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The Prevalence of Central Presbyacusis in a Clinical Population

Brad A. Stach
Maureen L. Spretnjak
James Jerger

Abstract

To evaluate the prevalence of central auditory disorder as a function of aging, we analyzed speech audiometric test results on 700 patients, 100 patients from each of seven half-decades beginning at age 50 years. In addition, we evaluated the extent to which prevalence estimates could be explained by the effect of hearing loss on measures of central auditory processing and the difference in prevalence of central presbyacusis between a clinical sample and a nonclinical sample. Results showed that the prevalence of central presbyacusis increased with age and that the highest prevalence was a striking 95 percent in the 80+ year age group. Results also showed that, even when degree of hearing loss and ability to perform the speech audiometric task were equated, the prevalence of central presbyacusis increased systematically with age. Finally, results showed that the prevalence was lower in the nonclinical sample than in the clinical sample at all ages, but that a substantial amount of central presbyacusis existed in the nonclinical subjects, especially in the oldest age groups.

Key Words: Presbyacusis, hearing disorders, central auditory disorder, aging

Hearing impairment in the elderly is complex. Many histopathologic and morphologic studies have documented age-related structural degeneration throughout the auditory system, including the cochlea (Jorgensen, 1961; Igarashi, 1972; Johnson and Hawkins, 1972), the eighth nerve (Schuknecht, 1964; Krmpotic-Nemanic, 1971), and the auditory brainstem and cortex (Brody, 1955; Hinchcliffe, 1962; Kirikae et al 1964; Hansen and Reske-Nielsen, 1965). The functional consequence of structural changes in the auditory peripheral structures is a loss in hearing sensitivity. For the most part, speech understanding deficits due to peripheral changes can be explained by the degree of loss and shape of the audiometric contour (Goetzinger et al, 1961; Jerger and Hayes, 1977). In contrast, the functional consequence of structural changes in the central auditory pathways is the degradation of speech processing (Hinchcliffe, 1962; Lutterman et al, 1966; Sticht and Gray, 1969; Antonelli, 1970; Bergman, 1971; Bergman et al, 1976; Konkle et al, 1977; Orchik and Burgess, 1977; Arnst, 1982; Bosatra and Russolo, 1982; McCroskey and Kasten, 1982). Aging patients have been shown to perform more poorly than would be predicted, on the basis of the audiogram alone, on a variety of speech audiometric measures that incorporate distorted and time-altered speech materials or speech presented against a background of competition (Pestalozza and Shore, 1955; Goetzinger et al, 1961; Konig, 1969; Jerger, 1973; Jerger and Hayes, 1977; Shirinian and Arnst, 1982; Dubno et al, 1984; Hayes, 1984; Price and Simon, 1984; Welsh et al, 1985). These age-related changes in central auditory processing ability are referred to collectively as central presbyacusis.

Since senescent changes occur throughout the auditory system, many patients will demonstrate behavior suggestive of both peripheral

The Methodist Hospital and Baylor College of Medicine, Houston, Texas

Reprint requests: Brad A. Stach, The Methodist Hospital Audiology Service, 6501 Fannin, NA200, Houston, Texas 77030

and central auditory disorder. Although much is known about the prevalence of peripheral hearing loss in the elderly, the prevalence of central auditory disorder is not known. In an effort to determine how common central auditory disorder is in the elderly, we carried out a retrospective analysis of central auditory function in a group of aging patients. We attempted to determine: (1) the prevalence of central presbyacusis in a clinical population as a function of age; (2) the extent to which prevalence estimates could be explained by the effects of peripheral hearing loss on measures of central auditory processing; and (3) the difference in prevalence of central presbyacusis in a clinical sample versus a nonclinical sample. For the purpose of this study, we defined central presbyacusis as central auditory processing disorder (CAPD) that had no known cause other than the aging process. CAPD was defined operationally on the basis of speech audiometric results. Finally, prevalence was defined as the percentage occurrence of CAPD in a specified population.

