TELE-AUDIOLOGY AS A MEANS TO INCREASING ACCESS TO AUDIOLOGIC SERVICES

Capstone Project

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By

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ABSTRACT

The need for audiologic services is significant across the world. Barriers to accessing health and health-related services in developing countries and in remote and rural areas of developed countries results in a greater need of those services. Tele-audiology is a proposed solution to the lack of access to audiologic services. While there are many considerations for providing services via tele-audiology, including the limitations to tele-audiology, studies have shown that tele-audiology can result in reliable and valid test results. Audiology services have been provided successfully using tele-audiology both within and across countries. Tele-audiology is an option for increasing audiologic services to those who need them.

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

The World Health Organization (WHO) has estimated that 642 million people, which constitutes nearly 10% of the world population, have a hearing loss of some degree and that 278 million people globally have a moderate-to-profound hearing loss (WHO, 2006a). Additionally, 80% of those with a moderate-to-profound hearing loss are living in low and middle-income countries (WHO, 2006a; Tucci, Merson, & Wilson, 2010). Hearing loss as a public health burden has often been ignored, even though it is considered "the most prevalent disabling condition globally" (WHO, 2008a, p. 35; Swanepoel et al., 2010, p. 196). The need for audiologic services is huge and wide-spread.

Globally, the number of health workers who have been educated, trained, and employed is insufficient for the number of people who need health services. The lack of health care workers has become a crisis requiring immediate action (Global Health Workforce Alliance, 2008). This is true for audiologic services as well. Communication problems resulting from hearing loss have been associated with higher unemployment rates, and those with hearing loss may earn lower incomes compared to those with normal hearing (Tucci et al., 2010). The financial burden of hearing loss is steep with hearing loss costing approximately $170 billion in the U.S. (Tucci et al., 2010). One proposed solution to the shortage of professionals and services is an expanded use of technology in the form of tele-health, tele-medicine, or tele-services.

With recent advances in technology and the widespread access to and use of the Internet, providing health care and health-care related services remotely has become a possibility. In 2007, nineteen percent of the world population had access to the Internet (Global Health Workforce Alliance, 2008). Access to the Internet, however, varies by country with 70% of the population in North America having access to the Internet in 2007 compared to only 4.7% of the population in Africa (Global Health Workforce Alliance, 2008). Technology and the Internet can expand the provision of services to reach those in rural or remote areas and those who lack access to care. As technology continues to grow and expand rapidly, the potential for remote provision of services will increase.

Remote provision of medical services has been termed *telemedicine*, which is defined as "the use of telecommunications technology for medical diagnostic, monitoring, and therapeutic purposes when distance separates the users" (ASHA, 2005, p. 1). While the term *telemedicine* has been used in reference to medical services provided by physicians, the term *tele-health* is used to describe a variety of health science services, rather than just medicine, that are delivered by both physician and non-physician providers (ASHA, 2005). Another common term with a more broad definition is *telepractice*, or "the application of telecommunications technology to deliver professional services at a distance" (ASHA, 2005, p. 1). Tele-audiology refers to audiology applications of tele-health and tele-practice.

As a relatively new option, tele-audiology has become a potential method of reaching those in need of audiologic services who have difficulty obtaining the services. Both the American Academy of Audiology (AAA) and the American-Speech-Language-Hearing Association (ASHA) have recognized the use of tele-health and tele-practice for audiology for clinical services, as well as education and supervision (AAA, 2008; ASHA, 2005). With the continuous and fast-paced changes and developments in technology, there are a variety of options and advances in tele-audiology. However, tele-audiology is certainly not without its limitations and difficulties. The implementation and management of a tele-audiology program is complicated and complex, as many factors need to be considered. The purpose of this paper is to discuss tele-audiology as a potentially feasible method of increasing access to audiologic services both in the U.S. and abroad.

CHAPTER 2: AUDIOLOGIC ISSUES IN DEVELOPING COUNTRIES

Hearing loss can have a negative impact on a person's life. Approximately one-third of the population in developing countries has a hearing loss that compromises their quality of life (Berman, 1995). One way to prevent and treat hearing loss is to prevent and appropriately treat otologic pathologies. If reoccurring or left untreated, otologic pathologies can lead to a permanent conductive hearing loss, which results from pathology affecting the outer ear and/or middle ear. Providing treatment for hearing loss, including the pathology causing the hearing loss, can improve a person's quality of life. In order to implement and provide the appropriate otolaryngologic and audiologic services in developing countries, it is necessary to know and understand the common pathologies that affect people living in those areas.

Otitis media is a common cause of hearing loss in developing countries (Berman, 1995). According to a literature review by Berman (1995), the prevalence of chronic suppurative otitis media (CSOM) and the prevalence of mastoiditis are higher in developing countries than in developed countries, including the U.S., where CSOM and mastoiditis are rare. The lower rates of CSOM and mastoiditis in developed countries is the result of the use of antibiotics, which are less readily available in developing countries. It was reported that the prevalence of CSOM and mastoiditis in developing countries in the 1990s was similar to the prevalence in the U.S. and Europe in the 1940s and 1950s, which was prior to the development of antibiotics for those pathologies (Berman, 1995).

It has been suggested that a vaccine is needed to prevent otitis media, which would be highly beneficial in developing countries (Berman, 1995). Due to concerns regarding antibiotic resistance, physicians from a variety of countries have reported that they would consider using a vaccine for the prevention of otitis media in children, if a vaccine was available that was safe and effective (Arguedas et al., 2010). Preventing otologic pathologies in turn can prevent some presentations of hearing loss, which could reduce the significant need for audiologic services in developing countries. However, the current high prevalence of otitis media and mastoiditis has led to the current considerable need for both audiologic and otologic services in developing countries.

