eEHDI: Functions and Challenges

William Campbell and Martyn Hyde

Introduction

Early hearing detection and intervention (EHDI) programs internationally face a common challenge; that of maintaining program efficacy, equity and effectiveness with limited service locations and across a population that often varies significantly in terms of geographic spread and population density. Structural, financial, and personal barriers have all been identified as factors governing access to EHDI services for families (Smith et al. 2007). The current state of communications technology offers a unique opportunity for EHDI programming. Use of such technology can serve to develop comprehensive intra-program networks that can bridge distances, improve access to services, and facilitate the achievement of critical program goals. This paper examines the role of telemedicine and telehealth as an adjunct to EHDI programming and highlights an example of infant auditory brainstem response (ABR) assessment conducted remotely using telemedicine.

Effectiveness

The effectiveness of any EHDI program is reflected in the extent to which it meets its defined overall goals and specific objectives. For most programs, this means a comprehensive screening, identification of a hearing loss, determination of the degree and nature of that hearing loss, and delivery of effective device-based interventions and/or language and communication development. Because the assessment information is critical to all subsequent actions, it must be complete and in a form that can be shared with other professionals in order to facilitate next steps for the child. Telemedicine is a method by which expertise can be effectively transmitted over distance to a client, thereby providing a common access to diverse providers. It is also an effective means of fostering protocol-defined assessment results for access by a wide range of related professionals who may be working with the child. This is essential because in delivering services via telemedicine it is foreseeable that the assessing audiologist may not be the professional involved in continuing care for the child. Telemedicine thereby has the potential to enhance program effectiveness through the promotion of greater development of standards to meet the need for shared, common information.

Equity

A program must be equitable in that all members of a targeted population are able to receive the same quality of clinical services regardless of geographical and socioeconomic barriers. It is not unreasonable to expect that every child with a specific disorder receives the best service possible. Indeed, it is a common theme in international program development that all aspects of a program should be as equal as possible. The Joint Committee on Infant Hearing (2007) states that "all children with hearing loss should have access to resources necessary to reach their maximum potential." This statement should be seen to reflect not only resource availability following the identification of a hearing loss, but appropriate and equitable assessment resources as well. Not only can telemedicine practices serve to increase access to services but, as discussed later, it can also facilitate a calibrated standard of practice across a program so that each child does receive the best possible service.

Address correspondence to: William Campbell, MClSc, Ontario Infant Hearing Program, Thunder Bay District Health Unit, Thunder Bay, ON, Canada, P7B 6E7, superioraudiology@shaw.ca

Efficiency

Lastly, an EHDI program must be efficient in meeting it's protocol-specified goals, meaning that members of the target population must enter and progress though the EHDI system in a timely manner regardless of geographic and socioeconomic barriers. As stated above, the factors that may limit access to services for families also act upon the EHDI program to reduce efficiency. An inefficient EHDI program will, to a large extent, fail to deliver the goal of early identification and intervention for children with hearing loss. Aside from the obvious impact of late identification to children and families, consequences in terms of threats to funding and program viability, are likely to occur where programs are unable to address the issues that they were originally intended to alleviate.

EHDI Program Challenges

Access to Services

There are both cultural and geographical variables that may act as barriers to families who need to access EHDI program services. Cultural variables may include a mistrust of public services, concerns regarding the potential impact of an identified disability to a family's identity or status, and/or a failure to understand the EHDI program process. Additionally, families may have varying awareness levels or cultural viewpoints of the consequences of a hearing loss. Language can be a significant barrier affecting the ability of a family to gain a complete understanding of their rights and options and of the nature of an identified hearing loss.

The challenges for a sparse population spread over a wide geographic area are often readily apparent. Infants and families in rural areas who require services must travel longer distances and in many locations, deal with travel in inclement weather in order to reach larger centres. Families may face financial hardship as the need to travel to an EHDI service access point may mean that parents must miss work and incur child-care and travel expenses. Families may not have the means to afford personal transportation and access to public transport may be limited. The probability of accessing services tends to be higher in an urban setting where a relatively stable base of clinicians often exists who are located in centres specifically established to serve a large population effectively. It can be more difficult to maintain service locations in remote regional areas with a small population where transient or temporary services are more likely to be encountered. In an EHDI program, regional birth rates dictate caseload and a limited caseload is often a challenge to maintaining adequate test administration and interpretation skills for a clinician.

Conversely and somewhat less apparent is the challenge faced by EHDI regions with a concentrated target population in a complex urban environment. Research has documented a variety of structural barriers for families accessing service locations including public or private transportation and parking costs (Young et al. 2005; Krumm 2008; Smith et al. 2007). Time away from work and accessing child care for siblings have been identified as significant barriers to initial program access and to follow up for many families (Krumm, Ribera and Schmiedge 2005). A key challenge faced by service locations in large urban centres can be seen in the sheer number of infants referred from hearing screening, where wait lists can frustrate the achievement of best practice targets for prompt assessment and intervention. As a result of these challenges, infants who have been referred from hearing screening often are delayed in accessing services or may never receive diagnostic assessment.

Protocol Drift

In order to provide comprehensive care in audiology, information must be standardized in order to make sense to other service providers who may be assisting the client (Hyde 2010). A standard in screening and assessment protocol ensures that all infants referred for assessment will have the same status. In other words, an assessment result will mean the same thing to all other service providers within an EHDI program, regardless of the location or region in which the assessment was performed. This serves to reduce confusion pertaining to issues such as high-risk factors, middle ear problems and the validity of obtained hearing thresholds. Having a standard assures providers delivering subsequent care to the child that the identification is applicable and reliable. When clinicians and administrators are operating in degrees of isolation, varying modifications to screening and assessment protocols can occur in response to local clinical, administrative or population variables. EHDI programs operating in regions where isolation due to geography and varying population density levels is an issue are more susceptible to the development of administrative and clinical "silos" within the program itself. Communication within a program is essential to maintaining standards. However, as a program

runs longer, effective communication can deteriorate as budgets fail to meet rising costs and as regions within a program become increasingly independent. If funding cannot keep up with rising expenses, travel and training budgets tend to suffer resulting in reduced communication among program members, particularly clinical staff. Early in a program's life, the perceived need for administrative staff to meet often is based on the challenges related to the development of service access points and the related clinical issues. Once a program has been running for an extended period of time, attention may shift from the clinical aspects of service delivery, changing focus to the day-to-day requirements of administration. A resultant drift from the overall evidence base will impair an EHDI program's ability to deliver services in an effective, efficient and equitable manner. Telemedicine can provide effective solutions to communication barriers.

