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Medical Student Knowledge Regarding Age Related Hearing Loss and Amplification

Max L. Rubin

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Medical Student Knowledge Regarding Age Related Hearing Loss and Amplification

by

Max Rubin

A Capstone research project submitted to the Graduate Faculty in Audiology in partial fulfillment of the requirements for the degree of Doctor of Audiology, The City University of New York

2017
This manuscript has been read and accepted for the Graduate Faculty in Audiology in satisfaction of the Capstone research requirement for the degree of Au.D.

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ABSTRACT

Medical Student Knowledge Regarding Age Related Hearing Loss and Amplification

by

Max Rubin

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The goal of this survey is to determine medical student knowledge regarding hearing loss, communication, audiology, treatment and diagnosis of age related hearing loss and the connection to health outcomes. A questionnaire was created, using Survey Monkey, to assess medical student knowledge of hearing loss, communication, audiology, treatment and diagnosis of age related hearing loss and the connection to health outcomes. The questions comprising the survey pertain to demographics, the profession of audiology, auditory system anatomy and physiology, hearing pathologies, and appropriate intervention and health outcomes associated with under-treatment of hearing loss. Questions were gathered from previous research studies attempting to gauge primary care physician knowledge attitudes towards age related hearing loss and its correlates in hopes to aid in the creation of an online module based curriculum for Medical schools. The survey was emailed to 41 medical students attending Medical Schools overseas and in the United States. Overall, the sample responded incorrectly to most of the questions in the survey demonstrated a general lack of knowledge regarding age related hearing loss and amplification. The only question areas in which participants...
tended to excel was in the medical and co-morbidities sections. The next best section pertained to treatment options where the majority (60%) responded correctly. The minority of the remaining sections (age-related hearing loss (ARHL), epidemiology, demographics) received mainly incorrect responses underscoring the need to educate medical students in these areas. A curriculum was developed based on survey questions where the majority of the participants responded incorrectly. It is anticipated that the proposed curriculum will help future physicians understand the impacts of untreated age related hearing loss and the benefits of hearing aids. Ultimately, it will help optimize patient centered care within the geriatric population.
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INTRODUCTION

The aging population in the United States is living longer due to advances in medicine and technology. Chronic conditions are on the rise with age related hearing loss (ARHL) in this population considered a public health problem. Hearing problems are increasingly prevalent among Medicare beneficiaries and are considered one of the most common chronic conditions affecting the Medicare population. Hearing loss has been declared as the fifth leading cause of years lived with disability meaning that older adults live longer with the burdens of reduced hearing sensitivity. Hearing loss, which is the third most common condition among the U.S. population, contributes to a decline in a patient’s physical and mental state if left untreated (Yueh, et al., 2003). According to the National Academies of Sciences, Engineering, and Medicine (2016), the risk of hearing loss in older adults is approximately 10 to 20 times greater than the risk of heart disease and about 100 times greater than the risk of cancer. Among persons over the age of 65, hearing loss is present in approximately 314 of every 1000 and about 40 to 50% of those 75 years or older (Johnson, et al., 2008). Two thirds of people over 70 years old suffer from loss of hearing sensitivity (Bainbridge, 2014). According to Mitchel, et al. (2011) one in three older adults presents with hearing impairment. According to the latest report by the National Academy of Sciences, hearing loss affects more than 80% of persons 85 years of age and older age. The National Academy of Sciences (2016) estimates that of aidable older adults, 67 to 86% do not use them which further supports the fact that hearing loss is undertreated and underserved. Chien and Lin (2012) estimated that only 14% actually use hearing aids.

Older adults, who are the largest consumers of healthcare, trust their primary care
physician above all other healthcare providers. In a survey by Paul, Popp, & Hackett (2002), 63% of participants stated that their primary care physician is the most important source of health information. Hence, primary care physicians are the most influential health providers when it comes to referrals and getting their patients to take health action. Johnson, et al. (2008) reported that primary care physicians are crucial pivotal points of breaking down barriers to entry for ensuring that their hearing impaired patients receive much needed audiology services. Hearing impaired elderly patients often see their primary care physician before anyone else on their healthcare team regarding their hearing and balance issues (Johnson, et al., 2008). These patients’ health needs are not being addressed soon enough due to primary care physicians not recognizing subtle signs and symptoms of age related hearing loss and the benefits of amplification. The longer treatment is delayed, the more frustrated their patients become and the more likely their hearing related quality of life will be impacted (Dalton, et al., 2003).

Physicians routinely screening for hearing loss could help increase hearing health literacy and can identify individuals with hearing loss who could potentially benefit from the use of hearing aids and other aural rehabilitation services; however, routine screening is not recommended by the U.S. Preventative Services Task Force (USPSTF, 2014) for adults aged 50 years or older who do not recognize that a hearing loss exists. Kochkin (2004) reported that only 14% of physicians routinely screen for hearing loss. Since many physicians lack understanding regarding the nature of hearing loss and that fact that patients are likely to not have difficulty hearing their physician in their quiet office, primary care physicians may not even notice that their patient has a hearing problem. According to Cohen, et al. (2005), 97.6% of physicians responded that hearing loss
affected patient’s quality of life, however only 60% assess patients for hearing loss. 75% of primary care physicians report only performing hearing screenings when they suspect a problem or if the patient complains about hearing or balance difficulties (Johnson, et al., 2008). In 2008, Danhauer, et al. (2008) stated that based on results of their survey, primary care physicians were unlikely to screen for hearing and balance issues unless their patient complains. Their survey of primary care physicians revealed that 25% of participants did not routinely screen for hearing and balance problems and 37.5% of them would only screen if the patient complained or if they suspected a hearing/balance problem (Danhauer, et al., 2008). Given that aging, smoking, genetics, noise exposure, ototoxic drugs, recurrent inner ear infections, diabetes (USPSTF, 2014), and hypertension are all risk factors for hearing loss, physicians should be performing hearing screenings on individuals who report any of the such and routinely screen those 65 years and older (Kochkin, 2004). In addition, Johnson, et al. (2008) reported that primary care physicians believed that hearing loss (91%) and balance problems (97%) negatively impact older patient’s quality of life, however, 18% of these physicians believe that screening for hearing loss in the elderly population is a waste of time and resources because they do not believe there are effective treatments for hearing loss. To the same question asking if screening was a waste of time, 17% of physicians remained neutral. Danhauer, et al. (2008) concluded that hearing related quality of life of elderly patients and their families is greatly impacted by primary care physicians’ decisions about whether to screen for hearing/balance problems and the seriousness and enthusiasm with which they make appropriate referrals for diagnosis and treatment. A number of physicians surveyed by Cohen, et al. (2005) attributed not performing hearing screenings to a lack of time due to
concern over more pressing health issues and the demands of a busy clinical practice.

One of the many reasons primary care physicians may not be addressing their hearing impaired patient’s needs is that they lack knowledge regarding the hearing health care delivery system. Cohen, et. al (2005) reported that the lack of physician referrals to hearing healthcare providers is due to physician uncertainty about where to refer and which patients qualify as hearing aid candidates. In Popp and Hackett’s (2002) survey, 24% of respondents referred only to Otolaryngologists (ENT), 32% only to an audiologist, and 32% referred to a combination of an ENT, audiologist, or hearing aid specialist. Additionally, when hearing loss was identified, only 48% of primary care physicians recommended that their patients schedule a complete audiological evaluation and even fewer (22%) counseled their patient on possible causes and treatment options (Popp and Hackett, 2002). Only one of the physicians surveyed reported that he or she would suggest to the patient that they should consider the use of a hearing aid. When asked which health care provider they would refer their patient to in order to learn more about treatment options for hearing loss, 24% said they refer only to an ENT, 28% referred only to an audiologist, and 12% referred to both ENTs and audiologists. The low number of referrals to audiologist could be due to primary care physician’s lack of knowledge about the devastating effects of hearing loss, ignorance regarding the audiologist’s scope of practice and uninformed about the successful outcomes associated with hearing aid use.

Schneider, et al. (2010) concluded that primary care physicians require education regarding age related hearing loss and amplification. According to Popp and Hackett (2002), about 60% of primary care physicians rated their knowledge of hearing
instruments as poor or fair. Only 36% rated their knowledge of hearing aids as good or satisfactory. According to Moeller, et al., (2006) many physicians indicated a lack of confidence in discussing follow up procedures and intervention needs with their hearing impaired patients. They concluded that physicians were not aware of risk factors and symptoms of hearing loss. A majority of physicians knew that a family history of sensorineural hearing loss was a risk indicator. Furthermore, approximately half of physicians were not well informed about the risk factors for late onset hearing loss (Moeller, et al., 2006). Hence, there are major gaps in physician knowledge regarding follow up care for their hearing impaired patients in terms of treatment and referral.

