Abstract
Analysis of data from the National Health and Nutrition Examination Survey (NHANES) 1999 - 2004 has shown that diabetes more than doubles the incidence of hearing loss. Most hearing loss in the general population is sensorineural. This is also true of diabetes-related hearing loss, which recent research has associated with the microvascular and neuropathic changes of diabetes. A hearing deficit creates an additional challenge to education for both the patient with the hearing loss and the registered dietitian (RD). Taking steps to ensure that the RD’s message is received clearly, such as eliminating background noises and facing the patient directly, are outlined in the article.

Introduction
Approximately 17% (36 million) of American adults reported difficulty hearing in 2006 (1). Recent research has shown a higher incidence of hearing loss among individuals with diabetes (2–8). Statistics from the National Institute on Deafness and Other Communication Disorders indicate that only 1 in 5 individuals who could benefit from a hearing aid actually wear one (9). Hearing impairment not only has a negative impact on an individual’s ability to learn the skills necessary for successful diabetes self-management, but it also negatively affects quality of life and promotes isolation (10–12). The RD needs to be aware of possible undiagnosed or unmentioned hearing loss in clients and determine how to communicate successfully with hearing-impaired individuals (10).

Anatomy of the Ear
The ear is divided into the external ear, middle ear, and inner ear (Figure). The external ear includes the pinna (auricle) and the auditory canal, and its function is considered primarily protective. The middle ear is between the tympanic membrane (“eardrum”), which separates the external ear from the middle ear, and the elliptical (oval) window of the osseous labyrinth. The middle ear is air-filled and contains the three smallest bones in the human body (malleus, incus, and stapes), which transduce sound waves from the tympanic membrane to the oval window of the fluid-filled inner ear. At this point, sound is amplified 30 to 40 dB. The inner ear, deep inside the temporal bone, includes the cochlea with the organs for hearing, the vestibular apparatus with organs for balance, and the vestibulocochlear (acoustic) nerve. The channels of the cochlea are lined with hair cells that are organized by the sound frequency they transmit and are rich in nerve fibers that synapse with the auditory nerve at the spiral ganglion (10,12).
Literature Review: Causes of Hearing Loss

Causes of hearing loss are classified into conductive, sensorineural (comprising more than 90% of cases of hearing loss), and mixed. Conductive hearing loss can be caused by fluid buildup in the middle ear, ear wax in the ear canal, perforated ear drum, and problems with the middle ear bones. Most conductive hearing loss can be medically treated. Sensorineural hearing loss is a type of hearing loss whose root cause lies in the vestibulocochlear nerve (cranial nerve VIII), the inner ear, or central processing centers of the brain. The cause of sensorineural or nerve deafness in a specific patient, on the other hand, is often unknown.

Exposure to loud noises, genetics, certain viral infections, aging, exposure to ototoxic medications, and smoking have all been found to increase hearing loss. More recently, cardiovascular disease, hypertension, and diabetes have been implicated as well. With age, most individuals develop presbycusis (age-related sensorineural hearing loss) from damage, drying, and loss of hair cells in the cochlea (10–12). This process appears to be accelerated in those with diabetes (2–4). The other class of hearing loss, mixed hearing loss, is a combination of sensorineural and conductive hearing loss.

Diabetes and Sensorineural Hearing Loss

Diabetes is a significant risk factor for hearing loss, more than doubling the incidence. An analysis by Bainbridge and associates (2) of data from the NHANES 1999–2004 found that the prevalence of mild or greater hearing loss of low or mid-frequency sounds was 9% for adults without diabetes and 21% for those with diabetes. The prevalence of mild or greater hearing loss of high frequencies was 32% for those without diabetes and 54% for those with diabetes. Overall, those with diabetes had 2.3 times the incidence of hearing loss of the general population. In addition, those with prediabetes, as measured by fasting glucose, had a 30% higher rate of hearing loss. When broken down by age, the difference in prevalence of high-frequency hearing loss between those with and without diabetes is greatest during the third and fourth decades of life. Extrapolation of the data to the general population suggests that 70% of individuals with diabetes between the ages of 50 and 69 years have high-frequency hearing impairment and 33% have low or mid-frequency hearing loss.