Because conductive hearing losses are common in developing countries, treatment options and amplification choices differ for an audiologist or other hearing professional in developing countries compared to those in developed countries. For example, patients with chronic ear infections may frequently have ear discharge, which can damage hearing aid components that are placed in the ear canal, such as in-the-ear (ITE) or receiver-in-the-canal (RIC) hearing aids. Therefore, a behind-the-ear style of hearing aid with a custom earmold may be more appropriate in these cases in order to prevent the electronic components from malfunctioning due to exposure to ear discharge. Additionally, cases of conductive hearing loss require collaboration with ear, nose, and throat physicians to treat and manage the ear pathologies and resulting hearing loss.

HIV/AIDS is an epidemic in developing countries that leads to poorer health outcomes and a shorter lifespan, affecting both children and adults. Ear pathologies and hearing loss may be more common in people with HIV/AIDS than those without HIV/AIDS (Gondim et al., 2000; Khoza-Shangase, 2010; Khoza & Ross, 2002; Kallail et al., 2008). A retrospective study in Thailand set out to determine the prevalence of ear, nose, and throat pathologies that affected pediatric AIDS patients. The study found that 18.4% of the children examined had otitis media (Chaloryoo et al., 1998). However, it should be noted that the authors did not report the percent of children in Thailand without AIDS with otitis media. An ear-swab culture of the patients in review revealed that every specimen in these cases showed co-trimoxazole resistance. However, this was not surprising to the researchers because co-trimoxazole is a prophylaxis regimen used to prevent Pneumocystis pneumonia in pediatric AIDS patients (Chaloryoo, et al., 1998). This indicates that common antibiotics used in developed countries to treat otitis media may not be effective in patients with AIDS. Therefore, treatment for otitis media may vary in developing countries, potentially making it more difficult to treat otitis media and to prevent hearing loss.

Various studies have reported different levels of prevalence and incidence of hearing loss in those with HIV/AIDS. The varying findings may be due to differences in incidence of otologic manifestations between pediatrics and adults. While some studies have looked at both pediatrics and adults, others have included only one age group. The incidence of otologic manifestations, including otitis media and conductive hearing loss, is much higher in children with HIV/AIDS than in adults, as the incidence in adults with HIV/AIDS is very low (Khoza-Shangase, 2010). A study by Gondim et al. (2000) compared the occurrence of otorhinolaryngological manifestations (ENTM) in children with HIV to the occurrence of ENTM in children without HIV. They found that both groups had similar manifestations, but ENTM occurred more frequently in the group of children with HIV (Gondim et al., 2000). A review of literature on HIV/AIDS in relation to auditory manifestations found that hearing loss in HIV/AIDS patients can be a conductive, sensorineural, or central type and either stable or fluctuating (Khoza-Shangase, 2010). The degree of loss varies from mild to profound with irregular configuration or sloping high-frequency loss. Both unilateral and bilateral cases occur in HIV/AIDS patients with gradual, intermittent, or sudden onsets (Khoza-Shangase, 2010). Therefore, there is no specific and clear presentation of hearing loss seen in patients with HIV/AIDS.

The causes of hearing loss in patients with HIV/AIDS have been shown to be the direct effect of HIV/AIDS, ototoxicity, or opportunistic infections (Khoza-Shangase, 2010). Researchers have found indirect causes of hearing loss in patients with HIV/AIDS due to opportunistic infections, such as tuberculosis, which require treatment using ototoxic or potentially ototoxic medications. Additionally, antiretroviral therapy (ART) is commonly used to suppress HIV and hinder the progression of the disease (Khoza-Shangase, 2010). Although the relationship between ART medications and hearing loss is not clear, there have been indications of an ototoxic effect of ART medications, thereby putting patients with HIV/AIDS at further risk for hearing loss (Khoza-Shangase, 2010). However, further research is necessary to better understand any existing correlation between ART and hearing loss. Similar to cancer treatments, some of which have known ototoxic effects, reducing or changing ART treatment may not be an option, as these can be life-saving or life-enhancing methods of treatment. Thus, preventing ototoxicity and the resulting hearing loss may not be an option, since hearing loss is a secondary concern to life-threatening and potentially debilitating diseases. Patients using ART may benefit from high-frequency puretone testing and distortion product otoacoustic emission (DPOAE) testing, since ototoxicity often affects high-frequency hearing first and damage often is demonstrated through DPOAE testing before it is shown in behavioral test results.

Another factor to consider is that people who are deaf or hard of hearing may lack access to information regarding health concerns, including HIV/AIDS, as a result of communication difficulties and lower literacy rates (Groce et al., 2007). A survey by Groce et al. (2007) compared the level of understanding of different aspects of HIV/AIDS between deaf and hard of hearing young adults to the level of understanding of normal hearing young adults in Nigeria. Results of the comparison indicated that the deaf and hard of hearing individuals were more likely to have misconceptions regarding the transmission and prevention of HIV and had less access to up-to-date information and quality of knowledge (Groce et al., 2007).

Therefore, deaf and hard of hearing patients may need additional resources to provide education and information regarding health concerns. These patient populations may benefit from audiologic treatment and management, but also their communication impairments and handicaps and how those affect various aspects of their lives must be considered. Therefore, providing education and other resources is necessary in addition to providing audiologic resources and intervention.

CHAPTER 3: AUDIOLOGIC SERVICES IN DEVELOPING COUNTRIES AND IN RURAL AND REMOTE AREAS OF DEVELOPED COUNTRIES

Because the healthcare and health-related needs of those living in developing countries and in rural or remote areas of developed countries are different than those living in developed areas of the world, the provision of audiologic services is different as well and can be difficult and complex. Services that are provided routinely in developed areas of the world are often less frequently available or rarely utilized in developing, rural, or remote areas of the world. However, audiologic services are expanding, especially in regards to newborn hearing screenings and the provision of amplification devices.

