Evidence Synthesis
Number 83

Screening for Hearing Loss in Adults Ages 50 Years and Older: A Review of the Evidence for the U.S. Preventive Services Task Force

Prepared for:
Agency for Health Care Research and Quality
U.S. Department of Health and Human Services
540 Gaither Road
Rockville, MD 20850
www.ahrq.gov

Contract Number: HHSA-290-2007-10057-I-EPC3, Task Order No. 3

Prepared by:
Oregon Evidence-based Practice Center
Oregon Health and Science University
3181 SW Sam Jackson Park Road, Mail Code BICC
Portland, OR 97239
www.ohsu.edu/epc

Kaiser Permanente Center for Health Research
3800 North Interstate Avenue
Portland, OR 97227

Investigators:
Roger Chou, MD
Tracy Dana, MLS
Christina Bougatsos, BS
Craig Fleming, MD
Tracy Beil, MS

AHRQ Publication No. 11-05153-EF-1
March 2011

This report is based on research conducted by the Oregon Evidence-based Practice Center (EPC) under contract to the Agency for Healthcare Research and Quality (AHRQ), Rockville, MD (Contract No. 290-2007-10057-I). The investigators involved have declared no conflicts of interest with objectively conducting this research. The findings and conclusions in this document are those of the author(s), who are responsible for its content, and do not necessarily represent the views of AHRQ. No statement in this report should be construed as an official position of AHRQ or of the U.S. Department of Health and Human Services.

The information in this report is intended to help clinicians, employers, policymakers, and others make informed decisions about the provision of health care services. This report is intended as a reference and not as a substitute for clinical judgment.

This report may be used, in whole or in part, as the basis for the development of clinical practice guidelines and other quality enhancement tools, or as a basis for reimbursement and coverage policies. AHRQ or U.S. Department of Health and Human Services endorsement of such derivative products may not be stated or implied.

Acknowledgements: The authors acknowledge Rongwei Fu, PhD, Oregon Health & Science University, for statistical assistance; Daphne Plaut, MLS, Kaiser Permanente Center for Health Research, for conducting literature searches; the expert reviewers of the draft report; AHRQ Medical Officer Mary Barton, MD, MPP; and U.S. Preventive Services Task Force leads Rosanne Leipzig, MD, PhD, Joy Melnikow, MD, MPH, and Diana Petitti, MD, MPH, for their contributions to this report.

Suggested Citation: Chou R, Dana T, Bougatsos C, Fleming C, Beil T. Screening for Hearing Loss in Adults Ages 50 Years and Older: A Review of the Evidence for the U.S. Preventive Services Task Force. Evidence Synthesis No. 83. AHRQ Publication No. 11-05153-EF-1. Rockville, MD: Agency for Healthcare Research and Quality; March 2011.

Structured Abstract

Background: Hearing loss is common in older adults. Screening could identify untreated hearing loss and lead to interventions to improve hearing-related function and quality of life.

Purpose: To update the 1996 U.S. Preventive Services Task Force evidence review on screening for hearing loss in primary care settings in adults ages 50 years and older.

Data Sources: We searched Ovid MEDLINE from 1950 to July 2010, the Cochrane Database of Systematic Reviews, and the Cochrane Central Register of Controlled Trials through the second quarter of 2010 to identify relevant articles. We supplemented electronic searches with reviews of reference lists of relevant articles and solicited additional citations from experts.

Study Selection: We selected randomized trials and controlled observational studies that directly evaluated effects of screening for hearing loss in older (ages $\geq$50 years) adults. To evaluate indirect evidence on screening, we also included studies on the diagnostic accuracy of screening tests for hearing loss used in primary care settings, and randomized trials and controlled observational studies that reported clinical outcomes associated with use of amplification.

Data Extraction: One investigator abstracted data and a second investigator checked data abstraction for accuracy. Two investigators independently assessed study quality using methods developed by the U.S. Preventive Services Task Force.

Data Synthesis: Evidence on benefits and harms of screening and treatments for hearing loss was synthesized qualitatively. One large (n=2305) randomized trial found that screening for hearing loss was associated with increased hearing aid use at 1 year, but screening was not associated with improvement in hearing-related function. There is good-quality evidence from 20 studies on diagnostic accuracy that common screening tests for hearing loss can help identify patients at higher risk for hearing loss. The whispered voice test at 2 feet and a single question regarding perceived hearing loss were comparable with a more detailed screening questionnaire or a hand-held audiometric device for identifying at least mild (>25 dB) hearing loss. Negative results using a hand-held audiometric device may be the most useful finding for ruling out at least moderate (>40 dB) hearing loss. One good-quality randomized trial found that immediate hearing aids were effective compared with wait-list control for improving hearing-related quality of life and function in patients with mild or moderate hearing loss and severe hearing-related handicap. We did not find direct evidence on harms of screening or treatments with hearing aids, but harms are likely to be small based on the non-invasive nature of screening and treatment, with no known serious adverse events.

Limitations: We excluded non-English language studies, included studies of diagnostic accuracy in high-prevalence specialty settings, and did not construct outcomes tables.

Conclusions: Additional research is needed to understand effects of screening compared with no screening on health outcomes, and to confirm benefits of treatment under conditions likely to be encountered in most primary care settings.

Table of Contents

Figure

Tables

Appendixes

I. INTRODUCTION

Scope and Purpose

Hearing loss is common in older adults, increases in prevalence and severity with age, and can affect quality of life and ability to function.[1-5] The U.S. Preventive Services Task Force (USPSTF) issued a recommendation on screening for hearing loss in adults ages 50 years and older in 1996.[6] In 2009, the USPSTF commissioned a new evidence review in order to update its recommendation. The purpose of this report is to systematically evaluate the current evidence on screening for hearing loss in adults ages 50 years and older in primary care settings.

Condition Definition

A person with normal hearing perceives sounds at frequencies between 20 and 20,000 Hz.[7] Frequencies between 500 and 4000 Hz are most important for speech processing. There is often discordance between objectively measured deficits in tonal perception at specific frequencies and intensity levels (measured as decibels) and subjective perceptions of hearing problems.[8, 9] One study found that 20 percent of persons reporting hearing difficulty had normal hearing tests, while 6.2 percent of those not reporting difficulty had significant hearing loss.[3] Hearing problems despite normal hearing tests could be caused by abnormal signal processing or sound discrimination. Because treatments for hearing loss are targeted at improving tonal perception by signal amplification, we use the term "hearing loss" in this review to refer specifically to deficits found on objective testing.

The standard objective test for hearing loss is the pure-tone audiogram, in which a patient is placed in a soundproof booth and tested on ability to hear tones at a series of discrete frequencies, typically in the range of 125 to 8000 Hz, at various decibels. There is no universally accepted definition for hearing loss. Reference criteria vary with regard to the frequencies and intensity thresholds used to determine hearing loss, and whether one or both ears are affected. Many studies define mild hearing loss as inability to hear frequencies associated with speech processing <25 dB and moderate hearing loss as inability to hear those frequencies <40 dB. Commonly used reference criteria include the Ventry and Weinstein criteria (>40 dB hearing loss at either 1000 or 2000 Hz in both ears, or >40 dB hearing loss at 1000 and 2000 Hz in one ear),[9] the speech frequency pure-tone average (SFPTA) criteria ($\geq$25 dB average hearing loss at 500, 1000, and 2000 Hz in the better ear),[10] and the high-frequency pure-tone average (HFPTA) criteria ($\geq$25 dB average hearing loss at 1000, 2000, and 4000 Hz in the better ear).[11]

Prevalence and Burden of Disease/Illness

In population-based studies of community-dwelling older adults (ages 50 years and older), the prevalence of hearing loss ranges from 20 to 40 percent depending on the population evaluated and the criteria used to define hearing loss.[1, 3-5] In adults ages 80 years and older, the prevalence

increases to over 80 percent.[1] In a prospective study of 1636 adults ages 48 to 92 years without hearing loss at baseline, the 5-year incidence of hearing loss was 21 percent.[1] In one population-based study, about one third of older adults with hearing loss reported that they never had a hearing test.[1]

Hearing loss can impact both quality of life and ability to function in older adults. Individuals with hearing loss may have difficulty with speech discrimination, participation in social activities, ability to enjoy music, and localization of sounds.[12] Hearing loss is associated with increased emotional dysfunction, depression, and social isolation.[13-15] Older adults with moderate to severe hearing loss are more likely to experience impaired activities of daily living and instrumental activities of daily living compared with those with mild or no hearing loss.[2]

Etiology and Natural History

Age-related hearing loss (presbycusis) is the most common cause of hearing loss in older adults. It refers to a type of sensorineural hearing loss involving degeneration of the cells of the organ of Corti. The hearing loss associated with presbycusis is typically gradual, progressive, and bilateral.[1, 16] The disease initially affects the higher frequencies before progressing to the lower frequencies.[12] Hearing loss in older adults is multifactorial. In addition to age-related degeneration, other contributing factors include genetic factors, exposure to loud noises, exposure to ototoxic agents, history of inner ear infections, and presence of systemic diseases such as diabetes mellitus.[8, 12, 17] Conductive hearing loss accounts for about 8 percent of cases of hearing loss in older adults.[1]

Risk Factors

In addition to advanced age, a number of other risk factors are associated with hearing loss in older adults, including male sex, white race, family history, service/blue-collar occupation, exposure to loud noises, lower education level, smoking, hypertension, and diabetes.[5, 17-21]

Rationale for Screening/Screening Strategies

While hearing loss is common in older adults, individuals may not realize that they have hearing loss because symptoms are relatively mild or slowly progressive, they may perceive hearing loss but not seek evaluation for it, or they may have difficulty recognizing or reporting hearing loss due to comorbid conditions, such as cognitive impairment. Screening could identify individuals with hearing loss who could benefit from the use of hearing aids or other therapies to address hearing loss.