Loss to Follow-Up

Regardless of variances in programming, essentially all EHDI programs have a common goal. Many follow the recommendations of the Joint Committee on Infant Hearing in mandating identification by 3 months of age and intervention by 6 months (JCIH 2007). A significant obstacle to timely identification and intervention is loss to follow up (Hyde 2005; JCIH 2007; Lui, Farrell, McNeil, Stone and Barfield 2008; Mason, Gaffney, Green and Grosse 2008), an issue faced by many EHDI programs to some degree. This loss to follow up can occur at several stages in the EHDI process. Infants may be discharged from birthing centers before screening can take place. Infants referred from screening may not return for follow up screening or for assessment. Even infants identified with hearing loss may not return for intervention, and families may lose contact with programs at various stages during the intervention process. Telemedicine lends itself readily to these issues, particularly with infants who have been referred for screening and who may not return for assessment. This population is comprised of infants with a potential prevalence of hearing loss as high as 1 in 3. Obviously, this is an important group to consider when addressing loss to follow up in an EHDI program.

Telehealth and Telemedicine

Telehealth is a broad term that encompasses health-related services delivered at a distance through electronic media. It is important to distinguish the term "telehealth" from "telemedicine", as the former is generally used to encompass both telemedicine practices and non-clinical activities that typically include training, research, and administration. Telemedicine can be said to be a subset of services under telehealth, referring more specifically to the provision of clinical services over distance utilizing videoconference and/or information technology (Krumm 2010). Telehealth is rapidly gaining in popularity world wide as the necessary technologies become increasingly available.

Clinical service delivery via telemedicine can be of two basic forms (Allely 1995). "Asynchronous" or "store and forward" applications involve the transmission and review of test outcomes after a test has been performed. A clinical test may be administered by a technician in a remote location; the raw test data is then forwarded to a health professional at a central location for analysis, interpretation, and diagnosis. "Synchronous" telemedicine refers to the direct administration of clinical procedures and may involve simple remote monitoring of test data in real time or may expand to interaction with the client and with technicians or clinicians at a remote location.

It has become more helpful, perhaps, to think in terms of online and offline activities rather than synchronous and asynchronous. There are few events in the delivery of services via telehealth that are solely synchronous or asynchronous. For each event that takes place in an online or synchronous fashion, there will be pre- and/or post-event activities that are asynchronous.

Professional Guidelines to Telepractice

Quality of Service

Professional practice guidelines are established by most associations and regulatory bodies related to audiology and provide a framework on which clinical practice is based. As is the case with other aspects of the profession of audiology, several guidelines have been published regarding the use of telemedicine and telehealth in audiological practice. In Ontario, Canada, the College of Audiologists and Speech Language Pathologists of Ontario (CASLPO) dictates that "The appropriate standard of services delivered via telepractices shall be equivalent to the standard expected in traditional delivery methods" (CASLPO 2004). In the United States, the American Academy of Audiology (AAA) guidelines direct clinicians that services "should be primarily provided to individuals who have limited access to providers in their communities (e.g., homebound)"

(AAA 2008). The American Speech and Hearing Association (ASHA) provides similar guidelines to that of CASLPO in stating that "the quality of telepractice services should be equal to that of services dispensed face-to-face" (ASHA 2005). Telemedicine is a rapidly growing field and as such often outpaces the ability of a regulatory body to develop detailed procedural guides. Although existing guidelines vary in the degree of detail, the underlying constant dictates that the client's experience should not differ significantly when services are delivered via telemedicine.

Qualified Professionals

The AAA (2008) indicates that "diagnostic and rehabilitative telehealth/telemedicine services should always be provided by, or supervised by, a qualified practitioner." An issue affecting EHDI programs internationally is the ability of clinicians to maintain effective ABR assessment and test interpretation skills in a low-caseload environment. Telemedicine is a means for transporting expensive and valuable skills to service locations that for various reasons are not normally serviced in person. Although satellite-type service locations in areas of low population could be staffed by technicians or by audiologists with less than a minimal skill set, this creation of varying tiers of service would be contrary to best practice guidelines and to program goals of equity.

Program Validation

The AAA (2008) states that "services should be validated before implementation." Validation of practice is a basic tenet of audiology and of EHDI program protocol; however, the reality of validation is difficult in terms of proving real equivalence. Certain aspects relating to clinical practices are relatively easily validated, showing for example, that remote interpretation of infant ABR assessment data is equivalent to a face-to-face assessment. However, other facets of service delivery do not readily lend themselves to validation. An example here would be the experience of the parent of a child during the actual test procedure and the communication of a diagnosis following an infant assessment. Telehealth is a new area for many disciplines and although the research base is growing, many questions remain unanswered. When establishing telehealth services as a part of an EHDI program, administrators and clinicians are well advised to carefully review and examine practices to ensure effectiveness and efficiency (Krumm 2010).

eEHDI

Telehealth offers a wide range of opportunities for EHDI programs. From administrative functions through training and quality control to direct delivery of clinical services through telemedicine, EHDI staff can realize program-wide benefits in both urban and rural areas. The term "eEHDI" recognizes that the scope of opportunities of incorporating telehealth and internet-based communications goes beyond the ability to simply provide clinical services. This chapter illustrates just one of the potential benefits through the example of a pilot program designed to deliver clinical services to remote rural areas; however, it is recognized that telehealth is by no means limited to this role. The following discussion outlines some of the potential uses of telehealth and telemedicine in EHDI programming.