Estimates of diabetes-associated hearing loss range from an increased incidence of 1.3 to 5 times the incidence of those without diabetes (Table). Agrawal and associates (3,4), evaluating NHANES data from 1999 through 2002, found a twofold incidence of hearing loss across the spectrum of frequencies in individuals with diabetes. A retrospective study by Kakarlapudi and colleagues (5) of both audiometric data and diagnosis of diabetes data from more than 65,000 individuals seen at the Veterans Affairs Maryland Health Care System found that 13.1% of those with diabetes had a hearing loss compared with 10.3% without diabetes. The severity of the hearing loss increased with progression of diabetes, as measured by serum creatinine. In a retrospective review of 990 patient charts, Handzo and coworkers (6) found a statistically significant correlation between a diagnosis of diabetes and hearing impairment in females but not males.

In a meta-analysis of 11 observational studies, Horikawa and associates (7) concluded that diabetes substantially contributes to the progression of hearing loss. In a small study of 50 individuals with diabetes who were age- and gender-matched with 50 individuals without diabetes, Ismail and Venkatesan (8) found that 94% of those with diabetes and 18% without diabetes had hearing deficits.

Research regarding the cause of the increased incidence of hearing loss in those with diabetes is ongoing. Diabetes is a systemic disease, known to cause microvascular and nerve damage, and it is postulated that both diabetes-related microvascular and neuropathic changes in the cochlea explain diabetes-associated hearing loss. Studies in diabetic animals found thickening of the capillary basement membranes in the ear. Autopsy studies documented damage to both the nerves and blood vessels of the inner ear in humans with diabetes (10,13).

Cardiovascular disease and risk factors for cardiovascular disease, including hypertension and hyperlipidemia, are associated with an increased incidence of hearing loss. The greater incidence of hearing loss in humans with diabetes may be associated with the increased risk of cardiovascular disease (14). Another hypothesis is the presence of a genetic component that predisposes an individual to both diabetes and hearing loss. Several known genetic mutations result in both hearing loss and diabetes (15,16).

Clinical Application: Educating Patients With Hearing Loss

Whatever the cause of hearing loss, a hearing deficit adds to the challenges faced by both the individual with diabetes and the RD. A suggested
Table. Studies on Reported Incidence of Hearing Loss