METHOD

Subjects

We analyzed, retrospectively, audiometric test results on 700 patients, aged 50 years and older, from the files of The Methodist Hospital Audiology Service, the Neurosensory Center of Houston, Texas. Files of 100 patients from each of seven half-decade age groups were chosen for evaluation. Files were chosen consecutively until 100 were identified for each of the seven age groups. By choosing files consecutively, we hoped to obtain a representative cross-section of the patient population from our service. Files were excluded only if there was evidence of middle ear disorder or if the patient had a history of known neurologic disorder. In particular, an attempt was made to eliminate patients whose speech audiometric results might be uninterpretable due to severe cognitive disorder. Therefore, exclusion criteria included any evidence of multi-infarct dementia or Alzheimer's disease. No other patients were excluded from the study.

Because of limited numbers of available patient files for the over 80-year-old group, patients were not confined to the half-decade. Instead, they ranged in age from 80 to 93 years, with a mean age of 84 years.

The distribution of subject sex and hearing loss across age groups is shown in Table 1. While males held a slight majority in the younger age groups, females held a slight majority in the older age groups. As expected, peripheral hearing loss, characterized by the pure-tone average (PTA—average of pure-tone thresholds at 500, 1000, and 2000 Hz), increased with increasing age. Mean PTAs ranged from 15.5 dB in the youngest group to 40.4 dB in the oldest group.

Prevalence was also estimated in a subgroup comprised of 138 "nonclinical" subjects. These subjects were volunteers who responded to advertisements soliciting participation in a study on aging. Their audiologic and neuropsychologic results are summarized elsewhere (Jerger et al, 1989a). Although the purpose of the aging study was unrelated to the present study, the speech audiometric data that were collected permitted a direct comparison of prevalence of central presbyacusis between the nonclinical research group and the clinical patient group. To the extent that these volunteers had not volitionally sought hearing health care, the nonclinical subgroup served to provide a prevalence estimate of central presbyacusis in the general population.

Definition of Central Presbyacusis

Central presbyacusis was defined, operationally, on the basis of patterns of test results from the Synthetic Sentence Identification (SSI) test (Jerger et al, 1968) and phonetically-balanced (PB) word test (PAL PB-50 word lists). Procedures for administration and interpretation of this speech audiometric battery have been described in detail previously (Jerger and Hayes, 1977). Briefly, performance-intensity

Table 1 Subject Characteristics of 700 Patients, Including Percentage of Females and Mean Pure-Tone Average (PTA) in Each Age Group

	Age Group in Years						
Subject Characteristics	*50-54*	*55-59*	*60-64*	*65-69*	*70-74*	*75-79*	*80+*
Percent female	50	39	46	45	55	56	63
PTA in dB							
Right ear	16	21	26	23	31	34	40
Left ear	15	21	23	27	33	35	40

functions were established for each ear for both sets of speech materials. PB-word lists of 25-items each were presented, without competition, at three or four intensity levels to establish a performance-intensity function. The SSI sentences were presented in the presence of continuous, single-talker competition at a 0 dB message-to-competition ratio (MCR) in a similar manner. While many other tests of central auditory function exist, this test battery has been found to be appropriate to study the question of central presbyacusis for two reasons. First, the battery has been validated on individuals with brain lesions as a measurement of central auditory disorder (Jerger and Jerger, 1975; Jerger and Hayes, 1977; Jerger et al, 1980; Jerger and Jerger, 1983). Second, it has been particularly useful in testing older patients because of the relative immunity of the SSI to peripheral sensitivity loss. Even when peripheral hearing loss is a factor, its influence on SSI and PB-word test results is predictable, and criteria have been established for normal ranges based on degree of hearing loss (Yellin et al, 1989).

A patient was designated as having central presbyacusis if (1) "rollover" of the SSI function exceeded 20 percent; (2) the discrepancy between PB-word scores presented in quiet and SSI scores presented in competition exceeded 20 percent; or (3) the absolute SSI score was lower than the empirically-defined boundary of normal performance based on degree of hearing loss (Yellin et al, 1989). A patient was designated as either central or peripheral based on these criteria. No attempt was made to evaluate degree of central involvement. By defining central presbyacusis in this manner, the influence of peripheral sensitivity loss was controlled to a great extent. Neither SSI rollover nor the PB-SSI discrepancy can be explained easily by cochlear hearing loss, and absolute SSI scores are interpreted only in the context of the degree of peripheral loss.

