TELEAUDIOLOGY: CLINICAL OUTCOMES FROM ADULTS WITH HEARING LOSS

by

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This project is dedicated to my parents, Barry and Deborah Hopwood, for always inspiring me to move forward and better myself. Their years of patient listening and thoughtful advice have helped me reach the position that I am in today. I am grateful for their unending support.
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ABSTRACT

Outside of major metropolitan areas, Arizona has limited options for hearing healthcare. The Arizona Affordable Hearing Aid Task Force proposed the development of a statewide program to provide low-cost hearing aids and audiology care to low-income residents. The purpose of this review was to determine the status of the literature on the clinical outcomes of teleaudiology services for evaluations and hearing aid fittings which could be used to serve inhabitants of rural counties and address the goals of the Task Force. A literature search was performed to identify articles with original research in teleaudiology in the areas of evaluation and treatment and yielded 234 results. After exclusion criteria were applied, there were 15 articles for review; 10 articles focused on audiological evaluation and 5 articles focused on verification, validation, and counseling for hearing aid fittings. Evaluation-related articles showed that pure-tone air conduction testing was generally within the ±5 dB acceptable range of variability, with little evidence on bone conduction or speech testing reliability. Studies reporting real-ear measurements with probe microphones were shown to yield similar results in traditional and teleaudiology fitting sessions and validation measures documented similar or better outcomes from teleaudiology fittings. Based on the literature, it is concluded that the use of teleaudiology is feasible for hearing aid fittings and counseling in rural areas, if associated barriers related to costs and limitations related to the availability of technology are overcome.
CHAPTER 1: INTRODUCTION

Epidemiology of Hearing Loss in the United States, Demand for Services, & Barriers to Healthcare Access

It is estimated that 35 million individuals in the United States have some degree of hearing loss in at least one ear (ASHA, 2016). The prevalence of hearing loss increases with each decade of life and by the age of 70, two out of every three adults has at least a mild degree of hearing impairment (Lin, Niparko, & Ferrucci, 2011a). Hearing loss is a public health concern at the state, national, and global levels, due to the social, emotional, and economic impacts associated with the disability. Individuals with hearing loss self-report a lower quality of life, with withdrawal from social interactions and poorer mental health and wellbeing (Arlinger, 2003). There have been a number of other emotional issues and conditions that have been shown to be associated with hearing loss, including uncertainty, anger, increased stress, and anxiety (Olusanya, Ruben, & Parving, 2006). A common treatment option for hearing loss is the use of hearing aids, which can include benefits such as increased audibility of speech and environmental sounds. Preliminary findings also suggest a possible association between hearing aid use and a small reduction in cognitive decline in adults aged 65 years and older (Amieva, Ouvrard, Guilioli, Meillon, Rullier, & Dartiques, 2015).

Despite the potential benefits of using amplification, less than 25% of hearing aid candidates obtain the devices (ASHA, 2016c) and based on a World Health Organization estimate, current hearing aid manufacturing meets less than 10% of the total global need (2015). Even with manufacturers not meeting the current global need, there are also barriers to consumers obtaining hearing aids related to the high cost of the devices and difficulty in accessing services. This paper will describe state-level barriers in access to hearing health care in
Arizona and review the status of the literature on clinical outcomes of one possible solution to increase access to care: teleaudiology.

**Hearing Loss in Arizona**

The United States has a high prevalence of hearing loss at nearly 15% of adults reporting difficulty hearing (Blackwell, Lucas, & Clarke, 2014); however, the size of Arizona and its rural areas pose a unique challenge to providing and receiving audiologic services. The most recent US Census data showed the population of Arizona to be 6,392,017 (United States Department of Commerce, 2012). Of those residents, it has been estimated that the number of adults, above age 20 years, with clinically significant hearing loss in at least one ear is 1,145,166, and the estimate for those with clinically significant bilateral hearing loss is 727,915 (Muller, Adamovich, Le, Marrone, Norrix, & Wong, 2015). These estimates were generated from National Health and Nutrition Examination Surveys data sets applied to US Census data for Arizona stratified by age. Despite the high-level of need for individuals to obtain hearing healthcare services, there are geographic and financial barriers to receiving care.

**Arizona Affordable Hearing Aid Task Force**

To address the limited hearing healthcare options for low-income Arizona residents and provide access to affordable hearing aids, the Arizona Commission for the Deaf and the Hard of Hearing (ACDHH) called for a task force to investigate these issues. The Arizona Affordable Hearing Aid Task Force was comprised of Tom Muller, Au.D., Stephanie Adamovich, Ph.D., Giau Le, Au.D., Nicole Marrone, Ph.D., Linda Norrix, Ph.D., and Aileen Wong, Au.D. and this group worked cooperatively with the ACDHH to develop a formal report exploring the need for
such a low-cost hearing aid program, provider perspectives on hearing healthcare affordability and accessibility, and recommendations to improve accessibility of hearing healthcare.

Muller et al. (2015) estimated that there are approximately 204,984 adult Arizonans (age 20 years and older) with bilateral hearing loss, living near or below the federal poverty threshold. The federal poverty threshold for a household with one individual, as of 2014, was $11,670 per year (Assistant Secretary for Planning and Evaluation, 2016). Although individuals who make less than 133% of the federal poverty level are eligible for Arizona’s Medicaid plan, Arizona Health Care Cost Containment System (AHCCCS), hearing aids are not covered as an AHCCCS benefit for adults. Based on consumer reports and epidemiological studies, the typical uptake of hearing aids is approximately 20-25% by individuals who need and want to use hearing aids (Kochkin, 2009; Chien & Lin, 2012). By using a 25% uptake rate on the 204,984 low-income adults in Arizona, this leaves 51,246 low-income individuals who potentially need and want hearing aids (Muller et al., 2015).

For Arizona adults with low income, there are programs and organizations available that can provide audiologic care and hearing aids at little or no cost, but they are not able to service all individuals in need, due to participation restrictions. Of the 51,246 individuals in need, it is estimated that 37,351 individuals could be serviced through the Veteran’s Administration, Indian Health Services, Vocational Rehabilitation, Medicare Advantage programs, and charitable organizations. The remaining 13,895 low-income Arizonans above age 21 have no obvious means of obtaining hearing aids (Muller et al., 2015). As part of the Task Force work, a survey of hearing healthcare providers in Arizona was conducted to assess hearing healthcare affordability and accessibility. It was found that many providers thought that transportation, cost, knowledge and acceptance of hearing loss would impact access to care and that low-income
users need additional education (an audiologic rehabilitation component) regarding their hearing loss and device maintenance. Most of the surveyed providers were already providing free or reduced cost services to low-income patients independently, but they expressed interest in a centralized statewide system to increase efficiency (Muller et al., 2015).

The Arizona Affordable Hearing Aid Task Force developed recommendations for improved accessibility for hearing healthcare, which was comprised of five components: Raising consumer and provider awareness of Medicare Part C plans, the addition of compensated hearing aid services via AHCCCS, the creation of a volunteer-based hearing aid service program (if required), a Link Specialist program, and the development of a statewide audiologic rehabilitation program (Muller et al., 2015). These recommended plans for service would increase the low-income population’s access to hearing healthcare; however, there would still be a portion of the population unable to utilize these services due to their remote locations and the low number of audiologists outside Maricopa, Pinal, Pima, and Coconino counties.

To address the goals of the Task Force and target the rural Arizonans that may have difficulty accessing services through a statewide program, a literature review and critical analysis was performed to obtain information about teleaudiology as a possible service model for adults. This review will summarize the clinical outcomes that have been found from teleaudiology-based audiological assessment and hearing aid fitting encounters with adult patients. The objective of this review was to determine the effectiveness and feasibility of using teleaudiology services to provide clinical hearing healthcare. If teleaudiology outcomes are comparable to traditional, in-person encounters, then this service model could potentially be used to serve rural, low-income adults living in Arizona.
The following sections will provide detailed information regarding the barriers to hearing healthcare access and the need for affordable services as found by the Arizona Affordable Hearing Aid Task Force. A review of hearing health services and types of clinical encounters in audiology will describe service delivery models in current use. Finally, the innovative service delivery model of teleaudiology will be introduced, with information regarding current efforts to use teleaudiology services. These topics provide the context for interpreting the subsequent review of the clinical literature on outcomes of teleaudiology programs for adults.