Hearing aids can improve self-reported hearing, communication, and social functioning in those who suffer from age related hearing loss (USPSTF, 2014). In addition to improving audibility, hearing aids likely reduce the listening effort required for communicating (Hornsby, 2013). Mener, et al. (2013) reported that hearing aid use is independently associated with a significant reduction in the odds of acquiring depression and any of its symptoms. This may be possible through hearing aids giving access to better communication ability thus promoting social engagement. Boi, et al. (2012) conducted a 6 month longitudinal study on older adults over 70 years of age with hearing loss and depression to gauge the how digital hearing aids effect mental health, hearing related quality of life, and caregiver burden. In their study, they found that increasing hearing acuity through the use of hearing aids quickly improved the subjects’ quality of life, self-perceived general health, and reduced symptoms of depression. In addition, Boi, et al. (2012) concluded that when quality of life of the patient improved so did caregivers. Caregiver burden was reduced through greater comfort and caregivers showed less
observable stress and anxiety when their companion was amplified. This could be due to improved communication ability at home through the use of hearing aids which could put less strain on the patient and caregiver relationship (Boi, et al., 2011). Dawes, et al. (2015) confirm that hearing loss is independently related to social isolation and depression which are both associated with cognitive decline. Based on their pattern of findings, they speculated that social isolation coupled with hearing loss resulted in higher incidence of depression and the combination of depression and social isolation was associated with reduced engagement and probable cognitive decline (Dawes, et al., 2015). Schneider, et al. (2010) concluded that hearing aid use in the elderly was associated with improved self sufficiency and independent living, reduced risk of depression, and longer life expectancy. Despite the emerging evidence demonstrating the many benefits of hearing aid use, there is still an unmet need for hearing services in the elderly population and the hearing aid adoption rate remains unchanged. In order to increase the hearing aid adoption rate, primary care physicians need to be made aware of the fact that hearing aids or cochlear implants are the primary treatment available for age related hearing loss which impacts more than 90% of all hearing impaired individuals (Popp and Hackett, 2002).

The Role of Primary Care

Hearing loss is an invisible condition causing and is therefore underdetected and undertreated which could be why only 25% of hearing impaired individuals with an aidable hearing loss are fitted hearing aids (Yueh, et al., 2003). Kochkin (2004) theorized that if hearing impaired patients received a positive recommendation from their primary
care physicians then they would be five times more likely to seek treatment than if the physician gives a negative recommendation (Kochkin, 2004). Cohen, et al. (2005) concluded that through community outreach and education programs, primary care physicians would be exposed to advances in hearing aids and cochlear implants, have a better understanding about auditory rehabilitation resources, and hearing aid and cochlear implantation candidacy.

Primary care physicians advocating for hearing healthcare intervention could help overcome barriers to hearing aid adoption such as cost. Dubno, et al. (2010) analyzed data on hearing aid candidates who decided not to pursue amplification and found that half of them indicated that cost was a definite reason why they chose not to get hearing aids. Hearing aids can be the most expensive purchase a hearing aid individual makes besides their home and car. Unfortunately, Medicare does not cover the cost of hearing aids along with most insurance programs, and of those that do, most only pay a fraction of the cost. Warren and Grassley (2017) discussed the growing interest in the U.S to increase affordability and access to hearing healthcare. The President’s Council of Advisors on Science and Technology (PCAST) and the National Academy of Sciences, Engineering, and Medicine (NAS) recommended that certain hearing devices be made available over the counter with the sole purpose of addressing mild to moderate hearing losses which are the degree which impacts most hearing impaired individuals. This recommendation is thought to expand access to hearing healthcare by offering low cost hearing devices such as personal sound amplifiers (PSAP) as an alternative to hearing aids. The cost of hearing aids can be too high causing many to go without treatment of their hearing loss which is why primary care physicians need to be aware of cost and
amplification options in order to counsel regarding their hearing impaired patient’s needs and make appropriate recommendations.

Primary care physicians must advocate for earlier access to hearing healthcare due to the better eventual outcomes associated with earlier hearing aid use. Earlier hearing aid users can take advantage of brain plasticity effects and may require less auditory retraining therapy (Dubno, et al., 2010). Sharma and Glick (2016) reported on the strong relationship between neuroplasticity and auditory deprivation associated with hearing impairment in adults. They speculated that auditory deprivation causes a cross modal re-organization of the brain where the auditory cortex recruits neighboring domain specific neural networks, such as those responsible for processing vision and somatosensory information, in order to carry out auditory processing (Sharma and Glick, 2016). In short, effortful listening and increased cognitive load may lead to the recruitment of cognitive resources in the pre-frontal and frontal cortex exhausting one’s working memory and executive functioning even in the presence of a mild hearing impairment. Primary care physicians need to initiate and advocate hearing health care before cognitive or other age related health declines occur. It can be theorized that younger adults will have an easier time manipulating and maintaining hearing aids than older adults with cognitive decline due to differences in overall manual dexterity and memory ability.

In summary: primary care physicians, who are the gatekeepers in the healthcare community, should understand and exercise the considerable power they have in their initial screening for identifying potential hearing problems and for making enthusiastic and appropriate referrals which will lead to the timely diagnosis and treatment of hearing problems for their elderly patients (Johnson, et al., 2008). Primary care physicians must
be alerted about the crucial role they and audiologists play in hearing health care and increasing hearing aid uptake in aging adults (Johnson, et al. 2008; Schneider, et al. 2010). It is incumbent on audiologists to take it upon themselves to update primary care physicians about the detriments of untreated hearing loss and about the strong evidence supported by research demonstrating the benefits of amplifications and how it improves one’s hearing related quality of life (Chisolm, et al., 2007). Johnson, et al. (2008) suggest that educating physicians regarding untreated hearing loss could be an effective strategy for motivating people with hearing loss to seek treatment from an appropriate hearing healthcare provider. By knowing the most current hearing treatment options, primary care physicians can offer persuasive, firm, and enthusiastic encouragement for patients to seek treatment for their hearing problem.

Physicians must become aware of the fact that hearing aids or implants are the main treatment available for the type of hearing loss that affects more than 90% of all hearing impaired individuals (Popp and Hackett, 2002). Physicians, audiologists, and the Medicare system need to partner to ensure timely referrals that will lead to effective diagnosis and treatment for hearing impaired patients as they enter their golden years. This will lead to maintenance or improvements in their hearing related quality of life and their families. Johnson, et al. (2008) and Popp and Hackett (2002) both support the need of current primary care physician education regarding their duty for screening for hearing loss, appropriate and effective treatment options, what referrals to make, and the audiologists role in working with hearing and balance problems in the elderly. Popp and Hackett (2002) concluded the existence of a need in both academic and continuing educations venues for the development of a curriculum for primary care physicians that
focuses on hearing loss identification, counseling, and hearing loss treatment options. Instead of educating current primary care physicians regarding the negative impacts of age related hearing loss and the benefits of amplification; the best way to do so is on the “ground floor” and educating medical students who will become future primary care physicians and internists.

There is currently no web-based curriculum for general practitioners on age related hearing loss available (Schneider, et al, 2010). The hope is that such a long-term effort will lead to a significant increase in the number of hearing impaired older adults who seek treatment for their hearing and communication difficulties. If resources are not allocated for increasing the primary care physician’s role in identifying hearing loss and counseling regarding the benefits of amplification, then the number of persons receiving timely and efficacious treatment for hearing loss will continue to be 15 percent or less of those affected (Popp and Hackett, 2002).

The purpose of this study is to assess medical students knowledge regarding age related hearing loss and hearing aid use in order to develop an educational course that can be utilized in Schools of Medicine. Cohen, et al. (2005) called for audiologists and otolaryngologists to advocate for those who suffer from age related hearing loss and educate medical students and primary care physicians about the detriments of untreated hearing loss and the increases in hearing technology and auditory rehabilitation.

**METHODS**

Participants

Participants were medical students enrolled in an accredited School of Medicine
in the United States or abroad. Individual medical students were independently contacted via email to participate in the survey and asked to share it with members of their cohort and others attending their respective School of Medicine. The participants were invited to participate at their discretion and were informed that all answers would remain anonymous. They were informed that the survey answers will aid in the development of an online module based curriculum regarding age related hearing loss and its treatment, and stressed the vitality of the communication ability between the physician and their elderly patients. Internet based informed consent forms were sent along with the survey to encourage participation and prove the legitimacy of the survey.

Materials

A questionnaire was created with responses gathered and analyzed using Survey Monkey, to assess medical student knowledge of hearing loss, communication, audiology, treatment and diagnosis of age related hearing loss and the connection to health outcomes. The questions comprising the survey pertained to demographics, the profession of audiology, auditory system anatomy and physiology, hearing pathologies, appropriate intervention, and health outcomes associated with under-treatment of hearing loss. Questions were derived from previous research studies attempting to gauge primary care physician knowledge and attitudes towards age related hearing loss and its correlates (Popp and Hackett, 2002; Danhauer, et al., 2008; Johnson, et al., 2008).

The survey consisted of 22 items. The questionnaire was divided into several categories: Demographics (6 questions), Epidemiology (1 question), Medical/Co-morbidities (6 questions), Treatment Options (4 questions), and Age Related Hearing
Loss (4 questions). Respondents were instructed to skip questions which did not pertain to them. Percentage of responses was analyzed based on the number of persons responding to the survey out of the total number of persons surveyed. The items on the questionnaire are displayed in Appendix A. Respondents were instructed to answer yes or no variety questions or participants were asked to choose one and sometimes multiple of the provided answers or asked to write a response.

Procedures

The study was approved by the Institutional Review Board of the Graduate Center, CUNY. Following approval, the survey was emailed to medical students at selected accredited 5 Medical Schools located in the United States and 2 overseas. In addition to the initial invitation to participate in the survey, participants were sent a reminder email two weeks later to help ensure participation. The proportion of people responding out of total sent out could not be calculated as participants independently shared the survey with classmates and may have broadcasted it to their entire Medical School. Respondents did not receive any feedback or score regarding their answers and all answers remained confidential. There was no financial incentive offered to participants. Responses were anonymous as respondents did not have to provide their names or any identifiers; therefore, all participants remained anonymous.