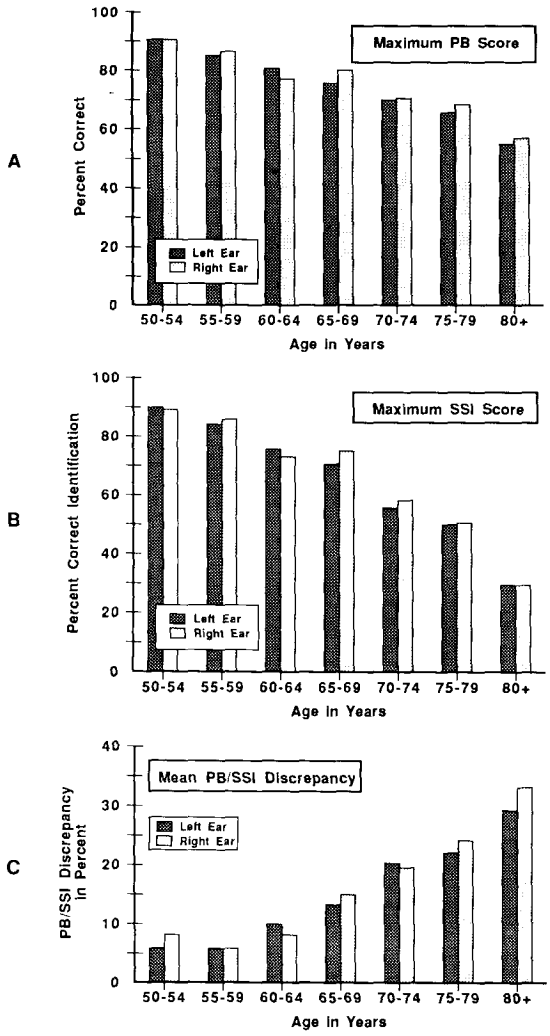

Figure 1 Speech audiometric results in 700 patients, 100 in each half-decade age group. *A*, Mean maximum percent-correct scores on PB-word test as a function of age. *B*, Mean maximum percent correct-identification score on the Synthetic Sentence Identification (SSI) test as a function of age. *C*, Mean difference between scores on the PB-word test and the SSI test as a function of age.

RESULTS

Speech Audiometric Results

As expected, speech understanding declined systematically with increasing age. Figure 1 shows the distribution of mean speech audiometric results as a function of age for all 700 patients. Mean maximum PB scores (Fig. 1A) declined by 34 percent from a high of 91 percent in the youngest age group to 57 percent in the oldest age group. Mean maximum SSI scores (Fig. 1B) declined to an even greater extent, from a high of 90 percent in the youngest group to 29 percent in the oldest group. Mean PB-SSI discrepancy (Fig. 1C), increased systematically above the age of 60 years.

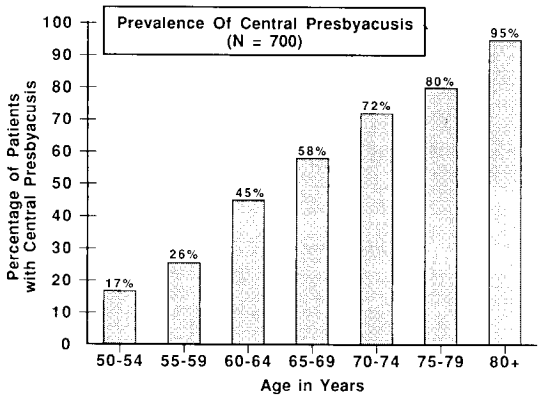

Figure 2 Percentage of right and left ears in each age group with speech audiometric results consistent with central presbyacusis.

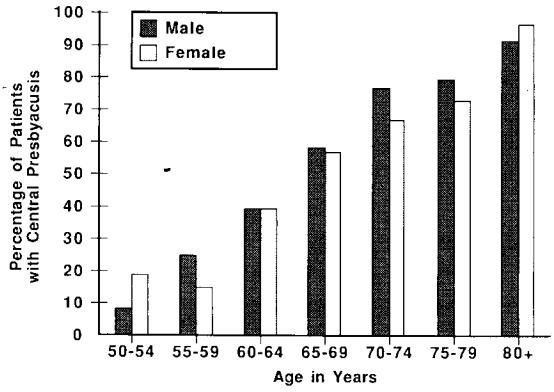

Figure 3 Percentage of male and female patients in each age group with evidence of central presbyacusis.

