented a realistic rural school environment in which to assess audiology telehealth services.

Students were screened in Fielding Elementary School’s library. This location complied with the noise criteria in ASHA’s (1997) screening guidelines. Hearing screenings were conducted on-site by a certified audiologist, Examiner 1, at Fielding Elementary School. A second certified audiologist, Examiner 2, provided telehealth screenings to students from Utah State University in Logan. This second site was approximately 30 miles away from Fielding.
but geographically separated by mountains. Examiner 2 screened students from a faculty office at Utah State University configured with a desktop computer interfaced to the Internet. A trained assistant acted as the site facilitator at Fielding Elementary School to perform a variety of tasks for Examiner 2, including video-otoscopy and headphone placement.

**Instrumentation**

Figure 1 illustrates the synchronous and asynchronous methods used to conduct telehealth testing by Examiner 2. Video-otoscopy and pure-tone testing were provided by Examiner 2 using synchronous technology. Examiner 2 also utilized asynchronous testing to interpret immittance results. The equipment configuration used to provide hearing screenings by telehealth is provided in the following text.

*Interactive video.* Both Fielding Elementary School’s and Utah State University’s test sites were equipped with personal computers configured with interactive video hardware and software (Vcon ViGO system; IVCi) to provide synchronous telehealth services. This interactive video system included a webcam, microphone, headphones, and video inputs for two sources and was capable of transmitting data up to 1.5 megabits per second. Utah State University’s desktop computer was configured with a Pentium IV processor, 512 megabytes of random access memory, and Windows XP. The laptop computer at Fielding Elementary School was configured with a Pentium III processor, 512 megabytes of random access memory, and Windows 2000.

*Otoscopy.* Examiner 1 used a hand-held otoscope for on-site screenings at Fielding Elementary School. The hand-held otoscope was provided to Examiner 1, as this is the type of otoscope commonly used for on-site screenings. Examiner 2 utilized a MedRx video-otoscope to examine student ears with the assistance of the trained assistant. The MedRx video-otoscope was used for this study, as it was easily interfaced to the interactive video system used in this study. To conduct otoscopy, the trained assistant positioned the video-otoscope in students’ ears for assessment as directed by Examiner 2. The output of the video-otoscope was connected to the auxiliary port of the interactive video system located at Fielding Elementary School. This configuration provided a synchronous method for Examiner 2 to view live video-otoscopy images over the Internet.

**Tympanometry.** Asynchronous telehealth technology was used to transmit immittance results to the examiner, as few immittance systems can be controlled with synchronous methods. Immittance systems that can be controlled by synchronous methods are costly and have not been validated for telehealth purposes. In contrast, transmission of immittance data by asynchronous methods is a less costly alternative solution.

A portable GSI-37 (Grason–Stadler) Auto Tymp screener was used for immittance screenings. The GSI-37 was calibrated to the American National Standards Institute’s (2002) specifications for audiometers. Examiner 1 used a portable GSI-17 (Grason–Stadler) audiometer to conduct on-site pure-tone screenings at Fielding Elementary School. Examiner 2 utilized an MA 40 audiometer (Maico Diagnostics), which was the same as described by Givens and Elangovan (2003). The use of two different audiometers permitted the two audiologists to conduct hearing screenings under blinded conditions. The MA 40 audiometer was located at Fielding Elementary School and interfaced to the school’s computer network. To conduct these screenings, the trained assistant was required to place headphones appropriately on each student. Examiner 2 then provided instructions for pure-tone screening and observed student responses through interactive video.