<table>
<thead>
<tr>
<th>Author</th>
<th>Population</th>
<th>Frequency Decibel (dB) Range</th>
<th>Definition of Hearing Loss</th>
<th>Results</th>
</tr>
</thead>
</table>
| Agrawal et al (3)       | 3,527 age 20 to 69 years who participated in NHANES 1999-2002 | 0.5 to 8 kHz                 | Loss if >25 dB before heard tone | Odds Ratio (for those with DM)*  
  2 (low frequency)  
  1.2 (mid-frequency)  
  3.2 (high frequency) |
|                         | 3206 without DM                                  | -10 to 120 dB                |                           |                                                                         |
|                         | 321 with DM                                      |                             |                           |                                                                         |
| Bainbridge et al (2)    | 5,140 age 20 to 69 years who participated in NHANES 1999-2004 | 0.5 to 8 kHz                 | Mild to moderate (>25 dB)  
  and Moderate or greater (>40 dB) before heard tone | Odds ratio 1.82 (low or mid-frequency)  
  for those with DM |
|                         | 4,741 without DM                                  | -10 to 120 dB                |                           |                                                                         |
|                         | 399 with DM                                      |                             |                           |                                                                         |
| Handzo et al (6)        | Retrospective study or 990 patients who had audiograms between 2000 and 2008 | Did not define measure of hearing loss in abstract Defined good/poor control as “by American Diabetes Association” | Females younger than 60 years:  
  Odds ratio of 1.35 for good control  
  Odds ratio of 1.49 for poor control  
  Females age 60 to 75 years:  
  Odds ratio of 1.14 with good control  
  Odds ratio of 1.25 with poor control  
  No differences in males, although hearing worse in males than females |
| Horikawa et al (7)      | Meta-analysis of 11 observational studies         | Hearing impairment defined by cut-off values including 2 kHz. | Pooled odds ratio of 1 for those without DM  
  Odds ratio of 1.99 with diabetes  
  Odds ratio of 2.62 for those <60 years with DM |
|                         | 28,459 total                                     |                             |                           |                                                                         |
|                         | 3,388 with DM                                    |                             |                           |                                                                         |
|                         | 5 of 11 studies performed in United States      |                             |                           |                                                                         |
| Ismail et al (8)        | 50 with DM                                       | Classified hearing loss as mild to severe, but kHz tested and dB not defined in abstract | 18% without DM had hearing loss  
  94% with DM had hearing loss  
  Odds ratio of 5.2 with DM  
  Correlated with increased incidence of hearing loss: length of time since diagnosis of DM, age >50 years, and HbA1c >7% |
|                         | 50 matched for age/sex without DM Research performed in India |                             |                           |                                                                         |
| Kakarlapudi et al (5)   | 53,461 without DM                                | 0.5 to 4 kHz                 | Measured average decibel needed to hear pure tone in each group | 10.3% without DM had hearing loss  
  13.1% with DM had hearing loss  
  Odds ratio of 1.27 with DM  
  Creatinine <1.0 hears on average at 51.7 dB  
  Creatinine >2.5 hears on average at 58 dB (P<0.05) |
|                         | 12,575 with DM                                   | 0 to 100 dB                  |                           |                                                                         |

DM=diabetes mellitus

*Odds ratios mean that a person in one group with a characteristic or condition is X times as likely as a person of the same age and gender without the characteristic/condition. For example, in the Agrawal citation, a person with diabetes is 2 times as likely to have low frequency hearing loss as a person of the same age and gender without diabetes.
approach is to ask, “Can you hear me?” upon first meeting a patient. Individuals with hearing deficits do not always recognize the condition and upon discovery are often hesitant to mention it to the educator. Because those with diabetes-related and age-related hearing loss have the most difficulty hearing high frequencies, they have more difficulty hearing a female educator than a male speaker. Some clues suggesting a hearing deficit are frequent requests that information be repeated, responses that do not match the question asked, short answers, and limited participation in group classes. As the population ages, presbycusis is becoming epidemic, and it occurs at an earlier age and higher prevalence in people with diabetes. Because hearing ability affects the educational process, hearing should be assessed, just as potential visual challenges and manual dexterity deficits are evaluated, to prevent barriers to diabetes self-management education.

The educator can use many techniques to improve communication with individuals with hearing deficits (see “Tips” on page 7). Vision and hearing are both important for understanding speech. People do not hear with their ears but with their brains. Individuals may “speech read,” meaning that they watch the lips and the rest of the face for clues as to what is being said. Often they are unaware that they are doing this. They should be seated where they can see the face of the individual who is speaking and wear glasses if needed. With one-on-one counseling, the RD should face the individual with nothing obstructing the view of the educator’s face. Seating in a circle works best in a group setting.

Limiting background noise includes turning the volume off on the computer, as much as possible, and making sure only one person is speaking at a time. If someone has a hearing deficit, that person should avoid sitting next to or below the heating and cooling vent or projector fan. The educator should enunciate clearly and speak at a normal rate, neither rapidly nor slowly. Speaking very loudly or yelling distorts the sounds of words. Educators should be careful not to cover their mouths and make sure lighting is adequate.

As with any client, when asked to repeat what you said, rephrase it, ask the learner to restate what you said, or ask a question to verify understanding and provide written materials that are at an appropriate level for the audience. Educators should keep in mind that the individual with a hearing deficit may have a vision deficit or limited manual dexterity as well.