RESULTS

41 medical students from 7 Medical schools responded to the survey. Slightly more males (56.10%) than females (43.9%) responded but this difference did not achieve statistical significance. In terms of years of Medical School completed: 39.02% reported
completing their first year of study, 19.51% their second year, 31.71% the third year and 9.76% their fourth year as is shown in Figure 1.

![Figure 1: Medical School Levels Completed](image)

Regarding rotations completed in medical school, only 9 participants (21.95%) responded. 11.11% completed Ophthalmology, 44.44% completed Cardiology, 11.11% completed Endocrinology, 44.44% completed Geriatric Medicine, and 33.33% completed Neurology rotations. In response to the question regarding specialty upon graduation, most (68.29%) reported that they see themselves working in a hospital setting, followed by private practice (17.07%) and the remaining respondents in a clinic setting (14.63%).
Responses to Each Item by Category

Demographic Items

Two questions comprised the demographic section of the survey. Participants were asked, “On average, what is the percentage of older adults 70 years of age and older with hearing loss who use hearing aids?” The majority (48.78%) responded that 21-40% of older adults used hearing aids. The next highest selected answer consisted of 32% of respondents answering that 41-60% of persons with age related hearing loss (ARHL) use hearing aids. Hence, most medical students queried were aware that hearing loss is undertreated.

Epidemiology Items

In response to the one question relating to prevalence of hearing loss among persons 70 years of age and older, a majority of respondents answered incorrectly with 41.46% and 19.51% (60.97% total) responding 80% and 31% respectively. 39.02% of participants answered correctly that prevalence is 63% of those 70 years of age and older have hearing loss. The majority (41.46%) of respondents responded that prevalence was 80% in this population. Hence, the majority of medical students responding were aware of the vast abundance of older adults affected by hearing loss.

Co-morbidity Items

When surveyed about potential deleterious effects on one’s physical and mental
health associated with untreated hearing loss, a majority (82.93%) responded correctly that untreated hearing loss has little relation to arthritis. Only 17.08% were not alert to the fact that untreated hearing loss could increase one’s risk of acquiring conditions such as dementia, depression, and increase one’s risk of falling.

In response to the question about the most prevalent condition affecting the outer ear which can interfere with hearing and the function of hearing aids, the majority responded correctly (78.05%). Medical students appear to be informed about increased cerumen production associated with aging and how it can affect hearing and hearing aid function.

In response to the question about the most common reasons for physician visits in the elderly which pertain to the ear or hearing, the majority (68.29%) selected the correct response being cerumen (wax) impaction. Only 31.71% of students responded incorrectly meaning that most medical students know and learn that they should look in their elderly patient’s ears during clinical visits or when they report aural fullness, ear itchiness, and difficulty hearing.

Medical students appeared knowledgeable about ototoxic effects of medication when asked about irreversible causes of sensorineural hearing loss and/or balance problems. The majority of respondents (63.41%) knew that salicylates do not cause irreversible sensorineural hearing loss. Only 36.59% of participants were unaware that cisplatin, aminoglycosides, and furosemide cause permanent damage to the cochlea and semicircular canals responsible for hearing and balance.

In response to the question about co-morbidities associated with hearing loss approximately half of the respondents (56.41%) correctly selected Amyotrophic Lateral
Sclerosis (ALS) as not being linked to hearing loss. However, 53.85% of responses were incorrect such that 23.1% responded vision impairment, and 12.8% responded diabetes and hypertension. Hence medical students do not appear to be mindful that hearing loss can be associated with diabetes, cardiovascular disease/hypertension, cognitive decline, and vision impairment. Analysis is shown in Figure 2.

Figure 2: Co-morbidities of Hearing Loss

Next, participants were asked about potential risk factors either directly or indirectly associated with age-related hearing loss. The majority (75.6%) selected mortality, 87.8% selected falls, 85.4% selected hospitalizations, 82.9% selected
functional limitations, and 95.1% selected social isolation responding correctly that untreated age-related hearing loss was associated with increased risk of mortality, falls, hospitalizations, functional limitations, and social isolation.

**Items on Treatment of Hearing Loss**

In terms of knowledge regarding non-medical or surgical treatments for sensorineural hearing loss ranging from mild to profound: 39% of participants responded that hearing aids were the only treatment and 14.63% responded that cochlear implants were the only treatment. 43.90% of participants were aware that hearing aids, cochlear implants, and brainstem implants are treatment options for hearing loss depending on candidacy. The finding that a majority (56.09%) of respondents answered incorrectly suggested a need for greater education in the area of hearing loss intervention and management. Results from this question can be viewed below in Figure 3.
In response to the question regarding medical student knowledge about audiologists and scope of practice, most respondents (75.61%) were aware of the profession in contrast to the 24.39% that responded incorrectly.

Regarding the question about cochlear implants, a majority (70.73%) of participants knew that a cochlear implant is a device that provides direct electrical stimulation to the auditory nerve in the inner ear as defined by The American Speech-Language-Hearing Association (2017). In response to a follow up question on medical student knowledge of cochlear implant a vast majority (87.8%) knew that the FDA determined that in order to be an adult and receive a cochlear implant he or she must have a severe to profound hearing loss, extremely poor speech discrimination, or receiving
little to no benefit from hearing aids (2015).

In response to the question about Medicare coverage for hearing aids for persons with age related hearing loss, the majority of respondents were aware of the lack of funding. Yet, close to 40% responded incorrectly suggesting that an effort should be placed into educating physicians about hearing health care benefits and perhaps recruiting them to join in the effort to advocate for funding. Please see Figure 4 below.

![Figure 4: Health Insurance Coverage of Hearing Related Services](image)

Items on Anatomy and Communication Difficulties

Participants were queried about the structure in the ear most susceptible to age related degenerative changes. Close to 50% of respondents answered incorrectly underscoring their lack of knowledge regarding the location of the atrophic age related
changes. Hence, there is a need for further education in this area.

The majority of respondents were not aware of the communication difficulties experienced by older adults with age related hearing loss with the majority (58.54%) responding incorrectly. Only 41.46% knew that those affected by age related hearing loss will report that they can hear people talking; however, they cannot understand the words (as shown in Figure 5).

Figure 5: Communication Impact of Age Related Hearing Loss

The majority of respondents were aware that untreated hearing loss can interfere
with patient and clinician communication and that this can affect case history and counseling. If there are communication breakdowns between the clinician and patient then the patient may be less likely to take health action.

Summary of Findings

Overall, participants responded incorrectly to most of the questions pertaining to age related hearing loss, epidemiology, and demographics demonstrating a general lack of knowledge regarding age related hearing loss and its treatment. The only areas in which participants appeared knowledgeable related to the Medical and Co-morbidities sections. Knowledge of age-related hearing loss, epidemiology, and demographics was severely lacking indicating need for a clear focus on hearing loss epidemiology, hearing aid usage, and the etiology, impacts, and detriments of age related hearing loss.

DISCUSSION

In order to fill medical student audiological knowledge gaps, the educational modules must be geared to optimize learning in order to influence behavior. Since the learners will be medical student, adult learning principles strongly influenced the design of the curriculum. Lindeman (1926) and Knowles (1998) asserted that adults are motivated to learn when they feel knowledge regarding a certain topic is lacking and qualifies for improvement. When physicians develop their own learning goals through reflecting on their clinical strengths and weaknesses, they will receive maximal benefit from the educational coursework provided (Epstein and Hundert, 2002). This means that any coursework should be directed at the medical student’s educational needs and should
not include much information they already know. Adult learning is life centered and educational materials should be based on clinical/life experience (Lindeman, 1926; Knowles, 1998). Physician learning is inseparable from their lives meaning that their coursework should force them to address real life scenarios (Koons, 2004).

Accordingly, educational content should include realistic case situations which the learner can relate to and instill reflection on how they can apply the lessons into their clinical practice in everyday situations. Reflection on clinical experience should be at the very root of adult education. Furthermore, Knowles (1998) concluded that adults learn most optimally when educational materials are self directing and taught from an andragogy approach. Smith (1982) wrote that educational content and the process of learning must relate to the learner’s past experiences. By linking educational material to a physician’s past experience, a new learning experience is created which the clinician could use as a resource for future practice. Lindeman (1926) noted that individual learning differences increases with age. Older physicians have more life and clinical experience which may pose as a greater challenge in influencing clinical behavior when compared to younger medical students. Also, Smith (1982) emphasized the importance of one’s learning climate which should be free of stress and anxiety by promoting freedom to learn at will and experiment. An online module based curriculum allows medical students to access the content at their own discretion and when they are internally motivated and interested in learning the material.

Educational materials aimed at informing or suggesting physicians to alter their approach to daily clinical practice must account for and apply adult learning principles in order to influence change in an ever-changing health care environment (Koons, 2004).
Providing appropriate education materials is vital to enhancing the quality of health care. Koons (2004) elaborates on points raised by Lindeman, Knowles, as well as Smith, by emphasizing the need for educational programs to include case scenarios which interact with the learner and promote self-dialogue and clinical thinking. Cases help to create an individualized, efficient, and pleasurable learning experience which in turn will lead to better patient health outcomes. Koons (2004) affirms that didactic instruction is not an effective approach in educating and influencing physician behavior. The USPSTF (2014) utilizes mostly case studies to educate the medical community in regards to changes in medical practice and prevention strategies. Medical curriculums used in classroom, pre-clinical, clinical, and continuing medical education settings often consist of evidence based coursework and case studies to help influence the learner to make clinical decisions (USPSTF, 2014). The USPSTF (2014) employs adult learning principles in their courses for physicians by using evidence based medical concepts and helping physicians implement them into clinical practice which will lead to improving patient health outcomes.