It is critical to define terms used to describe aspects of teleheath. Though by no means exhaustive, Table 1 below provides a list of terms and definitions from the Ontario Infant Hearing Program's pilot project that provided early experience in eEHDI programming.

eEHDI Structure

On a basic level, telehealth can be used to facilitate communication between various EHDI professionals. Although EHDI program structures vary in administrative and functional structure, many will have a central site responsible for administrative and/or program development. An example is the Infant Hearing Program (IHP) in Ontario, Canada, where a central hub or 'center of excellence' is responsible for program administration, protocol development, training, quality control, and statistical analysis of program progress. Radiating from the hub are regional locations responsible for administration of the program in their own regions. These regional locations ensure service delivery and interact with the central hub to maintain calibration and report statistics and outcomes. Connected to the regional administrative locations are regional clinical access sites responsible for direct client services. These clinical sites interact with the regional locations for direct administrative support and statistical reporting. The clinical sites also interact directly with the central hub for training, clinical direction, and consultation. This model allows communication between all levels of a program, maintaining efficiency, efficacy, and equality. Figure 1 illustrates IHP functional structure and de-

Term	Definition
Host Site	Generally referred to as the site where the expert or attending professional is located. This can be a center of excellence or a regional service access point.
Remote Site	Generally used to describe the site where the infant or client is located.
Bandwidth	The ability of a connection between two or more sites to transmit data and/or video/audio streams
Application Sharing Software	Software used to allow the remote operation of a computer's desktop or particular programs.
Virtual Private Network (VPN)	A secure connection between two or more sites, protecting information from being obtained from locations outside of the connection. Often protected by firewalls and encryption
SaaS	Software as a Service model exists when operating software is located on a central server and can be accessed from other computers via an internet browser
"Thin" client	A computer that accesses software sited on a server connected through a web browser.
"Fat" client	A computer where the working software exists on the hard drive of that computer.

Table 1: Useful terms and definitions used in eEHDI service delivery.

monstrates communication links between central and regional sites. Telehealth applications can link program coordinators and administrators, allowing for face-to-face discussion and ongoing policy development. Using telehealth in this manner reduces travel costs and allows decision-makers to meet without disruptions to schedules.

Linking within a program is a means to reducing protocol drift. Telehealth can be utilized to connect intra-program components, facilitating communication between centers of excellence, administrative agencies, and service access points. Improved communication helps to maintain the program as a whole, reducing the probability of the development of silos where individual protocol modifications can crop up. Linking a program to other EHDI programs enables the development of program-wide modifications to protocols in response to changes in the evidence and experiential base.

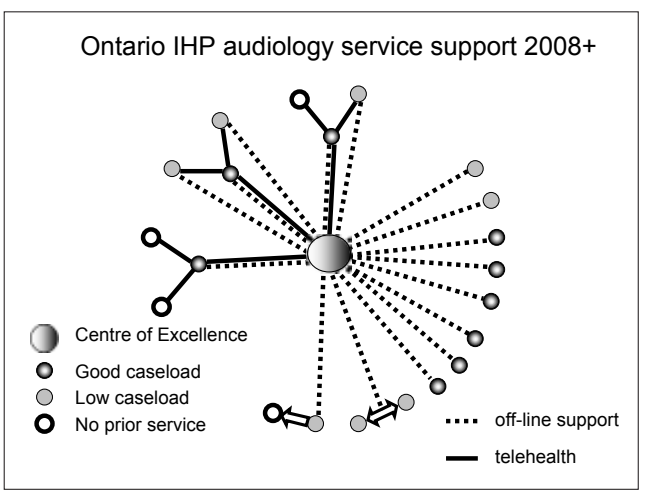

Figure 1. An EHDI structural model where regional clinical access points interact with each other and with a central center of excellence. This model is representative of the structure found in the Ontario Infant Hearing Program. The hub model lends itself to eEHDI service delivery applications.

Second Opinion

Telehealth and telemedicine can also be used to provide consultation and second opinions to clinicians and to families in situations in which procedural outcomes or interpretations are uncertain, complex, or disputed. This is particularly helpful when diagnostic results that are difficult to interpret are encountered by clinicians with low caseloads, usually located in a region with a low birth rate (and therefore a low assessment referral rate). Consultation with other clinicians or with a program center of excellence allows efficient diagnosis or direction for the assessing clinician, saving travel costs and inconvenience for the family. In such an example, the diagnosis may be facilitated in a number of ways. A program hub or center of excellence may elect to directly assess the infant through telemedicine or a consulting clinician may monitor an assessment session controlled in person by the original audiologist. The consulting clinician is able to observe the test procedure in real time and offer guidance and advice, facilitating a diagnosis. In the absence of real-time capability, assessment results may be forwarded to a program hub center for asynchronous analysis and consultation. Assessment records may be forwarded by conventional fax, by electronic transfer of raw assessment data files and/or via transfer of screen capture recordings of assessment proceedings. In the latter two examples the original clinician benefits not only in reaching a concise diagnosis, but also through education and experience gained in the consultation process.

Adherence to Program Standards and Protocols

Deviation from program standards and protocols over time is an issue often prevalent in large-scale clinical programs. Use of a network to link administrative and clinical resources allows for the formation of subnetworks intended to enhance EHDI programs. Peer support networks may be developed to facilitate case discussions, protocol development, and system improvements among clinicians and allow access to archived records that can be used as a teaching database. Online forum discussions have been shown to be effective in allowing clinical staff to interact. A prime example of this is found at www.aud.org.uk where audiologists discuss protocol, case studies, and other aspects of EHDI programming. A well-moderated online forum can guide discussion and lead to improved skill levels among program clinicians, as well as facilitating dynamic protocol development and improvement.

As mentioned above, adherence to program standards is critical to maintaining program efficiency, efficacy and equity. Telehealth allows central administrative hubs responsible for protocol and quality control to directly access regional PC-based equipment, ensuring that such equipment is correctly calibrated and that all collection and stimulus parameters adhere to protocol. The same means can be used to update software and equipment parameters, facilitating system-wide conformation to new standards as the evidence base and protocols evolve.