**Internet connectivity.** Examiner 2 was connected to Fielding Elementary School’s site over the Internet from Utah State University’s computer network. A separate data line was provided for the interactive video system and for the MA 40 audiometer at Fielding Elementary School. However, both the interactive video and the MA 40 audiometer software were controlled through the desktop computer utilized by Examiner 2. The speed of these connections was approximately 200 kilobits per second (Kbs), which generally resulted in interactive video rates of 10–15 frames per second. This speed was determined by periodically viewing data transmission characteristics recorded by the Media Statistics

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**Table: Telehealth Screening Model**

<table>
<thead>
<tr>
<th>Facilitator (Fielding Elementary)</th>
<th>Examiner #2 (USU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video-otoscopy</td>
<td>Synchronous</td>
</tr>
<tr>
<td>Tympanometry</td>
<td>Asynchronous (Store-and-Forward)</td>
</tr>
<tr>
<td>Pure Tone Audiometry</td>
<td>Synchronous</td>
</tr>
<tr>
<td></td>
<td>Test Through Remote Computing</td>
</tr>
</tbody>
</table>

**Figure 1.** Model used for the present study to conduct otoscopy, tympanometry, and pure-tone testing over the Internet. Note that this model required both synchronous and asynchronous data transmission to conduct the hearing screening described in this study. USU = Utah State University.
submenu embedded in the Polycom interactive video software program. Although there was some variance concerning connectivity, the speed of data transfer was generally equal to 200 Kbs. These rates provided sufficient video quality for Examiner 2 to observe students responding to pure-tone audiometry by hand raising at Fielding Elementary School.

Procedure

The examiners in this study followed the hearing screening guidelines specified by ASHA’s Audiologic Assessment Panel (ASHA, 1997). These guidelines consist of otoscopy and pure-tone audiometry for third-grade children. In addition, immittance screening was conducted on the students in this study. Although not prescribed by ASHA’s screening guidelines for third graders, immittance screenings may be conducted with children who are at risk. Therefore, immittance was conducted with all participants during this study in accordance with ASHA’s Audiologic Assessment Panel (ASHA, 1997).

In all screening procedures, each examiner conducting screening at Fielding Elementary School was blinded to the test results of the other examiner conducting telehealth screening services. The examiners were effectively blinded through the use of two separate screening stations. One hearing screening station was provided for the on-site evaluator, whereas a separate telehealth screening station was provided for Examiner 2. The screening protocols were counter-balanced so that half of the students were first screened on-site, with the remaining students receiving their initial screening by telehealth methods. In addition, the examiners alternated the first test ear of each student to reduce order effects.

Examiners screened each student beginning with otoscopy. Otoscopy outcomes were determined using the pass/refer criterion as prescribed by ASHA’s (1997) guidelines for otoscopy for children from birth to 18 years of age. A “pass” indicated that there was no condition requiring a medical referral or contraindicating hearing screening procedures. Those students who exhibited excessive cerumen or other ear pathology contraindicating further hearing screening were considered a “refer.”

Following otoscopy, Examiner 1 performed immittance screening on-site with half of the children and printed out the resultant tympanograms. As the remaining students were seen first by Examiner 2, the trained assistant conducted tympanometry measurements with these students. Examiner 1 reviewed tympanograms of all 32 students on the day of the screening so that proper medical management (or rescreenings) could be scheduled for children with ear pathology. This screening information was provided to the school administrator overseeing the hearing screening program at Fielding Elementary School. This administrator, who is also an audiologist, provided immittance rescreenings at a later date consistent with school district guidelines. Likewise, the pure-tone results of all children screened in this study were provided to this administrator so that rechecks or referrals could be conducted as per district screening guidelines.

The tympanograms of all children were scanned into a computer and sent by e-mail to Examiner 2 for analysis 2 weeks following the hearing screening. Examiner 2 classified each tympanogram under blinded conditions. These results were then compared with Examiner 1’s immittance classifications conducted at the time of student hearing screenings. Each examiner assigned a pass/rescreen/refer rating to each tympanogram according to ASHA’s (1997) immittance screening guidelines for children from 1 year to school age. A student passed unless criteria for referral or rescreening were met. A student was rescreened if the middle ear compliance was less than 0.3 cm$^3$ or the gradient was greater than 200 daPa. Examiners also referred students when ear canal volumes were greater than 1 cm$^3$ and accompanied by a tympanogram with an abnormally wide gradient.