The purpose of this survey of medical students was to ascertain their knowledge base regarding age related hearing loss. The pattern of responses then would guide in the development of a series of educational modules to be used by medical student to gain a working knowledge of hearing loss and its associated health risks, and hearing interventions. The content of the online module based curriculum was derived from questions which received less than 60% correct response from the study questionnaire. Questions that were mainly answered accurately (more than 60% of respondents selecting the correct answer) were not included in the curriculum. The curriculum presented below
was developed with the key principles of adult learning theory in mind.

1. Teaching Point: Epidemiology of Hearing Loss.

Question Stem: What is the prevalence of hearing loss among persons 70 years of age and older?

A. 80%
B. 31%
C. 15%
D. 63%
Answer: D. 63%.
Critique:

The aging population in the United States is living longer and longer due to advances in medicine and improved patient centered care which in turn means the average lifespan is increasing. Hearing and balance problems are increasingly prevalent amongst the Medicare population which is 65 years old or older. In persons over the age of 65 years, hearing loss is present in approximately 314 of every 1000 and about 40 to 50% of those 75 years or older (Johnson, et al., 2008). Lin, Niparko, and Ferrucci (2011) conducted the first national estimates of hearing loss prevalence in the United States based on audiometric data and a large sample size instead of self reported measures, and they estimated that about 30 million or 12.7% of Americans greater than or equal to 12 years of age had bilateral hearing loss from 2001-2008. That number estimates to grow to 48.1 million or 20.3% when including those with unilateral hearing loss in the same age group. Lin, Niparko, and Ferrucci (2011) elaborated on the above estimates analyzing
those 12 years or older further by concluding that nearly 1 in 8 individuals has bilateral hearing loss and nearly 1 in 5 individuals has a unilateral or bilateral hearing loss. In addition, the prevalence of hearing loss is expected to increase with every decade due to the aging of the U.S. population. Hearing loss is one of the most common conditions affecting the Medicare population. In a study that looked at 870 Australians, one in three persons had hearing impairment (Mitchell, et al., 2011). Hearing loss, which is the third most common condition among the U.S. population, can contribute to a decline in a patient’s physical and mental state if left untreated (Yueh, et al., 2003). It is considered a public health problem given the demographic realities.

2. Teaching Point: Aging Impacts on Central and Peripheral Auditory Pathways and Affects on Communication

Question Stem: Age-related speech understanding difficulties are due to degenerative changes in which of the following structures?

A. Inner ear, auditory nerve, auditory brainstem, auditory cortex
B. Eustachian tube, tympanum
C. Tympanic membrane, ossicles
D. Ear canal, pinna

Answer: A. Inner ear, auditory nerve, auditory brainstem, auditory cortex.

Critique:

Age related hearing loss is known as presbycusis. It is complex and degenerative in nature typically affecting bilateral cochlear transduction of acoustic stimuli.
There are both intrinsic (genetics and aging) and extrinsic (environmental and co-morbidities) factors acting on the inner ear/ cochlea over a lifetime. The sensory basal outer hair cells of the cochlea responsible for responding to high frequency stimuli are usually affected first then progressing to the apical end of the cochlea affecting outer hair cells responsible for low frequencies. Due to the progressive and gradual nature of presbycusis, the affected individual may not notice they have a hearing impairment or may have difficulty recognizing they are having difficulty hearing due to a comorbid cognitive impairment.

Age has a direct impact on the central auditory system. Auditory deprivation, due to sensory damage in the cochlea, can cause changes in the central auditory pathway/brain. Changes in peripheral hearing impacts cortical speech processing networks, and suggest that sensory acuity has cascading consequences for the neural processes supporting both perceptual and higher-level cognitive functions (Peelle, et al., 2011). There are plastic changes in the auditory brain resulting from loss of cochlear hair cell sensitivity with age, this can be referred to as a peripherally-induced central effect. This means that the damage in the peripheral auditory nervous system can lead to structural changes in the central auditory nervous system.

Neural presbycusis causes shrinkage in the size of auditory neurons which affects the synchronous firing of auditory stimuli at the level of the auditory nerve and in turn will negatively impact speech understanding. Poor neural synchrony also leads to poor speech understanding in the presence of noise. Age related hearing loss causes direct changes in temporal resolution taking place at level of the cochlear nucleus. Lack of auditory input from age related hearing loss causes a reduction in the amount of
neurotransmitters at the inferior colliculus which impacts intensity and temporal coding important for speech understanding. Peelle and Wingfield (2016) explained that age related hearing loss can involve degradation in spiral ganglion neurons (which can negatively affect one’s ability to hear in noise), cochlear nuclei (which impacts the ability to process rapid speech and detect brief temporal gaps in a continuous stimulus leading to reduced speech comprehension), superior olivary complex (affecting one’s sound localization ability), and other midbrain higher order auditory pathway structures including the inferior colliculus.

Not only are the sensory hair cells of the cochlea and auditory neurons subject to age related damage, the prefrontal cortex is subject to considerable atrophy with age with the lateral prefrontal region subject to the most atrophic changes (Kryla-Lighthall & Mather, 2009). A brain exposed to auditory input functions much better than a brain that is deprived of auditory stimulation. Untreated hearing loss can lead to significant shrinkage of the prefrontal cortex which has been shown to have an association with one’s ability to discern and understand speech in the presence of noise. A larger and more active prefrontal cortex can more successfully inhibit irrelevant information from the peripheral system, facilitating identification of important details in speech thus optimizing one’s ability to communicate especially when in noisy environments. Kyrla-Lighthall & Mather (2009) concluded that there was a link between sensory stimulation and cortical volume which is supported by the fact that gray matter density in the prefrontal cortex is predicted by the health of the peripheral auditory system. Changes in older adults’ peripheral hearing ability may have a causal role in reducing gray matter volume in the auditory cortex (Peelle, et al., 2011). Therefore, untreated hearing loss may
lead to a faster rate of atrophy to the prefrontal cortex and frontal lobe which can impair one’s ability to understand and identify speech in the presence of noise.

Furthermore, Lin, et al. (2014) investigated 1984 older adults without prevalent cognitive impairment who received periodic cognitive and audiometric testing for 6 years in order to observe the structural changes of a typical hearing brain compared to a hearing impaired brain over time. Along with atrophy to the frontal cortex, hearing impaired older adults had significantly more shrinkage in the superior, middle and inferior temporal gyri which are structures responsible for processing sound and speech (Lin, et al., 2014). These researchers found that individuals with hearing loss had accelerated rates of brain atrophy and decline in whole brain volume and temporal lobe gray matter volume which is linked to cognitive decline. Lin, et al. (2014) concluded that if the brain is deprived of auditory stimulation, like it is in those with age related hearing loss, then the frontal part of the brain has to work a lot harder to listen. When listening effort is increased, then this overexertion to hear can take a toll on cognitive resources.

The brain is plastic even in adulthood (Mahncke, et al., 2006). In a study by Sharma and Glick (2016), they examined the effect of auditory deprivation on cross modal reorganization of the brain. They deduced that when the auditory cortex is deprived of auditory stimulation or receives a degraded speech signal then it recruits neighboring domain specific neural networks such as vision or somatosensory to carry out auditory sensory processing (Sharma and Glick, 2016). Sharma and Glick (2016) support this by comparing cortical visual evoked potential in a group of normal hearing adults to a group of adults with mild to moderate hearing loss. The normal hearing group demonstrated cortical responses to visual stimuli in higher order visual and cerebellar
regions as opposed to the mild to moderate hearing loss group which displayed responses to visual stimuli in the auditory cortex and temporal lobe suggesting recruitment of auditory domain specific regions of the brain to process visual stimuli. Furthermore, Sharma and Glick (2016) analyzed cortical auditory evoked potentials in typical hearing adults versus adults with mild to moderate hearing impairment. In typical hearing adults, auditory stimuli elicited neural responses in the auditory cortex as opposed to the hearing impaired group which elicited significant cortical responses in the frontal and pre-frontal cortex, and less activity in the auditory cortex. In summary, effortful listening and increased cognitive load leads to the recruitment of cognitive resources in the pre-frontal and frontal cortex exhausting one’s working memory and executive functioning even in the presence of a mild hearing impairment. On the topic of effortful listening, Peelle and Wingfield (2016) reasoned that the recruitment of neural networks located in the frontal and pre-frontal cortex in order to maintain successful communication can have negative behavior consequences on perception, comprehension, and memory. Put simply, it takes more brain power to understand degraded speech than clear speech.

Age related hearing loss can lead to slower perceptual and cognitive operations, a decline in working and auditory memory, and decreased efficiency in executive functioning and inhibition (Peelle and Wingfield, 2016). Peelle and Wingfield (2016) propose that this could explain why older adults have more difficulty processing complex auditory signals than younger adults. There is already heavy burden on one’s working memory to follow rapid and variable speech involved in a conversation and understanding syntactically complex speech. The domain specific areas of the brain that would ordinarily be used for encoding what was just heard, remembering what was just
said, and speech comprehension are being recruited to assist hearing degraded speech. This could affect one’s memory and ability to encode speech. Peelle and Wingfield (2016) state that speech comprehension involves large scale neural networks both cortical and subcortical which are being exhausted and limited due increased listening effort by hearing impaired individuals. Peelle and Wingfield (2016) offer that even those with mild hearing losses, which contains the highest prevalence in terms of severity of hearing loss, has a profound impact on neural and cognitive processing involved in speech comprehension. Therefore, one can concluded that age related hearing loss causes peripheral and central changes to the auditory pathway and brain structure and functioning making it more difficult to comprehend complex acoustic stimuli, syntax, foreign accents, and rapid speech.