Prevalence Estimation

The percentages of patients who had speech audiometric patterns consistent with central presbyacusis are shown in Figure 2. The prevalence of central presbyacusis increased substantially as a function of increasing age. Central presbyacusis was particularly prevalent in the older age groups. While 17 percent of the patients in the 50 to 54 year age group had some degree of central involvement and 58 percent of patients in the 65 to 69 year age range had central disorder, a remarkable 95 percent of those 80 years or older showed evidence of central presbyacusis.

There were no systematic differences in the prevalence of central presbyacusis between males and females as a function of age. Results are shown in Figure 3. The difference in prevalence between groups was greatest in the youngest age range, with females more likely to have evidence of central auditory disorder. However, this difference was not consistent across age ranges.

Figure 4 shows the laterality of abnormality as a function of age. In the two younger age groups, the abnormality was more likely to be unilateral in nature. However, bilateral abnormality was more prevalent in the older groups. The relative percentage of bilateral to unilateral abnormality increased systematically with increasing age above the age of 60 years.

Effect of Hearing Loss

Not unexpectedly, hearing loss also increased with age. It was necessary, therefore, to consider the possibility that the speech audiometric changes could be explained as the simple consequence of increasing sensitivity loss. Therefore, a substudy was carried out in which degree of peripheral hearing loss was controlled. Twenty subjects from each of the seven half-decade groups were matched for degree of hearing loss, based on pure-tone average. The mean pure-tone averages for each group are shown in Figure 5. No statistically significant differences were found as a function of age ($F=1.11$, $p=0.36$).

In order to be sure that subjects were able to perform the basic SSI task, when the MCR was more favorable, we tabulated SSI scores at +10 dB MCR. If performance in this relatively easier listening situation were not affected by age, then age effects observed at the test MCR of 0 dB could not reasonably be attributed to inability to perform the task for reasons relat-

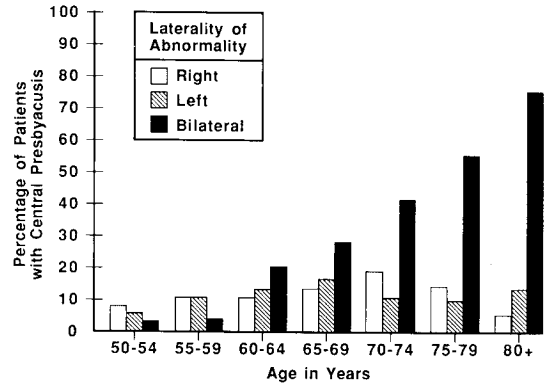

Figure 4 Percentage of patients in each age group with evidence of central presbyacusis in the right ear only, the left ear only, or in both ears (bilateral).

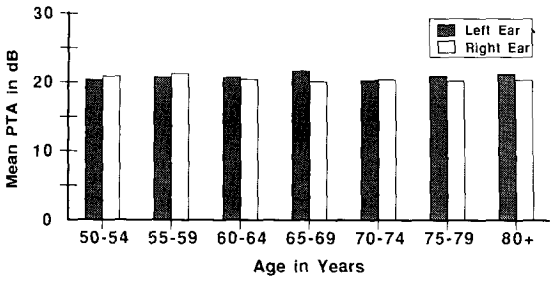

Figure 5 Mean pure-tone average (PTA) for the right and left ears of 140 patients. Twenty patients in each age group were matched for hearing loss.

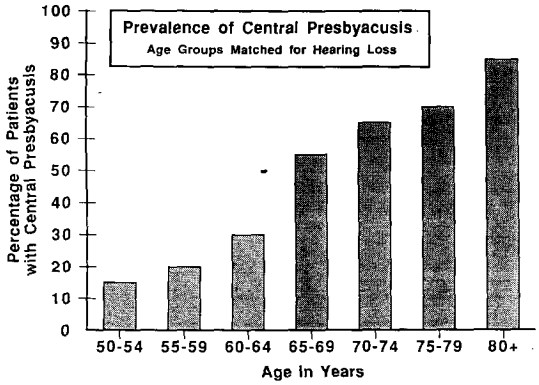

Figure 6 Percentage of patients as a function of age with speech audiometric results consistent with central presbyacusis. Each group consists of 20 patients matched for degree of hearing loss.

ed to cognitive decline. And, indeed, no statistically significant differences in the SSI scores at +10 dB were found as a function of age ($F=1.57$, $p=0.16$).