Clinical Studies

Telehealth can be utilized in developing the evidence base, allowing collection of clinical data from populations ordinarily beyond the reach of research centers. This can include direct, synchronous collection of clinical data or asynchronous data transfer using store and forward methods. Telehealth can be of benefit in clinical studies of rare or complex cases or in evaluation of novel methods of clinical procedure or outcome measurement. Use of telehealth allows greater access to clients by research centers, avoiding the need for extensive travel by families. Aspects of ongoing clinical research can be served by a combination of data gathering using both face-to-face and telehealth methods. Clinical procedures may be demonstrated to large groups for review and discussion. Utilizing telehealth, this can be accomplished quickly and efficiently without the need for travel.

Training

Telehealth reduces or avoids the need to physically assemble large numbers of staff. Special cases of interest can also be presented to specific groups. Telehealth in EHDI programs can utilize several methods of knowledge transfer. At a basic level, an online repository can allow storage and access to case studies, allowing clinicians to examine data from a wide range of diagnostic examples. The delivery of clinical services via telemedicine facilitates the recording of events, ranging from screen capture recordings of an assessment to the video recordings of client interaction. It is also possible to establish multi-point connections, allowing several clinicians to observe an assessment or to participate as a group in a simulated event. EHDI programs can benefit

from a partnership with forward-thinking information technology (IT) personnel to develop innovative training opportunities with minimal expense.

Other Applications

Looking beyond the realm of assessment, other functions including hearing aid (Wesendahl 2003) and cochlear implant processor programming (Norby 2007; Ramos et al. 2008) can easily be conducted using remote communications. The potential for combining current and emerging amplification technologies with internet- and wireless-based communication facilitates all manner of clinician/client interaction in a variety of environments not limited to clinical sites (Krumm 2010). Successful delivery of communication development options has been demonstrated. In Australia, the Royal Institute for Deaf and Blind Children offers auditory-verbal therapy (AVT) and Australian Sign Language (Auslan) delivered via telecommunications media (McCarthy, Nunoz and White 2010). American Sign Language instruction and interaction is widely used over media such as videoconferencing, internet, and smart phone applications. An example of this can be seen at www.alldeaf.com. Table 2 is a non-exhaustive list of the potential applications for telehealth in EHDI programming and the online and offline activities that are components of each event.

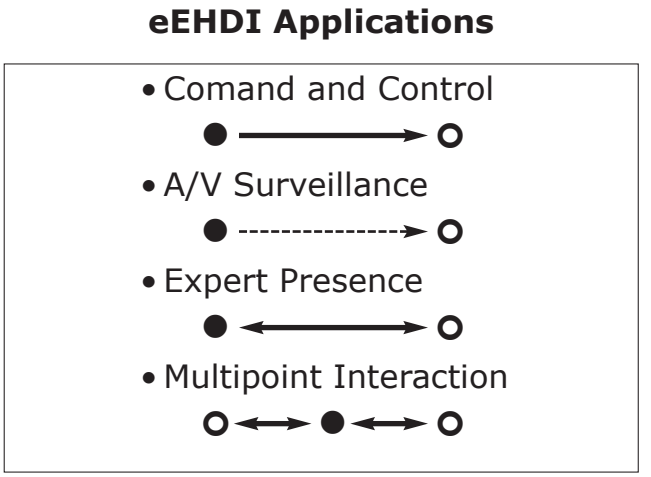

Figure 2. eEHDI applications will take several forms, depending on the type of access. Command and control applications involve one-way control of a test or procedure from a host site to a remote site. A/V Surveillance consists of simple observation or monitoring of a test or procedure. Expert Presence involves the interaction between host and remote clinicians in performing a test or procedure. Multipoint Interaction facilitates the linking of several sites to a central expert site for training, calibration or networking purposes.

The use of telehealth in EHDI programming is not restricted to one-way communication. Depending on the task at hand, the communication between sites will take on a variety of configurations (see Figure 2).

eEHDI applications		
Application	Online	Offline
Infant ABR/OAE assessment	ABR/OAE assessment	Case review/quality control
Screener Training	A/V monitoring	Refer rate review
Second opinion/consult	A/V monitoring of assessment	Peer conferencing
Test Protocol/Calibration	Equipment audit	Direct download
Quality control	A/V monitoring	Case review
Hearing aid programming	Minor programming changes	Verification, when required
Behavioural Audiometry	Standard, Play and VRA	Reporting
Cochlear implant programming	MAP update/modification	Reporting

Table 2: eEHDI applications involve the use of both synchronous and asynchronous activities. It is difficult to separate the two forms of telehealth-based service delivery, as almost all eEHDI activities will require some form of real-time interaction as well as pre- or post-event offline activity.

Command and Control ●➔○

Several aspects of telehealth in EHDI service delivery will entail a "command and control" approach. This is seen in the practice of ABR and OAE assessment of infants, behavioral audiometry, and hearing aid/cochlear implant programming. Although the situation in which a clinician is in control of the entire process through application sharing software from a host site that is distant from the client has a command implication at face value, it is never truly a one-way setting. Even when assessing a sleeping infant, the clinician will be alert to changes in behaviour of the infant, questions and concerns from the family members present, and feedback from the attending technician. However, these types of service delivery can be considered command and control in that the clinician is the sole operator in control of the test situation. Essentially, this is the teleportation of the professional to the test site. This practice enhances the effectiveness of a program. Efficiency is served through enabling the program to better meet the goal of assessing all infants requiring follow up from screening, and program equity is evident in the improved access to service for families.

Audio/Visual Surveillance ●➔○

Often in an EHDI program it is required to monitor the practices of various program service providers. For example, a regional administrator may notice an unacceptably high refer rate from a screening technician or volunteer. In another example, a center of excellence may note inconsistencies in assessment results from a particular clinician. In such cases, program effectiveness is served by a follow up audit or surveillance of clinical practices. Given that EHDI programs cover wide regions and expert staff are widely disbursed, it can be difficult to fund travel and staff resources to provide such monitoring and observation. Telehealth can act as a conduit to simple observation of clinical procedures, with asynchronous follow up to the staff with the intent of addressing issues that would otherwise affect program efficiency. In this example, telehealth serves as a one-way monitoring role, with information directed from the remote site to the observing or host site.