3. Teaching Point: Presbycusis and its Affect on Communication Ability

Question Stem: Which of the following best describes how age related hearing loss affects communication?

A. Able to hear people talking, but unable to make out the words

B. Difficulty hearing male voices and voices of children

C. Difficulty understanding low frequency noise in quiet

D. Difficulty hearing but no difficulty understanding

Answer: A. Able to hear people talking, but unable to make out the words
Critique:

Age related hearing loss is typically associated with inability to perceive high frequency sounds. In terms of sensory damage to the cochlear, the outer hair cells in the basal region of the cochlea responsible for responding to high frequency stimuli are usually degraded first then progressing to the apical end of the cochlea affecting outer hair cells responsible for low frequencies. This means that those who suffer from presbycusis have better hearing sensitivity in the low frequencies meaning that they will hear vowels and volume in speech but lack high frequency information such as consonants which help to discriminate between different words. Typically, they have audibility but lack clarity in speech. A typical complaint of a presbycusis patient is: I am able to hear people talking, but I cannot make out the words. However, Bernabei, et al. (2014) stated that reduced speech understanding among older adults during more complex, multiple talker or noisy listening scenarios seem to include multiple factors not necessarily predictable from one’s audiogram and may be due to overall reduced mental processing speed typically seen in the elderly population.

Aging is associated with anatomical and physiological changes to the stria vascularis and its associated endocochlear potential, and the spiral ganglion of the auditory nerve. The stria vascularis is often referred to as the battery of the cochlea and its degeneration is the most prominent anatomical feature of presbycusis (Gates and Mills, 2005). Age related degeneration of the stria vascularis leads to a reduction in voltage of the endocochlear potential responsible for the cochlear amplifier. In terms of perceived loudness, this will cause auditory stimuli to be perceived as softer in volume.
than originally presented by the speaker. Mills and Gates (2005) state that this reduction in voltage of cochlear action potential in aging ears most likely results in asynchronous firing of neurons in the auditory nerve. These auditory nerve asynchronies could potentially lead to poor temporal resolving abilities in older adults which affects one’s ability to process speech, especially in noise.

Untreated hearing loss has bottom up and top down deleterious effects beginning with the auditory periphery and continuing up through the cortical regions which govern human behavior. Hearing loss increases one’s listening effort leading to an increased cognitive load. With increased cognitive effort comes increased mental fatigue because presbycusis sufferers require more expansive neural network to hear than typical hearing adults (Hornsby, 2013). Speech comprehension engages extensive neural networks from cortical and subcortical areas in those who suffer from hearing impairment. When speech information is distorted or missing, the auditory cortex or speech processing regions of the brain will recruit neighboring neural networks to help maintain successful communication which could have significant downstream consequences in terms of behavior (Peelle and Wingfield, 2016). Working memory is usually worse for degraded or muffled speech stimuli than for acoustically clear words. Often this symptom is mitigated by older adults’ high linguistic knowledge and their use of semantics to recognize degraded speech and filtered words. In addition, Pichora-Fuller and Singh (2006) assert that increased listening effort caused by multiple talker scenarios or noisy environments leads to processing resources becoming diverted by putting more cognitive emphasis on listening and less on memory. In general, working and functional memory, both front end cortical processes, is typically poorer in hearing impaired individuals due
to increased cognitive load even when they successfully recognized the words. Domain specific regions of the brain important for encoding and attaching meaning to words and sentences are being exhausted trying to assist the auditory cortex in hearing and following a conversation. Peelle and Wingfield (2016) found this to be true even in the presence of a mild hearing impairment. Eckert, et al., (2017) discuss how peripheral and central age related changes, unrelated to hearing thresholds, could explain hearing handicap and speech processing difficulties commonly seen in older adults. Age related changes to auditory periphery and central higher order structures impair one’s hearing sensitivity causing sound to be less audible, difficulty with speech recognition, and increases one’s difficulty to hear in challenging listening environments such as noisy restaurants (Eckert, et al., 2017). Eckert, et al. (2017) confirm that peripheral and central hearing changes are significantly associated with increased self perceived hearing handicap.

In summary, age related peripheral and central auditory changes make it difficult for older adults to comprehend complex syntax, foreign accents, and rapid spoken speech. It is important for hearing impaired older adults to seek management for their chronic condition and the detriments associated with untreated hearing loss. Hornsby (2013) notes that clinically fit hearing aids could reduce listening effort, increase attentiveness, and lower the risk of mental fatigue associated with the increased speech processing demands of the hearing impaired. Bernabei, et al. (2014) surmised that untreated hearing loss accelerates age related cognitive decline, and suggest that timely and appropriate auditory intervention could assist in delaying cognitive decline and dementia.
4. Teaching Point: Presbycusis and Co-morbidities

Question Stem: Which of the following is not a comorbidity associated with age related hearing loss?

A. Hypertension, cardiovascular disease
B. Diabetes
C. ALS
D. Cognitive decline
E. Vision impairment

Answer: C. ALS

Critique:

Sensorineural hearing loss, specifically age related hearing loss, is a chronic condition which can be associated with other common age related health conditions. Many medical conditions are linked to presbycusis such as cardiovascular factors including diabetes and hypertension (Bernabei, et al., 2014). Kakarlapudi, et al. (2003) conducted a retrospective study examining electronic medical records of 53,461 non-diabetic patients and 12,575 diabetic patients and found that sensorineural hearing loss was more common in the diabetic population than in the nondiabetic. In addition, they found that poor management of diabetic symptoms led to decreased hearing thresholds in diabetic patients with sensorineural hearing loss. In other words, there was a significant correlation with the progression of diabetes and the severity of hearing loss (Kakarlapudi, et al., 2003). Hypertension/cardiovascular disease is prevalent in the aging population and when blood circulation is affected, blood flow to the cochlea can be restricted. Bernabei,
et al. (2014) reported that hypertension/cardiovascular which results from environmental toxins, such as smoking and noise exposure, can lead to an accumulation of oxidative stress which can lead to hypoxic events resulting from the impaired homeostasis of cochlear blood supply due to atherosclerosis.

Vision and hearing impairments are both associated with aging. Coexisting hearing and vision impairment (dual sensory impairment-DSI) is common in the geriatric population; however, less common than those who suffer from only hearing loss (Kiely, et al., 2016). Fisher, et al. (2014) concluded that older men with hearing loss or both vision and hearing loss had an increased risk of mortality with a greater risk of dying from a cardiovascular event. Keily, et al. (2015) looked at sensory impairments and their impact on mortality. On average, men over 65 have a life expectancy of 19.4 years. Men over 65 years old with both vision and hearing loss had a life expectancy of 2.2 years. Women over 65 years old had an average life expectancy of 23.2 years, but in the presence of both hearing and vision loss only had an estimated 3.2 additional years lived. Primary care physicians providing services to seniors must be aware that multiple sensory impairments are common and may predict deleterious health conditions enhancing risk of mortality (Fisher, et al., 2014). To reduce the consequences of vision, hearing, or dual sensory impairments, primary care physicians must ensure periodic sensory assessments and advocate for appropriate sensory rehabilitation services aimed to treat hearing and/or vision in older adults in order to increase quality of life, overall health and well being, and longevity.

Peripheral hearing impairment has been independently associated with brain function/structural changes leading to cognitive decline (Lin, et al. 2014). In a study by
Lin, et al. (2014) comparing brain volumes of typical hearing and hearing impaired older adults ranging from 56 to 86 years old, individuals with hearing impairment had accelerated brain atrophy displayed in the reduction in whole brain and right temporal lobe volumes. In greater detail, hearing impaired older adults had significantly more shrinkage in the frontal cortex, superior, middle and inferior temporal gyri which are structures responsible for processing sound and speech. This finding was illustrated by a significant reduction in gray matter volumes in the hearing impaired brain as compared to a hearing brain. Furthermore, Peelle and Wingfield (2016) stated that age related hearing loss can lead to reductions in the number of parvalbumin-positive (PV+) neurons, GABA (gamma-aminobutyric acid) and myelin in the auditory cortex which can have a negative impact on speech processing speeds and cognition.

Age related hearing loss is associated with social isolation which is linked to cognitive decline and dementia (Bernabei, et al., 2014). Impaired communication ability caused by hearing loss contributes to social isolation and feelings of loneliness. Nicholson (2012) submitted that older adults with restricted or limited social engagement are at a significantly increased risk of cognitive decline and dementia as opposed to those with extensive social networks. Bernabei, et al. (2014) discussed the strong association between social isolation and cognitive decline. In short, social isolation contributes to depression which is associated with reduced cognitive and physical functioning from lack of social engagement, and poorer health behavior pathways such as smoking, reduced adherence to medical treatment, unhealthy diet, limited exercise, poor self-esteem, decreased self efficacy, and affects on one’s overall sense of well being. Additionally, there are many negative health implications of social isolation such as increased risk of
mortality (Eng, et al., 2002), hospitalization (Mistry, et al., 2001), and falls (Faulkner, et al., 2003).