Although formal audiometric testing is required to diagnose hearing loss, the equipment is expensive and testing is time intensive and requires specially trained staff.[8] Screening in primary

care settings is therefore typically based on the use of more readily performed tests that can identify those who should undergo a full audiometric evaluation. Clinical tests used to screen for hearing impairment include testing whether a patient can hear a whispered voice, a finger rub, or a watch tick at a specific distance. Perceived hearing loss or hearing-associated problems can be assessed by asking a single question (e.g., "Do you have difficulty with your hearing?") or with a more detailed questionnaire. The Hearing Handicap Inventory for the Elderly-Screening (HHIE-S), the most commonly used screening questionnaire, is a 10-item self-administered questionnaire that assesses social and emotional factors associated with hearing loss and requires about 2 minutes to complete.[9, 22] The AudioScope (Welch Allyn, Inc., Skaneateles Falls, NY) is a handheld screening instrument consisting of an otoscope with a built-in audiometer. It assesses the ability of patients to hear tones of 20, 25, and 40 dB at frequencies of 500, 1000, 2000, and 4000 Hz and requires approximately 90 seconds to administer.[22]

Interventions/Treatment

Signal amplification is the primary treatment for hearing loss. Hearing aids vary widely in style, technology, features, and cost.[12, 23] Hearing aid styles include behind-the-ear, in-the-ear, in-the-canal, and completely-in-the-canal designs. Digital signal processing has become the standard technology for hearing aids. Despite the high prevalence of hearing loss and many options for amplification, only 10 to 20 percent of those with hearing loss have ever used hearing aids, and 20 to 29 percent of patients who have used hearing aids at some point stop using them.[3, 24, 25] Patients often experience dissatisfaction with hearing aids due to their appearance, background noise, discomfort, difficulty handling, and unmet expectations regarding effects on hearing impairment.[12, 26] Other options for treatment of hearing loss include assistive listening devices (off-the-ear devices that amplify directional noise using a microphone or similar instrument), hearing rehabilitation, and cochlear implants for those with profound hearing loss who do not improve with hearing aids.[12, 23]

Current Clinical Practice

Surveys indicate that although physicians overwhelmingly (92 to 98 percent) believe that hearing loss negatively affects quality of life in older adults, many do not routinely screen patients (40 to 86 percent).[27-29] Barriers to screening include lack of time, perception that there are more pressing clinical issues, and lack of reimbursement.[27-29]

Recommendations of Other Groups

The American Speech-Language-Hearing Association recommends that adults be screened at least every decade through age 50 and at 3-year intervals thereafter.[30] Recommendations from the American Academy of Family Physicians[31] and the American Academy of Audiology[32] refer to prior USPSTF recommendations. In 1994, the Canadian Task Force on Preventive Health

Care found fair evidence to screen the elderly for hearing impairment (B recommendation).[33] The American Geriatrics Society and the American Academy of Otolaryngology Head and Neck Surgery do not have recommendations.

Previous USPSTF Recommendation

In 1996, the USPSTF recommended "screening older adults for hearing impairment by periodically questioning them about their hearing, counseling them about the availability of hearing aid devices, and making referrals for abnormalities when appropriate (B recommendation)."[6]

II. METHODS

Using the methods of the USPSTF that are fully described in **Appendix A** and with the input of members of the USPSTF, we developed an analytic framework (**Figure 1**) and key questions (KQs) to guide our literature search and review. We defined the target population as persons ages 50 years and older who did not have diagnosed hearing loss and were evaluated in primary care settings, including patients both with and without perceived hearing loss. For the purposes of this review, both groups are referred to as "asymptomatic," so long as they have not sought evaluation for a perceived hearing problem. The target condition for this review was chronic sensorineural hearing loss, the most common type of hearing loss in older adults. We excluded conductive hearing loss, congenital hearing loss, and sudden hearing loss or hearing loss due to recent occupational or other exposure, as these were considered to be outside the scope of hearing screening in primary care. For treatments, we focused on hearing aids. Outcomes of interest were hearing-related function, quality of life, and adverse events related to screening or treatment (such as anxiety, labeling, or other psychosocial effects, and false-positive results).

The KQs used to guide this evidence synthesis were:

1. Does screening for hearing loss in asymptomatic adults ages 50 years and older lead to improved health outcomes?

2. How accurate are the methods for hearing loss screening in older adults, including questionnaires, clinical techniques, and handheld audiometric devices?

3. How efficacious is the treatment of screening-detected hearing loss, namely amplification, in improving health outcomes?

4. What are the adverse effects of screening for hearing loss in adults ages 50 years and older?

5. What are the adverse effects of treatment of screening-detected hearing loss in adults ages 50 years and older?

Search Strategies

We searched Ovid MEDLINE from 1950 to July 2010 and the Cochrane Database of Systematic Reviews and the Cochrane Central Register of Controlled Trials through the second quarter of 2010 to identify relevant articles (**Appendix A1**). We identified additional studies from citations in relevant articles and experts in hearing screening and treatment.

Study Selection

We selected studies pertaining to screening, diagnosis, and treatment of hearing loss based on predefined inclusion and exclusion criteria for each KQ (**Appendix A2**). Two reviewers evaluated each study at the title/abstract and full-text article stages to determine eligibility for inclusion. The flow of studies from initial identification of titles and abstracts to final inclusion or exclusion is diagrammed in **Appendix A3**. We also included studies of hearing screening in specialty settings, but evaluated their applicability to primary care settings. The target sample was persons ages 50 years and older who did not have diagnosed hearing loss and were evaluated in primary care settings, including those with and without self-perceived hearing problems. The target condition for this review was chronic sensorineural hearing loss, the most common type of hearing loss in older adults.[1] Although hearing problems can occur despite normal tonal perception,[3] hearing loss is generally defined based on pure-tone audiometric testing because the primary treatment is signal amplification. For screening tests, we focused on clinical tests (e.g., detection of a whispered voice, finger rub, or watch tick), a single question (e.g., "Do you have difficulty with your hearing?"), questionnaires (e.g., HHIE-S)[9, 22] and handheld audiometric devices (e.g., the AudioScope). The purpose of all screening tests was to identify individuals at higher risk for hearing loss who should be referred for formal audiometry. We excluded the Rinne and Weber tests because their main purpose is to distinguish conductive from sensorineural hearing loss, not to screen patients for hearing loss. For treatments, we focused on hearing aids and assistive listening devices (instruments with an off-ear microphone to pick up and amplify targeted sounds). Outcomes of interest were hearing-related function, quality of life, and adverse events related to screening or treatment. We used randomized controlled trials (RCTs) and controlled observational studies to assess the effectiveness and harms of screening and treatment. For diagnostic accuracy, we included studies that compared a screening test with a reference standard.

We excluded congenital hearing loss, sudden hearing loss, and hearing loss due to recent occupational or other exposure. We also excluded conductive hearing loss because it is uncommon in older adults.[1] We restricted our review to published studies available in the English language. Studies that were excluded after review of the full-text article and reasons for exclusion are listed in **Appendix A4**.

Data Abstraction and Quality Rating

We abstracted details about the patient population, study design, data analysis, follow-up, and results. One author abstracted data and another author verified the abstracted data for accuracy. Two authors independently rated the internal validity of each study as "good," "fair," or "poor" using predefined criteria developed by the USPSTF (**Appendix A5**).[34, 35] We also evaluated the applicability of studies to primary care screening, based on whether patients were recruited from primary care or community settings, the prevalence and severity of hearing loss, the proportion of patients with perceived hearing loss, and factors related to access to hearing aids (e.g., free hearing aids provided to eligible veterans). Discrepancies in quality ratings were resolved by discussion and consensus.

For diagnostic accuracy studies, we used the diagti procedure in Stata (Stata Version 10, StataCorp, College Station, TX) to calculate sensitivities, specificities, and likelihood ratios. We used the cci procedure to calculate diagnostic odds ratios with exact confidence intervals.

Data Synthesis

We assessed the overall strength of the body of evidence for each KQ ("good," "fair," or "poor"), or part of a KQ, using methods developed by the USPSTF, based on the number, quality and size of studies, consistency of results between studies, and directness of evidence.[34] We did not quantitatively pool results of studies on diagnostic accuracy of screening tests for hearing loss due to differences across studies in populations evaluated, definitions of hearing loss, specific screening tests evaluated, and screening cutoffs applied. Instead, we created descriptive statistics with the median sensitivity, specificity, and likelihood ratios for detecting hearing loss of >25 and >40 dB, along with associated ranges. The total range rather than the interquartile range was chosen because several findings were reported in few studies, and because the summary range highlights the greater uncertainty we have in the estimates. For studies that reported diagnostic accuracy based on more than one definition of hearing loss, we estimated median values based on the Ventry and Weinstein criteria (for >40 dB hearing loss), the SFPTA criteria (for >25 dB hearing loss), or another definition most like the ones used by other relevant studies. There were too few randomized trials of treatments for hearing loss to perform meta-analysis.

External Review

We distributed a draft of the report for review by four external experts not affiliated with the USPSTF (**Appendix A6**), and revised the report based on their comments.

III. RESULTS

Key Question 1. Does Screening for Hearing Loss in Asymptomatic Adults Ages 50 Years and Older Lead To Improved Health Outcomes?

Summary

One trial found that screening with the HHIE-S, the AudioScope, or both was associated with greater hearing aid use at 1 year compared with no screening.[36] Effects of screening on hearing aid use appeared to be limited to patients with perceived hearing loss at baseline. Screening was not associated with any differences in hearing-related quality of life compared with no screening. Because three quarters of patients enrolled in the trial reported perceived hearing loss at baseline and all patients were eligible to receive free hearing aids, results are likely to be most generalizable to high-prevalence settings in which the cost of hearing aids is not a barrier.

Evidence

We identified one randomized trial of screening for hearing loss (**Table 1, Appendixes B1** and **B2**).[36] Aspects of this trial were also described in a preliminary abstract[37] and in an article describing its study design, baseline characteristics, and rates of positive screening results.[38] We rated the Screening for Auditory Impairment—Which Hearing Assessment Test (SAI-WHAT) trial as fair quality primarily because of high loss to follow-up and unclear blinding status of outcomes assessors.[36] The trial compared three different screening strategies (the AudioScope, based on inability to hear a 40 dB tone at 2000 Hz in either ear; the HHIE-S, based on a score $\geq$10; or the AudioScope plus the HHIE-S) versus usual care without screening in 2305 predominantly (94 percent) male patients ages 50 years and older (mean age, 61 years) at a Department of Veteran Affairs (VA) Medical Center. Some study design factors could limit the applicability of the SAI-WHAT trial to screening in other primary care settings. Specifically, all participants in the trial were eligible to receive free VA-issued hearing aids. In addition, about three quarters of patients reported perceived hearing loss at enrollment (based on the question, "Do you think you have hearing loss?").