The prevalence of central auditory disorder was once again determined for each group in the substudy. Figure 6 shows that, even when degree of hearing loss and ability to perform the task were controlled, the prevalence of central presbyacusis increased systematically with age.

Clinical Versus Nonclinical Prevalence

Prevalence estimates of central presbyacusis in our patient group were compared to identical estimates in a group of 200 "nonclinical" volunteer research subjects. Results are shown in Figure 7. Data for the clinical group are from the 700 patients shown in Figure 2. Prevalence for the nonclinical group ranged from 0 percent in the youngest group to 72 percent in the oldest group. At all ages, the prevalence of central auditory disorder was less in the nonclinical group. The differences were greatest in the middle age groups and began to diminish in the older groups. In the 70 to 74 year group, the difference was 42 percent. However, in the oldest age group, the difference in prevalence decreased to 23 percent.

DISCUSSION

The prevalence of central auditory processing disorders in these two elderly populations was quite high. A remarkable 70 percent of all patients over the age of 60 in the clinical sample had some degree of speech understanding deficit that could not be explained on the basis of the pure-tone audiogram. Previous prevalence estimates of central presbyacusis are difficult to determine because either no decision was made about presence or absence of the disorder or degree of peripheral hearing loss was not carefully controlled. In general, however, studies are in agreement that a large percentage of older subjects have some degree of speech understanding difficulty. For example, Shirinian and Arnst (1982) reported that 38 of 62 (61 percent) patients over the age of 60 years showed a central pattern on PB-word and SSI speech audiometric testing. Welsh and colleagues (1985) found that 15 percent of subjects in a 60 to 69 year old group failed 5 of 10 subtests of speech understanding. In their 70 to 79 year age group, 40 percent failed at least half of the tests, and in the over 80 year group, all subjects failed at least half of the tests.

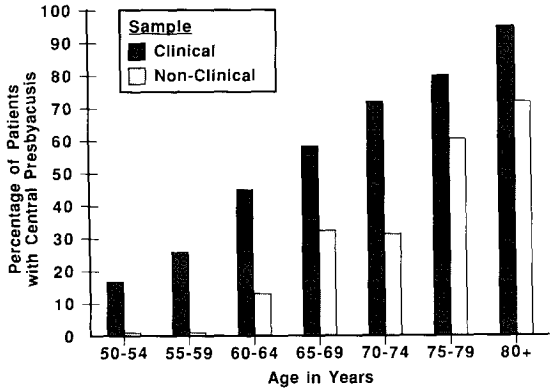

Figure 7 Percentage of patients with speech audiometric results consistent with central presbyacusis in a clinical sample (N=700) and a nonclinical sample (N=138) as a function of age.

It has been frequently suggested that performance by the elderly on speech audiometric measures of central auditory function is predicted by degree of peripheral sensitivity loss. That is, the argument is made that speech audiometric deficits in the elderly are related solely to changes in the cochlea. This is an important question because, in fact, some speech-based measures can be adversely affected by peripheral hearing loss, and the relative contributions of peripheral and central components cannot always be separated.

In the present study, two factors minimized the influence of peripheral hearing loss on the speech audiometric manifestations of central presbyacusis. First, the definition of central presbyacusis was based on rollover of the SSI function, the PB-SSI discrepancy, or disproportionately poor absolute SSI scores. Both rollover and PB-SSI discrepancy are relatively immune to the effects of cochlear hearing loss. Furthermore, absolute SSI scores were interpreted only in relation to empirically established boundaries previously determined on a large number of patients with cochlear hearing loss. Second, subgroups were matched for degree of peripheral hearing loss; still, the prevalence of central deficits increased with age.