Finally, students were screened with pure-tone air conduction audiometry at 20 dB HL at 1000, 2000, and 4000 Hz. Instructions were given to each student to respond to pure tone with a raised hand. The students were screened both on-site and via telehealth, and responses were judged as “pass” or “rescreen.” A “pass” was indicated if the student correctly responded to a pure-tone signal two out of three times. A “rescreen” indicated that the student did not respond when the signal was presented. The total time involvement for each student to complete the requirements of this study was no longer than 15 min.

Data Analysis

The results were tallied for otoscopy, immittance, pure tone, and overall screening classifications and grouped by on-site and telehealth screening protocols. No statistical analyses were performed for immittance and otoscopy because these results were identical for both the on-site and telehealth protocols (see Table 1).

SPSS (Version 14) was used to calculate statistical analyses that were performed in this study. The binomial test was used to determine whether the overall screening results between the on-site and telehealth protocols were significantly different. The binomial test was also used to determine whether pure-tone results between the on-site and telehealth protocols were significantly different. The binomial test was chosen, as it is an appropriate statistic to evaluate differences of two protocols measuring the same outcomes (Pett, 1997). In addition, screening data were collapsed from three categories (pass, rescreen, or refer) to the two categories of “pass” or...
“rescreen/refer,” as there were only two student “referrals” resulting from this study.

**Results**

**Overall Hearing Screening Outcomes**

Overall otoscopy, immittance, and pure-tone screening results were compared for telehealth and on-site protocols. Results obtained from both of these screening protocols indicated that 21 students passed hearing screenings, another 5 students required middle ear rescreening, and 1 student needed referral for external ear pathology. However, the examiners did not agree on overall screening results of 5 students because of different pure-tone screening results obtained with telehealth and on-site protocols. Even though overall screening outcomes varied between the on-site and telehealth screening protocols, the binomial test indicated that these differences were not statistically significant ($p = .37$).

**Otoscopy and Immittance Results**

Examiners for both on-site and telehealth protocols were in full agreement on all otoscopy examinations (see Table 2), referring 1 student for cerumen management in one ear. Likewise, both on-site and telehealth examiners were in complete agreement for their participants’ immittance results (see Table 3). Specifically, 55 student ears were examined and passed immittance testing. However, 9 other student ears required rescreening or referral (see Table 3). Table 2. Decision matrix table of otoscopy screening results comparing on-site and telehealth outcomes from 64 student ears.

<table>
<thead>
<tr>
<th>Otoscopy on-site screening</th>
<th>Telehealth screening</th>
<th>Pass</th>
<th>Rescreen/refer</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass</td>
<td>63</td>
<td>0</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Rescreen/refer</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>1</td>
<td>64</td>
<td></td>
</tr>
</tbody>
</table>

*Note. “Rescreen/refer” includes children who required either rescreening at school or a referral to a physician for management of ear pathology.*

**Pure-Tone Screening**

The pure-tone outcomes of the two protocols were judged to be in agreement if no differences between protocol results occurred. As noted previously, Examiner 1 and Examiner 2 did not agree on pure-tone screening outcomes of 5 students when on-site and telehealth results were compared (see Table 4). Specifically, telehealth pure-tone screening outcomes resulted in four false positive responses and one false negative response when compared with on-site pure-tone screening results. However, even though pure-tone screening outcomes varied between the on-site and telehealth screening protocols, the binomial test indicated that these differences were not statistically significant ($p = .37$).

Finally, the observed differences for pure-tone screening results between on-site and telehealth protocols were due to the lack of a response at only one frequency by each student. This is significant, as each student was presented six pure-tone stimuli (at 1 kHz, 2 kHz, and 4 kHz in both ears) for telehealth and on-site protocols. As there were 32 students tested for this study, there were a total of 192 individual pure-tone screening comparisons of telehealth and on-site screening protocols. Of those 192 total individual pure-tone comparisons, only 5 pure-tone screening results did not agree (see Table 5).

**Discussion**

The purpose of this study was to examine the feasibility of telehealth technology to provide comprehensive hearing screenings for students at rural elementary schools. Identical otoscopy and immittance results were obtained by two examiners using on-site and telehealth protocols. However, pure-tone screening results for telehealth and on-site screening protocols were different for 5 of the 32 students. Using the on-site pure-tone screening protocol as the “gold standard,” the telehealth pure-tone screening protocol yielded four false positive responses and one false negative response. Although differences were found for pure-tone hearing screening results for telehealth and on-site screening protocols, overall results of this study suggest telehealth is a promising method for hearing screening programs.