A model for newborn hearing screenings (NHS) in areas where accessibility to audiologic services is limited has been proposed by the Health Professions Council of South Africa (HPCSA, 2002). The proposed NHS model uses a 2-stage otoacoustic emission (OAE) screen, which means that any infant who fails the initial OAE screening is referred for a second OAE screening. If the second screening is failed, the infant is referred for a full diagnostic evaluation. Each infant only needs to pass a screening in one ear, since the model solely targets bilateral hearing losses. High-frequency tympanometry using a 1000 Hz probe tone is used for bilateral OAE referrals, in order to determine risk for middle ear effusion versus risk for sensorineural hearing loss. A pilot study performed at two immunization clinics in South Africa investigated the proposed NHS model (Swanepoel et al., 2006; Swanepoel et al., 2007). Over a five month period of time, any infant who attended the clinics was enrolled in the hearing screening program. The infants included in the study ranged in age from newborn to 12 months. The pilot study had a high hearing screening coverage rate of 93% for bilateral screening using OAEs (Swanepoel et al., 2006; Swanepoel et al., 2007). This is an example of the potential for hearing screenings to reach a significant number of infants.

Similar to NHS in the U.S., the largest barrier to the program described above was poor follow-up. However, the pilot study only looked at the hearing screening program for a brief period of time, and it has been shown that follow-up rates increase over time as screening programs develop and mature (Swanepoel et al., 2007; Mehl & Thomson, 2002). Therefore, long-term research would be beneficial. Another barrier was the presence of middle ear effusion, which was responsible for over 50% of the initial referrals (Swanepoel et al., 2006; Swanepoel et al., 2007). Other barriers included language, external noise, lack of knowledge caregivers had about hearing loss and its implications, and difficulty testing older infants who were awake more often and restless compared to the newborns. Assets of the program included adequate facilities, positive and cooperative clinic nursing staff, and nurses who could act as language interpreters for caregivers.

Some NHS programs have already been implemented in developing countries. For example, in Lagos, Nigeria a community-based program and a hospital-based program both use transient otoacoustic emissions (TEOAEs) for NHS. The community-based program has four immunization clinics where hearing screenings are performed. The hospital-based program, which includes the well-baby nursery (WBN) and the special care baby unit (SCBU), performs hearing screenings in the wards, at the nurses' stations, and in test rooms. A recent study assessed the noise levels of these two NHS programs and set out to determine the effects of the noise levels on the TEOAE results (Olusanya, 2010). Noise levels were measured at the different screening sites using an integrated sound level meter.

The noise levels ranged from 63.1 to 67.9 dBA SPL at the community-based clinic sites (Olusanya, 2010). The average ambient noise levels in the SCBU ranged from 62.3 to 90.5 dBA and in the WBN from 61.0 to 76.0 dBA (Olusanya, 2010). There were no significant differences in the noise levels found in the hospital sites compared to the four community-based clinics. Nevertheless, the noise levels measured in these two programs were higher than those typical of NHS sites in developed countries. All of the average noise levels measured in this study exceeded the recommendation of the American Academy of Pediatrics of 45 dBA (Olusanya, 2010; American Academy of Pediatrics, 1997). However, the noise levels measured at the programs in Nigeria are comparable to those found in other developing countries, such as Brazil, Turkey, and India (Olusanya, 2010).

Keeping the windows open for ventilation, traffic and human noise from the busy street on which the hospital is located, crying babies, noise from the nursing staff, and incubators in the SCBU are some of the factors contributing to the high noise levels measured in the study (Olusanya, 2010). While some of these factors are causes for concern in developed countries, others are problems more specific to underdeveloped areas. This includes having windows open for ventilation. Utilizing an air conditioner allows the option of turning it off while screenings are performed to decrease noise levels, while also providing ventilation, but air conditioners can be costly and difficult to access in developing countries. Cost is also a major reason hearing screening sites in developing countries have not made changes to improve the acoustic conditions of the environments in which hearing screenings are completed. Using less advanced or older equipment cuts down on costs but typically results in poor responses due to noise. On the other hand, some simple and cost-effective precautions can be taken to keep noise levels within 60 dBA, and include instructing nursing staff to speak at lower volumes and to avoid shouting across the room, applying rubber to furniture, and replacing metal files with plastic ones (Swanepoel et al., 2007; Ramesh et al., 2009).

Ambient noise levels are commonly found to be significantly higher in developing countries than in developed countries (Olusanya, 2010). Not all commercially available TEOAE screening instruments can be used successfully in developing countries due to high ambient noise levels. The two OAE screening systems used in the study by Olusanya (2010) were the Echo-Screen and ECHOCHECK. The noise levels were often too high for the "Noise Ok" indicator to light up when using the ECHOCHECK system. More modern OAE equipment, including the Otoport Series that has replaced the ECHOCHECK, have more aggressive and more effective noise-rejection mechanisms, and therefore would be more appropriate for the screening conditions found in the sites in the study. However, more modern systems are more expensive than older systems and therefore are unattainable for many NHS programs in developing countries.

Despite the high ambient noise levels found in the NHS programs in Nigeria, no significant correlation between the noise levels and the TEOAE referral rates was found (Olusanya, 2010). A proposed reason for this is that OAEs are reportedly more robust in the Negroid race than in Caucasians, and thus higher signal-to-noise ratios allow for measurable emissions, despite high ambient noise levels (Olusanya, 2010). Therefore, appropriate noise levels may vary depending on the test population. Factors related to both the test population and the test environment should be thoroughly considered when analyzing screening results.