Rates of positive screening results were 19 percent in the AudioScope arm, 59 percent in the HHIE-S arm, and 64 percent in the combined arm. Hearing aid use at 1 year, the primary outcome, was 6.3 percent in the AudioScope arm, 4.1 percent in the HHIE-S arm, 7.4 percent in the combined arm, and 3.3 percent in the control arm (p=0.03). In a post-hoc stratified analysis, hearing aid use was greater among patients with perceived hearing loss (5.7 to 9.6 percent in screened arms vs. 4.4 percent in control arm), but among those without perceived hearing loss, hearing aid use was minimal regardless of screening status (0 to 1.6 percent).

There was no difference in the proportion of patients that experienced a minimum clinically important difference ($\geq$6 points of improvement on a 0 to 100 scale) on the Inner Effectiveness of Aural Rehabilitation scale (a measure of hearing-related function), a secondary outcome of the

trial, at 1 year (36 to 40 percent in the screened arms vs. 36 percent in the control arm; p=0.39). In post-hoc analyses, there were also no differences in the proportion that experienced improvement in hearing-related function when patients were stratified according to whether they had perceived hearing loss at baseline, except in a subgroup that was also ages 65 years and older (54 percent in the AudioScope arm, 34 percent in the HHIE-S arm, 40 percent in the combined arm, and 34 percent in the control arm).

Key Question 2. How Accurate Are the Methods for Screening for Hearing Loss in Older Adults?

Summary

Twenty studies evaluated the diagnostic accuracy of clinical tests, a single question, a questionnaire, or a handheld audiometric device for identification of hearing loss in older adults. For detection of >25 or >30 dB hearing loss, four studies (one good-quality) found that the whispered voice test at 2 feet was associated with a median positive likelihood ratio (PLR) of 5.1 (range, 2.3 to 7.4) and median negative likelihood ratio (NLR) of 0.03 (range, 0.007 to 0.73).[39-42] For detection of >25 dB hearing loss, six studies (four good-quality) found that a single question was associated with a median PLR of 3.0 (range, 2.4 to 3.8) and median NLR of 0.40 (range, 0.33 to 0.82),[39, 43-45] and four good-quality studies[22, 44-46] found that the HHIE-S (based on a cutoff score of 8) was associated with a median PLR of 3.5 (range, 2.4 to 11) and median NLR of 0.52 (range, 0.43 to 0.70). Likelihood ratio estimates were similar for detection of >40 dB hearing loss. For detection of >40 dB hearing loss, three studies (two good-quality) found that the AudioScope (based on ability to hear tones between 500 and 4000 Hz at 40 dB) was associated with a median PLR of 3.4 (range, 1.7 to 4.9) and median NLR of 0.05 (range, 0.03 to 0.08).[22, 40, 46]

In direct comparisons, one good-quality study found that the watch tick and finger rub tests were associated with similar NLRs but substantially stronger PLRs compared with the whispered voice test or a single screening question.[39] Three studies showed a consistent trade-off between lower sensitivity and higher specificity for the HHIE-S compared with a single screening question, resulting in somewhat stronger PLRs and weaker NLRs.[39, 44, 45, 47] Two studies found that the AudioScope was associated with stronger NLRs compared with the HHIE-S, with relatively small differences in PLR estimates.[22, 46]

Evidence

Twenty studies evaluated the diagnostic accuracy of various screening tests against a reference standard (usually pure-tone audiometry) for identification of hearing loss in older adults.[9, 22, 39-56] Four studies evaluated clinical tests (**Table 2**, **Appendix B3**),[39-42] eight evaluated a single question (**Table 3**, **Appendix B4**),[39, 43-45, 47, 52, 54, 55] nine evaluated a hearing questionnaire (**Table 4**, **Appendix B5**),[9, 22, 44-47, 51, 53, 56] and six evaluated a handheld audiometric device (**Table 5**, **Appendix B6**).[22, 40, 46, 48-50] Four studies were population-based[43-45, 47] and four[22, 46, 53, 56] recruited patients from primary care or community-based settings. The remainder recruited

patients from specialty (usually an audiology or otolaryngology clinic) or other high-prevalence settings, or evaluated older adults dwelling in nursing homes.[49, 55]

We rated seven studies as good quality[22, 39, 43-47] and the remainder as fair quality (**Appendix B7**). The most common methodological shortcomings were failure to describe enrollment of a representative spectrum of patients (nine studies met this criterion), failure to report interpretation of the reference standard blinded to results of the screening test (five studies met this criterion), and failure to describe enrollment of a random or consecutive series of patients (11 studies met this criterion). All studies except for one used pure-tone audiometry as the reference standard for hearing loss, though four studies used a portable (bedside) audiometer instead of standard audiometry.[49, 52, 54, 55] The exception was one study that performed an audiometric examination but used an audiologist as its reference standard.[56]

Table 6 summarizes the main results on diagnostic accuracy. Results for each screening test are described in more detail below.

Whispered voice, finger rub, and watch tick tests. One good-quality[39] and three fair-quality[40-42] studies evaluated the diagnostic accuracy of a whispered voice at 2 feet for identification of >25 or >30 dB hearing loss (**Table 2**, **Appendix B3**). Likelihood ratio estimates varied, with a median PLR of 5.1 (range, 2.3 to 7.4) and median NLR of 0.03 (range, 0.007 to 0.73). The good-quality study reported the weakest likelihood ratios.[39] Based on a sensitivity of 0.40 (range, 0.32 to 0.49) and specificity of 0.82 (range, 0.72 to 0.90), the PLR was 2.3 (95% CI, 1.3 to 3.8) and the NLR was 0.73 (95% CI, 0.61 to 0.87). In the three fair-quality studies, sensitivity was higher (range, 0.90 to 1.0), with similar specificity (range, 0.80 to 0.87), resulting in stronger likelihood ratios (PLR range, 4.6 to 7.4; NLR range, 0.007 to 0.12).[40-42] One fair-quality study found that inability to hear a whispered voice at 6 inches (PLR, 72 [95% CI, 4.6 to 1140]) or a conversation at 2 feet (PLR, 46 [95% CI, 2.9 to 740]) was more useful than inability to hear a whispered voice at 2 feet (PLR, 5.7 [95% CI, 3.1 to 11]), but estimates were imprecise and the confidence intervals overlapped.[41] On the other hand, normal results on the first two tests were less useful than the whispered voice test at 2 feet for identifying those without hearing loss (NLR, 0.27 [95% CI, 0.19 to 0.39] and 0.53 [95% CI, 0.43 to 0.66], respectively, vs. 0.008 [95% CI, 0.0005 to 0.13]), primarily due to lower sensitivities.

The one good-quality study also evaluated the accuracy of the finger rub and watch tick tests at 6 inches for detecting >25 dB hearing loss (**Table 2**, **Appendix B3**).[39] Compared with the whispered voice test, inability to hear a finger rub or watch tick was more useful for identifying hearing loss (PLR, 10 [95% CI, 2.6 to 43] and 70 [95% CI, 4.4 to 1120], respectively), with normal results similarly useful for identifying individuals without hearing loss (NLR, 0.75 [95% CI, 0.68 to 0.84] and 0.57 [95% CI, 0.46 to 0.66], respectively), based on similar sensitivities (0.27 [95% CI, 0.19 to 0.35] and 0.44 [95% CI, 0.35 to 0.53], respectively) and higher specificities (0.98 [95% CI, 0.91 to 1.0] and 1.0 [95% CI, 0.95 to 1.0], respectively).

Single-question screening. Five good-quality[39, 43-45, 47] and three fair-quality[52, 54, 55] studies evaluated the diagnostic accuracy of a single question regarding perceived hearing difficulties (e.g., "Do you have difficulty with your hearing?") for detection of hearing loss (**Table 3**, **Appendix B4**). For detection of >25 dB hearing loss, six studies reported a median sensitivity of 0.67 (range, 0.27 to 0.78) and median specificity of 0.80 (range, 0.67 to 0.89).[39, 43-45, 52, 54] A

positive response to a single question increased the likelihood of hearing loss (median PLR, 3.0 [range, 2.4 to 3.8]), though the usefulness of a negative response was variable (median NLR, 0.40 [range, 0.33 to 0.82]). For detection of >40 dB hearing loss, three good-quality studies reported a median sensitivity of 0.81 (range, 0.71 to 0.93) and median specificity of 0.72 (range, 0.56 to 0.74), resulting in a median PLR of 2.5 (range, 2.1 to 3.1) and median NLR of 0.26 (range, 0.13 to 0.41).[43, 45, 47] One fair-quality study of nursing home residents reported a weaker PLR (1.4 [95% CI, 1.1 to 1.8]) and similar NLR (0.61 [95% CI, 0.43 to 0.87]) compared with the other studies, which evaluated community-dwelling older adults.[55]

Screening questionnaires. Five good-quality[22, 44-47] and three fair-quality[9, 53, 56] studies evaluated the diagnostic accuracy of the HHIE-S screening questionnaire, and one fair-quality study evaluated the diagnostic accuracy of the 5-Minute Hearing Test[51] (**Table 4**, **Appendix B5**).