Expert Presence ●➔○

Akin to second opinion, this is a case in which telehealth facilitates two-way communication between a remote and host site. In the event that a service provider encounters a difficult case where it would be beneficial to seek the advice of a more experienced clinician at a center of excellence, telehealth can be used to allow that expert to virtually sit in on an assessment. The expert sitting in can observe the session, provide suitable input and advice and actually take control of aspects of the assessment if necessary. The original service provider can ask questions, demonstrate the clinical process used, and benefit from input offered. Program effectiveness is addressed in improved service to the client and skills gained by the service provider. The program becomes more equitable as the client gains access to all levels of clinical expertise, and efficiency is enhanced as the ability to provide diagnosis is improved.

Multi Point Interaction ○←➔●←➔○

The ability to link multiple sites, with not only an audio-visual link but also an interactive capacity in regards to clinical software, facilitates group observation and review of clinical events. This model may be used for a single case diagnosis, where a clinician requests expert presence from several program staff. It is most useful, however, in a training scenario. Multiple sites might be linked to the center of excellence, allowing presentation of simulations of assessment cases. In this example, clinicians would interact with each other and with the trainer to follow an assessment procedure through to diagnosis.

eEHDI in the Ontario Infant Hearing Program

The use of telemedicine to deliver diagnostic assessment of hearing in infants was postulated as early as 2005 (Krumm et al. 2005). However, technical limitations had previously prevented actual practice. Now, as diagnostic systems have evolved and ready access to high bandwidth telemedicine networks and internet connections is commonplace, the conjecture has become a reality. Although limited, the evidence base for telemedicine practices in audiology provides validation for the provision of infant ABR assessment. As the practice is intended to transport valuable clinical expertise to locations that would not normally receive such services, it is evident that appropriately-trained technicians should be present at the remote site, with the clinician at the host site (Elangovan 2005). Available data indicate that results obtained for tone specific ABR and OAE assessment of infants using telemedicine are not significantly different from those obtained in face-to-face

assessments (Towers, Pisa, Froelich and Krumm 2005; Elangovan 2005). Although it is more difficult to validate the client and family experience, reports suggest that clients have confidence and acceptance of telemedicine-based assessment (Gustke, Balch, West and Rogers 2000; Stalfors, Holm-Sjogren, Schwieler, Tornqvist and Westin 2003; Whitten and Love 2005; Styles 2008).

Thunder Bay is a community of 120,000 in the northwestern region of the province of Ontario, Canada. The city serves as a regional center for the Infant Hearing Program (IHP), an EHDI program delivered by the Ontario Ministry of Children and Youth Services (Hyde, Friedburg, Price and Weber 2004), which mandates infant screening, assessment and communication development in the province. The majority of births (approximately 2000 annually) from Thunder Bay and the surrounding region occur at a central birthing center. Many babies are born to families who live in remote communities where air transport provides the only access. Often mothers and infants are discharged to their home communities after a short stay at the birthing center. Although the vast majority of these infants receive hearing screening prior to discharge, they rarely remain in an area where assessment services are accessible. It is those infants living in remote rural communities who have been referred from the screening process that make up the target population for a remote assessment pilot project.

Face-to-face infant assessment in the Ontario EHDI program is performed according to protocols developed by the IHP (Hyde 2008). Like most diagnostic ABR equipment, the infant is connected to a headbox or similar unit containing the hardware needed to deliver stimuli and to collect evoked potentials. The infant is connected to the head box with scalp electrodes, and stimuli are delivered through insert earphones. The insert earphones are ER-3A style pediatric inserts, modified manually to fit infant ears. The headbox is connected to and controlled by a laptop running a Windows™ environment operating system. The ABR test procedure is then controlled by proprietary software on the laptop. In "remote assessment" all of the diagnostic equipment is sited at the infant's location (called the remote location), while the assessing audiologist works from a central location or "host" site. There is a laptop or PC computer running a Windows™ environment operating system at the host site. Using remote application software, the audiologist establishes a connection to the laptop at the remote location and assumes control of the ABR software. This forms the basis of remote assessment.

The Ontario Telemedicine Network (OTN) exists to provide telehealth services to all areas of the province, primarily through videoconference. Access to this network offered a unique opportunity for the development of the pilot remote assessment project. The OTN consists of a network of over 1100 sites served by secure high-speed broadband connections (100 Mb/sec or greater as limited by location router), all under the auspices of the Ontario Ministry of Health and Long Term Care. In partnership with the OTN, the IHP gained access to several remote sites in rural communities located in northwestern Ontario, all serviced by a host site located in Thunder Bay. Not only does this partnership provide access to the connected sites, but also to the considerable technical and administrative support that exists within the OTN.

With the pilot project, there are four "satellite" packages of assessment equipment. The IHP uses the Natus NavPro™ system for evoked potentials and the Natus Scout™ system for otoacoustic emissions (OAE). Each equipment package consists of a laptop, headbox, and all associated cabling along with the "switch" and cables needed to tie in to the existing OTN network connections. Disposables and illustrated instructions for infant prep and equipment connections are also included. The equipment is packaged in a secure and durable case to protect it during shipping. Equipment is shipped to the technician at the remote site community prior to the assessment appointment. Technicians serving the remote communities are trained in preparing the infant for testing. Generally, the technicians are IHP screeners who provide OAE and automated ABR screening. The training needed to act as a remote site technician is supplemental to automated ABR screening training and is done face-to-face. The technician is at the remote site to set up the equipment and to prepare the infant for testing under the supervision of the audiologist at the host site. The technician is also able to respond to directions from the audiologist during the test procedure. At the host site, the audiologist initiates the video conference call and assumes control of the assessment equipment at the remote site. Once the infant is settled, the assessment is performed with the audiologist providing instruction to the technician when necessary. The actual assessment takes no longer when done remotely than it does when done face-to-face.