Ethical issues also impact the delivery of audiologic services in developing countries. For example, an essential requirement for a NHS screening program is the ability to provide early intervention (Olusanya et al., 2006). Ethical issues arise when a diagnosis is made but treatment or management cannot be provided. Knowing that a newborn has a hearing loss without being able to provide treatment and management of the hearing loss is problematic. Therefore, in order to implement a screening program, some type of intervention needs to be available. This leads to a question that is highly applicable in developing countries, “Should limited intervention services forestall early detection of hearing loss?” (Olusanya et al., 2006, p. 590). Although certain intervention services and options, such as amplification devices, are lacking in developing countries, other appropriate services may be available or may be made more easily and readily available, even if not commonly used currently in developed countries. For example, education services for individuals with hearing loss, including sign language, in developing countries are relatively well-established (Olusanya et al., 2006). While sign language is an intervention option, it can restrict a person's options for employment later in life. It is difficult to determine what options in particular should be made available and to what degree they must be available, but intervention must be taken into consideration when implementing hearing screening services.

Although audiologic intervention is limited in developing countries, initiatives exist that provide audiologic services and amplification devices in developing countries in a feasible and cost-effective way. One of those initiatives is Godisa, a Botswana initiative that provides solar-rechargeable hearing aids and related services for individuals with hearing loss in Africa and other areas of the developing world. Godisa strives to provide affordable amplification that is of good quality and is appropriate for the person with hearing loss. The initiative considers that hearing aids and batteries are costly and that batteries are difficult to access. Additionally, the initiative takes into account that the hearing aids they provide need to withstand the conditions, such as humidity and dust, often sustained in those countries. Moreover, the hearing aids are designed to provide appropriate amplification, unlike the devices commonly marketed in developing countries, which are often over-the-counter devices that provide mostly low-frequency amplification (Cheng & McPherson, 2000; McPherson & Brouillette, 2004).

Godisa provides behind-the-ear hearing aids available in three different levels of technology that use either zinc air or rechargeable batteries and that can be adjusted using trimpots. The hearing aids cost between $35 and $99 for patients. To keep in line with the WHO objective of providing hearing aids for $20 or less in developing countries, Godisa is working to decrease the price of the hearing aids, while also striving to include directional microphones, digital signal processing, and programmable multiple memories, which typically increase the cost of a hearing aid significantly (McPherson & Brouillette, 2004). Prototypes of the hearing aids provided by Godisa have undergone and continue to undergo field trials in developing countries. Godisa is also collaborating with EARS Inc, a charitable organization of Australia, to develop low-cost, basic earmold production kits that are of good quality. The objective is to provide appropriate amplification, which may require a custom earmold, such as for medium-gain or high-gain hearing aids.

Another initiative designed to provide hearing aids and services to those in underserved communities and developing countries is WWHearing- Worldwide Hearing Care for Developing Countries. This global initiative uses the framework of the "WHO Guidelines for Hearing Aids and Services for Developing Countries," which was launched in 2001. Similar to Godisa, one of its main purposes is to provide appropriate and affordable amplification and hearing services. WWHearing is working to collect information on the need and provision of services in developing countries, begin pilot studies in various regions to evaluate feasibility, facilitate partnerships, and promote training, fitting, follow-up, and repair projects (Garms & Smith, 2008). WWHearing and Godisa are examples of existing audiologic services in developing countries and can be models for future provisions.

Another highly important consideration when providing audiologic services is determining patient satisfaction and the effectiveness of the services provided. A study by Olusanya (2004) evaluated hearing aid user self-report outcomes using the International Inventory for Hearing Aids (IOI-HA) to determine the effectiveness of aural rehabilitation at a private hearing center in Nigeria. The clinic provides screening and diagnostic audiometry, as well as electrophysiologic tests, for all ages. They dispense analog and digital hearing aids and provide earmolds that are made at the in-house laboratory. They also have a repair unit where specially trained technicians repair hearing aids. Results of the study indicated that IOI-HA scores at the clinic in Nigeria were comparable to those reported in developed countries, including the U.K., U.S., and The Netherlands, with the exception of IOTH (impact on others) scores, which are related to significant others. IOTH scores were correlated with the following variables: gender, type of hearing aid, and user's experiences. That is, female users and first-time users of hearing aids reported feeling that other people were more bothered by their hearing difficulties, whereas completely-in-the-canal hearing aid users reported feeling that others were less bothered by their hearing difficulties (Olusanya, 2004). However, 72% of participants felt that other people were not significantly bothered by their hearing difficulties. Perceptions of improved quality of life were reported by 89% of the participants, indicating effective treatment (Olusanya, 2004). This study demonstrated the information that can be obtained from hearing aid outcome measures and the feasibility of using outcome measures in developing countries.

Similar to people living in developing countries, people living in rural and remote areas of developed countries also face obstacles in receiving health care and health-related services. These obstacles exist mainly because of the limited availability of services in rural and remote areas. Those living in rural and remote areas of the U.S. typically have decreased access to specialist physicians and live farther from health care resources, compared to urban areas that typically have a greater number of health care providers (Glasser et al., 2003). Specialty physicians can include otolaryngologists, who often provide services in conjunction with audiologists. In order to receive care, people in remote and rural areas frequently must travel long distances, which requires significant amounts of time and money, as well as potential loss of wages from taking time off work.

Winters et al. (2011) report that "for many uninsured, impoverished, rural Americans, access to specialty care is nearly as unattainable as in Africa" (p. 298). They collected data in seven Southeastern states in the U.S. to compare patient demographics and availability of otolaryngology practices in urban versus rural counties. In six of the seven states, urban counties had a significantly higher number of otolaryngologists per capita than rural counties. Most of the states had higher rates of Medicaid recipients and higher rates of uninsured patients in the rural counties compared to urban counties. These findings imply that the patient to physician ratio is higher in rural areas for otolaryngology services compared to urban areas (Winters et al., 2011). This further supports the notion that patients in rural areas of the U.S. may be required to travel in order to receive otolaryngology services or may not be able to receive services due to distance.