**Arizona’s Unique Population**

Arizona’s rural areas have a unique population distribution with a large portion of residents being of Latino and/or Native American heritage. In 2015, it was estimated that nearly 30% of Arizona’s population identified as Hispanic or Latino and 5.3% identified as American Indian or Alaska Native (United States Census Bureau, 2016). Rural areas in Arizona also have a large population of individuals and families living at a lower socioeconomic level. It has been shown that lower socioeconomic status is associated with several risk factors for hearing loss, with an increased likelihood of noise exposure from work environments, a higher prevalence of obesity, and an increased likelihood of smoking (Newman & Cauley, 2012). These factors can lead to increased rates of cardiovascular and/or metabolic disorders, which can be risk factors in an of themselves for hearing loss (Newman & Cauley, 2012).

There are also social determinants of health related to racial and ethnic disparities which contribute to the population health of Arizonans. Among the Hispanic/Latino population, more than a quarter of adults do not have a primary care provider and more than eight in ten adults receive their health-related news from the radio or television sources (Livingston, Minushkin, & Cohn, 2008). It has also been found that the prevalence of hearing loss in Hispanic/Latino adults
is approximately 15%, with approximately 8% having bilateral hearing impairment, which is similar to the prevalence of hearing loss in the overall general population in the U.S. (Cruickshanks et al., 2015). However, the prevalence of treatment for hearing loss is much lower among Hispanic/Latino older adults as compared to non-Hispanic whites in the U.S. (Nieman et al., 2016). Hearing loss among Hispanic/Latino adults has been associated with socioeconomic factors, including noise exposure from work environments (Cruickshanks et al., 2015).

Arizona’s borders contain twenty-one different Native American tribes, with reservations covering a quarter of the state (Inter Tribal Council of Arizona, 2017). Native Americans and Alaskan Native self-report health problems at a higher rate than the general United States population over the age of 65 years. A survey found that 39% of Native Americans, aged 65 years or older, describe their health status as “fair” or “poor” compared to 26% percent of the same age group reporting “fair” or “poor” health statuses in the general population (Boccuti, Swoope, & Artiga, 2014). Members of each distinctive tribe have access to Indian Health Services, which provides health benefits in primary care and healthcare specialties at facilities across the state. However, each location may not provide access to all of the same services, such as audiologic fittings, hearing aid services, or generalized hearing healthcare. This can make it difficult to access services, particularly as many reservation lands fall into counties with few known audiologic service providers. Indian Health Services utilizes telemedicine for other medical specialty areas, but has not, as of yet, branched out into teleaudiology.

**Geographic Access Barriers and Distribution of Medicare-registered Audiologists**

In Arizona, the physical access barriers are the long travel distances required to visit service providers. One-fifth of the fifteen counties in the state do not have any access to registered Medicare or Medicaid audiology providers, which include Greenlee, La Paz, and
Santa Cruz counties (American Medical Association [AMA], 2016). These counties are large in size and travel times to the nearest audiologist can take hours. The distance that adults in these counties must drive can become problematic when the average number of follow-up visits for hearing aids ranges from 2.4 to 3.6 visits, depending on the type of verification and validation measures used to fit the hearing aids (Kochkin et al., 2010). These visits are in addition to the initial audiologic evaluation and hearing aid selection appointment. It has also been shown that patients are often willing to forgo free or low-cost care, if it means travelling 20 miles or more (Chan, Hart, & Goodman, 2006). The counties with the highest percentages of residents over the age of 65 are those with the lowest population densities (US Department of Commerce, 2012). Because older adults have a higher prevalence of hearing loss, with a prevalence of 63.1% in adults aged 70 and older (Lin, Thorpe, Gordon-Salant, & Ferrucci, 2011b), it is important that access to hearing healthcare is readily available. However, the bulk of Arizona’s audiologists are located in the most densely populated counties in the state: Maricopa, Pima, Pinal, and Coconino.

It is plausible that there are audiologists who are not Medicare or Medicaid-registered providers in these counties; however, based on the Health Workforce Mapper, there are 12,273 Medicare-registered audiologists (AMA, 2016) and approximately 13,200 audiologists in the US workforce (Bureau of Labor and Statistics, 2016). With fewer than 1,000 non-Medicare or Medicaid-registered providers nationwide, the likelihood of an audiologist practicing in one of these Arizona counties is small. The presence of otolaryngologists in these rural counties may also be limited, but residents could have access to licensed hearing aid dispensers. Mobile audiology services have also been periodically available in some areas, such as Santa Cruz
County; however, access is not consistently provided. The use of teleaudiology could bridge the geographic gap for many individuals living in rural areas in need of hearing healthcare.

**Financial Access Barriers**

Hearing aids can be cost prohibitive for many patients who would benefit from the use of these devices. A survey conducted in 2015 by The Hearing Review found that “mid-range hearing aids average around $4,000 a pair” and that a single hearing aid typically costs between $800-$4000, depending on the style and technology level (Dyba, 2015). As mentioned previously, only 25% of hearing aid candidates obtain amplification devices. A MarkeTrak VII survey showed that 76% of non-hearing aid adopters listed financial reasons as a barrier to uptake (National Institute on Deafness and Other Communication Disorders, 2009).

Previous studies have shown that lower income-level work, informal jobs, and underemployment are prevalent in rural areas (Mosely & Miller, 2004; Jensen, Cornwell, & Findeis, 1995), leaving these residents with reduced financial access to hearing healthcare. Providing access to individuals who would not otherwise be able to afford hearing healthcare and amplification is important for reasons beyond simply improving communication ability. In recent years, hearing loss has been associated with depression, cognitive decline, and unemployment and lower income (Li, Zhang, Hoffman, Cotch, Themann, & Wilson, 2014; Tomioka, Okamoto, Morikawa, & Kurumatani, 2015; Hogan, 2012). Hearing loss has been shown to be more strongly associated with the development of depression in older adults than other comorbid conditions (Mener, Betz, Genther, & Lin, 2013).

National Medicare services provide coverage for diagnostic hearing and balance evaluations, but the standard Medicare part B plan pays nothing toward the cost of hearing aids, exams for fitting hearing aids, or rehabilitative services provided by audiologists (Medicare,
There are some Medicare Advantage plans (Medicare part D) that are available that will provide hearing aid-related benefits; however, these plans are not managed at the federal level and are, instead, managed by private companies. A number of large insurance providers, such as Cigna and Aetna, follow standard Medicare policies and have not provided coverage for hearing aids (Blustein & Weinstein, 2016). Medicaid insurance plans provide healthcare benefits to those who meet low-income requirements; however, hearing aid coverage is only provided to children through age 21 in Arizona through AHCCCS (Arizona Health Care Cost Containment System, 2016).

The median household income in the Arizona counties with no Medicare-registered audiologists ranges from $32,147 to $48,696 per year (United States Census Bureau, 2016). With current hearing aid price ranges, the cost of obtaining hearing aids is prohibitive for low-income Arizonans and particularly those in more rural areas. Individuals living in rural areas have to contend with spatial inequality, or unequal amounts of resources and services when compared to urban areas, and their health and healthcare issues often intersect with social issues, such as reduced levels of education, poverty, and inadequate housing options (Aday, 1991). With lagging educational attainment and smaller populations in rural areas, the drive to create new jobs is reduced (Council of Economic Advisers, 2016). Additionally, there is a higher proportion of individuals with disabilities in rural areas, which prohibits them from participating in the workforce (Council of Economic Advisers, 2016).