Following extensive trials with the technology, the first remote assessment of an infant was conducted in February of 2008. Tone specific ABR tracings at 500 and 2000 Hz, along with diagnostic otoacoustic emissions

(OAE) at 1 – 4 kHz were obtained for an infant in a community some 380 kilometers from the host site in Thunder Bay. From 2008 to early 2011, the project has expanded to assess approximately 90 infants in seven remote sites from the central host site in Thunder Bay. Initial data gained from this project are still under evaluation, but appear to be positive in terms of reducing loss to follow up and increasing the efficacy, efficiency, and equity of the EHDI program. Family feedback is positive towards accessing the service via videoconference. In communities where health care recipients are familiar with receiving a significant portion of their health care through eEHDI means, both acceptance and attendance rates tend to be high. Families report that they would be far less likely to access the service if they had to travel to the regional IHP assessment centers. In providing infant hearing assessment services through remote means, the pilot project has thus far reduced loss to follow up and has improved access to service for families. The Ontario pilot project continues to perform regularly scheduled infant assessments while collecting data needed to provide a solid evidence base for further protocol development.

eEHDI Toolkit

Bandwidth

In the last decade, a significant area of advancement in telemedicine is the ever-increasing available bandwidth used in data transfer between points. To establish a reliable connection between a host and a remote site(s), a reliable network connection capable of relatively high-speed data transfer or bitrate (both download and upload) is required. In conducting ABR assessments through an internet-based telemedicine connection of limited bandwidth, Towers et al. (2005) reported connectivity issues that affected video and data transfer rates and software viability. Krumm (2007) suggests a minimum bitrate of 384 kb/sec for synchronous telemedicine applications using videoconferencing.

In 2009, the average download speed for open internet connections in the United States was 5.1 Mb/sec, more than enough to manage data transfer for the purposes of ABR testing. Telehealth networks typically have data transfer capacity in the range of 100 Mb/sec and higher, facilitating equivalent two-way transfer of information, which is sufficient for data, video, and audio signal transfer. This differs from most conventional internet connections where available download speeds are typically many times faster than upload speeds. The ability to transfer a reliable video and audio signal is dependent on the devices used for video, and audio transmission, and the encoding or format of the video and audio signal and minimum data transfer rates will vary considerably. Fortunately, the development of widespread broadband connectivity has become a priority for governments in developed nations (i.e., the FCC National Broadband Plan, 2010, in the US) and is rapidly becoming a priority for developing countries as well, setting the stage for effective use of telemedicine and telehealth applications.

Network Options

There are several options for connectivity that can be explored. Some involve establishing access to existing networks and infrastructure, and some are based on development and creation of novel resources. One key item that affects all connectivity options, however, is the level of technological knowledge required on the part of involved staff. Staff such as clinicians located at a center of excellence or at host sites will, over time, generally become more experienced at manipulating the technology. However, staff at remote sites with less activity will tend to be less experienced, as they may have fewer practice opportunities. The level of technology used in establishing trouble-free connections will be based on the ability of involved staff to effectively handle the needs of the system.

Existing Network

A network may exist as part of an existing telehealth organization using secure point-to-point connections and managing bandwidth in accordance with varying intra-network needs. Connections may be established within such a network or as a secure bridging of separate networks. Generally, such connections will have broad available bandwidth and secure firewalls and encryption systems to protect data. There are several advantages to accessing an existing telehealth network:

- Established Information Technology (IT) services and Help Desk access
- Faster network connections
- Established firewall and encryption systems
- Network service access points in targeted areas of need
- Established infrastructure
- Established scheduling procedures
- Less dependent on technological skills of EHDI staff.

However, there are some drawbacks to using existing networks. These include, but may not be limited to the following:
- Limited access points
- Cumbersome IT security measures
- Difficulty scheduling busy access points
- Limited flexibility in changing or adding access points
- Issues in navigating administrative barriers and policy.

Virtual Private Network

A network may also be a "virtual private network" (VPN) within a greater public access network. EHDI programs may choose to establish a VPN by linking sites through secure firewalls and isolating host and remote sites from the greater network. This allows for a higher degree of flexibility in terms of access points, but may be technologically challenging for a program. Some readily apparent benefits of a VPN model are:
- Access points are limited only by internet access
- Data security and encryption can be tailored to program needs
- Reduced scheduling issues
- Reduced dependency on outside IT policy and procedures
- No competition for access points by other telemedicine services
- Reduced administrative procedural barriers.

The establishment of an intra-program VPN does raise some issues and potential challenges. By its nature, establishment of a VPN model requires additional technology that can result in barriers to access:
- Higher degree of technological competence required by EHDI staff, particularly at remote sites
- Subject to varying bandwidth
- Connections may be less reliable
- More equipment is required for both the host and remote sites.

SaaS

Software as a Service Model exists when the pertinent software resides on a server that can be accessed through an internet browser. Both the host and remote sites (regardless of whether there is a point-to-point or multi-point connection) are connected through open internet and security; encryption and actual software operation is handled by the server. The server can be maintained by the EHDI program itself. It may also be a leased service or part of a greater network that spans multiple EHDI programs. Opportunities offered by the SaaS model are limited only by budget and bandwidth. Potentially, software for any aspect of EHDI programming can be located on a server and accessed through the internet. Software for ABR assessment, behavioral assessment, hearing aid/cochlear implant programming, as well as conventional office and screen recording software can be accessed from any internet connection. This model has the potential to significantly broaden the application of telehealth to EHDI programming. One can conceive of virtual Centers of Excellence, serving multiple EHDI programs. Pools of expertise could be established where clinicians who specialize in rare disorders could assume assessment and diagnostic roles when called upon. The use of SaaS and "thin" clients has the potential to take service access points into the client's home, facilitating limitless access to EHDI program components. Benefits of the SaaS model are listed below:
- Potential to bring all aspects of EHDI programming to underserviced or limited service areas
- Reduced dependency on the transportation of hardware
- Reduced dependency on technological skill level of both host and remote site staff
- Ability to develop virtual Centers of Excellence and specialized pools of expertise
- Ability to create a shared knowledge base
- Expanded training opportunities.

As in other models of connectivity, there are inherent limitations as indicated below:
- Subject to varying bandwidth
- Subject to potentially varying degrees of reliable connections
- Need to develop and maintain a central server to house software.

With any model, the assistance of capable IT staff is required for success, particularly when addressing security, encryption, and bandwidth requirements.