Australia is another developed country in which people in remote and rural areas have shown a need for but lack access to otolaryngology and audiology services. The incidence of ear infections and resulting complications is high in rural and remote areas of Western Australia. People living in those areas also need to travel long distances to receive specialty health services, including otolaryngology services. Blackham et al. (2004) reviewed statistics and records of patient visits between July 2000 and June 2001 to determine the rate of ear, nose, and throat (ENT) surgical service use at Perth hospitals in Western Australia. All patients included in the study required ENT surgery, 25% of which were ear-related procedures (Blackham et al., 2004). The researchers found that in Western Australia the number of patients that travel a long distance for ENT services is high. Patients from the area closest to Perth had the lowest cost of travel with an average of $66.84 per trip, while those from the farthest area had the highest cost of travel, averaging $1,027. 78 per trip (Blackham et al., 2004). These studies in the U.S. and Australia demonstrate that living in remote and rural areas of developed countries results in barriers to access for health services, including otolaryngologic and audiologic services.

CHAPTER 4: TELE-AUDIOLOGY

Tele-audiology has become a method of reaching those in need of audiologic services and is a proposed method of addressing the lack of availability and barriers to access to services, some of which are described above. Both the American Academy of Audiology (AAA) and the American-Speech-Language-Hearing Association (ASHA) have recognized the use of tele-health and telepractice for audiology (AAA, 2008; ASHA, 2005). With the continuous and fast-paced changes and developments in technology, there are a variety of options and advances in tele-audiology. However, tele-audiology is certainly not without its limitations and difficulties. The implementation and management of a tele-audiology program is complicated and complex, as many factors should be considered.

The administration of tele-audiology services can vary greatly with the many components that are necessary for its utilization. Some tele-audiology programs employ self-test procedures using the telephone and/or a computer. The three types of tele-health systems are self-guided tools, synchronous applications (i.e., real-time and live interactive tele-health) and asynchronous service delivery (also referred to as "cloud-based" or "store and forward") (Freeman, 2010). Online hearing tests and adjustments to hearing devices made through a patient's phone are self-guided tools. Synchronous applications involve live contact between patients and service providers through the Internet, telephone, etc., with the use of computers or video-teleconferencing systems. This can include the use of remote audiometers and video-otoscopes. With asynchronous applications, patient information, including digital images or video, is transmitted or delivered off-line and reviewed at a later time (Freeman, 2010). Additionally, a hybrid model has been described, which combines synchronous and asynchronous technology. This allows some live contact with patients to obtain test results, such as puretone audiometry, while other test results, such as tympanometry are stored and sent to the provider at a later time. It has been suggested that a hybrid delivery method could be best for providing hearing services (Krumm, & Syms, 2011). The type of application used will depend heavily on the purpose of the tele-audiology program, the specific audiologic services that are being provided, and the available resources.

Potential uses of tele-audiology include hearing screenings, diagnostic testing, and intervention, as well as determining patient perceptions regarding their audiologic care. Education and training for health care providers, paraprofessionals, and parents, as well as mentoring, can also be accomplished through tele-audiology systems and interactive online modules (Swanepoel et al., 2010; Swanepoel, Olusanya, & Mars, 2010). Video-otoscopy, pure tone audiometry, immittance testing, automated auditory brainstem response (AABR), otoacoustic emissions (OAEs), speech-in-noise testing, and vestibular assessment are potential tools for screenings and diagnostic testing performed via tele-audiology. Hearing aid fitting, verification, and counseling, as well as cochlear implant programming and tinnitus therapy, also can be performed using tele-audiology. For tinnitus assessment, online evaluation forms allow patients to provide information on perceived effects that tinnitus has on their life activities and functioning, as well as anxiety and depression that may be related to tinnitus. Internet-based cognitive behavioral self-help treatment and online administration of outcome measures can be applied for tele-health tinnitus treatment and management. Many studies that have assessed these various tools used in tele-audiology systems found that remote testing was as reliable as face-to-face testing (Swanepoel & Hall, 2010). An important consideration in any method of providing audiology services, including tele-audiology, is the reliability and validity of the results. That is, will tele-audiology have the same results that on-site testing would provide? Ensuring that the tests and procedures are reliable and valid leads to a successful tele-audiology program.

Newborn hearing screenings, including those using tele-audiology systems, have become more feasible with decreased costs, increased availability of portable devices, and the digitization of instruments (Nemes, 2011). While tele-audiology systems have been designed to perform hearing screenings, implementation has not occurred widely. Emerging tele-audiology includes Early Hearing Detection and Intervention (EDHI) programs for infant hearing assessment using OAEs and ABR. Krumm and Syms (2011) compared in-person OAE and ABR infant hearing screening results with results from remote hearing screening performed via videoconferencing. They found that the remote test results were exactly the same as the in-person test results, indicating that remote infant hearing screening can provide reliable test results.

In comparison to hearing screenings, full diagnostic audiometric testing is more complex. Therefore, the feasibility of remote audiometric testing for diagnostic purposes may vary from that of screenings. A study by Givens and Elangovan (2003) evaluated an Internet-based tele-audiology system designed for determining puretone thresholds in adult participants in North Carolina. Audiologists performed the testing using the same audiometer for both in-person testing and remote testing, in which the audiologist used a computer and an Internet connection to perform the testing. Results from conventional in-person testing were comparable to that of the Internet-based system for both air conduction thresholds and bone conduction thresholds (Givens & Elangovan, 2003; Elangovan, 2005). In another study, Yao et al. (2010) compared air conduction thresholds obtained by conventional pure-tone audiometry, remotely with a gateway access point, and remotely with a computer access point. The comparisons revealed that results of the conventional and remote methods of assessment did not differ significantly, indicating that the remote systems produced valid and reliable results. These studies demonstrate that remote puretone threshold testing is feasible and provides accurate audiometric results, thereby supporting tele-audiology.