Another possible contaminating influence on speech-based measures of central auditory function is generalized cognitive decline (Working Group on Speech Understanding and Aging, 1988). Although cognitive decline can occur without adversely affecting speech audiometric results, and although central auditory disorder can occur in the absence of cognitive decline, when both occur simultaneously, their interactive influence is difficult to separate out (Jerger et al, 1989b; Jerger et al, 1989a). In an effort to minimize influences of cognitive decline on speech audiometric results in the present study, results from patients with known or suspected dementia or other neurologic disorder were not used. In addition, the possible influence of cognitive factors was studied indirectly in the subgroups that were matched for hearing loss. The potential problem relating to cognitive decline is that a patient would not be able to carry out the SSI task and that poor performance might be misinterpreted as central auditory disorder. However, since the subgroups at all ages performed well on the SSI at +10 dB MCR, the age-related central deficits characterized by SSI decline at 0 dB MCR could not be attributed to the patients' inability to perform the required task.

The choice of speech audiometric materials used to estimate the prevalence of central presbyacusis was based on the fact that these materials have been used in our clinical facility on a routine basis in all patients over the last two decades, thus facilitating the establishment of a large database. Were other speech audiometric procedures, particularly dichotic tests, included in this analysis, the prevalence of abnormality might have increased further. Since there is no biologic marker for central auditory processing disorder, any definition of its existence must be operationally defined on the basis of test results. Defined on the basis of PB/SSI patterns, the prevalence of central presbyacusis was quite high. The extent to which that prevalence would change as a function of the definition of CAPD remains to be evaluated.

Since data were extracted from the clinical files of a large metropolitan hospital in a large medical center, we assumed that the prevalence of central disorder would be higher than in the population at large. Prevalence data from the nonclinical study showed that this was, indeed, the case. No central auditory disorder was present in the younger groups, and the prevalence was lower than in the clinical study in each of the older age groups. Nevertheless, there was still a substantial amount of central presbyacusis in the nonclinical subjects. For example, 61 percent of those subjects in the 75 to 79 year age group and 72 percent of those subjects in the 80+ age group had some degree of central auditory disorder. Considering that these were subjects who had volunteered to be tested, rather than patients who had visited the clinical facility because of auditory complaints, these percentages are striking. Certainly, a selection process could have occurred in the solicitation of volunteers. Those who were having difficulty hearing a spouse, for example, were probably more likely to volunteer. But even if the data from the nonclinical subjects overestimated the problem for the population in general, the results should direct attention to the fact that the problem of central presbyacusis is not a minor one in any group of elderly patients.

The present results suggest that central presbyacusis is a prevalent consequence of aging, even when defined solely on the basis of PB-word understanding in relation to sentence

identification in the presence of competition. Since central auditory processing disorder has been associated with increased hearing handicap (Jerger et al, 1990) and reduced benefit from amplification (Hayes and Jerger, 1979; Stach, 1990), its high prevalence in the elderly cannot be ignored.

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REFERENCES

Antonelli A. (1970). Sensitized speech tests in aged people. In: Rojskjaer C, ed. *Speech audiometry.* Second Danavox Symposium. Odense, Denmark: Danavox, 66-79.

Arnst D. (1982). Staggered spondaic word test performance in a group of older adults. A preliminary report. *Ear Hear* 3:118-123.

Bergman M. (1971). Hearing and aging. *Audiology* 10:164-171.

Bergman M, Blumfield V, Cascardo D, Dash B, Levitt H, Marguiles M. (1976). Age-related decrement in hearing for speech: sampling and longitudinal studies. *J Gerontol* 31:533-538.

Bosatra A, Russolo M. (1982). Comparison between central tonal tests and central speech tests in elderly subjects. *Audiology* 21:334-341.

Brody H. (1955). Organization of the cerebral cortex, III: a study of aging in human cerebral cortex. *J Comp Neurol* 102:511-556.

Dubno JR, Dirks DD, Morgan DE. (1984). Effects of age and mild hearing loss on speech recognition in noise. *J Acoust Soc Am* 76:87-96.

Goetzinger C, Proud G, Dirks D, Embrey J. (1961). A study of hearing in advanced age. *Arch Otolaryngol* 73:662-674.

Hansen C, Reske-Nielsen E. (1965). Pathological studies in presbyacusis: cochlear and central findings in 12 aged patients. *Arch Otolaryngol* 82:115-132.

Hayes D. (1984). Hearing problems of aging. In: Jerger J, ed. *Hearing disorders in adults.* Boston: College-Hill Press, 311-337.

Hayes D, Jerger J. (1979). Aging and the use of hearing aids. *Scand Audiol* 8:33-40.