There are existing programs in Arizona that are able to provide low-income adults with hearing healthcare and hearing aids, including Vocational Rehabilitation, the Veteran’s Administration, Indian Health Services, the Sertoma Arizona Hearing Aid Bank, and the Lions Sight and Hearing Foundation. Additionally, there are national programs that provide free or
low-cost hearing aids to those in need, such as HearNow and Audient. The state-level programs have restrictions for participation and the philanthropic organizations are not capable of handling the volume of those in need of assistance (Muller et al., 2015).

The Field of Communication Disorders and Clinical Encounters in Audiology

In considering access to hearing health care, it is important also to define the types of services and service delivery models in current use. Hearing loss is one form of a communication disorder, or an impairment in the ability to “receive, send, process, and comprehend concepts or verbal, nonverbal and graphic symbol systems” (American Speech-Language-Hearing Association [ASHA], 1993). Within the field of communication disorders, professionals screen, assess, diagnose, treat, and educate the public on the disorders themselves and the implications of having such an impairment. The practitioners within this field are speech-language pathologists and audiologists, with the former serving those with language and speech disorders and the latter serving those with auditory and vestibular disorders.

Audiologists work with a wide variety of patients, ranging from newborns through geriatrics, and their families and/or caregivers. The scope of practice for individuals with doctoral-level clinical degrees includes identification of hearing disorders, assessment and diagnosis, treatment, hearing conservation, intraoperative neurophysiologic monitoring, research, and screening of speech and language disorders (American Academy of Audiology [AAA], 2004).

The purpose of the audiologic evaluation is to “determine the patient’s type and magnitude of hearing loss, communication needs, audiologic rehabilitation needs, and potential candidacy for amplification” (ASHA, 2016a). Assessment and diagnosis of hearing loss is completed through comprehensive audiological evaluations, which typically include
measurement of frequency-specific thresholds to determine the severity, configuration, and type of hearing loss, a patient’s ability to recognize words with in quiet and in background noise, and the status of the middle ear and the acoustic reflex pathway (ASHA, 2016a). This battery of tests provides the audiologist with information about the health and integrity of the auditory system. There are several other subtests that can be included in the test battery, including vestibular function and electrophysiological tests. The addition of these components is based on the overall goal of the examination and whether or not it is geared toward selection of treatment options.

There are three basic types of hearing loss, which include sensorineural, conductive, and mixed losses (ASHA, 2016a). Sensorineural hearing losses are typically permanent and primarily involve lesions within the sensory cells of the cochlea, the organ of hearing, and/or the nerve pathways leading to the brain. This type of hearing loss can be a result of genetic factors, noise exposure, ototoxic substance exposure, head trauma, illnesses, and is commonly associated with age-related hearing loss, or presbycusis (ASHA, 2016a). Treatment for sensorineural hearing losses includes hearing devices and auditory prostheses, depending on the severity of the condition and the listening goals of the patient. Conductive hearing losses are caused by structural impairments or obstructions in the outer and/or middle ear spaces. Dependent on the abnormality, this type of loss may be remediated by medical or surgical intervention. If surgical intervention does not fully resolve the issue, is unsuccessful, or is not indicated for a patient, he or she may be fit with traditional hearing aids or use a bone conduction hearing device on a soft-band to overcome the conductive hearing loss. Mixed hearing losses are a combination of sensorineural and conductive disorders.

The treatment of hearing loss also includes audiologic (re)habilitation services such as counseling, verification, and validation of outcomes. Audiologic rehabilitation includes a mix of
sensory management, perceptual training, instruction, and counseling (Boothroyd, 2007). Some of the primary goals of counseling are to set realistic expectations for intervention, discuss patient goals, and provide information to help patients acclimate to their disability (English, 2008). Audiologic (re)habilitation and counseling are ongoing services that take place over the lifetime of a provider-patient relationship. Verification measures are objective data that is used, in the context of hearing aid fittings, to ensure that the proper amount of amplification has been provided in the frequencies which the patient has a hearing loss. This is generally completed through real-ear measurements using probe microphones to verify the output of the hearing aid and the results are compared to a prescriptive formula (Lucks Mendel, 2009). Validation refers to subjective outcome measures that are designed to assess the efficacy of the treatment that has been utilized. Validation measures are often questionnaires that are provided to the patient prior to and following the treatment to assess if the patient’s social well-being, emotional well-being, or quality of life has been impacted by the treatment (Lucks Mendel, 2009).

**Teleaudiology as a Service Model**

Teleaudiology has been defined as “the use of electronic information and telecommunications technologies to support remote and distance clinical hearing healthcare, professional and public education, public health matters, and health administration” (Dworsack-Dodge, 2013). Telehealth can connect rural residents with healthcare specialty providers, through the use of telecommunications and electronic means, to provide the same healthcare services available to those in urban areas. The use of telehealth services can reduce the cost associated with receiving healthcare through reduced patient travel times, improved clinical efficiency, and improved health outcomes (Swanepoel et al., 2010a). Improved clinical efficiency can be viewed through the lens of the patient receiving telehealth services compared to receiving no type of
evaluation or treatment services. The burden of untreated hearing loss can have an impact on the economic standing of an individual, his or her quality of life, and his or her psychological well-being (Olusanya, Neumann, & Saunders, 2014). Reduced cost associated with shorter travel time and decreased time away from work are noted benefits for the patient; however, teleaudiology can also be cost-effective for the audiologist and the clinical practice as well. Teleaudiology services require fewer audiologists to see patients and reduce their travel time to more remote locations (Davis, 2017). Depending on the type of teleaudiology model used, multiple patients could be evaluated simultaneously at different remote sites, freeing the audiologist to attend to other duties while still having the ability to check on a patient’s status, as needed (Davis, 2017). With increased patient encounters, revenue for the practice or organization increases.

Diagnostic audiology equipment has gradually become more computerized and hearing aid software has taken advantage of current wireless technology. This has allowed clinical audiologists to meld diagnostic and rehabilitative equipment with telehealth technology “to provide a variety of hearing healthcare services to underserved communities” (Krumm & Symes, 2011). Teleaudiology services have been used to complete hearing screenings, audiological evaluations and monitoring, hearing aid fittings and follow-ups, auditory brainstem evoked response testing, vestibular assessments, cochlear implant mapping, and management of tinnitus support groups. The body of evidence has been growing which shows the efficacy and effectiveness of telerehabilitation services, demonstrating that this delivery model can lead to similar, or better, clinical outcomes when compared to traditional face-to-face interactions (World Health Organization & World Bank, 2011). In a survey conducted by ASHA, 51.9% of audiologists stated that they provide at least some of their clinical services through telepractice delivery (2014); however, this survey was answered by just 54 audiologists within ASHA’s
special interest group for telepractice services, with 13 of the respondents currently working in state or federal positions, such as the Veterans Health Administration.

**Current Teleaudiology Utilization in the Veterans Health Administration**

One of the largest providers of teleaudiology services in the United States is the Veterans Health Administration (VHA), which currently provides remote audiological evaluations, hearing aid fittings, and home-based aftercare and auditory rehabilitation (Gladden, 2013a). VHA has actively tried to increase access to services for their more rurally-located patients, through the use of community-based outpatient clinics. Telehealth services have only increased their reach (Gladden, Beck, & Chandler, 2015).

Telehealth services are provided through three methods: Real-time interactive clinical video telehealth (CVT), monitoring and management home telehealth (HT), and acquired data through store-and-forward telehealth (SFT) (Dennis, Gladden, & Noe, 2012). The CVT method involves the provider being at a clinical site with the patient at a remote site, with the patient often accompanied by a technician who sets up equipment or acts at the provider’s “hands” on site. The patient and provider are connected through a real-time video conferencing connection, which can also support peripheral technologies such as hearing aid fitting software or testing software. HT services can be conducted through video or non-video means and are typically provided to those with chronic illnesses or to those who cannot frequently travel. The use of mobile health applications and other technologies are used in addition to web-cameras to allow patients to interact with their provider from home. The SFT method allows the patient to visit a remote site for examination or testing, with the resulting data forwarded to a professional for review at a later time. Services from the VHA are primarily provided through real-time videoconference interactions with the patient with the CVT delivery method (Gladden, 2013b).
The VHA has conducted numerous studies to assess the effectiveness of teleservices, since their pilot programs began in 2009. Echoing the findings of the World Health Organization and World Bank 2011 report, Dennis et al. summarized VHA findings of teleaudiology and found no significant differences in clinical outcomes from teleaudiology appointments than those obtained from traditional encounters, as assessed by the International Outcome Inventory for Hearing Aids (2012). Since the inception of the teleaudiology within the VHA, the number of patients served each fiscal year has grown. In fiscal year 2011, there were 1,016 Veterans who participated in teleaudiology services and in fiscal year 2014, that number had grown to 10,589 participating Veterans (United States Department of Veterans Affairs, 2014). With the large-scale use and success of teleaudiology at the national level in the VHA, there is reason to look into its application for the private sector.