OAEs are a useful tool both for hearing screenings and for diagnostic testing. OAEs can supplement other audiologic testing and therefore may be beneficial when included in a test battery. In order for this to be true in tele-audiology systems, the feasibility of remote OAE testing and the validity of remote OAE results must be evaluated. Remote OAE testing has been performed in pilot studies using interactive video and desktop sharing software (Swanepoel & Hall, 2010). Elangovan (2005) performed a pilot study to determine the feasibility of measuring DPOAEs via tele-audiology. DPOAE testing was performed on participants both with a conventional OAE system and a remote OAE system. Results between systems were compared and DPOAE amplitudes were comparable. Because the DPOAE testing was part of a pilot study, the sample size was small and only included 5 people. However, the results suggest that testing DPOAEs through a remote system yields reliable results. Further research should be completed to confirm the reliability of remote DPOAE testing.

Questionnaires are commonly used during in-person appointments with patients as a subjective measure of benefit from and satisfaction with audiologic services and hearing devices. In a limited number of studies, patient perceptions of audiologic services delivered through remote systems have been assessed, mostly using questionnaires (Swanepoel & Hall, 2010). Patients have been asked to rate their willingness to participate in telemedicine for audiology services. In one study, about one half of the patients had not used telemedicine before, while some were not even aware of telemedicine (Eikelboom & Atlas, 2005; Swanepoel & Hall, 2010). Another study has compared face-to-face and remote cochlear implant programming sessions. Patient satisfaction was comparable between face-to-face and remote provision of services. However, patients who participated in the remote sessions were more likely than the face-to-face session participants to report that the sessions were too long (Ramos et al., 2009; Swanepoel & Hall, 2010). As tele-audiology becomes more widely employed, greater opportunities will arise for assessing patient perceptions on their experiences with tele-audiology.

Hearing aid manufacturing companies have also embraced tele-audiology as a way to communicate both with patients and with professionals. In 2004 the Starkey Group, Inc. developed a tele-health service to provide hearing aid fitting assistance to audiologists. Since 2009, Starkey also has allowed hearing professionals to adjust the volume and memory settings in patients' hearing aids using Dual Tone Multifrequency (DTMF) phones through Starkey's T2 Tele-health OnDemand (Freeman, 2010). The patient calls the hearing professional and holds the phone close to the hearing aid. The hearing professional enters a code into the phone and then can make adjustments to the hearing aids by using the key pad on their phone, which must be capable of emitting DTMF signals. This could be advantageous for patients who need adjustments but live far away or have other barriers to getting to the clinic. Although tele-audiology can be useful in a variety of ways and can benefit many people, a myriad of challenges must be addressed.

CHAPTER 5: TELE-AUDIOLOGY IN DEVELOPING COUNTRIES AND IN RURAL AND REMOTE AREAS OF DEVELOPED COUNTRIES

Recent studies have been designed to determine the feasibility of tele-audiology for developing countries so that tele-audiology programs can be implemented there. For example, Swanepoel, Koekemoer, and Clark (2010) compared air conduction thresholds for a group of adult patients in South Africa obtained from two delivery methods: face-to-face delivery and remote administration. The remote audiometric testing was performed by a clinician in Dallas, Texas, while a physician acted as a facilitator in South Africa. The researchers found that the patients' thresholds between the two delivery methods did not differ significantly and that the observed threshold differences were no greater than normal test-retest variability, indicating that remote audiometric testing yields valid air conduction puretone thresholds. The longest distance previously reported for remote synchronous audiometry was 1100 km and had been conducted within the same country (Krumm, Ribera, & Klich, 2007; Swanepoel, Koekemoer, and Clark, 2010). Swanepoel, Koekemoer, and Clark (2010) demonstrated that remote audiometry is feasible between even further distances and can be accomplished between the U.S. and Africa (Swanepoel, Koekemoer, &

Clark, 2010). Utilization of tele-audiology across significant distances and between countries can open many possibilities for providing audiologic services.

Lancaster et al. (2008) compared on-site hearing screening results to tele-health screening results for a rural elementary school in Utah. The screening, which utilized otoscopy, pure-tone audiometry, and immittance measures, was conducted on 32 children in the 3rd grade. All of the children were screened in-person by an audiologist. They also were screened remotely by an audiologist, while a trained assistant acted as the on-site facilitator, whose tasks included video-otoscopy and placement of the headphones. In-person otoscopy and remote video-otoscopy results yielded the same outcome for all of the children. However, because only one child was referred based on otoscopy, this study does not provide insight on abnormal otoscopy. That is, future research should compare in-person otoscopy to remote video-otoscopy for children with abnormal findings from otoscopy to ensure that results are comparable between the two methods. Tympanometry screening results also yielded the same outcomes for all of the children, when comparing remote and in-person testing. Five of the children in the study responded differently to the pure-tone stimuli during the tele-health testing compared to the on-site testing. Further research should investigate why there was a difference and what implications it could have for future use of tele-audiology. However, no statistically significant differences between delivery methods were found in the screening tools utilized (Lancaster et al., 2008). This study only included 3rd graders, and therefore further research should evaluate tele-health screening for other grades and age-groups to determine if those tele-health screenings also provide valid results. Additionally, further studies should compare in-person results to remote results for otoscopy with abnormal findings. Nonetheless, this study does suggest that remote hearing screening is feasible and valid, at least for the age group tested.