Furthermore, hearing loss has also been linked to cognitive decline through increased cognitive load. Bernabei, et al. (2014) discussed the fact that hearing loss is associated with auditory deprivation which leads to reductions in language driven activity in the central auditory nervous system. In 2016, Peelle and Wingfield concluded that even a mild hearing impairment can lead to neural recruitment of other domain general executive systems in order to maintain successful communication. When the auditory cortex receives constant degraded auditory information, this can lead to increased compensatory language driven activity from pre-frontal cortical areas, temporoparietal cortex and neighboring neural networks (Lin, et al., 2013; Bernabei, et al., 2014; Peelle and Wingfield, 2016). This concept of neural compensation is increasing cognitive load which could impact one’s ability to perform activities for daily living and cognitive tasks such as working memory. Diminished ability to perform activities of daily living and cognitive tasks involving working memory are among the criteria for the diagnosis of dementia. In addition, Lin, et al. (2013) theorized that this pattern of neural compensation for lack of auditory stimulation in the auditory cortex may explain the general preservation of language comprehension that is commonly displayed in older adults with advanced dementia. Sharma and Glick (2016) further hypothesize that mild hearing loss may induce increased listening effort leading to cross modal re-organization whereby the vision and somatosensory areas of the brain are recruited by the auditory cortex to aid in speech and auditory processing. Cross modal re-organization can negatively impact and exhaust one’s cognitive reserve further strengthening the association between hearing
impaired listeners and cognitive decline (Sharma and Glick, 2016). In summary: hearing loss, irrespective of the degree, can have negative consequences on the aging population’s cognitive abilities which allow them to execute vital activities for daily living and reduces their risk of mortality.

As healthcare professionals, we must limit the risk factors for debilitating conditions like cognitive decline and dementia, which is a public health priority. Bernabei, et al. (2014) estimated that if healthcare professionals could delay the onset for dementia by 1 year, it could lead to a more than 10% decrease in global prevalence by 2050. They summated that appropriate aural rehabilitation that incorporates amplification and communication strategies to maximize audibility of speech signals, increase auditory stimulation, and promote social interaction could lead to a reduction in cognitive load and reduce the risk of cognitive decline. In their research, they cited outcomes of a randomized longitudinal study of hearing impaired individuals with typical cognitive ability which found that the treatment group utilizing hearing aids demonstrated improved social and emotional function, communication abilities and cognitive function when compared to the control group which received no intervention. Hearing aids and amplification could be a necessary intervention to preserve the cognitive state of our fragile elderly population.

5. Teaching Point: Hearing Healthcare Treatment Options.

Question Stem: (Case scenario)

Mrs. T. an 87 year old woman in good health reported for a routine annual check-up. Mrs. T takes no medications and the only concern she raised was that she was
experiencing difficulty hearing her grandchildren. She first noticed a hearing problem 2 years ago and thinks that it is getting progressively worse in both ear. No evidence of depression or cognitive decline is suspected. Otoscopy revealed clear ear canals and there was no sign of infection bilaterally. Mrs. T appeared to be straining to understand her physician during the assessment combined with her complaints, you recommend a comprehensive audiological evaluation (CAE). At her follow up appointment, Mrs. T provides you with an audiogram revealing a mild sloping to moderately severe sensorineural hearing loss bilaterally. Mrs. T informs you that she did not want to talk about treatment options with the audiologist until she spoke to her primary care physician (you). Which of the following non-medical or surgical treatments for bilateral mild sloping to moderately severe sensorineural hearing loss would you recommend?

A. Hearing aids  
B. Cochlear implants  
C. Brainstem implant  
D. All of the above  
E. None of the above  

Answer: A. Hearing aids  

Critique:  

Cohen, et al. (2005) reported that most primary care physicians are aware of the vast deleterious impacts of hearing loss on their patient’s overall health and quality of life. However, these researchers report that lack of time and more pressing health matters prevented primary care physicians from addressing hearing loss with their patients (Cohen, et al., 2005). They suggest that if primary care physicians discuss hearing loss
and amplification with their patients then it could help to reduce any social stigma associated with wearing a form of amplification such as a hearing aid, cochlear implant or brainstem implant. In addition, Cohen, et al. (2005) challenge primary care physicians to help identify patients who are not benefiting from amplification and make appropriate referrals to audiologist for re-evaluation. The results from both our and Cohen, et al. (2005) surveys indicated the need to educate primary care physicians regarding hearing healthcare intervention options in regards to hearing aids, cochlear implants, and brainstem implants.

Unmanaged sensorineural hearing loss associated with aging can be an insidious and demoralizing chronic health condition in those who suffer from it. It is important to treat it in a timely manner upon diagnosis. The most effective non-surgical, non-invasive, and low risk treatment for sensorineural hearing loss is hearing aids (Chisolm, et al., 2007). Hearing aids can improve communication ability by increasing hearing sensitivity, improving hearing related quality of life, and reducing listening effort (Sharma and Glick, 2016). According to Chisolm, et al. (2007), hearing aids improve hearing related quality of life by reducing psychological, social, and emotional effects of untreated sensorineural hearing loss. In addition, treating hearing loss can be useful in limiting risk factors for cognitive decline and dementia.

Cognitive decline can be exacerbated by the effects of sensorineural hearing loss and auditory deprivation on cognitive load and brain structure/function (Bernabei, et al., 2014). Significant sensorineural hearing loss is associated with a reduction in linguistic driven activity in primary auditory pathways, and increased compensatory linguistic driven activity in the pre-frontal cortex. Bernabei, et al. (2014) addressed that this
increased cognitive load could have a major impact on one’s ability to perform activities for daily living and cognitive tasks which are among the criteria for the medical diagnosis of dementia. Lin, et al. (2011) reported about one moderate sized randomized controlled trial where the experimental group wearing hearing aids demonstrated the positive impacts of hearing aids on cognition and other functional domains. Sharma and Glick (2016) theorize that the devastation caused by cross modal brain re-organization on cognitive reserve from auditory deprivation is exacerbated by the fact that hearing impaired individuals wait so long to adopt hearing aids. The earlier the intervention, the less stress there is on the cognitive reserve.

Primary care physicians must be made aware of adult cochlear implant candidacy in order to counsel and make appropriate recommendations if surgical audiological intervention is deemed necessary due to presence of residual disability. The Food and Drug Administration (FDA) (2015) described its guidelines for suitable cochlear implant candidates as pediatric or adult patients with bilateral severe to profound sensorineural hearing loss who receive little to no benefit from hearing aids. In order to receive optimal benefit from their cochlear implant, candidates must be motivated and understand that they will require periodic visits to their cochlear implant center for regular speech mapping programming, audiological assessments, and auditory training therapy. There are three FDA approved cochlear implant manufacturers Med-El, Cochlear, and Advanced Bionics, each with their own candidacy criteria which are discussed when deciding on which cochlear implant to pursue.

Speaking specifically to the adult population, cochlear implants are a surgical method of restoring hearing in post-lingually deafened adults through direct electrical
stimulation of the auditory nerve (Green, et al. 2007). Green, et al. (2007) evaluated 117 post-lingually deafened cochlear implant recipients seeking to determine independent predictors of surgical outcomes. The longer the period of auditory deprivation, the worse the speech comprehension ability was in those with cochlear implants. Conversely, as duration of auditory deprivation decrease, the better the outcomes of cochlear implantation in post-lingually deafened adults. Interestingly, age of implantation for post-lingually deafened adults was not a predictor of cochlear implant user performance. Green, et al. (2007) reported that those implanted over 65 years received similar Bamford–Kowal–Bench (BKB) scores as those implanted younger than 65 years. This is interesting to note considering older adults are being implanted with shorter durations of deafness and with even more residual hearing better than severe to profound sensorineural hearing loss. Cochlear implant technology keeps improving which may increase the speech recognition outcomes in all cochlear implanted post-lingually deafened adults.

Patients who receive insufficient benefit from their cochlear implant may have excessive damage to the auditory nerve causing poor signal transmission to the central auditory nervous system. In these scenarios, an auditory brainstem implant may be more appropriate and provide better benefit by bypassing the damaged auditory nerve and providing direct electrical stimulation to the cochlear nuclei given no evidence of mid-brainstem damage (Colleti, et al., 2009). The cochlear implant and the auditory brainstem implant use similar signal processing and number of electrodes. An auditory brainstem implant provides patients with environmental sound awareness and auditory information about stress and rhythm in speech which help with improved lipreading ability, patient
safety and sense of belonging auditorily. Those who receive an auditory brainstem implant typically lost their hearing to a temporal bone fracture, prolific ossification after meningitis, severe ossification of the cochlea, congenital malformations of the cochlear or the absence of a cochlea and/or auditory nerve. Better auditory brainstem implant performance was seen in those who lost their auditory nerve from either head trauma or severe ossification while poor auditory brainstem implant performance was typically seen in patients with neurological disorders, neuropathy, and congenital cochlear malformation. Colleti, et al. (2009) studied 112 auditory brainstem implant patients with profound hearing loss and divided them into two groups: nontumor and tumor adults. The nontumor group scored significantly better on open set speech perception tests than did the tumor group hence better brainstem implant performance can be expected if the underlying anatomy is intact. The nontumor group showed dramatic improvements in brainstem implant performance over the first few months post activation and were observed to converse on the telephone similarly to cochlear implant users. Colleti, et al. (2009) concluded that damage to the auditory nerve may produce insufficient benefit from a cochlear implant but excellent benefit with an auditory brainstem implant.