**Definition of Terms**

The following terms will be used in this document: Telemedicine, telepractice, teleaudiology, audioligic evaluation, hearing aid, and hearing aid fitting. The following terms are defined below:

- Telemedicine is defined as the exchange of medical information from one site to another, using electronic communications, to improve patients’ health status (American Telemedicine Association, 2016).

- Telepractice will be defined as the application of telecommunications technology to deliver professional communication disorders services remotely, by connecting clinicians to patients or other clinicians for assessment, intervention, or consultation (ASHA, 2016b).
Teleaudiology was defined previously as the use of electronic telecommunications technologies to allow for remote and clinical hearing healthcare, administration, and the provision of professional and public education (Dworsack-Dodge, 2013).

Audiologic evaluations have been described previously and as part of the post-evaluation counseling, hearing aid selection can be completed. For the purposes of this document, auditory brainstem response testing and otoacoustic emissions testing will be excluded from the definition of audiologic evaluations, as these are not tests needed to complete standard audiologic evaluations for hearing aid candidacy in adult populations.

Hearing aids are devices regulated by the US Food & Drug Administration and will be defined as “sound-amplifying devices designed to aid people who have a hearing impairment” (US Food & Drug Administration, 2016).

Hearing aid fitting includes the following activities: Device fitting, verification, hearing aid orientation, rehabilitation, counseling, and validation (ASHA, 2016c).

CHAPTER 2: METHODOLOGY

A literature review was completed to locate information relevant to teleaudiology and adult populations, particularly those in rural areas, to determine what outcomes have been found in clinical encounters for audiologic evaluation and hearing aid fittings, as these are the targeted services of the Arizona Affordable Hearing Aid Task Force. Any type of clinical outcome was considered, including subjective or objective measures and test-retest reliability. By including the clinical outcomes from a wide range of adult patients, they are likely generalizable to the specific population of adult Arizonans.

The initial search for literature was conducted with the following database systems: PubMed, Medline, Google Scholar, and the Cochrane Database. The University of Arizona’s
library feature, Summon, was also used. The search topics used to collect articles included the following: Teleaudiology, teleaudiology and hearing aids, teleaudiology and amplification, teleaudiology and audiological evaluations, teleaudiology and hearing evaluations, and teleaudiology and rural areas. Each of these combination search terms were repeated with the following lead term: tele-audiology, telehealth, and telemedicine. See Appendix A for a full listing of search terms. The reference sections of selected articles were also reviewed for relevant articles related to patient outcomes for audiological evaluations and/or hearing aid fittings.

Articles had to have subjects who met the following criteria to be included in the review: Adult subjects (18+ years old), normal hearing listeners, any degree of hearing loss, any type of hearing loss, bilateral or unilateral hearing losses, and subjects from any country. Articles containing normal hearing listeners were included to provide further information about the reliability of audiological evaluation measures. Articles that included non-rural populations were included in the literature review, as there were few studies that looked exclusively at rural populations. The search term “rural areas” was included, as opposed to “low socioeconomic status” as an initial search revealed that only one article mentioned the socioeconomic status of their subjects.

Exclusion factors for articles included pediatric populations, tinnitus-related treatments, cochlear implant treatments, auditory brainstem response testing, and any vestibular treatments. Articles with pediatric populations were excluded because the Task Force population of interest was adults. Articles involving cochlear implants, tinnitus- and vestibular-related treatments, the auditory brainstem response test, and otoacoustic emissions tests were excluded because these were not targeted treatments or tests considered by the Task Force.
The initial search yielded 251,080 results. The high number of search results can be attributed to the use of general search terms, such as “telehealth,” “telehealth and rural areas,” “telemedicine,” and “telemedicine and rural areas.” When audiology-specific search filters were applied, using services such as PubMed’s MeSH filter, or Medical Subject Headings, there were a total of 234 articles available for review. After the exclusion factors were applied to the search results, duplicate articles were removed, abstract and full-article reviews were completed, there were 15 articles left to be included in the review, which spanned from 2003-2016.

The levels and strength of evidence for each article were assessed using the scale outlined in Cox’s “Evidenced-based practice in provision of amplification” (2005). The levels of evidence range from one to six, with a one being a systematic review or meta-analysis of randomized control trials and a six being expert opinion without data (Cox, 2005). See Table 1 for more detail. The strength of evidence scale can be seen in Table 2.

**Table 1: Levels of Evidence**

<table>
<thead>
<tr>
<th>Level of Evidence</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Systematic reviews and meta-analysis of randomized control trials</td>
</tr>
<tr>
<td>2</td>
<td>Well designed RCT</td>
</tr>
<tr>
<td>3</td>
<td>Non-randomized intervention studies</td>
</tr>
<tr>
<td>4</td>
<td>Descriptive studies such as cohort studies, case-control studies, cross-sectional surveys, or uncontrolled experiment</td>
</tr>
<tr>
<td>5</td>
<td>Case report</td>
</tr>
<tr>
<td>6</td>
<td>Expert opinion without data</td>
</tr>
</tbody>
</table>

**Table 2: Strength of the Evidence.**

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 or 2 with consistent conclusions</td>
<td>A</td>
</tr>
<tr>
<td>Level 3 or 4 with consistent conclusions or extrapolated evidence from Level 1 or 2 studies</td>
<td>B</td>
</tr>
<tr>
<td>Level 5 studies or extrapolated evidence from Levels 3 or 4</td>
<td>C</td>
</tr>
<tr>
<td>Level 6 or inconsistent or inconclusive studies of any level or any studies that have a high risk of bias</td>
<td>D</td>
</tr>
</tbody>
</table>

Source: Cox, 2005.
CHAPTER 3: RESULTS

The following articles have been separated into two different categories: Evaluation and treatment related to hearing aids. These categories were selected to align with specific responsibilities that the Arizona Affordable Hearing Aid Task Force was charged with from the ACDHH. These categories were selected to address the following responsibility: “Develop a statewide model to provide hearing healthcare options and hearing aids to low-income Arizona residents or to those who live at or below poverty level” (Muller et al., 2015, p.4). Component two of the Task Force’s recommendations included the addition of compensated hearing aid service via Arizona’s Medicaid program, AHCCCS. The following literature review will provide information to determine if teleaudiology is a potential option to address the second component of the recommendations. Although audiologic evaluations were not specifically addressed by the Task Force, an evaluation would be necessary to determine if a patient is a hearing aid candidate. Therefore, teleaudiology literature related to evaluations was included. The treatment category addresses the efficacy and effectiveness of teleaudiology as a service model, with regard to the responsibility listed above.

Audiologic Evaluation Studies

Ten research articles explored the efficacy and feasibility of obtaining diagnostic test results through teleaudiology methods and compared the results obtained from traditional, clinic-based encounters. Additionally, two studies examined bone conduction thresholds with teleaudiology methods and compared the results to traditional, in-person test results (Eikelboom, Swanepoel, Matakef, & Upson, 2013; Margolis, Glasberg, Creeke, & Moore, 2010). A single study also compared word recognition scores obtained through teleaudiology testing methods with those obtained in clinic-based procedures (Yao, Yao, & Givens, 2015). These studies were
all conducted on adult populations (Choi, Lee, Park, Oh, & Park, 2007; Eikelboom et al., 2013; Givens & Elangovan, 2003a; Givens, Blanarovich, Murphy, Simmons, Blach, & Elangovan, 2003b; Margolis et al., 2010; Pearce, Ching, & Dillon, 2009; Swanepool, Koekemoer, & Clark, 2010b; Swanepool, Mngemane, Molemong, Mkwanazi, & Tushini, 2010c; Yao, Wan, & Givens, 2010; Yao et al., 2015). See Table 3 for additional details and evidence ratings for each audiologic evaluation study.