While tele-audiology may be ideal for hearing screenings or diagnostic testing, other services, such as hearing aid fittings and rehabilitation, are more challenging because of the need for audiologists or highly-skilled technicians (Nemes, 2011). Hearing aid services offered through tele-health systems are certainly complicated, and little research has been performed to determine the feasibility of providing remote hearing aid services. During a visit to China, Christine Yoshinaga-Itano, Ph.D., found that many children who had been fit with hearing aids were under-amplified (Nemes, 2011). This highlights the limitations to services in some areas of the world and a way in which tele-audiology may be able to fill in service gaps. One way to improve hearing aid services in underserved areas is to use validation measures, which ensure that the hearing aid settings are appropriate for the hearing aid user. The Tele-Audiology Network (TAN), a newly established non-profit organization, is working on a pilot project in South Africa that will assess the cost-efficiency and validation of technology for tele-audiology that includes hearing aid services. TAN is designed to allow audiologists from other regions of the world to volunteer services to underserved regions using tele-audiology. There are public health hospitals in South Africa where patients can obtain hearing aids, and validation of remote hearing aid fittings is one of the goals of TAN.

As discussed earlier, people living in rural or remote areas of developed countries face many significant barriers to healthcare and related services, including audiologic services. Lack of access and barriers to access can deter a person from seeking services they need (Krumm et al., 2005). Due to the higher patient to physician ratios for otolaryngology services and distances needed to travel to receive services in rural areas of the U.S., domestic outreach clinics can be set up to provide services in rural areas and staff can include an audiologist. Domestic outreach clinics can reduce the financial burden that patients in rural areas currently experience from travel costs (Winters et al., 2011). Expanding accessibility for services can encourage people to seek the healthcare or health-related care they need. Telemedicine is a suggested method for combating the lack of accessibility to health services in Western Australia also (Blackham et al., 2004). Developed countries, including the United States and Australia, can benefit from tele-audiology.

Universal newborn hearing screening (UNHS) and school hearing screening programs can also utilize tele-audiology. It is difficult to set up UNHS programs due to the lack of essential resources, including personnel, in rural communities (Krumm et al., 2005). However, it is likely that more UNHS will be implemented in rural communities, largely because of tele-audiology, which will lead to more timely diagnoses of hearing loss and increase provisions of audiologic habilitation and rehabilitation. Providing school hearing screenings through tele-audiology can reduce the amount of time and money that audiologists spend travelling to perform screenings, while also saving the school districts money (Lancaster et al., 2008). Otoacoustic emissions, auditory brainstem evoked potentials, and high-frequency tympanometry are the common tools used for hearing assessment in rural areas (Krumm et al., 2005). Tele-audiology can be used for a variety of services.

A rare and unforeseen opportunity for tele-health and tele-audiology is following natural disasters. A relatively recent example is Hurricane Katrina, which severely affected Louisiana. In the aftermath of the hurricane, those living in the areas most affected or outside of the major cities had and still have limited access to certain health and health-related services, including otolaryngology and audiology services. One example is the Louisiana State University Health Science Center New Orleans Otolaryngology Department. Following Hurricane Katrina, the department could no longer provide neurotology services for patients, neurotology education for residents, or academic research in neurotology. One component of a plan to reinstate clinical services and education for residents was the presentation of otology lectures via teleconference (Arriaga, 2010). This led to the implementation of tele-medicine in 2007 for providing neurotology services, in conjunction with audiology services provided by an audiologist.

A retrospective study of the first year of the tele-medicine program at the Louisiana State University Otology-Neurotology clinic reported that 50% of the patients were diagnosed with a vestibular disorder, 20% with sensorineural hearing loss, and 10% with chronic otitis media (Arriaga, 2010). Patients ranged in age from

5 to 87 years old, and a total of 450 patient encounters were completed via telemedicine alone. A specialty-trained nurse practitioner worked with the patients at the Baton Rouge clinic, while the physician viewed the visit on a computer in another city. The nurse practitioner performed video-otoscopy and sent digital photographs to the physician to assess the patient's ear canals and tympanic membranes. The need for adequate sound volume for patients with hearing loss was taken into consideration before offering telemedicine to patients. That is, telemedicine was not offered to cochlear implant candidates except for one case in which the visit was transcribed by a deaf interpreter. Thus, the dialogue was displayed on a computer screen, similar to closed captions, for the deaf patient. Although not described in detail in the study, audiovestibular assessments included videonystagmography, rotational chair, and posturography, as well as electrocochleography, auditory brainstem response, and vestibular evoked myogenic potentials. Although clinical outcomes and patient satisfaction were not assessed, the researchers noted anecdotally that both seemed equivalent between on-site evaluations and evaluations performed via telemedicine. The researchers plan on doing a formal analysis to assess patient satisfaction and clinical outcomes using standardized measures in a clinical study. This telemedicine program has been considered to validate the use of telemedicine for neurotology services in settings with limited resources (Arriaga, 2010). It also can be an example for future telemedicine and tele-audiology programs.

CHAPTER 6: CHALLENGES AND CONSIDERATIONS FOR TELE-AUDIOLOGY

The issues that accompany tele-audiology are both complex and significant. Potential drawbacks and challenges to tele-audiology include technical, socio-cultural, and organizational/infrastructural aspects of programs (Swanepoel, Olusanya, & Mars, 2010). State licensure and reimbursement are two of the main concerns regarding tele-health services. A major issue with remote audiologic services is the potential for excessive noise levels that could cause the results to be inaccurate. Testing time is also an area of concern for tele-audiology services, as well as the many factors regarding the technology that is used.

The Academy of Doctors of Audiology, the American Academy of Audiology, and the Audiology Foundation of America formed a task force in 2005 that developed a model license law that permits audiologic services to be delivered remotely and allows audiologists in the U.S. to provide tele-health services across states (Freeman, 2010). In regards to reimbursement, health services in general have become more commonly covered by insurance, though coverage for audiologic services is often limited and highly variable across insurance companies. Medicare does cover some services provided through tele-health systems. The Balanced Budget Act of 1996 included tele-health services for Medicare beneficiaries in rural areas in which the number of healthcare professionals is insufficient (Freeman, 2010). In 2001 the law was expanded to include funding for tele-health applications in Hawaii and Alaska. In at least 27 states in the U.S., Medicaid provides some degree of reimbursement for tele-health services, and many private insurers also reimburse for tele-health services (Freeman, 2010). While it is important to determine that a tele-audiology program is sustainable financially, determining what specific aspects of the program will make it feasible is important as well.