Further research appears necessary to further understand the sensitivity and specificity of telehealth hearing screening procedures. Sensitivity is the “hit” rate, and specificity is the “false alarm” rate (see Table 6). The results of this study suggest that sensitivity and specificity were high for otoscopy and immittance procedures. However, for telehealth pure-tone screening procedures, although sensitivity would also be high (approaching 100%), specificity would be low.

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**Table 3. Decision matrix tables of immittance screening results comparing on-site and telehealth results by Examiner 1 and Examiner 2 for 64 student ears.**

<table>
<thead>
<tr>
<th>On-site screening</th>
<th>Pass</th>
<th>Rescreen/refer</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass</td>
<td>55</td>
<td>0</td>
<td>55</td>
</tr>
<tr>
<td>Rescreen/refer</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>9</td>
<td>64</td>
</tr>
</tbody>
</table>

*Note. “Rescreen/refer” includes children who required either rescreening at school or a referral to a physician for management of ear pathology.*

**Table 4. Decision matrix table of overall pure-tone (PT) screening results using on-site and telehealth audimetry for 32 participants.**

<table>
<thead>
<tr>
<th>On-site PT screening</th>
<th>Pass</th>
<th>Rescreen</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass</td>
<td>21</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Rescreen</td>
<td>1</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>10</td>
<td>32</td>
</tr>
</tbody>
</table>
Specificity = True negative  
Sensitivity = True positive

Table 5. Decision matrix table of PT screening results comparing on-site and telehealth audiometry for all frequencies tested for 32 participants.

<table>
<thead>
<tr>
<th>On-site PT screening</th>
<th>Telehealth PT screening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Rescreen</td>
<td>Rescreen</td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
</tr>
</tbody>
</table>

(approximately 20%). This low specificity suggests that more false positive responses may occur with pure-tone telehealth screening protocols than when hearing screenings are conducted on-site.

It should be noted that the study evaluated only 32 students of the same age and, in most cases, with normal hearing. Therefore, a limitation of the present study is that more children with hearing loss and from various age groups are needed to fully assess telehealth hearing screening sensitivity and specificity. Hence, further telehealth hearing screening studies with larger numbers of children experiencing outer and middle ear disorders appear to be indicated.

The sources of variability found with pure-tone telehealth procedures are not clear. It is possible that telehealth technology itself is a factor related to errant responses, as children may be distracted by telehealth technology. In addition, the examiner conducting the telehealth screening procedures may have missed important environmental visual or auditory cues that interfered with the results of students. The use of two different audiometers to conduct hearing screenings on-site and by telehealth technology may have been a factor resulting in increased errant responses with the telehealth protocol. Although the use of two audiometers was employed to blind examiners from one another, this paradigm may have introduced unintended variance resulting from audiometer location or differences in audiometer performance. Finally, the differences found in response patterns between telehealth and on-site screening procedures might be random, and, with larger participant numbers, these differences may be minimal.

There are other issues to consider to successfully provide hearing screenings by telehealth technology. Probably the most important component related to telehealth procedures is a properly trained facilitator. Telehealth projects commonly employ nurses, other skilled health care professionals, or trained aides to be the facilitator at the patient location. If potential facilitators are already employed at the patient site, costs for facilitators should be minimal. However, adjustments for time and responsibilities may be required of these individuals to be effective facilitators. If no facilitator is available at the patient site, costs may be prohibitive to recruit and employ a facilitator. In such a circumstance, telehealth services may not be possible.

Other costs related to telehealth hearing screening programs (beyond audiometer equipment costs) include an updated computer, a webcam, and interactive video software. The computer does not need to be the best available but will need to have sufficient memory and processing power to provide adequate interactive video images. Such a computer at present will cost approximately $1,500. Webcams are an effective means to provide interactive video and cost approximately $100. Interactive video software that permits high-resolution images, as well as effective video transmission algorithms and encryption, will cost about $150. Of course these expenses are per site, and each system will require periodic maintenance by computer network professionals. Fortunately, connectivity to the Internet or a state-supported network system is possible for most school systems at little or no cost.