Seven studies examined the efficacy of internet-based pure-tone and/or speech audiometry systems and compared them to test results from traditional, in-person audiometry (Choi et al., 2007; Givens & Elangovan, 2003a; Givens et al., 2003b; Pearce et al., 2009; Swanepool, Koekemoer, et al., 2010; Yao et al., 2010; Yao et al., 2015). These studies utilized standard, non-experimental audiometers and audiologists conducted the hearing test with the patient, via the internet, with an assistant or facilitator onsite to place the transducers. The majority of the studies completed real-time evaluations using the CVT method.

Each of these studies conducted pure-tone air audiometry testing and found that the difference between the internet-based and in-person thresholds were 10 dB HL or below. This difference is within the acceptable range for test-retest reliability (Aguiar de Mello, Almeida Machada da Silva, & Gil, 2015). Similarly, there were no clinically significant differences in bone conduction testing with the internet-based application, when the bone oscillator was placed by a trained lab assistant (Yao et al., 2015). Yao et al. (2015) conducted the only study to examine speech testing reliability. It was found that speech testing conducted using their developed audiometer application yielded no difference in speech recognition threshold and word recognition results (Yao et al., 2015). Swanepool, Koekemoer, & Clark reported that the average test was approximately 21% longer via teleaudiology delivery than the conventional
testing (2010), possibly due to connectivity issues and lagging signals.

Table 3: Results from Literature Review of Audiologic Evaluation Studies.

<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Sample Size</th>
<th>Subject Age Range</th>
<th>Experimental Design</th>
<th>Measures</th>
<th>Outcomes</th>
<th>Level of Evidence</th>
<th>Grade of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choi et al. (2007)</td>
<td>37</td>
<td>&gt;18 years old</td>
<td>Prospective, blind comparison to a gold standard</td>
<td>Test-retest reliability of air conduction thresholds: Conventional and internet-based teleaudiology</td>
<td>89.3% of results within +/- 5 dB acceptable test-retest clinical range</td>
<td>3</td>
<td>B</td>
</tr>
<tr>
<td>Eikelboom et al. (2013)</td>
<td>10 (test-retest), 44 (accuracy)</td>
<td>30-68 years old</td>
<td>Prospective, blind comparison to a gold standard, Randomized controlled trial</td>
<td>Test-retest reliability of air and bone conduction thresholds: Conventional and automated audiometry</td>
<td>Within +/- 5 dB test-retest acceptable clinical range, automated audiometry had slightly higher thresholds</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>Ovens et al. (2003)</td>
<td>31</td>
<td>20-53 years old</td>
<td>Prospective, blind comparison to a gold standard, Randomized controlled trial</td>
<td>Test-retest reliability of air conduction thresholds: Conventional and internet-based teleaudiology</td>
<td>Within +/- 5 dB test-retest acceptable clinical range</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>Ovens &amp; Elangovan (2005)</td>
<td>45</td>
<td>20-53 years old</td>
<td>Prospective, blind comparison to a gold standard, Randomized controlled trial</td>
<td>Test-retest reliability of air and bone conduction thresholds: Conventional and internet-based teleaudiology</td>
<td>Within +/- 5 dB test-retest acceptable clinical range</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>Margolis et al. (2010)</td>
<td>30</td>
<td>&gt;18 years old</td>
<td>Prospective, blind comparison to a gold standard</td>
<td>Test-retest reliability of air and bone conduction thresholds: Conventional and automated audiometry</td>
<td>Within +/- 5 dB test-retest acceptable clinical range</td>
<td>3</td>
<td>B</td>
</tr>
<tr>
<td>Pearce et al. (2009)</td>
<td>1</td>
<td>&gt;18 years old</td>
<td>Case reports</td>
<td>Test-retest reliability of air and bone conduction thresholds: Internet-based teleaudiology</td>
<td>Within +/- 5 dB test-retest acceptable clinical range</td>
<td>5</td>
<td>D</td>
</tr>
<tr>
<td>Swanepoel, Keelman &amp; Clark (2010)</td>
<td>30</td>
<td>18-65 years old</td>
<td>Prospective, blind comparison to a gold standard</td>
<td>Test-retest reliability of air conduction thresholds: Conventional and internet-based teleaudiology</td>
<td>96% of results within +/- 5 dB acceptable test-retest clinical range</td>
<td>3</td>
<td>B</td>
</tr>
<tr>
<td>Swanepoel et al. (2010)</td>
<td>30</td>
<td>18-59 years old</td>
<td>Prospective, blind comparison to a gold standard</td>
<td>Test-retest reliability of air conduction thresholds: Conventional and automated audiometry</td>
<td>Within +/- 5 dB test-retest acceptable clinical range</td>
<td>3</td>
<td>B</td>
</tr>
<tr>
<td>Yao et al. (2010)</td>
<td>20</td>
<td>25-96 years old</td>
<td>Prospective, blind comparison to a gold standard</td>
<td>Test-retest reliability of air conduction thresholds: Conventional and internet-based teleaudiology</td>
<td>Within +/- 5 dB test-retest acceptable clinical range</td>
<td>3</td>
<td>B</td>
</tr>
<tr>
<td>Yao et al. (2015)</td>
<td>18</td>
<td>19-82 years old</td>
<td>Prospective, blind comparison to a gold standard</td>
<td>Test-retest reliability of air and bone conduction thresholds, plus speech testing: Conventional and internet-based teleaudiology</td>
<td>Puretone and speech testing within +/- 10 dB test-retest acceptable clinical range</td>
<td>3</td>
<td>B</td>
</tr>
</tbody>
</table>

Three studies reviewed the efficacy of using automated audiometers and compared the test-retest results to those obtained from conventional audiometric testing methods (Eikelboom et al., 2013; Margolis et al., 2010; Swanepoel, Mngemane, et al., 2010). Automated audiometry does not require an audiologist to conduct testing and subjects respond to computer-based prompts to complete the evaluation. Automated audiometry can be completed asynchronously.
with the results forwarded to an audiologist at a later time for interpretation, which is the premise for SFT methods of teleaudiology. There are technicians on site to place circumaural headphones and, in these studies, bone oscillators were placed on the forehead of each subject. Each study found that the pure-tone air conduction thresholds obtained by the automated audiometry system resulted in clinically acceptable ($\leq 10$ dB HL) differences from results obtained through conventional means. Margolis et al. (2010) highlighted that there were variations in bone conduction thresholds in each testing condition; however, this could be due to forehead placement of the bone oscillator by the facilitator and individual anatomical differences of the subjects tested. The in-person testing was also completed with the bone oscillator placed on the mastoid. Due to potential anatomical differences in the subjects, the bone conduction threshold differences may be unassociated with the teleaudiology service model itself.

The overall findings suggest that the differences in threshold results from internet-based, automated, and remotely controlled audiometers are within the clinically acceptable range of variability when compared to conventional, face-to-face audiological results. The evidence from these studies was generally strong, with consistent conclusions; however, the article from Pearce et al. (2009) was a case study which lacked specific details about how the evaluation was conducted. The studies primarily examined the reliability of pure-tone air thresholds, which provides only a piece of the data needed to make a determination about the severity of a hearing loss and what type of treatment plan or referral is necessary to assist the patient.
Table 4: Summary of Audiologic Evaluation Studies.