Question Stem:

Which of the following is (are) associated either directly or indirectly with age-related hearing loss (please choose all that apply)?
A. Mortality 
B. Falls 
C. Hospitalizations 
D. Functional limitations 
E. Social isolation 

Answer: A, B, C, D, E. Mortality, falls, hospitalizations, functional limitations, and social isolation 

Critique: 

Lin, et al. (2013) reported that hearing impaired older adults had a 24% increased risked of acquiring cognitive impairment than normal hearing individuals. In their study, they found that hearing loss was independently associated with faster rates of cognitive decline and cognitive impairment in community dwelling older adults. In addition, Lin, et al. (2013) found that severity of the hearing loss was directly related to cognitive function. There was a significant association between degree of hearing loss and severity of cognitive performance on both verbal and non verbal tests of cognition. They suggested that hearing loss may be mechanistically related to cognitive decline through social isolation and/or increased cognitive load. It is crucial for healthcare providers to provide the best patient centered care by modifying and limiting potential health risk factors. Perhaps through fostering of social engagement, hearing health care rehabilitation can be seen as a way to forestall the many harmful impacts of age related hearing loss such as cognitive decline.
Hearing loss contributes to communication breakdowns which can lead to social isolation, loneliness, and depression which in turn can lead to functional and cognitive decline (Lin, et al., 2011). Lin, et al. (2013) speculated that social isolation and loneliness is associated with accelerated rates of cognitive decline and dementia. Dalton, et al. (2003) assert that social isolation can lead to poor health behavior. Lin, et al. (2011) retrospectively surmised that there is an independent association between hearing loss and poor driving ability and walking difficulty causing one to feel restricted, handicapped, and isolated. When an individual is restricted or handicapped by their hearing loss it can have detrimental downstream health and functional consequences.

Dawes, et al. (2015) concluded that social isolation coupled with hearing loss resulted in higher incidence of depression and the combination of depression and social isolation was associated with cognitive decline. Schneider, et al. (2010) concluded that hearing aid use in the elderly was associated with improved self sufficiency and independent living, reduced risk of depression, and longer life expectancy. Despite the emerging evidence demonstrating the many benefits of hearing aid use, most especially improved social engagement, there is still an unmet need for hearing services in the elderly population (Schneider, et al., 2010).

Age related hearing loss can alter speech processing from the peripheral system all the way to higher level cortices, even in the presence of a mild hearing loss. When the brain receives distorted auditory speech stimuli from a damaged cochlea, typically seen in age related hearing loss, the auditory cortex recruits neighboring neural networks to compensate for the poor speech signal in order to maintain and sustain a conversation (Peelle and Wingfield, 2016; Lin, et al., 2013). Lin, et al. (2013) analyzed neuroimaging
of the hearing impaired brain in older adults and proved that the hearing impaired brain recruits regions in the prefrontal and temporoparietal cortex in order to effectively process speech. This increased cognitive effort could exhaust one’s cognitive reserve and impair working memory and one’s ability to remember what was just said. Lin, et al. (2013) hypothesize that this pattern of neural compensation could explain how language comprehension is generally preserved in those with advanced dementia. In addition, peripheral hearing impairment has been found to cause structural changes in the auditory cortex. When comparing the brain of a typical hearing older adult to a hearing impaired older adult, Peelle and Wingfield (2016) discovered that there was significantly less GABA (gamma-Aminobutyric acid) in hearing impaired brains. GABA is an inhibitory neurotransmitter in the central nervous system which helps to regulate muscle tone (Bergen, et al., 1991). Also, Peelle and Wingfield (2016) deduced that there is a significant correlation between hearing sensitivity and gray matter volume in the auditory cortex. Those with a significant hearing loss had decreased gray matter volume in the auditory cortex.

Untreated age related hearing loss has been linked to increased risk of mortality, falls, hospitalizations, reduced functional limitations, and social isolation. Fisher, et al. (2014) recruited adults over 67 years of age with sensory impairments and found that hearing impairment and dual sensory impairment (both hearing and vision loss) were significantly associated with increased risk of death from all causes, especially cardiovascular related. Mortality rates were found to be higher in men with hearing loss and dual sensory impairment than women. Furthermore, they found that hearing impairment alone was the highest risk of cardiovascular related death among all sensory
impairments while dual sensory impairment was the highest risk for all causes of mortality (Fisher, et al., 2014). Interestingly, Fisher, et al. (2014) determined that hearing aid users had a significantly lower risk of mortality, and had a reduced risk of a cardiovascular related death in men. They concluded that older adults who use hearing aids, no matter the degree of hearing loss, have a significantly lower risk of mortality when compared to unaided older adults with hearing loss.

Kiely, et al. (2016) found that untreated hearing loss has a significant impact on mortality in the senior population. They estimated that the life expectancy of men over 65 is 19.4 years (Kiely, et al., 2016). However, those with a mild hearing loss over 65 were estimated to live another 10.4 years which is most of their remaining years with the burden of hearing loss. Those with both vision and hearing loss were estimated to live a mere 2.2 additional years over the age of 65. Kiely, et al. (2016) calculated that women over 65 were expected to live an additional 23.2 years; 12.9 years with solely hearing loss. With both hearing and vision loss, women were estimated to live only 3.2 years past the age of 65. Kiely, et al. (2016) concluded that older adults live most of their remaining years with hearing loss and all the deleterious effects associated with it, which is why treating hearing loss with hearing aids could be an effective strategy for reducing their risk of mortality.

Poor walking ability, fear of falling, and sensory impairments such as hearing and vision loss are very common concerns in the aging population. Viljanen, et al. (2013) determined that the odds of falling are directly related to number of sensory impairments. Individuals who have a fear of falling and three sensory impairments are at a 5 times
greater risk of falling (Viljanen, et al., 2013). Lin and Ferrucci (2012) concluded that hearing loss was independently associated with balance function and the incidence of falls; meaning that the greater the hearing impairment, the greater the likelihood of the patient reporting a fall. Their study revealed a strong association between audiometric hearing loss and incidence of falls, stating that there was a 1.4 times greater chance of falling for every 10 dB of hearing loss. Viljanen, et al. (2013) reported that hearing and vision loss are both associated reduced mobility; however, the combination of the two could lead to significantly greater debilitating impacts on mobility. Walking is a vital aspect of independent living and maintaining an active lifestyle; however, sensory impairments hamper one’s ability to receive auditory and spatial information from one’s surroundings which could lead to immobility. With loss of independence and restriction from activities comes decreased physical and mental function and reduced quality of life.

Hearing loss is highly prevalent in older adults and is vastly undertreated. Untreated hearing loss is a risk factor for falling in the elderly which is a major public health concern and should be mitigated through hearing rehabilitation (Lin and Ferrucci, 2012). Viljanen, et al. (2013) suggest that improving hearing may prevent the risk of falling in the elderly. They also recommend regular audiological testing to monitor hearing in older adults followed by appropriate hearing intervention in order to prevent the risk of falls, hospitalizations, and the deleterious effects caused by immobility and inactivity.

Just like hearing, vestibular function declines with age. The vestibular system is responsible for maintaining balance and posture. Vestibular loss has been evidenced to
result in cognitive impairment (similarly to hearing loss) through increased cognitive load and decreased cognitive reserve (Agrawal, et al., 2016). Unstable eye gaze and poor posture caused by vestibular dysfunction can lead to the recruitment of other domain specific areas (attention and memory) of the brain in order to compensate for the lack of vestibular information and maintain one’s balance and posture. In a study by Agrawal, et al. (2016), they found that vestibular dysfunction resulted in lower scores on tests of cognition such as the digit symbol substitution (DSS) test. The strong association between vestibular dysfunction and poor cognitive performance is alarming due to cognition’s crucial role in mediating the risk of falls. The vestibular system is a pivotal source of spatial information/awareness for higher order domains responsible for spatial memory and orientation which helps to mediate the relationship between aging and cognitive performance. Hearing impaired older adults may be handicapped by their hearing and cognitive loss which may cause them to become more dependent and require more assistance in performing activities that would normally be routine (Dalton, et al., 2003). Agrawal, et al. (2016) show that vestibular loss significantly reduces one’s ability to perform activities of daily living (ex: shopping, toothbrushing, bathing, dressing, getting out of a chair or bed, eating, and traveling) and increases one’s odds of falling by 2.6 times. Impairment in the performance of activities for daily living is a known cause of rapid decline in cognition and global functioning, social isolation, loss of independence, and institutionalization. In addition, Agrawal, et al. (2016) stated that vestibular dysfunction is associated with depression which evidence suggests is a variable that could lead to cognitive decline.
7. Teaching Point: Hearing Aid Insurance Benefits.

Question Stem: Does Medicare pay for the cost of hearing aids in adults with age related hearing loss?

A. Yes
B. No

Answer: B. No

Critique:

The Food and Drug Administration recognize hearing aids as Class 1 medical devices. Medicare does not cover hearing services related to hearing aid use (Whitson and Lin, 2014). According to the Medicare.gov website, Medicare does not pay for the cost of hearing aids nor does it cover rehabilitation conducted by audiologists or hearing tests completed to determine candidacy for hearing health care interventions. The Medicare client is liable for 100% of the cost of audiological exams necessary for the fitting of hearing aids and 100% of the cost of hearing aids. However; with doctor approval for diagnostic purpose, Medicare clients are liable for 20% of the cost of a complete audiological evaluation. Medicare is not alone, most insurance programs do not cover hearing aids and of those that do, most pay only a fraction of what binaural hearing aids would cost (Dubno, et al., 2010; Warren and Grassley, 2017). According to New York Medicaid regulations, Medicaid will only approve the purchase of one hearing aid even in the presence of age related hearing loss which typically causes bilateral hearing loss in low income persons. One of the biggest barriers to hearing aid adoption is cost (Dubno, et al., 2010). Untreated age related hearing loss is associated with higher risk of mortality, especially in the presence of a dual sensory impairment (Fisher, et al., 2014).
Fisher, et al. (2014) concluded that hearing aid users had a significantly lower risk of mortality, and had a reduced risk of a cardiovascular related death in men. Older adults who use hearing aids, no matter the degree of hearing loss, have a significantly lower risk of mortality when compared to unaided older adults with hearing loss.