For detection of >25 dB hearing loss, four good-quality studies reported a median sensitivity for the HHIE-S (based on a cutoff score >8) of 0.58 (range, 0.32 to 0.66) and median specificity of 0.82 (range, 0.76 to 0.97), resulting in a median PLR of 3.5 (range, 2.4 to 11) and NLR of 0.52 (range, 0.43 to 0.70).[22, 44-46] One fair-quality study reported a somewhat lower PLR and similar NLR (2.3 and 0.38, respectively), but the reference standard was an audiologist recommendation for evaluation, rather than strictly results of pure-tone audiometry.[56] Studies on the accuracy of HHIE-S cutoff scores >8 for identification of >40 dB hearing loss reported slightly better sensitivity and slightly worse specificity compared with identification of >25 dB hearing loss, resulting in similar likelihood ratios (**Table 4**).[9, 22, 45-47] Changing the HHIE-S threshold from >8 to >24 increased the PLR for identification of >40 dB hearing loss (based on Ventry and Weinstein criteria) from 3.1 to 10 and increased the NLR from 0.37 to 0.77 in one good-quality study (due to decreased sensitivity but higher specificity),[46] but had little effect on likelihood ratio estimates for either >25 dB or >40 dB hearing loss in another good-quality study.[22]

One fair-quality study evaluated the accuracy of the 5-Minute Hearing Test for identification of >25 dB hearing loss at various cutoff scores.[51] Sensitivity ranged from 0.90 at a cutoff score of 10 to 0.26 at a cutoff score of 40, with specificities of 0.20 and 0.97, respectively, resulting in PLRs of 1.1 to 9.9 and NLRs of 0.47 to 0.76, depending on the cutoff score evaluated.

Handheld audiometric devices. Two good-quality[22, 46] and four fair-quality[40, 48-50] studies evaluated the diagnostic accuracy of the AudioScope handheld audiometric device for identification of hearing loss (**Table 5**, **Appendix B6**). The frequencies and intensities of the tones tested with the AudioScope varied across studies. For detection of >25 dB hearing loss, one good-quality study found that the AudioScope (based on ability to hear a 2000 Hz tone at 40 dB) was associated with a sensitivity of 0.64 (95% CI, 0.52 to 0.77) based on SFPTA criteria and 0.71 (95% CI, 0.63 to 0.80) based on HFPTA criteria, with specificities of 0.89 (95% CI, 0.83 to 0.94) and 0.91 (0.84 to 0.97), respectively.[22] Corresponding PLRs were 5.8 (95% CI, 3.4 to 9.8) and 7.5 (95% CI, 3.7 to 15), and NLRs were 0.40 and 0.32 (CIs not calculable).[22] For detection of >30 dB hearing loss, a fair-quality study found that the AudioScope (based on ability to hear 500, 1000, 2000, and 4000 Hz at 25 dB) was associated with a sensitivity of 0.93, specificity of 0.70, PLR of 3.1, and NLR of 0.10 (CIs not calculable).[48] For detection of >40 dB hearing loss, three studies of community-dwelling older adults found that the AudioScope (based on ability to hear tones between 500 and 4000 Hz at 40 dB) was associated with a median sensitivity of 0.96 (range, 0.94 to 1.0), median specificity of 0.72 (range, 0.42 to 0.80), median PLR of 3.4 (range,

1.7 to 4.9), and median NLR of 0.05 (range, 0.03 to 0.08).[22, 40, 46] A fair-quality study of older adult nursing home residents reported a very high sensitivity (0.98 [95% CI, 0.91 to 1.0]) but very low specificity (0.21 [95% CI, 0.08 to 0.41]) for identification of >40 dB hearing loss using the AudioScope (based on failure to hear 1000 or 2000 Hz in both ears), resulting in a much weaker PLR (1.3 [95% CI, 1.0 to 1.5]) but similar NLR (0.08 [95% CI, 0.01 to 0.61]) compared with results from the studies of community-dwelling older adults.[49]

Direct comparisons of different types of screening tests. Six good-quality studies directly compared the diagnostic accuracy of different screening tests for hearing loss in older adults.[22, 39, 44-47] One study found that the whispered voice test and single question screening were associated with similar PLRs (2.3 [95% CI, 1.3 to 3.8] and 2.5 [95% CI, 1.0 to 5.9], respectively) and NLRs (0.73 [95% CI, 0.61 to 0.87] and 0.82 [95% CI, 0.68 to 0.99], respectively), but the watch tick and finger rub tests were associated with substantially stronger PLRs (70 [range, 4.4 to 1120] and 10 [range, 2.6 to 43], respectively) and comparable NLRs (0.57 [95% CI, 0.49 to 0.66] and 0.75 [95% CI, 0.68 to 0.84], respectively).[39] Three studies showed a consistent trade-off between lower sensitivity and higher specificity for the HHIE-S compared with a single screening question, resulting in somewhat stronger PLRs and weaker NLRs.[39, 44, 45, 47] Two studies found that normal results on the AudioScope were generally associated with stronger NLRs (0.05 and 0.24) compared with the HHIE-S (0.37 and 0.76), with relatively small differences in PLR estimates, though likelihood ratio estimates varied depending on the HHIE-S cutoff score evaluated and the criteria used to define hearing loss.[22, 46]

Key Question 3. How Efficacious Is the Treatment of Screening-Detected Hearing Loss in Improving Health Outcomes?

Summary

Four RCTs evaluated benefits of amplification compared with no amplification for treatment of screening-detected hearing loss. One good-quality RCT found that immediate hearing aids were associated with near normalization of hearing-specific quality of life and communication difficulties in veterans with primarily screening-detected moderate to severe hearing loss, compared with essentially no changes in these outcomes in wait-list controls.[13] A smaller, fair-quality RCT found no clear difference between an assistive listening device and no treatment in veterans ineligible for free hearing aids with less severe hearing loss.[57] Another fair-quality RCT found no difference between a hearing aid, an assistive listening device, or both compared with no amplification in a subgroup of patients not using hearing aids at enrollment with mild baseline hearing loss and hearing-related handicap. A fourth RCT of hearing aids versus no hearing aids reported outcomes very poorly.

Evidence

We identified four RCTs on treatment for hearing loss in older adults (**Table 1**, **Appendixes B1** and **B2**).[13, 57-59] Two trials[13, 57] evaluated older male veterans and two[58, 59] evaluated community-

dwelling older adults. Numerous measures were used to assess both hearing-related and general quality of life and function (**Appendix C**).

One trial was rated good quality,[13] two were rated fair quality,[57, 58] and one was rated poor quality[59] (**Appendix B2**). Shortcomings of the fair-quality trials included potentially important baseline differences between groups and failure to describe intention-to-treat analysis,[57] and failure to describe randomization or allocation concealment methods or loss to follow-up.[58] The poor-quality trial did not describe allocation concealment, use of intention-to-treat analysis, or loss to follow-up, and reported outcomes incompletely.[59] All of the trials had characteristics which could limit generalizability to screening in typical primary care settings, including recruitment of mostly white male veterans,[13, 57] restriction to patients eligible for free hearing aids,[57] inclusion of patients referred for suspected hearing problems,[13] and inclusion of patients already using hearing aids.[58]

The good-quality RCT (n=194) randomly assigned veterans (mean age, 72 years) to immediate hearing aids or wait-list control for 4 months.[13] About two thirds of patients were recruited from a primary care setting based on a positive AudioScope screening for >40 dB hearing loss. The others were referred into the trial due to suspected hearing problems. The mean pure-tone threshold was 52 dB and similar among screening-detected and referred patients. The mean baseline HHIE score was about 50 (standard deviation [SD], 28), indicating severe (HHIE score >42) effects on hearing-related quality of life and function.[60] Hearing-related quality of life outcomes were measured using the HHIE and the Quantified Denver Scale of Communication Function (QDS). General quality of life was assessed with the Geriatric Depression Scale (GDS), a 0 to 15 scale, the Short Portable Mental Status Questionnaire (SPMSQ), a 0 to 10 scale, and the Self-Evaluation of Life Function (SELF), a 54 to 216 scale.

At 4 months there was no change from baseline in HHIE or QDS scores in the control group, but the hearing aid group HHIE score improved from a mean of 49 at baseline to 15 at 4 months, and the QDS score improved from 59 to 36. The mean between-group difference in change from baseline was 34 (95% CI, 27 to 41) on the HHIE and 24 (95% CI, 17 to 31) on the QDS. Results were similar in the subgroup of screening-detected patients. Greater improvements in HHIE scores were associated with increased hearing aid use (p=0.05), but not with changes in QDS scores. Statistically significant but small (<1 point) effects on GDS and SPMSQ scores were also observed in the hearing aid group compared with the control group. However, the potential for improvement may have been limited because the baseline scores indicated only mild baseline depression or cognitive dysfunction. In both groups, there were no significant differences from baseline in SELF scores. A follow-up study found that improvements in HHIE and QDS scores were sustained in the hearing aid group through 12 months, even though the proportion of patients that reported 4 hours or more of daily hearing aid use decreased from 90 to 76 percent between 4 and 12 months.[61]

A second, fair-quality trial (n=64) enrolled veterans (mean age, 68 years) with less severe (mean pure-tone threshold, 32 dB) hearing loss.[57] Patients eligible for free VA-issued hearing aids (n=30) were randomly assigned to a standard non-directional or programmable directional digital hearing aid. Patients ineligible for free hearing aids (n=30) were randomly assigned to an assistive listening device (an instrument used to pick up and amplify targeted sounds while

reducing background noise) or no treatment. Although this design resulted in essentially two separate randomized trials, the investigators analyzed results as a single, four-armed randomized trial. A revised (shortened) version of the QDS (Revised Quantified Denver Scale of Communication Function [RQDS]), a 1 to 5 scale,[62] the HHIE, and the Abbreviated Profile of Hearing Aid Benefit (APHAB), a 0-to-100 scale questionnaire designed to assess self-reported communication ability,[63] were used to assess hearing-specific quality of life. Baseline differences across the intervention groups in APHAB scores were statistically significant (range, 38 to 52; p=0.04). For baseline HHIE scores, differences across groups were not statistically significant, but ranged from moderate to severe and were likely to be clinically significant (range, 28 to 50).

At 3-month follow-up, there were trivial improvements from baseline on HHIE scores in the assistive listening device and no treatment groups (mean change of 4.4 and 2.2 points, respectively), but both types of hearing aids were associated with clinically significant improvements (mean change of 17 and 31 points in the standard and programmable hearing aid groups, respectively). Changes in APHAB scores were small in the assistive listening device and no treatment groups (mean change of 6.4 and 2.7 points, respectively), with no change in RQDS scores. Improvements in the APHAB score were larger in both hearing aid groups (mean change of 7.7 and 16 for standard and programmable hearing aids, respectively). Although both hearing aid groups experienced greater improvements in hearing-related outcomes compared with the no treatment and assistive listening device groups, there were baseline differences between groups. In addition, statistical significance was only reported for differences across all four groups, but such results are subject to additional confounding because patients were separately randomly assigned based on eligibility for free hearing aids.