<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Teleaudiology Method</th>
<th>Remote Site Facilitator</th>
<th>High-speed Internet Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choi et al. (2007)</td>
<td>CVT</td>
<td>Not described</td>
<td>Yes</td>
</tr>
<tr>
<td>Eikelboom et al. (2013)</td>
<td>SFT</td>
<td>Researcher acted as facilitator</td>
<td>No</td>
</tr>
<tr>
<td>Givens et al. (2003)</td>
<td>CVT</td>
<td>Audiologist acted as facilitator</td>
<td>Yes</td>
</tr>
<tr>
<td>Givens &amp; Elangovan (2003)</td>
<td>CVT</td>
<td>Audiologist acted as facilitator</td>
<td>Yes</td>
</tr>
<tr>
<td>Margolis et al. (2010)</td>
<td>SFT</td>
<td>Audiologist acted as facilitator</td>
<td>No</td>
</tr>
<tr>
<td>Pearce et al. (2009)</td>
<td>CVT</td>
<td>Assistant acted as facilitator</td>
<td>Yes</td>
</tr>
<tr>
<td>Swanepoel, Koekemoer &amp; Clark (2010)</td>
<td>CVT</td>
<td>Physician acted as facilitator</td>
<td>Yes</td>
</tr>
<tr>
<td>Swanepoel et al. (2010)</td>
<td>SFT</td>
<td>Not described</td>
<td>No</td>
</tr>
<tr>
<td>Yao et al. (2010)</td>
<td>CVT</td>
<td>No assistant present</td>
<td>Yes</td>
</tr>
<tr>
<td>Yao et al. (2015)</td>
<td>CVT</td>
<td>Not described</td>
<td>Yes</td>
</tr>
</tbody>
</table>

CVT = Clinical video telehealth. SFT = Store-and-Forward telehealth

**Audiological Treatment Studies**

Five research articles explored the efficacy and outcomes related to completing hearing aid fittings via teleaudiology methods. These studies were all conducted on adult patients. Two of the studies involved a comparison of real-ear measurements in traditional and teleaudiology settings (Campos & Ferrari, 2012; Ferrari & Bernardez-Braga, 2009). Three studies examined the subjective outcome measures obtained post-hearing aid fitting in traditional and
teleaudiology settings (Campos & Ferrari, 2012, Penteado, Bento, Battistella, Silva, & Sooful, 2014; Pross, Bourne, & Cheung, 2016). One article examined the use of an online support system for individuals who were recently fit with hearing aids (Brannstrom et al., 2016). See Table 5 for additional details and evidence ratings for each treatment study.

Brannstrom et al. (2016) used an internet-based support system, originally developed for psychologists and their patients, to assess the application of this support system for audiologists working with first-time hearing aid users. The internet-based support system provided patients with access to their audiometric test results, an online library of resources and materials, a “to-do” section for patients to complete tasks prior to appointments, and the ability to fill out the Client-Oriented Scale of Improvement (COSI) to update and rate their audiologic goals (Brannstrom et al., 2015). Twenty-three patients, under the care of four audiologists, utilized the online system to participate in post-fitting appointments and audiologic rehabilitation (Brannstrom et al., 2016).

Additionally, patients were able to use a messaging service with an audiologist to ask questions, as needed. After two post-fitting follow up appointments, patients were asked to complete various validation surveys approximately three weeks after the second follow-up, including the Hearing Handicap Inventory for the Elderly (HHIE), Measure of Audiologic Rehabilitation Self-Efficacy for Hearing Aids (MARS-HA), and the International Outcome Inventory for Hearing Aids (IOI-HA). Five patients agreed to take part in phone interviews to discuss their reactions to the internet-based support system. The patients with more positive experiences and satisfaction with the support system had a greater reduction in self-reported hearing loss consequences and reported better outcomes with their hearing aids (Brannstrom et al., 2016). Positive associations were found between higher satisfaction with the support-system
intervention and improved HHIE and IOI-HA scores (Brannstrom et al., 2016). It was found that not all of the patients and providers were satisfied with the internet-based support system, as it did not meet the needs of all patients. It was suggested that patients who use the internet more frequently already had access to the information provided in the support system, so there was no new information to be gained by using the system regularly (Brannstrom et al., 2016).

Table 5: Results from Literature Review of Hearing Aid Treatment Studies.

<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Sample Size</th>
<th>Subject Age Range</th>
<th>Experimental Design</th>
<th>Measures</th>
<th>Outcomes</th>
<th>Level of Evidence</th>
<th>Grade of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blamey et al. (2015)</td>
<td>1,001</td>
<td>&gt;38 years old</td>
<td>Prospective, blind comparison to a gold standard</td>
<td>Objective outcome measures: Unaided versus unaided speech scores in conventional and teleaudiology hearing aid fittings.</td>
<td>Significant improvement in aided speech scores using teleaudiology hearing aid fitting method</td>
<td>3</td>
<td>B</td>
</tr>
<tr>
<td>Brannstrom et al. (2016)</td>
<td>23</td>
<td>47-81 years old</td>
<td>Cohort study</td>
<td>Subjective outcome measures: Pre- and post-hearing aid fitting HHIE, MARS-HA scores. Post-fitting IOI-HA scores.</td>
<td>Significant improvement in global and subscale scores on post-fitting HHIE scores. No significant change in MARS-HA score. Post-fitting IOI-HA score slightly higher than normative IOI-HA data</td>
<td>4</td>
<td>B</td>
</tr>
<tr>
<td>Campos &amp; Ferrari (2012)</td>
<td>50</td>
<td>39-88 years old</td>
<td>Prospective, blind comparison to a gold standard, Randomized controlled trial</td>
<td>Objective outcome measures: IOI-HA scores compared between conventional and teleaudiology hearing aid fittings.</td>
<td>No significant difference in HINT-Brazil scores, real-ear measures, or IOI-HA scores between conventional and teleaudiology hearing aid fittings</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>Ferrari &amp; Bernardes-Braga (2009)</td>
<td>60</td>
<td>18-94 years old</td>
<td>Prospective, blind comparison to a gold standard</td>
<td>Objective outcome measure: Comparison of REUR, REAR, and REIG completed in conventional and teleaudiology hearing aid fittings.</td>
<td>Differences between conventional and teleaudiology real-ear measures were within normal variability range</td>
<td>3</td>
<td>B</td>
</tr>
<tr>
<td>Penteado et al. (2014)</td>
<td>8</td>
<td>18-90 years old</td>
<td>Prospective, blind comparison to a gold standard</td>
<td>Subjective outcome measure: SADL scores compared between normative SADL data and teleaudiology hearing aid fittings.</td>
<td>Average SADL scores from teleaudiology hearing aid fittings were higher than mean scores from SADL normative data</td>
<td>4</td>
<td>C</td>
</tr>
<tr>
<td>Pross et al. (2015)</td>
<td>42,976</td>
<td>&gt;18 years old, mean age: 75</td>
<td>Retrospective case control.</td>
<td>Subjective outcome measure: IOI-HA scores compared between conventional and teleaudiology hearing aid fittings.</td>
<td>Teleaudiology and conventional hearing aid fittings led to comparable average IOI-HA scores</td>
<td>4</td>
<td>B</td>
</tr>
</tbody>
</table>

HHIE= Hearing Handicap Inventory for the Elderly, MARS-HA= Measure of Audiologic Rehabilitation Self-Efficacy for Hearing Aids, IOI-HA= International Outcome Inventory for Hearing Aids, HINT= Hearing in Noise Test, REUR= Real Ear Unaided Response, REAR= Real Ear Aided Response, REIG= Real Ear Insertion Gain, SADL= Satisfaction with Amplification in Daily Life.
Campos and Ferrari (2012) evaluated the efficacy of traditional, in-person hearing aid fittings versus those conducted through teleaudiology delivery. Fifty patients with hearing loss were equally split into control and experimental treatment groups for hearing aid fitting services through in-person or teleaudiology delivery, respectively. Real-ear measurements, hearing aid programming, and orientation counseling were completed during the appointments, with the amount of time measured for each portion of the appointment. At the remote location, an assistant placed the probe tube in the patient’s ear. However, there was no description of how accuracy of the probe tube placement was verified. Following the fitting, an evaluator blinded to the fitting conditions conducted Hearing in Noise Testing (HINT) to each member of the control and experimental groups. One month after the hearing aid fitting, the IOI-HA was administered and datalogs for hearing aid usage were measured. It was found that the experimental group’s real-ear measurements and programming took longer than the control group, but the overall appointment time was approximately the same at 81 minutes (Campos & Ferrari, 2012). Real-ear measurements obtained with probe microphones showed that each patient’s targets were similarly matched and there was no difference between groups for HINT testing, IOI-HA scores, or amount of hearing aid use (Campos & Ferrari, 2012).