Clinicians should consider not only whether a client has a hearing loss, but also whether he or she has
hearing aids and whether the hearing aids work and are used. There are a wide variety of hearing aids. Some are placed in the ear, some are in the ear canal, and some sit behind the ear. The effectiveness and cost varies widely. The more sophisticated hearing aids have various settings that can be selected via a remote control device for group conversation, phone conversation, or watching TV alone.

Most insurance, including Medicare, pays for an audiologic evaluation or audiology examination every few years. Insurance coverage for the hearing aids tends to be limited to very few plans. Cost ($1,000 to $4,000 per ear on average) may be a factor in whether hearing is corrected and to what degree it is corrected. Because hearing aids, which are small and have very small batteries, require frequent cleaning, limited vision and manual dexterity may make their use difficult or require assistance. For more information on hearing aids and organizations for the deaf and hard of hearing, Gallaudet University has an extensive resource list that can be downloaded online (17).

Hearing loss can be very isolating. Loss of hearing affects both quality of communication and often quantity; those with a hearing loss often avoid social occasions that require conversations. In one study, participants with mild hearing loss were three times as likely and those with a moderate to severe hearing loss were almost eight times as likely to report difficulty with communicating compared to those without hearing loss (11). Self-reported difficulties with communication correlate with a reported reduced quality of life, including the frustration involved in attempting to communicate and feeling left out because people do not hear what is going on around them (10,11). By taking steps to ensure their message is heard, the diabetes educator not only communicates effectively but lessens the psychological and social burden on the individual being counseled for diabetes.

Summary

Hearing loss is about twice as prevalent in those with diabetes as those without diabetes. The cause of diabetes-associated hearing loss is being investigated and is hypothesized to be related to both the microvascular changes and neuropathy of other diabetes complications. The diabetes educator should be aware that along with vision loss and decreases in manual dexterity, hearing loss can be a barrier to diabetes care and education. Steps can be taken, such as asking “Can you hear me?” and looking for appropriate responses to questions to ascertain whether the patient has a hearing loss. The diabetes educator also should take steps to accommodate the hearing-impaired patient. Making sure the individual has an unobstructed view of the speaker in individual or group settings, minimizing background noise, and asking the patient to rephrase what has been said can aid in ensuring that the educator’s message is received.

References

Abstract

Multiple oral signs and symptoms are associated with diabetes. Literature indicates a bidirectional relationship between periodontitis and diabetes. Glycemic control can greatly affect the progression of periodontal disease and may be more pronounced in patients with diabetes than unaffected individuals. More frequent preventive dental care may be recommended for those with diabetes to monitor any oral changes that could put them at risk for periodontal disease. A working knowledge of the oral complications of diabetes is beneficial for the registered dietitian (RD). Collaboration among the person with diabetes, the RD, the medical provider, the dental team, and other members of the health care team can enhance oral health and desired quality-of-life outcomes.

Introduction

Peridontal disease, xerostomia, dental caries, Candida infection, burning mouth syndrome, lichen planus, fruity breath, poor wound healing, and asymptomatic parotid gland swelling are among the signs and symptoms associated with diabetes that are commonly noted by oral health professionals when providing a comprehensive screening examination (Table 1) (1). Such symptoms may be present in both those who have diagnosed and undiagnosed diabetes. A comprehensive examination, usually performed annually, may involve but is not limited to a thorough review of the medical history, dental history, periodontal assessment, and radiographs.

The literature suggests a two-way interaction between periodontal disease and diabetes. Periodontal infection is associated with poorer glycemic control in people with diabetes and individuals with diabetes who have poor glycemic control are at higher risk of periodontitis (2,3). Periodontal disease has been touted as the sixth complication of diabetes (4,5). Alterations in host response, subgingival microflora, and hereditary factors are among the proposed mechanisms that increase susceptibility. Periodontal disease is two times more likely to occur in a young adult with diabetes compared