It is our experience that although connectivity to a network or the Internet is usually available for schools, bandwidth may be limited. About 200 Kbs was available for operating the interactive video and pure-tone audiometer systems. This bandwidth speed was lower than anticipated by the investigators and most likely resulted from network congestion at the Box Elder School District. However, bandwidth speeds did not significantly affect telehealth services in this study, as the examiner could still view video-otoscopy images online, present pure-tone stimuli, and monitor student responses to these stimuli. As a result of these experiences, we suggest that bandwidths exceeding 200 Kbs should be utilized when possible. Clinicians must also realize that bandwidth rate is fluid and can be subject to substantial fluctuations. Therefore, care must be taken to choose telehealth environments that are capable of delivering desired bandwidths for sustained periods of time.

Another consideration for establishing a telehealth screening program is securing the network or Internet capabilities of the connecting sites. In this study, the researchers connected to a school district network system that permitted access to Fielding Elementary School. To obtain this connection, considerable coordination with the district’s network engineer was necessary. The network engineer opened the district’s network firewall, allowing Examiner 2 from Utah State University to connect with Fielding Elementary School through the Internet. Network engineers can also provide extensive support for network quality of services pertaining to bandwidth characteristics. Desirable quality of service properties that can be provided by the network engineer include symmetrical bandwidth properties for interactive video and allocation of appropriate bandwidth regardless of network traffic.

Audiologists providing telehealth services will also need to comply with the Health Insurance Portability and Accountability Act (1996) when storing and retrieving electronic patient information. In addition, practitioners should implement guidelines established by the American Telemedicine
Association (2008) to ensure patient privacy when delivering telemedicine services. A virtual private network (VPN) is ideal for maintaining privacy while data are being obtained through the Internet (Krumm, Ribera, & Schmiedge, 2005). A VPN is similar to a firewall in its ability to protect electronic information, yet it is encoded specifically to be hidden from Internet hackers. One other means to ensure data privacy is having a minimum of 128-bit encryption (Krumm, 2007). Neither of these safeguards was available for this study, although unauthorized reception of student video would have been nearly impossible without another Vcon ViGO interactive video system in use by an Internet hacker. However, encryption is now standard on virtually all software used for interactive video and should be utilized when VPN technology is not available. Regardless of the privacy method used, network engineers must be consulted to successfully utilize VPN or encryption through firewalls.

As described by ASHA’s Telepractice Working Group (ASHA, 2005b), other issues still must be verified and evaluated to successfully conduct telehealth hearing services. A complete description of ASHA’s designated telehealth research needs is provided in the Appendix. In addition, school-based audiology telehealth research should be conducted with different populations of children and in educational environments located substantial distances away from the examiner (e.g., 100 miles away). Other areas of telehealth research for educational purposes include facilitator training, implementing complete hearing conservation programs, and ultimately determining whether telehealth screening services in distant communities have a positive long-term impact. One of the most important components of a school hearing screening program may be follow-up procedures pertaining to referral for hearing disorders and student education of hearing conservation. These issues may be difficult to address via telehealth. However, trained facilitators who are supervised by audiologists could provide on-site support for hearing conservation programs in distant communities. Therefore, although different programmatic modifications may be required, it appears that telehealth technology has considerable potential to support school-based hearing screening programs in rural areas.

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**Appendix**

Research Needs for Telepractice in Audiology (ASHA, 2005c)

Determine appropriate applications of telepractice in audiology.

Develop and validate telepractice clinical protocols.

Develop appropriate reliability and validation techniques to ensure quality of service.

Support advocacy for reimbursement.

Investigate the efficacy and effectiveness of clinical outcomes; client and clinician satisfaction; and quality of care, cost, and cost-effectiveness of telepractice applications.

Set minimal acceptable technical specifications to support clinical procedures and the application of service delivery models.