Ferrari and Bernardez-Braga (2009) conducted an experiment to assess the feasibility of completing probe-microphone measurements for hearing aid fittings at a distance. Sixty hearing aid users were tested in face-to-face appointments and through teleaudiology methods with a different audiologist acting as a facilitator at the off-site location on the same day. The facilitator was not aware of the results of the real ear unaided response (REUR), real ear aided response (REAR), or real ear insertion gain (REIG) obtained at the face-to-face appointment. Speech testing was conducted at 65 dB SPL at both the in-person and remote locations and real-ear
responses were measured at seven frequencies between 250 Hz and 6000 Hz. Differences between real-ear measurements at the on-site and distance location were within the acceptable range of variability and ranged from 0 to 2.2 dB across the REUR, REAR, and REIG measurements (Ferrari & Bernardez-Braga, 2009).

Penteado et al. (2014) examined the feasibility of conducting remote hearing aid adjustments. Eight subjects underwent audiologic testing, hearing aid selection, and the initial hearing aid fitting over the course of two traditional, in-person appointments. Fifteen days following the fitting appointment, subjects were seen for a follow-up appointment via teleaudiology, in which remote hearing aid adjustments were performed with an audiologist in each location (clinic and remote units). Immediately following the remote appointment, the Satisfaction with Amplification in Daily Life (SADL) questionnaire was administered. It was found that the subjects who underwent remote follow-up adjustments had higher SADL scores, meaning higher satisfaction levels with their hearing aids, than those reported in four other similar studies (Penteado et al., 2014). The four studies that Penteado et al. compared their work to were Cox & Alexander (1999), Danieli, Castiquini, Zambonato, & Bevilacqua (2011), Mondelli, Magalhaes, & Lauris (2011), and Farias & Russo (2010). The largest difference in SADL scores was found in the comparison of Penteado et al.’s and Cox & Alexander’s data; however, the target population differed as the population in the former group received donated hearing aids, while the latter had purchased their own devices. This could have an impact on patient expectations for the hearing aids, which could be a primary reason for the differences in SADL scores (Penteado et al., 2014).

Pross et al. (2016) conducted a retrospective study which examined the outcome measures from the IOI-HA survey from patients seen through conventional, in-person
appointments and those seen through teleaudiology delivery. The IOI-HA data from 41,688 patients seen at conventional appointments and 1,009 teleaudiology patients were reviewed. The average IOI-HA score for conventional patients was 28.7 on average and teleaudiology patients had an average score of 29.6 (Pross et al., 2016). The mean difference between the scores was not statistically significant or clinically meaningful.

These studies examined subjective and objective outcome measures for hearing aid fittings, with questionnaires, real-ear probe tube measurements, and aided versus unaided word recognition scores. The evidence from these articles was moderately strong, as the sample sizes were smaller and some of the methods used, particularly in the collection of the SADL scores in the Penteado et al. (2014) article, were questionable due to the short length of time between the hearing aid fittings and the administration of the SADL. However, the findings suggest that there was little difference between teleservices provided for hearing aid fittings and programming adjustments with those provided in-person and, in some cases, the outcomes for those using teleservices were better than traditional appointments in terms of patient satisfaction. Although the Brannstrom et al. (2016) article did not specifically address the initial hearing aid fitting, it provides an insight into other uses of teleaudiology for audiologic rehabilitation purposes.
Table 6: Summary of Hearing Aid Treatment Studies.

<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Teleaudiology Method</th>
<th>Remote Site Facilitator</th>
<th>High-speed Internet Required</th>
<th>Patient Internet Connection Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brannstrom et al. (2016)</td>
<td>Quasi-SFT (Portal can be accessed by both parties)</td>
<td>No assistant present</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Campos &amp; Ferrari (2012)</td>
<td>CVT</td>
<td>Undergraduate student acted as facilitator</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ferrari &amp; Bernardes-Braga (2009)</td>
<td>CVT</td>
<td>Audiologist acted as facilitator</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Penteado et al. (2014)</td>
<td>CVT</td>
<td>Audiologist acted as facilitator</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Pross et al. (2016)</td>
<td>CVT</td>
<td>Audiology Technician acted as facilitator</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

CVT= Clinical video telehealth, SFT= Store-and-Forward telehealth

CHAPTER 4: DISCUSSION AND CONCLUSION

The purpose of this review was to identify and critically evaluate the subjective and objective clinical outcomes from adults with regard to audiologic evaluation and hearing aid-related treatment. The studies examining various methods for teleaudiology were promising, showing that test-retest reliability of pure-tone air conduction thresholds were within the clinically acceptable range of 10 dBHL (Choi et al., 2007; Eikelboom et al., 2013; Givens et al., 2003b; Givens & Elangovan, 2003a; Pearce et al., 2009; Swanepoel, Koekemoer & Clark, 2010b; Swanepoel et al., 2010a; Visagie et al., 2015; Yao et al., 2010; and Yao et al., 2015) with some differences noted in the one article examining thresholds of bone conduction testing compared to the traditional, in-person testing method (Margolis et al., 2010). A single study
reviewed the reliability of word recognition testing at a distance, but found that the results were reliable when compared to the conventional testing method using recorded stimuli, though only participants with normal hearing (Yao et al., 2015). Remote hearing aid fittings, although taking slightly longer than a conventional appointment in some cases, resulted in similar verification and/or validation results when compared to conventional hearing aid fitting appointments (Campos & Ferrari, 2012; Ferrari & Bernardz-Braga, 2009; Penteado et al., 2014; and Pross et al., 2016). Real-ear measurements made with probe microphones, placed by facilitators at remote sites, resulted in clinically acceptable differences when compared to conventional hearing aid fittings (Campos & Ferrari, 2012, Ferrari & Bernardz-Braga, 2009), demonstrating that the gold standard method for fitting hearing aids can be accomplished at a distance.

Little information regarding patient or provider attitudes toward teleaudiology were available for review, but the general consensus across existing studies showed that if a patient or an audiologist has increased familiarity with technology, they feel more positively about teleaudiology and are willing to use appointment methods outside the traditional, face-to-face delivery (Eikelboom & Atlas, 2005; Singh, Pichora-Fuller, Malkowski, Boretzki, & Launer, 2014). In a rural population, access to and familiarity with newer technology may be limited, which could potentially reduce a patient’s willingness to use teleaudiology; however, it was noted in Brannstrom et al.’s study (2016) that patients who did not routinely use the internet to search for medical information found the internet-based support system much more useful following the initial hearing aid fitting appointment. Additionally, current practitioners, including audiologists and hearing instrument specialists, are not opposed to using teleaudiology as a means of practice, but the majority of the practitioners surveyed by Singh et al. were most comfortable using the telephone rather than video conferencing (2014). It was noted that 48% of
survey respondents thought that teleaudiology services would have little impact on the quality of care provided, with just 19% thinking that quality of would be reduced with tele-services (Singh et al., 2015).