Typically audiologic testing is performed with the patient in a sound-treated room, or sound booth, to eliminate environmental noise and distractions. Therefore, if a sound-treated room is not available, measures must be taken to ensure that the audiometric test results are not impacted by excessive noise levels. That is, it must be determined that the results are comparable to results obtained in a sound-treated room. Live monitoring of environmental noise, sound attenuation from insert and circumaural earphones, and active noise cancellation can be used to decrease the need for sounds booths (Swanepoel, Olusanya, & Mars, 2010). These are more practical options for underdeveloped, rural, and remote areas, where sound booths may not be an option, likely due to cost.

Another potential challenge to tele-audiology is the time that is required to perform testing. Swanepoel, Koekemoer, and Clark (2010) found that remote puretone threshold testing took 21% longer to perform than in-person testing. The average time required for in-person testing was 8.2 minutes, whereas the average time for remote testing was 10.4 minutes, resulting in a 2.2 minute difference in the averages (Swanepoel, Koekemoer, & Clark, 2010). Although it took longer on average to perform testing remotely, the time required was still a relatively short duration. However, this was only for puretone audiometry, so if further testing and procedures were to be performed, the time would increase. Further research should evaluate the time required for remote testing in comparison to in-person testing using a complete test battery to give a more broad representation of the time requirements of tele-audiology.

The advent of the Internet has expanded the methods that allow for audiologic services to be administered remotely. However, the use of web services is not without its limitations and complications. If Internet based tele-audiology is used, the software and the browser-server network that are chosen should be easily maintainable, easy to upgrade, and compatible with existing telemedicine systems, such as reimbursement, billing, and scheduling (Yao et al., 2010). Interfacing an Internet-based, computerized remote hearing assessment system with electronic medical records could encourage the use of web services for remote hearing assessment and make its use more viable (Yao et al., 2010). Equipment needs to provide sufficient quality for images and sound, and with advances in technology, higher levels of security may be needed to ensure privacy and confidentiality (ASHA, 2005). In designing and choosing the necessary equipment for tele-audiology services, a variety of factors must be considered and resolved.

Tele-audiology can be more limited in developing countries compared to developed countries, such as the U.S. In developing countries, the availability of electricity and internet access are likely to be scarce and/or less efficient than in developed countries. Therefore, the use of battery-operated instruments can be highly beneficial in regions where electricity is not readily available (Nemes, 2011). The development of tele-health services requires flexibility and ingenuity to explore options properly suited for tele-audiology delivery methods.

A tele-audiology program for remote hearing assessment can be initiated fairly easily, with some important considerations. If a sound booth is not available, circumaural headphones can be placed over insert phones. Additionally, a sound level meter can be used to monitor noise levels and ensure that they are satisfactory. A health technician would be at the same location as the patient, while the audiologist would be at a different location. Prior to the application of the tele-audiology program, the health technician would receive on-site training with the audiologist. The health technician would be responsible for holding the video-otoscope, placing transducers on the patient, providing instructions to the patient, and taking earmold impressions. A tele-conference system would be available for both the health technician and the audiologist at their respective locations. The tele-conference system would include a monitor screen with a built-in camera and microphone, thereby allowing the health technician and audiologist to see and hear what was occurring at the other person's location. A video-otoscope would be connected to the monitor screen at the patient site, and live video of otoscopy could be viewed on the audiologist's monitor screen. For audiometry, the audiologist would utilize a desktop computer, which includes the monitor screen, with an

Internet connection and tele-audiometry software. At the patient site, a standard audiometer is connected to a "controller" and a "web server." The controller interfaces with the audiometer to make adjustments to the sound presentation (i.e. intensity and frequency adjustments, stimulus presentation on/off, etc.). The controller is connected to a web server that manages an Internet connection and allows the audiologist to make adjustments to the controller via the tele-audiometry software on his/her desktop computer. For instance, the audiologist can increase the stimulus intensity and present a tone on the computer using the software. The tone with its frequency and intensity information is sent from the audiologist's computer via the Internet to the web server at the patient site. The web server sends the information received to the controller, which tells the audiometer itself to present the appropriate tone via the attached transducers. Although this set-up may not be ideal, it is an option for those in areas where audiologic care and services are not available. Valid and reliable results can be obtained with this type of tele-audiology program.

CHAPTER 7: CONCLUSION

Tele-audiology is a feasible method of increasing access to audiologic services for people living in developing countries and in rural and remote areas of developed countries. Many studies have demonstrated that tele-audiology is a viable option within a country and across countries and can provide accurate and reliable test results (Elangovan, 2005; Givens & Elangovan, 2003; Lancaster et al., 2008; Swanepoel & Hall, 2010; Swanepoel, Koekemoer, & Clark, 2010; Yao et al., 2010). Tele-audiology can open a significant number of opportunities for audiologists and patients. However, many important factors must be taken into consideration and evaluated before, during, and after designing a tele-audiology program. Additionally, further research is needed regarding tele-audiology, including audiologic services beyond audiometric testing, such as hearing aid services and vestibular assessment, as well as clinician and patient satisfaction. Further research should also include bone conduction testing, if tele-audiology is to be used for diagnostic purposes. Future studies should take advantage of the ability to assess patient satisfaction and should evaluate measurements of benefit and satisfaction to ensure quality care and success of a program. Long-term data on tele-audiology programs is necessary to ensure that tele-audiology programs for developing countries and remote and for rural areas of developed countries are a viable option to increase access to audiologic care.

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