Hinchcliffe R. (1962). The anatomical locus of presbycusis. *J Speech Hear Disord* 27:301-310.

Igarashi M. (1972). Pathology of the inner ear endorgans. In: Minkler J, ed. *Pathology of the nervous system,* Vol 3. New York: McGraw Hill, 2856-2879.

Jerger J. (1973). Audiological findings in aging. *Adv Otorhinolaryngol* 20:115-124.

Jerger J, Hayes D. (1977). Diagnostic speech audiometry. *Arch Otolaryngol* 103:216-222.

Jerger S, Jerger J. (1983). Neuroaudiologic findings in patients with central auditory disorder. *Semin Hear* 4:133-159.

Jerger J, Jerger S, Oliver T, Pirozzolo F. (1989a). Speech understanding in the elderly. *Ear Hear* 10:79-89.

Jerger J, Neely JG, Jerger S. (1980). Speech, impedance, and auditory brainstem response audiometry in brainstem tumors. *Arch Otolaryngol* 106:218-223.

Jerger J, Oliver TA, Pirozzolo F. (1990) Impact of central auditory processing disorder and cognitive deficit on the self-assessment of hearing handicap in the elderly. *J Am Acad Audiol* 1:

Jerger J, Speaks C, Trammel J. (1968). A new approach to speech audiometry. *J Speech Hear Disord* 33:318-327.

Jerger J, Stach B, Pruitt J, Harper R, Kirby H. (1989b). Comments on "Speech understanding and aging." *J Acoust Soc Am* 85:1352-1354.

Jerger J, Jerger S. (1975). Clinical validity of central auditory tests. *Scand Audiol* 4:147-163.

Johnson L, Hawkins J. (1972). Vascular changes in the human inner ear associated with aging. *Ann Otol Rhinol Laryngol* 81:364-376.

Jorgensen M. (1961). Changes of aging in the inner ear: histological studies. *Arch Otolaryngol* 74:164-170.

Kirikae I, Sato T, Shitaro T. (1964). Study of hearing in advanced age. *Laryngoscope* 74:205-221.

Konig E. (1969). Audiological tests in presbycusis. *Int Audiol* 8:240-259.

Konkle D, Beasley D, Bess F. (1977). Intelligibility of time-altered speech in relation to chronological aging. *J Speech Hear Res* 20:108-115.

Krmpotic-Nemanic J. (1971). A new concept of the pathogenesis of presbycusis. *Arch Otolaryngol* 93:161-166.

Lutterman D, Welsh O, Melrose J. (1966). Responses of aged males to time altered speech stimuli. *J Speech Hear Res* 9:226-230.

McCroskey R, Kasten R. (1982). Temporal factors and the aging auditory system. *Ear Hear* 3:124-127.

Orchik D, Burgess J. (1977). Synthetic sentence identification as a function of age of the listener. *J Am Audiol Soc* 3:42-46.

Pestalozza G, Shore I. (1955). Clinical evaluation of presbycusis on the basis of different tests of auditory function. *Laryngoscope* 65:1136-1163.

Price PJ, Simon HJ. (1984). Perception of temporal differences in speech by "normal-hearing" adults: effects of age and intensity. *J Acoust Soc Am* 76:405-410.

Schuknecht H. (1964). Further observation on the pathology of presbycusis. *Arch Otolaryngol* 80:369-382.

Shirinian M, Arnst D. (1982). Patterns in performance intensity functions for phonetically balanced word lists and synthetic sentences in aged listeners. *Arch Otolaryngol* 108:15-20.

Stach B. (1990). Hearing aid amplification and central processing disorders. In: Sandlin RE, ed. *Handbook of hearing aid amplification,* Vol. II: Clinical considerations and fitting practices. Boston: College-Hill Press, 87-111.

Sticht T, Gray B. (1969). The intelligibility of time-compressed words as a function of age and hearing loss. *J Speech Hear Res* 12:443-448.

Welsh LW, Welsh JJ, Healy MP. (1985). Central presbyacusis. *Laryngoscope* 95:128-136.

Working Group on Speech Understanding and Aging. (1988). Speech understanding and aging. *J Acoust Soc Am* 83:859-893.

Yellin MW, Jerger J, Fifer RC. (1989). Norms for disproportionate loss in speech intelligibility. *Ear Hear* 10:231-234.