In another fair-quality crossover trial (n=80), a subgroup of patients not using hearing aids at enrollment (mean pure-tone threshold hearing loss, 37 dB; mean HHIE score, 30) found no clear differences between hearing aids, an assistive listening device, or both compared with no amplification on HHIE scores and other measures of function or quality of life.[58] Improvements in HHIE scores for all four intervention groups were small and not clinically significant, ranging from 2.2 points in the no amplification group to 5.2 points in the hearing aid only group. A poor-quality trial (n=133) found that older adults randomly assigned to hearing aids did not experience improvement in GDS scores at 6 months, and did not report results in those randomly assigned to no hearing aids.[59]

Key Question 4. What Are the Adverse Effects of Screening for Hearing Loss in Adults Ages 50 Years and Older?

Summary

We identified no studies on harms associated with screening for hearing loss in older adults. Harms are unlikely to be greater than minimal because screening and confirmatory testing are non-invasive and treatment with hearing aids is not associated with significant harms.

Evidence

No randomized trials or controlled observational studies evaluated harms associated with screening for hearing loss in older adults. Because screening and confirmatory testing are non-invasive and hearing aid treatment is not known to be associated with major harms, it is unlikely that adverse effects of screening for hearing loss would be greater than minimal. It is possible that screening could be associated with anxiety, labeling, or other psychosocial effects, but no studies are available to estimate these outcomes.

Key Question 5. What Are the Adverse Effects of Treatment of Screening-Detected Hearing Loss in Adults Ages 50 Years and Older?

Summary

No randomized trials of hearing aids evaluated harms, and we identified no relevant controlled observational studies. However, serious harms appear to be rare.

Evidence

Hearing aids are non-invasive and generally believed to be safe, although potential harms include dermatitis, accidental retention of molds, cerumen impaction, otitis externa, or associated middle ear problems,[64-66] as well as psychosocial effects. Harms were not reported in any trials of hearing aids, and we identified no controlled observational studies on adverse effects associated with hearing aid use. Although it has been postulated that the amplification from hearing aids might lead to further deterioration in hearing, particularly in those with severe hearing loss because they require marked amplification, no study has addressed this issue.[67]

IV. DISCUSSION

Summary of Review Findings

Results of this evidence synthesis organized by KQ are summarized in **Table 7**.

SAI-WHAT is the only study that compared screening with no screening.[36] Although hearing aid use was higher after 1 year with screening, there was no difference in the likelihood of experiencing a clinically important improvement in hearing-related function. Interpretation of SAI-WHAT is critically dependent on whether hearing aid use is an acceptable surrogate marker for hearing-related quality of life and functional outcomes. Hearing aid use at 1 year was less than 10 percent in all arms of SAI-WHAT, and the trial was not powered to assess improvements in hearing-related function. Nonetheless, over one third of patients (screened or unscreened) in SAI-WHAT experienced a clinically significant improvement in hearing-related function, suggesting that factors other than hearing aid use may affect functional outcomes. SAI-WHAT also restricted enrollment to veterans eligible for free hearing aids, three quarters of whom reported perceived hearing loss. Therefore, results are likely to be most applicable to populations with a high prevalence of perceived hearing loss, in settings where treatment cost is not a barrier.

There is good evidence from 20 studies of diagnostic accuracy that common screening tests for hearing loss are useful for identifying patients at higher risk for hearing loss. One challenge in interpreting studies of diagnostic accuracy is that studies used different thresholds and criteria to define hearing loss. The clinical relevance of detection of mild (25 to 40 dB) hearing loss as it pertains to effectiveness of screening is also uncertain, as the only trial showing benefits of hearing aids enrolled patients with screening-detected >40 dB hearing loss.[13] Relatively simple tests, such as the whispered voice at 2 feet and a single question regarding perceived hearing loss, appear to be nearly as accurate compared with a more detailed hearing loss questionnaire or a handheld audiometric device for detecting hearing loss. A negative screening result based on a handheld audiometric device may be particularly useful for ruling out >40 dB hearing loss. Choices regarding which screening test to use may also depend in part on factors other than diagnostic accuracy, such as cost or convenience. For the whisper test, an important consideration is the need for clinicians to administer the test in a standardized and consistent fashion (such as the method described in published studies of diagnostic accuracy).[39] Although the finger rub and watch tick tests may be easier to standardize, more studies are needed to clarify their diagnostic accuracy, as both were only evaluated in one study.[39]

Our conclusions regarding diagnostic accuracy are generally in accord with another recently published systematic review.[8] That systematic review estimated stronger likelihood ratios for the whispered voice test, largely because it was conducted before the publication of a recent, good-quality study[39] that reported substantially weaker estimates. The other review also pooled likelihood ratio estimates, included studies[2, 68, 69] that analyzed the same populations reported in other studies,[42, 44] included studies less applicable to U.S. primary care settings (e.g., studies of nursing home patients in Lebanon or Singapore),[70, 71] and did not include studies that we deemed relevant.[47, 52] For the whispered voice test, the other review calculated a pooled PLR of 6.1 (95% CI, 4.5 to 8.4) and NLR of 0.03 (95% CI, 0 to 0.24); for the single question screening, a pooled

PLR of 2.5 (95% CI, 1.7 to 3.6) and NLR of 0.13 (95% CI, 0.09 to 0.19); for the HHIE-S (with a cutoff score >8), a pooled PLR of 3.8 (95% CI, 3.0 to 4.8) and NLR of 0.38 (95% CI, 0.29 to 0.51); and for the AudioScope, a pooled PLR of 2.4 (95% CI, 1.4 to 4.1) and NLR of 0.07 (95% CI, 0.03 to 0.17).[8]

Evidence on the efficacy of treatments for screening-detected hearing loss is limited. One good-quality RCT found that hearing aids resulted in near normalization of hearing-related quality of life and function in a subgroup of patients identified by screening, based on >40 dB hearing loss using a handheld audiometric device.[13, 61] Because this trial was conducted in a VA center and almost exclusively enrolled white males, its generalizability to other settings may be limited. Two fair-quality RCTs found no clear differences in hearing-related quality of life or function between amplification and no treatment in patients with milder baseline hearing loss.[57, 58]

We did not find direct evidence on harms of screening or treatments with hearing aids. In community-based and primary care populations, rates of false-positive results from screening for >25 dB hearing loss ranged from 5 to 41 percent,[43-47] depending on the screening test and population evaluated. However, harms of screening are likely to be minimal because screening is non-invasive, the reference standard (audiometric testing) is also non-invasive, and treatment with hearing aids is not known to be associated with serious adverse events. No study has validated the hypothesis that hearing aid use might lead to further hearing deterioration in those with severe to profound hearing loss because of the increased amplification required (the intensity level of sound rises by a factor of 10 for each additional decibel of amplification).[67]

Contextual Issues

Several contextual issues could help inform the interpretation of the findings of this evidence review.

Does Adherence to Hearing Aid Use Improve Health Outcomes in Screened Asymptomatic Adults Who Are Prescribed Hearing Aids?

Older adults with hearing loss may not adhere to hearing aid use for cosmetic or psychosocial reasons, because of difficulty using the hearing aids, discomfort, cost, or perceived lack of benefit. In large population-based cohort studies, among the approximately one-third of older adults with hearing loss who had ever used hearing aids, 20 to 30 percent were no longer using them.[1, 3] Despite the high rate of non-use or non-adherence to hearing aids, evidence showing that increased adherence improves health outcomes is limited. In one randomized trial, more hours per day of hearing aid use was positively correlated with greater improvements in HHIE (but not QDS) scores.[13]

Are There Characteristics That Can Predict Adherence to Hearing Aid Use Among Screened Populations?

Several observational studies have attempted to identify factors that predict adherence to hearing aid use. The large (n=1629) Beaver Dam population-based cohort study probably provides the best evidence.[25] It found that among older adults (84 percent ages 60–92 years) who had ever had a hearing aid, factors associated with adherence were older age (age vs. age plus 5 years: adjusted OR, 1.2 [95% CI, 1.1 to 1.3]), more severe hearing loss (moderate loss vs. mild loss: adjusted OR, 5.0 [95% CI, 3.0 to 8.6]), better education (≥16 years of education vs. <12 years of education: adjusted OR, 3.2 [95% CI, 1.7 to 6.1]), lower word recognition scores (<80 vs. ≥90 percent: adjusted OR, 2.7 [95% CI, 1.6 to 4.4]), worse HHIE scores (>26 vs. 0: adjusted OR, 7.8 [95% CI, 3.1 to 19]), and self-reported hearing loss (presence vs. absence of self-reported loss: adjusted OR, 4.9 [95% CI, 2.0 to 12]). A smaller (n=131) observational study found non-statistically significant trends toward greater adherence among college-educated women with a higher income (>$40,000 per year) compared with women without a college education and/or lower income,[73] though these factors did not predict adherence in men. A long-term retrospective cohort study found that among 116 participants who received hearing aids, 43 percent were still using their hearing aids 12 years later.[74] Presence of hearing loss in the better ear (dB vs. dB plus 10: OR, 2.4 [95% CI, 1.4 to 3.8]) and presence of moderately severe tinnitus (presence vs. absence of moderately severe tinnitus: OR, 4.6 [95% CI, 1.6 to 13]) predicted adherence.

Are There Treatments or Other Behavioral Interventions in Addition to Hearing Aid Use That Improve Health Outcomes in Adults With Hearing Loss?

We identified no studies on the effectiveness of behavioral interventions in addition to or instead of hearing aids to help patients cope with or manage hearing loss.