Software

A key component in performing remote ABR infant assessment is a means to control the test in real time. Current desktop sharing or application sharing software options are readily available commercially and are most applicable to Existing Network or VPN models of

connection. Common software packages, such as PC Anywhere, Real VNC, Microsoft Shared View and others are widely used by IT services to remotely troubleshoot computer problems. This software lends itself readily to audiology applications in telemedicine, allowing clinicians to assume control of programs from a distance.

eEHDI Challenges

Standardized Equipment

Use of standard equipment for diagnostic assessment throughout any given program is desirable, though it is often not achieved and is not a necessity. However, if assessment equipment is the same in all clinical access sites, it will facilitate activities such as remote assessment. Regardless of telehealth aspects, maintaining program-wide standard protocols is simplified when all equipment is the same. Moreover, different systems may have very different functionality, or they may implement common and important procedural functions in quite different ways that are not easy to relate or compare. Clinicians operating assessment equipment remotely need not gain expertise on a wide range of systems when standard assessment equipment is used program-wide. Clinician skill level and test interpretation reliability is likely to be enhanced with familiar equipment. The level of standardization is highly dependent on the type of connection utilized. If an EHDI program is using an existing network, the equipment in use may well vary within program regional service access points. For example, an EHDI program may have been developed using existing regional resources and allowing individual agencies to provide EHDI services with a degree of latitude as to how those services are delivered.

Modified Assessment Protocol

An important factor to consider is the ability to execute all elements of a standard protocol for audiologic assessment, for example, when attempting to deliver the assessment remotely. There may be a need to modify an EHDI program's existing assessment protocol. For example, in the IHP assessment protocol, 1000 Hz probe tone tympanometry is specified. In the pilot remote assessment project example, it has not yet been feasible to have technicians performing tympanometry so it has been excluded from the remote assessment process, at least in the pilot's initial stages. Still under review is the possible impact that this deviation from protocol may have on the assessment process and outcome. Tympanometry results may be obtained from an infant who is identified with hearing loss using remote assessment at a later date during follow-up. However, an infant who is discharged as having normal hearing may not have tympanometry results. Review is still needed to determine whether automated tympanometry can be substituted and, more generally, whether any ultimate modifications of protocol may compromise the equivalence of the direct and the remote methods of audologic assessment. While such aspects of EHDI programming raise challenges, it is possible to consider the use of automated or remotely controlled methods where assessment components such as tympanometry can be incorporated into the process.

Ambient Noise Levels

Typically, acoustically treated sound rooms will not be available at remote sites. The challenge that this poses is to determine the permissible ambient noise levels for infant ABR and OAE assessment. Although standards exist for permissible ambient noise levels with insert earphones, these apply to behavioral testing to audiometric zero. In most cases, "normal" hearing as it applies to an EHDI program is determined by target disorder criteria that reflect program goals, as well as limitations of screening instruments. The range of hearing defined by any program as effectively "normal" may not correspond to international audiometric standard norms. Typically, it may include hearing levels up to 25 dB HL or even higher. There are no current high-quality data on levels of ambient noise that would impact infant ABR results, such as to increase the probability of response detection failure. In the absence of hard data, the Ontario remote assessment pilot program has adopted ANSI/ASA S3.1-1999 (R2008) as a guideline for selecting a remote site. However, this standard is unnecessarily restrictive, given that target threshold limits are at least 25 dB HL, common insert phones typically provide at least 30 dB of sound field attenuation from 500 Hz to 4 kHz (e.g., Google 'CRC R.3.6.4') and the averaging aspect of ABR measurement reduces sensitivity to transient noise.

Remote Site Staff

Remote site technicians in the Ontario IHP remote assessment project are typically IHP Stage II screeners,

staff who normally conduct automated ABR screens in their home community. Because these technicians are already trained in infant preparation and handling, including electrode and insert tip placement, it is an effective solution to provide additional training for diagnostic ABR management under the supervision of the audiologist. In the Ontario program, screeners are trained during face-to-face infant assessment sessions, allowing for hands-on training in infant ABR preparation. They are also familiarized with the steps involved in setting up the ABR equipment and connecting it to the OTN network. In other programs and regions internationally, training for remote site technicians would vary by program, but it is important to have appropriately-trained technicians to ensure reliable results. It is the connection model and the purpose for which the connection is established that will dictate the required skills at remote sites. In terms of the ability to perform an infant ABR assessment, the person at the remote site must be able to prepare the infant for testing. It is conceivable that even parents could perform this task with close monitoring and supervision from a host site. As part of the ongoing introduction of eEHDI to universal hearing screening programs, the development of equipment designed to facilitate infant preparation by non-audiologists would promote the use of eEHDI in areas of the world where access to technical expertise may be limited. Other aspects such as hearing aid/cochlear implant programming and some facets of behavioral testing, for example, would require a relatively minimal skill set at the remote site. When used for training, surveillance, monitoring and multipoint consultation, the ability to connect to the internet is the only required skill. EHDI programs considering telehealth applications will need to develop procedures and skill sets based on their regional needs and resources.

Communication of Assessment Results

The appropriateness and effectiveness of communication with families is a major area of interest for the Ontario IHP. In telehealth applications the issue poses additional challenges. Generally, in infant assessment, the assessing audiologist provides the family with the test results (normal or abnormal) immediately following the assessment. However with telemedicine applications, there may be factors that prevent the appropriate delivery of results. Telemedicine sites and assessing audiologists are generally tightly scheduled and time for assessment may be limited, depending on program specifics. Following an assessment, particularly when abnormal results are obtained, there may only be a few minutes remaining in the allotted time. It would be inappropriate to deliver the news of a hearing loss to a family when sufficient time for counseling is not available.