Simpson, et al. (2016) analyzed health care costs of adult patients. They concluded that middle aged adults with hearing loss had significantly higher health care costs than typically hearing middle aged adults. Of adult patients with hearing loss, those who received hearing services ended up paying lower overall mean health care costs than those who did not (Simpson, et al., 2016). Abrams, et al. (2002) investigated to see if the benefits of hearing aids outweighed its monetary cost. Aided benefit was measured by comparing pre- and post mental component summary (MCS) scale scores which deal with health areas including vitality, social engagement, social isolation, and mental health. They determined that hearing aid use is associated with better MCS scale scores meaning overall improved quality of life (Abrams, et al. 2002). In addition, Abrams, et al. (2002) calculated the cost effectiveness of two forms of hearing interventions. They found that the cost of hearing aids equated to about $60 per additional year gained. With combined hearing aids and aural rehabilitation lead to an estimated cost of $32 per additional year gained. In comparison, a knee replacement is estimated to be about $49,700 per additional year gained. Their research reveals that hearing aids are cost effective in the improvement of quality of life in the adult patient’s remaining years.

Dubno, et al. (2010) found that 20% of those with hearing loss who are aidable candidates actually seek treatment. Primary care physicians need to be able to discuss
barriers to hearing aid adoption, treatment options, and the importance of amplification in order to meet the ever-increasing demand of America’s hearing impaired population. Dubno, et al. (2010) estimated that by 2026 about 30% of the U.S. population will be over 55 years old and 18% will be over 65 years old which is Medicare age. This means that there will be a parallel increase in the amount of hearing aid candidates and most will have an initial hearing loss of mild to moderate level while maintaining active in the workforce. Lin, et al. (2011) reported that the hearing aid adoption in the United Kingdom, where bilateral hearing aids are completely covered by the National Health Service, is not higher than the U.S.. This indicates that access and affordability are not the only factors that limit individual’s from taking hearing healthcare action (Lin, et al., 2011). Primary care physicians must be advocates for hearing healthcare due to the benefits of earlier hearing aid use could have better eventual outcomes with amplification and earlier hearing aid users can take advantage of plasticity effects and may require less auditory retraining therapy. Primary care physicians need to initiate and advocate hearing health care before cognitive or other age related health declines occur.

CONCLUSIONS

The online based curriculum described above evolved from incorrect responses of 41 medical students questioned about audiological issues ranging from epidemiological variables to cochlear implantation. According to the response analytics, knowledge of age-related hearing loss, epidemiology, and demographics was severely lacking indicating need for education with a clear focus on hearing loss epidemiology, amplification, and the etiology, impacts, and detriments of age related hearing loss. It is anticipated that the curriculum in the discussion developed based on adult learning theory
principles, could help to fill the gaps in medical student knowledge regarding age related hearing loss and the benefits of amplification.

In conclusion, our survey results reveal a significant lack of knowledge in medical students attending seven accredited Schools of Medicine regarding age related hearing loss and its associated health and communication implications, along with auditory intervention. This could explain prior research demonstrating a need to educate primary care physicians regarding their role in identifying and addressing hearing loss in their elderly patients, and raising awareness of the benefits of amplification (Popp and Hackett, 2002; Johnson, et al., 2008; Schneider, et al., 2010). By educating medical students about age related hearing loss and hearing intervention, one could hope that the next generation of primary care physicians will be more equipped to address and identify patients with age related hearing loss, counsel and advocate to seek hearing intervention, and make timely and appropriate referrals to audiologist for hearing diagnosis and treatment. If medical students and primary care physicians were aware of the health detriments and potential risk factors associated with untreated age related hearing loss, it could be assumed that they would be more inclined to urge patients to take hearing health action. We hypothesize that through primary care physician and medical student education, hearing aid adoption and audiology referral rates could increase. The online module based curriculum could be used in Schools of Medicine and/or accessible online via a hyperlink where students and primary care physicians can access the educational material at their own discretion.

Some potential study limitations were that more than half of the participants (21 subjects) represented Stony Brook School of Medicine and there was not an even
distribution of medical students from every year level and from various accredited medical schools across the country. Almost all of the medical student participants attend schools on the east coast of the U.S and hearing health care may be more emphasized in medical schools on the west coast of the U.S. Future studies should try to recruit a more diverse and representative sample of medical students. Another limitation could be that medical students knew an audiology doctoral student sent the survey and could infer that most of the answers to questions would be audiology related. For example question 13 of the survey asks, “Which profession by virtue of academic degree, clinical training, and license to practice and/or professional credential, is uniquely qualified to provide a comprehensive array of professional services related to the prevention of hearing loss and the identification, assessment, diagnosis, and treatment of persons with impairment of auditory and vestibular function, and to the prevention of impairments associated with them?” Since an audiologist created the survey, one could infer that the correct answer is audiologist out of the presented selection: audiologist, hearing instrument specialist, otolaryngologist, and neuro-otologist.
Appendix A: Survey Questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is your gender?</td>
<td>Male, Female</td>
</tr>
<tr>
<td>2. Where do you see yourself practicing in the future?</td>
<td>Hospital, Clinic, Private Practice, Other</td>
</tr>
<tr>
<td>3. What year of your medical school are you currently completing?</td>
<td>First year, Second year, Third year, Fourth year, Resident</td>
</tr>
<tr>
<td>4. Which accredited medical school are you currently enrolled in?</td>
<td></td>
</tr>
<tr>
<td>5. Please select the rotations you have completed:</td>
<td>Ophthalmology, Cardiology, Geriatric Medicine, Endocrinology, Neurology</td>
</tr>
</tbody>
</table>
6. On average, what is the percentage of older adults 70 years of age and older with hearing loss who use hearing aids?
   - 0-20%
   - 21-40%
   - 41-60%
   - 61-80%
   - 81-100%

7. What is the prevalence of hearing loss among persons 70 years of age and older:
   - 80%
   - 31%
   - 15%
   - 63%

8. Age-related speech understanding difficulties are due to degenerative changes in which of the following structures?
   - Inner ear, auditory nerve, auditory brainstem, auditory cortex
   - Eustachian tube, tympanic membrane, ossicles
   - Ear canal, pinna

9. Which of the following best describes how age related hearing loss affects communication:
   - Able to hear people talking, but unable to make out the words
   - Difficulty hearing male voices and voices of children
   - Difficulty understanding low frequency noise in quiet
   - Difficulty hearing but no difficulty understanding

10. What is the most effective treatment for tinnitus (ringing in the ears)?
    - Biofeedback
    - Hearing aids
    - Antidepressants
    - Tinnitus masker
11. In older adults, which of the following conditions affecting the outer ear is prevalent and can interfere with hearing and the function of hearing aids?

- Wax (cerumen) buildup
- Otosclerosis
- Meniere’s Disease
- Superior Canal Dehiscence

12. Untreated hearing loss in the elderly does not increase the risk of which of the following conditions?

- Depression
- Dementia
- Falls
- Arthritis

13. Which profession by virtue of academic degree, clinical training, and license to practice and/or professional credential, is uniquely qualified to provide a comprehensive array of professional services related to the prevention of hearing loss and the identification, assessment, diagnosis, and treatment of persons with impairment of auditory and vestibular function, and to the prevention of impairments associated with them?

- Audiologist
- Hearing instrument specialist
- Otolaryngologist
- Neuro-otologist

14. Which medication does not cause irreversible sensorineural hearing loss and/or balance problems?

- Cisplatin
- Furosemide
- Aminoglycosides
- Salicylates
15. Which of the following is not a comorbidity associated with hearing loss:

- Hypertension, cardiovascular disease
- Diabetes
- ALS
- Cognitive decline
- Vision impairment

16. Which of the following are non-medical or surgical treatments for sensorineural hearing loss that ranges in severity from mild to profound:

- Hearing aids
- Cochlear implants
- Brainstem implant
- All of the above
- None of the above

17. A cochlear implant is:

- A device that provides direct electrical stimulation to the auditory nerve in the inner ear
- A surgically implanted hearing aid
- Surgically implanted into the middle ear
- Recommended method for treating those with age-related mild hearing loss

18. Older adults, who are candidates for a cochlear implant, should meet which of the following criterion:

- Severe to profound hearing loss
- Extremely poor speech discrimination
- Persons who receive little to no benefit from hearing aids
- All of the above
- None of the above
19. Which of the following is associated either directly or indirectly with age-related hearing loss (please choose all that apply)?

- Mortality
- Falls
- Hospitalizations
- Functional limitations
- Social isolation

20. Does Medicare pay for the cost of hearing aids in adults with age related hearing loss?

- Yes
- No

21. When taking a medical history which conditions can interfere with communication and patient centered care?

- Untreated hearing loss
- ALS
- Cerebral Palsy
- Vasovagal insufficiency

22. Which of the following is one of the most common reasons for physician visits in the elderly which pertain to the ear or hearing?

- Cerumen (wax) impaction
- Acoustic neuroma
- Otosclerosis
- Otitis media
References


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