Limitations

Our evidence review has some potential limitations. First, evidence was very limited for benefits and harms of screening and treatments for hearing loss, making it difficult to reach strong conclusions. Second, we excluded non-English language studies, which could introduce language bias, though we identified no relevant non-English language studies in literature searches or when searching reference lists. Third, a number of studies evaluated diagnostic accuracy of screening tests or programs in high-prevalence populations recruited from specialty settings, which could limit the generalizability to primary care settings. Finally, we did not attempt to construct outcomes tables due to the lack of sufficient direct or indirect evidence to reliably estimate benefits and harms.

Emerging Issues

We found no ongoing trials of screening for hearing loss or trials of hearing aids versus no treatment in searches of www.clinicaltrials.gov or the Computer Retrieval of Information on Scientific Projects database of federally funded research. One trial on effectiveness of group versus individual fitting of hearing aids and group versus individualized follow-up has completed recruitment and reported baseline characteristics of participants, but results are not yet available.[75]

Future Research

Further research is needed to understand the potential benefits of screening and treatment for hearing loss in older individuals. Additional research is needed on the effectiveness of screening in typical primary care settings, the optimal age at which to start screening, and the severity of hearing loss that is likely to benefit from hearing aids, in order to help define optimal screening test thresholds and methods. In addition, RCTs to test the efficacy of hearing aids (including more effective or usable designs) or other interventions in improving health, function, and quality of life outcomes should be carried out in patients with screening-detected hearing loss who are representative of those seen in typical primary care settings. Particular efforts should be made to enroll patients with comorbid clinical conditions such as depression or cognitive dysfunction that may be associated with or exacerbated by hearing loss.[13] Because effectiveness of any hearing screening strategy will depend on how likely those who might benefit from hearing aids are to actually use them, research is needed on effective methods for enhancing follow-up rates and uptake of recommended treatment following screening.

Conclusions

Additional research is needed to understand effects on health outcomes of screening adults ages 50 years and older for hearing loss compared with no screening, and to confirm benefits of treatment under conditions likely to be encountered in most primary care settings.

References

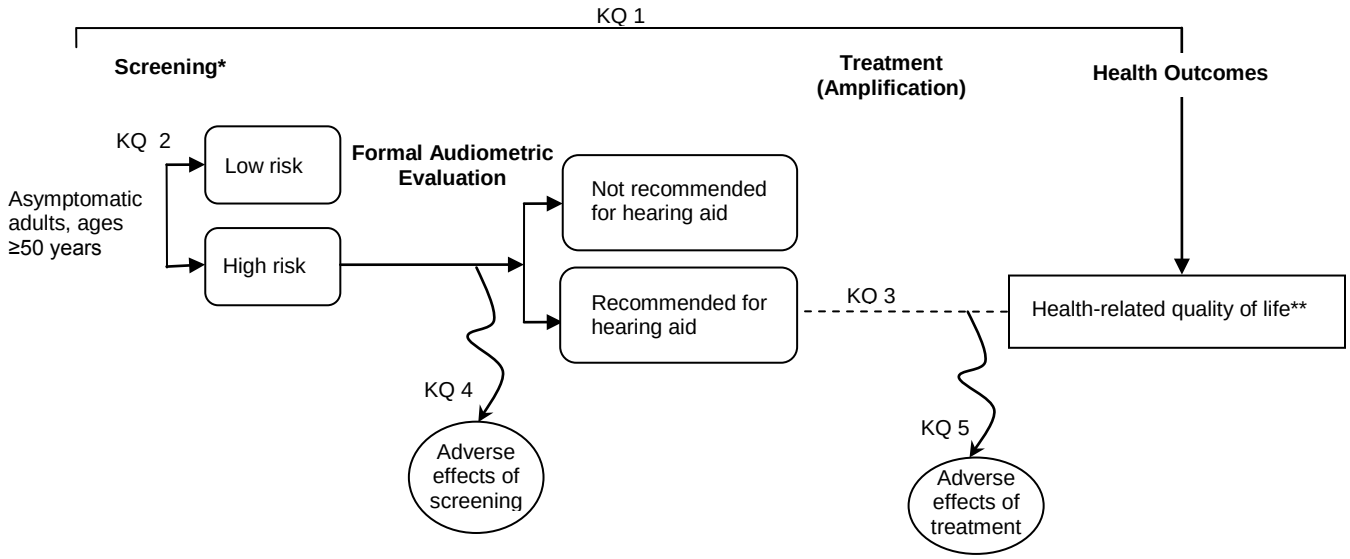
1. Cruickshanks KJ, Wiley TL, Tweed TS, et al. Prevalence of hearing loss in older adults in Beaver Dam, Wisconsin. The Epidemiology of Hearing Loss Study. *Am J Epidemiol.* 1998;148(9):879-886.
2. Dalton DS, Cruickshanks KJ, Klein BE, Klein R, Wiley TL, Nondahl DM. The impact of hearing loss on quality of life in older adults. *Gerontologist.* 2003;43(5):661-668.
3. Gates GA, Cooper JC Jr, Kannel WB, Miller NJ. Hearing in the elderly: the Framingham cohort, 1983–1985, part I: basic audiometric test results. *Ear Hear.* 1990;11(4):247-256.
4. Reuben DB, Walsh K, Moore AA, Damesyn M, Greendale GA. Hearing loss in community-dwelling older persons: national prevalence data and identification using simple questions. *J Am Geriatr Soc.* 1998;46(8):1008-1011.
5. Wallhagen MI, Strawbridge WJ, Cohen RD, Kaplan GA. An increasing prevalence of hearing impairment and associated risk factors over three decades of the Alameda County Study. *Am J Public Health.* 1997;87(3):440-442.
6. U.S. Preventive Services Task Force. Screening for hearing impairment in older adults. In *Guide to Clinical Preventive Services*. 2nd ed. Washington, DC: Department of Health and Human Services; 1996: pp 393-405.
7. Yueh B, Shapiro N, MacLean CH, Shekelle PG. Screening and management of adult hearing loss in primary care: scientific review. *JAMA.* 2003;289(15):1976-1985.
8. Bagai A, Thavendiranathan P, Detsky A. Does this patient have hearing impairment? *JAMA.* 2006;295(4):416-428.
9. Ventry IM, Weinstein BE. Identification of elderly people with hearing problems. *ASHA.* 1983;25(7):37-42.
10. Clark JG. Uses and abuses of hearing loss classification. *ASHA.* 1984;23:493-500.
11. Goldstein D. Hearing impairment, hearing aids and audiology. *ASHA.* 1984;26:24-35.
12. Gates GA, Mills JH. Presbycusis. *Lancet.* 2005;366(9491):1111-1120.
13. Mulrow CD, Aguilar C, Endicott JE, et al. Quality-of-life changes and hearing impairment: a randomized trial. *Ann Intern Med.* 1990;113(3):188-194.
14. Weinstein BE, Ventry IM. Hearing impairment and social isolation in the elderly. *J Speech Hear Res.* 1982;25(4):593-599.
15. Carabellese C, Appollonio I, Rozzini R, et al. Sensory impairment and quality of life in a community elderly population. *J Am Geriatr Soc.* 1993;41(4):401-407.
16. Mulrow CD, Lichtenstein MJ. Screening for hearing impairment in the elderly: rationale and strategy. *J Gen Int Med.* 1991;6(3):249-258.
17. McMahon CM, Kifley A, Rochtchina E, Newall P, Mitchell P. The contribution of family history to hearing loss in an older population. *Ear Hear.* 2008;29(4):578-584.
18. Brant LJ, Gordon-Salant S, Pearson JD, et al. Risk factors related to age-associated hearing loss in the speech frequencies. *J Am Acad Audiol.* 1996;7(3):152-160.
19. Cruickshanks KJ, Klein R, Klein BE, Wiley TL, Nondahl DM, Tweed TS. Cigarette smoking and hearing loss: the epidemiology of hearing loss study. *JAMA.* 1998;279(21):1715-1719.
20. Cruickshanks KJ, Tweed TS, Wiley TL, et al. The 5-year incidence and progression of hearing loss: the epidemiology of hearing loss study. *Arch Otolaryngol Head Neck Surg.* 2003;129(10):1041-1046.

21. Agrawal Y, Platz EA, Niparko JK. Prevalence of hearing loss and differences by demographic characteristics among US adults: data from the National Health and Nutrition Examination Survey, 1999–2004. *Arch Intern Med.* 2008;168(14):1522-1530.
22. McBride WS, Mulrow CD, Aguilar C, Tuley MR. Methods for screening for hearing loss in older adults. *Am J Med Sci.* 1994;307(1):40-42.
23. Cook JA, Hawkins DB. Hearing loss and hearing aid treatment options. *Mayo Clin Proc.* 2006;81(2):234-237.
24. Gussekloo J, de Bont LE, von Faber M, et al. Auditory rehabilitation of older people from the general population—the Leiden 85-plus study. *Br J Gen Pract.* 2003;53(492):536-540.
25. Popelka MM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein BE, Klein R. Low prevalence of hearing aid use among older adults with hearing loss: the Epidemiology of Hearing Loss Study. *J Am Geriatr Soc.* 1998;46(9):1075-1078.
26. Bogardus ST Jr, Yueh B, Shekelle PG. Screening and management of adult hearing loss in primary care: clinical applications. *JAMA.* 2003;289(15):1986-1990.
27. Danhauer JL, Celani KE, Johnson CE. Use of a hearing and balance screening survey with local primary care physicians. *Am J Audiol.* 2008;17(1):3-13.
28. Cohen SM, Labadie RF, Haynes DS. Primary care approach to hearing loss: the hidden disability. *Ear Nose Throat J.* 2005;84(1):26-31.
29. Johnson CE, Danhauer JL, Koch LL, Celani KE, Lopez IP, Williams VA. Hearing and balance screening and referrals for Medicare patients: a national survey of primary care physicians. *J Am Acad Audiol.* 2008;19(2):171-190.
30. American Speech-Language-Hearing Association. Hearing Screening and Testing. Rockville, MD: American Speech-Language-Hearing Association; 2011. Accessed at http://www.asha.org/public/hearing/Hearing-Testing/ on 8 February 2011.
31. American Academy of Family Physicians. Recommendations for Clinical Preventive Services: Hearing Difficulties. Leawood, KS: American Academy of Family Physicians; 1996. Accessed at http://www.aafp.org/online/en/home/clinical/exam/f-j.html on 8 February 2011.
32. American Academy of Audiology. Hearing Impairment in Aged People: Report of the Task Force on Hearing Impairment in Aged People. Reston, VA: American Academy of Audiology; 2011. Accessed at http://www.audiology.org/resources/documentlibrary/Pages/HearingImpairmentinAgedPeople.aspx on 8 February 2011.
33. Canadian Task Force on Preventive Health Care. Prevention of Hearing Impairment and Disability in the Elderly. Ottawa, ON: Canadian Task Force on Preventive Health Care; 1994. Accessed at http://www.canadiantaskforce.ca/_archive/index.html on 8 February 2011.
34. Harris RP, Helfand M, Woolf SH, et al. Current methods of the U.S. Preventive Services Task Force: a review of the process. *Am J Prev Med.* 2001;20(3 Suppl):21-35.
35. Leeflang MM, Deeks JJ, Gatsonis C, Bossuyt PM; Cochrane Diagnostic Test Accuracy Working Group. Systematic reviews of diagnostic test accuracy. *Ann Intern Med.* 2008;149:889-897.
36. Yueh B, Collins MP, Souza PE, et al. Long-term effectiveness of screening for hearing loss: the Screening for Auditory Impairment—Which Hearing Assessment Test (SAI-WHAT) randomized trial. *J Am Geriatr Soc.* 2010;58:427-434.