Research has indicated that families form a strong and trusting bond with the clinician who first delivers a diagnosis of a child with hearing loss (Pretto 2010). However, with eEHDI, it will often be the case that the assessing audiologist will have no further contact with the child or the family. Medical models suggest that delivery of a diagnosis via videoconference is appropriate, well-accepted by clients and does not cause undue psychological harm. Although this model for delivery of a diagnosis is common practice in other areas of telemedicine (Stalfors et al. 2003; Gustke et al. 2000), it is not generally done immediately following testing. In most cases, a physician or specialist will be delivering a diagnosis after asynchronous analysis of test results. Additionally, there are many models of connection and communication available to eEHDI, and not all involve seamless audio/video communication. Individual EHDI programs will have different protocols that address the communication of a diagnosis. Each program will have to examine this issue in the context of their population and practices. Further research is needed in this area before consensus is reached; however, it will be nearly impossible to apply a blanket policy to address the issue of the communication of test results.

Equipment

In areas where there is sufficient population to support a permanent remote site, equipment may be permanently located. The amount of equipment to be used is dependent on the eEHDI delivery mode and purpose. For example, ABR assessment may require the transport of equipment ranging from a complete ABR system to select pieces of hardware. Whether a program is able to establish permanent remote site(s) or will use multipurpose satellite remote sites depends on a host of program specific factors.

Existing Network

When accessing an existing network, it is most likely (given existing ABR equipment) that a complete ABR system will have to be in place at the remote site. With remote assessment of infants in smaller communi-

ties, equipment may have to be shipped from place to place. Unique Internet Protocol (IP) addresses have to be entered into laptop network communication software, and disposables must be refreshed between assessment events. A thorough knowledge of the operating network is essential to avoid technical issues that may disrupt or delay a scheduled session. It is best to have a firm procedure in place to avoid equipment and software issues.

VPN

When eEHDI is conducted using a virtual private network model, the scenario is similar to that described above. As the remote site is a "fat" client, the operating software is required at that site. As such, it will be necessary to have the complete ABR system at the remote site. Again, certain parameters such as internet protocol addresses may need to be fixed and known to the host site. Programs using a VPN model for eEHDI will require ready access to IT support in development and in the performance of scheduled events.

SaaS

When SaaS models are used, the amount of equipment and the technical expertise required for performance of assessments and events is reduced. When the operating software resides on a central server, both the remote and host sites will be "thin" clients, and programming of connection parameters will not be necessary. It is conceivable that in the development of ABR software that can operate in this manner, diagnostic equipment manufacturers could also develop systems that operate with minimal equipment at the remote site.

Scheduling

The nature and ease in which eEHDI events are scheduled will differ greatly depending on specific regional variables and on the mode and purpose of the connection. In scheduling an assessment, there are several parties involved. Coordinating the audiologist, the family, the remote technician, the telemedicine sites (remote and host) and telemedicine network staff (if a telemedicine network is employed) can be a challenge. In some areas in Ontario, the scheduling staff must also coordinate funding agencies and flights for families. If a region is using existing telemedicine network sites, the scheduler must be aware that these sites are often busy, and no allowances are made for extended appointments. It is important that the scheduler is able to consider several factors when arranging an assessment. Families may need travel directions to an agency. Infant age is an important factor. The scheduler needs to be aware that a 7 month-old is less likely to sleep on demand than a 2 month-old child. An efficient scheduler will work closely with the audiologist, as well as maintaining a good relationship with related agencies and staff. Concise scheduling procedures need to be developed in order to ensure the telemedicine site time is used effectively.

Client Confidentiality

The integrity and privacy protection of client's personal and health information is a high priority in all aspects of health care and no less so in telehealth applications. Most EHDI programs will already have policy and procedures in place to ensure client confidentiality, as will most telehealth networks. Most remote access software includes strong encryption. In most cases and by the nature of remote application sharing software, the host computer will not contain client data. However when an existing network or VPN is used to connect sites, the remote laptop or PC that is linked directly to the test equipment (such as in the case of ABR and OAE assessment) will contain client data files. Whether or not this equipment travels from site to site, it can be vulnerable to loss or theft. In many jurisdictions, including Ontario, the consequences of such loss are expensive and problematic if the lost or stolen device contains client-identifying information. To prevent inappropriate access to personal information data, it may be most prudent to assign to each client file an unique identifier that relates to a separate identification/contact information file maintained at a central site (such as the infant's home regional EHDI agency). The actual file will contain the client's demographic data while the code in the software will merely be a file identifier. If an existing telehealth network were accessed, then by the nature of the network itself, testing would be performed over a secure, encrypted point-to-point connection within a network. In the Ontario pilot example, the infant's home region is responsible for maintaining the client file and for reporting test results. The client file is maintained under that agency's privacy policies and the applicable audiology governing policy. The host site may track the number of tests performed for statistical and billing purposes, but does not record client information. Screen capture software may record the actual test for later training and evaluation purposes, but client information is not visible. Recording video components of

the testing should not be permitted except under certain conditions where the client has provided full and informed consent.

Ethical and Legal Issues

Frequently EHDI programs exist in an environment wherein licensure, funding, and regulatory restrictions apply and, often, clinical service delivery across borders between regions having different systems can be problematic (Denton and Gladstone 2005). With telemedicine, it is more likely than ever that a given clinician could be assessing an infant across state, provincial or even national borders. EHDI programs often will have local and regional differences governing licensure and funding and must take this into account when planning telehealth programming. Regulations governing supportive personnel, informed consent and client confidentiality and privacy will also need to be considered from a local and regional perspective. However, the increasing popularity and applicability of telehealth to audiology is likely to result in changes to restrictions to practice. It is to be hoped that such changes will be reasonable, responsible, and motivated primarily by the needs of affected children and families.

Conclusion

Despite some inherent challenges, the opportunities for beneficial utilization of telehealth applications in EHDI programs are numerous. Programs may adopt eEHDI to deliver many of the standard clinical service components, including screening, initial diagnostic assessments, behavioral assessment, hearing aid and cochlear implant programming, and the delivery of communication development options. eEHDI can also make important contributions to many facets of program infrastructure, including communications, training and quality management. Although a research and experience base exists with regard to the application of eEHDI to infant hearing programs, it is clear that there is more work to be done. Audiology as a profession must ensure that a sound evidence base for novel practice exists, and EHDI programs as a whole must ensure that novel procedures and protocols lead to genuine and lasting improvements in program effectiveness, efficiency, and equity.

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