There were a number of limitations in the studies reviewed that should be taken into account when considering the results. The number of subjects in most of the studies was limited, with most having approximately 30-35 subjects, which makes it difficult to generalize the findings to a larger population. Additionally, there were only four randomized control trial studies out of the 19 studies reviewed. Some of the recruitment of study participants occurred in clinics (Brannstrom et al., 2016) or on college campuses (Yao et al., 2010; Yao et al., 2015), which could skew the representation of the average individual who could be participating in teleaudiology services. Among the evaluation studies reviewed, bone conduction threshold testing and speech testing were not completed routinely across studies, resulting in pure-tone air conduction methods having the most data. The validation measures used, such as the IOI-HA, SADL, and HHIE were collected at intervals that could lead to results that are not truly representative of the impact that hearing aids can have on a person’s quality of life. For example, the SADL questionnaire was administered immediately after a remote hearing aid adjustment (Penteado et al., 2014), which would not allow the patient enough time to fully adjust to the hearing aid and provide a realistic and thoughtful response. The quality of the research was also limited by the study designs used in some of the articles, such as the case reports used in Pearce et al. (2009), which reduced the strength of the evidence.

Teleaudiology is a rapidly-developing specialty and new approaches to audiologic evaluation and hearing aid-related treatment have been investigated by multiple research groups. In the area of audiologic evaluation, two studies examined the efficacy of using teleaudiometry
in a natural environment and compared the results to traditional testing conducted in a sound
booth and in a natural environment with no sound booth (Swanepoel & Biagio, 2011; Visagie,
Swanepoel, & Eikelboom, 2015). In both studies, sound-attenuating circumaural headphones
have been used to collect audiologic evaluation results and had the results compared with
conventionally obtained thresholds. Swanepoel & Biagio (2011) completed testing for both
conditions within a sound booth and obtained reliable test results within the acceptable range of
variability. Visagie et al. completed a portion of their experiment in a natural environment setting
using the sound-attenuating headphones and also obtained reliable test results that were within
the clinically accepted 10 dBHL range of variability (2015). Blamey, Blamey, & Saunders
(2015) have explored the use of internet-based tools to capture speech perception scores and fit
hearing aids without using the traditional audiogram. They utilized an internet-based speech
perception test to generate speech audiograms, which are then used to fit hearing aids and have
yielded similar objective outcomes to patients fit with hearing aids using traditional audiometric
test results. These studies provide an insight into the directions that teleaudiology could go in the
future and demonstrate, on a small scale, that traditional methods are not the only reliable option
for those seeking hearing healthcare services from a distance.

Future directions for research in this area should specifically examine the outcomes for
audiologic intervention via teleaudiology in the 65 years and older population. A surprising
result of this literature review revealed that there were no studies that looked exclusively at the
65 years and older population. This population in particular warrants further examination
because they have the highest prevalence of hearing loss at 63.1% (Lin et al., 2011). By
examining this population, the effects of comorbidities such as vision loss, cognitive difficulties,
and reduced dexterity could be investigated to determine their impact on the accuracy of
assessment, outcomes, and patient/provider experiences with teleaudiology. However, other areas of the medical field have evaluated telemedicine applications with geriatric populations and found that “unless they have cognitive difficulties, the upcoming elderly will be the vanguard of electronic medicine in geriatrics if we invite them and listen to them without prejudice” (Merrell, 2015). The test-retest reliability of bone conduction and speech testing should be explored, as there were very few studies that looked at these additional test components.

Additional areas for future research should examine the reliability of immittance measures as performed by remote site facilitators, as this is a critical component of an audiologic evaluation. Future avenues of research could also explore the requirements for training a remote site facilitator or assistant, with the goal of creating a training program. The article from Swanepoel, Koekemoer, & Clark (2010) stated that teleaudiology evaluations took approximately 21% longer than the traditional in-person test method, but provided no explanation for the reason why. The amount of time needed to efficiently complete teleaudiology evaluations should be investigated further.

Telemedicine has already been effectively used in other areas with geriatric patients. One area includes depression management and a recent study showed that the severity of a patient’s depression was reduced through medication adherence, education, and programming, by using existing home healthcare tele-monitoring equipment (Sheeran et al., 2011). Success has also been found in English and Spanish populations with diabetes education delivered via telemedicine, showing that rural patients, as defined as living in federally designated medically underserved areas, and urban patients were able to find high levels of satisfaction and learn from the materials through tele-services (Bakken et al., 2006). Additionally, the Arizona Latino community has been engaged with community health workers in a variety of health disciplines to
facilitate access to services and improve cultural competency to those receiving healthcare services. These specialty services, such as diabetes education, have been delivered via traditional, in-person encounters; however, the use of a community health worker as a teleaudiology facilitator could provide similar benefits. The community health workers have been shown to build individual and community capacity by increasing health-related knowledge and self-sufficiency (Rosenthal, Wiggins, Ingram, Mayfield-Johnson, & De Zapien, 2011).

With the success of telehealth services in other medical specialties, there is little reason to suspect that teleaudiology would not be as successful. Teleaudiology can utilize the same methods already established in other fields to conduct counseling and aural rehabilitation. It was shown in the review of audiologic evaluation and treatment studies that there is evidence that the equipment-heavy aspects of testing and hearing aid fitting can be accomplished with the use of on-site facilitators. In addition to audiologic evaluations and hearing aid fittings, many other specialty areas of audiology including electrophysiology, vestibular testing, and cochlear implant mapping have successfully been completed via teleaudiology.

Clinical Implications

The use of telemedicine services in audiology is feasible with an adult population, like the intended target of the Arizona Affordable Hearing Aid Task Force. Prior to setting up teleaudiology clinics, there are many considerations to be made for staffing of the main office and remote sites, equipment costs, building rental or purchase costs, and most importantly, the infrastructure of the rural areas of the state that would be utilizing this service. Without reliable telephone and dedicated internet services, real-time teleaudiology would not be feasible due to the nature of the tasks to be completed. Automated audiometry could serve a role in an area without stable internet connectivity, as the patient could complete the test and the results could
be transmitted at a later date for professional review and interpretation. However, if the goal of the Arizona Affordable Hearing Aid Task Force is to provide hearing healthcare and low-cost hearing aids, it would be advisable to utilize synchronous services to provide real-time feedback to the patient, fit hearing aids at a distance, and complete follow-up appointment.

**Conclusion**

Until additional research in the area of audiologic evaluation has been completed, it is not recommended that teleaudiology be used to evaluate adults in rural Arizona. The data from speech testing, bone conduction, and immittance measures provides valuable information that an audiologist would need in order to make a recommendation about hearing aids or, depending on the results found, a referral to a physician for medical evaluation. Although audiologic evaluations via teleaudiology are not recommended at this time, hearing aid fittings and audiologic rehabilitation services could be feasibly performed with the Task Force’s intended population, as long as the proper infrastructure is in place to provide sufficient bandwidth to complete those clinical activities. With a synchronous service delivery method, the use of an onsite facilitator would be needed to assist the patient with appointment set-up and to act as the “hands” of the audiologist. By using onsite facilitators who are already integrated into the rural communities, such as the Latino or Native American communities, the facilitator could function in a similar capacity to the community health workers to increase cultural competency and provide social support to the patients. The evidence in the articles is promising to show that in-person and teleaudiology fittings and follow-up appointments can have similar, or better, subjective and objective outcomes.
APPENDIX A – LITERATURE REVIEW SEARCH TERMS

The following search terms were used to locate the articles selected for the literature review. The search yielded a total of 251,080 articles, with 15 articles meeting the inclusion criteria.

- Teleaudiology
- Teleaudiology + hearing aids
- Teleaudiology + amplification
- Teleaudiology + audiologic evaluations
- Teleaudiology + hearing evaluations
- Teleaudiology + rural areas
- Teleaudiology
- Teleaudiology + hearing aids
- Teleaudiology + amplification
- Teleaudiology + audiologic evaluations
- Teleaudiology + hearing evaluations
- Teleaudiology + rural areas
- Telehealth
- Telehealth + hearing aids
- Telehealth + amplification
- Telehealth + audiologic evaluations
- Telehealth + hearing evaluations
- Telehealth + rural areas
- Telemedicine
- Telemedicine + hearing aids
- Telemedicine + amplification
- Telemedicine + audiologic evaluations
- Telemedicine + hearing evaluations
- Telemedicine + rural areas
REFERENCES