37. Yueh B, Collins M, Souza P, Heagerty P, Loovis C, Hedrick S. Long-term effectiveness in a randomized trial of hearing loss screening. *AAS Bulletin.* 2005;30:31-32.
38. Yueh B, Collins MP, Souza PE, et al. Screening for Auditory Impairment—Which Hearing Assessment Test (SAI-WHAT): RCT design and baseline characteristics. *Contemp Clin Trials.* 2007;28(3):303-315.
39. Boatman DF, Miglioretti DL, Eberwein C, Alidoost M, Reich SG. How accurate are bedside hearing tests? *Neurology.* 2007;68(16):1311-1314.
40. Eekhof JA, de Bock GH, de Laat JA, Dap R, Schaapveld K, Springer MP. The whispered voice: the best test for screening for hearing impairment in general practice? *Br J Gen Pract.* 1996;46(409):473-474.
41. Macphee GJ, Crowther JA, McAlpine CH. A simple screening test for hearing impairment in elderly patients. *Age Ageing.* 1988;17(5):347-351.
42. Swan IR, Browning GG. The whispered voice as a screening test for hearing impairment. *J R Coll Gen Pract.* 1985;35(273):197.
43. Clark K, Sowers M, Wallace RB, Anderson C. The accuracy of self-reported hearing loss in women aged 60–85 years. *Am J Epidemiol.* 1991;134(7):704-708.
44. Nondahl DM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein R, Klein BE. Accuracy of self-reported hearing loss. *Audiology.* 1998;37(5):295-301.
45. Sindhusake D, Mitchell P, Smith W, et al. Validation of self-reported hearing loss: the Blue Mountains Hearing Study. *Int J Epidemiol.* 2001;30(6):1371-1378.
46. Lichtenstein MJ, Bess FH, Logan SA. Validation of screening tools for identifying hearing-impaired elderly in primary care. *JAMA.* 1988;259(19):2875-2878.
47. Gates GA, Murphy M, Rees TS, Fraher A. Screening for handicapping hearing loss in the elderly. *J Fam Pract.* 2003;52(1):56-62.
48. Bienvenue GR, Michael PL, Chaffinch JC, Zeigler J. The AudioScope: a clinical tool for otoscopic and audiometric examination. *Ear Hear.* 1985;6(5):251-254.
49. Ciurlia-Guy E, Cashman M, Lewsen B. Identifying hearing loss and hearing handicap among chronic care elderly people. *Gerontologist.* 1993;33(5):644-649.
50. Frank T, Petersen DR. Accuracy of a 40 dB HL Audioscope and audiometer screening for adults. *Ear Hear.* 1987;8(3):180-183.
51. Koike KJ, Hurst MK, Wetmore SJ. Correlation between the American Academy of Otolaryngology-Head and Neck Surgery five-minute hearing test and standard audiologic data. *Otolaryngol Head Neck Surg.* 1994;111(5):625-632.
52. Rawool V, Keihl J. Perception of hearing status, communication, and hearing aids among socially active older individuals. *J Otolaryngol.* 2008;37(1):27-42.
53. Sever JC Jr, Harry DA, Rittenhouse TS. Using a self-assessment questionnaire to identify probable hearing loss among older adults. *Percept Mot Skills.* 1989;69(2):511-514.
54. Torre P, Moyer CJ, Haro NR. The accuracy of self-reported hearing loss in older Latino-American adults. *Int J Audiol.* 2006;45(10):559-562.
55. Voeks SK, Gallagher CM, Langer EH, Drinka PJ. Self-reported hearing difficulty and audiometric thresholds in nursing home residents. *J Fam Pract.* 1993;36(1):54-58.
56. Weinstein BE. Validity of a screening protocol for identifying elderly people with hearing problems. *ASHA.* 1986;28(5):41-45.
57. Yueh B, Souza PE, McDowell JA, et al. Randomized trial of amplification strategies. *Arch Otolaryngol Head Neck Surg.* 2001;127(10):1197-1204.

58. Jerger J, Chmiel R, Florin E, Pirozzolo F, Wilson N. Comparison of conventional amplification and an assistive listening device in elderly persons. *Ear Hear.* 1996;17(6):490-504.
59. Tolson D, Swan I, Knussen C. Hearing disability: a source of distress for older people and carers. *Br J Nurs.* 2002;11(15):1021-1025.
60. Ventry IM, Weinstein BE. The hearing handicap inventory for the elderly: a new tool. *Ear Hear.* 1982;3(3):128-134.
61. Mulrow CD, Tuley MR, Aguilar C. Sustained benefits of hearing aids. *J Speech Hear Res.* 1992;35(6):1402-1405.
62. Tuley MR, Mulrow CD, Aguilar C, Velez R. A critical reevaluation of the Quantified Denver Scale of Communication Function. *Ear Hear.* 1990;11(1):56-61.
63. Cox RM, Alexander GC. The abbreviated profile of hearing aid benefit. *Ear Hear.* 1995;16(2):176-186.
64. Kohan D, Sorin A, Marra S, Gottlieb M, Hoffman R. Surgical management of complications after hearing aid fitting. *Laryngoscope.* 2004;114(2):317-322.
65. Sood A, Taylor JS. Allergic contact dermatitis from hearing aid materials. *Dermatitis.* 2004;15(1):48-50.
66. Lear JT, Sandhu G, English JS. Hearing aid dermatitis: a study in 20 consecutive patients. *Contact Dermatitis.* 1998;38(4):212.
67. Macrae JH. Prediction of deterioration in hearing due to hearing aid use. *J Speech Hear Res.* 1991;34(3):661-670.
68. Browning GG, Swan IR, Chew KK. Clinical role of informal tests of hearing. *J Laryngol Otol.* 1989;103(1):7-11.
69. Wiley TL, Cruickshanks KJ, Nondahl DM, Tweed TS. Self-reported hearing handicap and audiometric measures in older adults. *J Am Acad Audiol.* 2000;11(2):67-75.
70. Abyad A. Screening for hearing loss in the elderly. *Geriatrics Today.* 2004;7(2):43-45.
71. Wu HY, Chin JJ, Tong HM. Screening for hearing impairment in a cohort of elderly patients attending a hospital geriatric medicine service. *Singapore Med J.* 2004;45(2):79-84.
72. Leong ST, Laortanakul P. Monitoring and assessment of daily exposure of roadside workers to traffic noise levels in an Asian city: a case study of Bangkok streets. *Environ Monit Assess.* 2003;85(1):69-85.
73. Garstecki DC, Erler SF. Hearing loss, control, and demographic factors influencing hearing aid use among older adults. *J Speech Lang Hear Res.* 1998;41(3):527-537.
74. Davis A, Smith P, Ferguson M, Stephens D, Gianopoulos I. Acceptability, benefit and costs of early screening for hearing disability: a study of potential screening tests and models. *Health Technol Assess*. 2007;11(42):1-294.
75. Collins MP, Souza PE, Liu CF, Heagerty PJ, Amtmann D, Yueh B. Hearing aid effectiveness after aural rehabilitation–individual versus group (HEARING) trial: RCT design and baseline characteristics. *BMC Health Serv Res.* 2009;9:233.

Figure 1. Analytic Framework and Key Questions



*In primary care applicable settings.

**Such as emotional and social function, communication, and cognitive function. Does not include outcomes related to hearing aid performance and efficacy, such as speech intelligibility and quality of the listening experience.

Key Questions

KQ 1. Does screening for hearing loss in asymptomatic adults ages 50 years and older lead to improved health outcomes?

KQ 2. How accurate are the methods for hearing loss screening in older adults?

KQ 3. How efficacious is the treatment of screening-detected hearing loss in improving health outcomes?

KQ 4. What are the adverse effects of screening for hearing loss in adults ages 50 years and older?

KQ 5. What are the adverse effects of treatment of screening-detected hearing loss in adults ages 50 years and older?

Contextual Questions

1. Does adherence to hearing aid use improve health outcomes in screened asymptomatic adults who are prescribed hearing aids?
2. Are there characteristics that can predict adherence to hearing aid use among screened populations?
3. Are there treatments or other behavioral interventions in addition to hearing aid use that improve health outcomes in adults with hearing loss?

Table 1. Randomized Controlled Trials of Screening and Treatment

Study, year	Country & Setting	Population	Main outcomes	Quality score
Screening				
Yueh et al, 2010[36]	US VA primary care clinics	Mean age: 61 years Sex: 94% male Mean baseline hearing loss: NR	Screening with AudioScope vs. HHIE-S questionnaire vs. both vs. no screening, results at 1 year Hearing aid use: 6.3% vs. 4.1% vs. 7.4% vs. 3.3% (p=0.003) ≥6-point improvement on the Inner Effectiveness of Aural Rehabilitation Scale: 40% vs. 36% vs. 40% vs. 36% (p=0.39)	Fair
Treatment				
Jerger et al, 1996[58]	US Setting not reported	Mean age: 74 years Sex: 63% male Mean pure-tone threshold: 37 dB* Mean baseline HHIE-S score: 30	Hearing aid vs. assistive listening device vs. both vs. no amplification, mean score at 6 weeks HHIE-S: 25 vs. 27 vs. 26 vs. 28 (p>0.05 for any intervention vs. no amplification) Speech perception in noise: 53% vs. 75% vs. 71% vs. 42% (p<0.05 for any intervention vs. no amplification) Brief Symptom Inventory, Activity Scale, Life Satisfaction in the Elderly Scale, Affect Balance Scale: no differences between interventions (data NR)	Fair
Mulrow et al, 1990[13]	US VA primary care clinic	Mean age: 72 years Sex: 99% male Race: 97% white Mean pure-tone threshold, better ear: 52 dB* Mean baseline HHIE-S score: 50	Immediate hearing aid vs. wait list, mean score at 4 months (mean difference in change from baseline) HHIE-S: 15 vs. 51 (34 [95% CI, 27 to 41]; p<0.001) Quantified Denver Scale: 36 vs. 62 (24 [95% CI, 17 to 31]; p<0.001) Short Portable Mental Status Questionnaire: 0.29 vs. 0.28 (0.28 [95% CI, 0.08 to 0.48]; p=0.008) Geriatric Depression Scale: 2.6 vs. 3.8 (0.80 [95% CI, 0.09 to 1.5]; p=0.03) Self Evaluation of Life Function: 92 vs. 97 (1.9 [95% CI, -1.6 to 5.4]; p=0.27)	Good
Tolson et al, 2002[59]	UK General practice clinic attendees	Mean age: 77 years Sex: 23% male Other baseline characteristics: NR	Hearing aid vs. no hearing aid, results at 6 months Data for Mini Mental State Examination, Geriatric Depression Scale, Malaise Inventory (caregiver), Family Relationship Index, and 14-item caregiver's assessment of hearing difficulties NR; authors state “depression scores were unchanged at 6-month follow-up” in the intervention group	Poor
Yueh et al, 2001[57]	US VA audiology clinic	Mean age: 68 years Sex: 100% male Race: NR Mean pure-tone threshold, right ear: 33 dB Mean pure-tone threshold, left ear: 32 dB Mean baseline HHIE-S score: 28 vs. 35 (assistive listening device vs. no treatment); 50 vs. 36 (programmable vs. standard hearing aid)	Assistive listening device vs. no treatment, mean change from baseline at 3 months HHIE-S: 4.4 vs. 2.2 Abbreviated Profile of Hearing Aid Benefit: 6.4 vs. 2.7 Revised Quantified Denver Scale: 0.03 vs. -0.05 Proportion reporting less social isolation: 0/15 (0%) vs. 0/15 (0%) Programmable hearing aid vs. standard hearing aid, mean change from baseline at 3 months HHIE-S: 31 vs. 17 (p<0.05) Abbreviated Profile of Hearing Aid Benefit: 16 vs. 7.7 Revised Quantified Denver Scale: 0.84 vs. 0.70 Proportion reporting less social isolation: 10/16 (62%) vs 2/14 (14%)	Fair

* Average of 1000, 2000, and 4000 Hz hearing levels.

Abbreviations: CI = confidence interval; HHIE-S = Hearing Handicap Inventory for the Elderly-Screening; NR = not reported; UK = United Kingdom; US = United States; VA = Veterans Administration.

Table 2. Whispered Voice, Watch Tick, and Finger Rub Clinical Tests

Study, Year	Screening test, Definition of a positive screening exam	Definition of a case	Sensitivity (range)	Specificity (range)	Positive likelihood ratio (95% CI)	Negative likelihood ratio (95% CI)	Diagnostic odds ratio (95% CI)	Quality score
Boatman et al, 2007[39]	Whispered voice at 2 feet Inability to repeat two or more words from two 3-word combinations	>25 dB hearing loss at 500, 1000, and 2000 Hz	0.40 (0.32-0.49)	0.82 (0.72-0.90)	2.3 (1.3-3.8)	0.73 (0.61-0.87)	3.1 (1.5-6.6)	Good
Eekhof et al, 1996[40]	Whispered voice at 2 feet Inability to repeat two or more combinations correctly	>30 dB hearing loss in either ear (frequency NR)	0.90 (0.81-0.96)	0.80 (0.67-0.90)	4.6 (2.6-8.1)	0.12 (0.06-0.24)	39 (12-130)	Fair
Macphee et al, 1988[41]	Whispered voice at 2 feet Inability to repeat one triplet set of numbers correctly or 50% of four sets of triplet numbers	>30 dB hearing loss at 500, 1000, and 2000 Hz	1.0 (0.95-1.0)	0.83 (0.70-0.93)	5.7 (3.1-11)	0.008 (0.0005-0.13)	730 (41-12,950)	Fair
Swan et al, 1985[42]	Whispered voice at 2 feet Unable to repeat at least three out of six letters or numerals correctly	>30 dB hearing loss at 500, 1000, and 2000 Hz	1.0 (0.96-1.0)	0.87 (0.79-0.93)	7.4 (4.7-12)	0.007 (0.0005-0.10)	1140 (70-19,240)	Fair
		Total	**0.95 (0.40-1.0)**	**0.82 (0.80-0.87)**	**5.1 (2.3-7.4)**	**0.03 (0.007-0.73)**	--	--
Macphee et al, 1988[41]	Whispered voice at 6 inches Inability to repeat one triplet set of numbers correctly or 50% of four sets of triplet numbers	>30 dB hearing loss at 500, 1000, and 2000 Hz	0.74 (0.62-0.83)	1.0 (0.93-1.0)	72 (4.6-1140)	0.27 (0.19-0.39)	270 (16-4540)	Fair
Macphee et al, 1988[41]	Conversation voice at 2 feet Inability to repeat one triplet set of numbers correctly or 50% of four sets of triplet numbers	>30 dB hearing loss at 500, 1000, and 2000 Hz	0.47 (0.36-0.59)	1.0 (0.93-1.0)	46 (2.9-740)	0.53 (0.43-0.66)	87 (5.2-1470)	Fair
Boatman et al, 2007[39]	Watch tick at 6 inches No response to two or more of six presentations of watch tick	>25 dB hearing loss at 500, 1000, and 2000 Hz	0.44 (0.35-0.53)	1.0 (0.95-1.0)	70 (4.4-1120)	0.57 (0.49-0.66)	120 (7.5-2040)	Good
Boatman et al, 2007[39]	Finger rub at 6 inches No response to two or more of six finger rubs	>25 dB hearing loss at 500, 1000, and 2000 Hz	0.27 (0.19-0.35)	0.98 (0.91-1.0)	10 (2.6-43)	0.75 (0.68-0.84)	14 (3.4-120)	Good

Abbreviations: CI = confidence interval; NR = not reported.

Table 3. Single Screening Question

Study, Year	Screening question	Definition of a case	Sensitivity (range)	Specificity (range)	Positive likelihood ratio (95% CI)	Negative likelihood ratio (95% CI)	Diagnostic odds ratio (95% CI)	Quality score
Community-dwelling older adults								
Boatman et al, 2007[39]	Do you think you have difficulty hearing?	>25 dB hearing loss at 500, 1000, 2000, or 4000 Hz in either ear	0.27 (0.16-0.41)	0.89 (0.78-0.96)	2.5 (1.0-5.9)	0.82 (0.68-0.99)	3.0 (0.96-10)	Good
Clark et al, 1991[43]	Would you say that you have any difficulty hearing?	≥25 dB hearing loss at 1000 and 2000 Hz in better ear	0.66 (0.55-0.75)*	0.80 (0.74-0.86)*	3.3 (2.4-4.6)*	0.43 (0.32-0.58)*	7.7 (4.2-14)*	Good
Clark et al, 1991[43]	Would you say that you have any difficulty hearing?	≥25 dB hearing loss at 1000, 2000, 3000, and 4000 Hz in better ear	0.56 (0.47-0.65)	0.82 (0.75-0.88)	3.1 (2.1-4.5)	0.53 (0.43-0.67)	5.8 (3.2-10)	Good
Nondahl et al, 1998[44]; Wiley et al, 2000[69]	Do you feel you have hearing loss?	>25 dB hearing loss at 500, 1000, 2000, and 4000 Hz in either ear	0.67 (0.64-0.70)	0.80 (0.77-0.83)	3.4 (2.8-4.0)	0.41 (0.38-0.45)	8.1 (6.4-10)	Good
Rawool et al, 2008[52]	Do you think you have hearing loss?	≥25 dB hearing loss at 500, 1000, 2000, 3000, and 4000 Hz in better ear	0.68 (0.43-0.87)	0.81 (0.48-0.98)	3.8 (1.0-13.7)	0.39 (0.19-0.79)	9.8 (1.3-110)	Fair
Sindhusake et al, 2001[45]	Do you feel you have hearing loss?	>25 dB hearing loss at 500-4000 Hz	0.78 (0.75-0.81)	0.67 (0.64-0.70)	2.4 (2.2-2.6)	0.33 (0.29-0.38)	7.2 (5.8-8.9)	Good
Torre et al, 2006[54]	Do you feel you have hearing loss? (English and Spanish)	≥25 dB hearing loss at 500, 1000, 2000, and 4000 Hz in worse ear	0.76 (0.59-0.88)	0.73 (0.50-0.89)	2.8 (1.4-5.6)	0.33 (0.18-0.62)	8.3 (2.2-33)	Fair
		Total	**0.67 (0.27-0.78)**	**0.80 (0.67-0.89)**	**3.0 (2.4-3.8)**	**0.40 (0.33-0.82)**	**--**	--
Clark et al, 1991[43]	Would you say that you have any difficulty hearing?	>40 dB hearing loss at 1000 and 2000 Hz in worse ear	0.81 (0.67-0.91)	0.74 (0.68-0.80)	3.1 (2.4-4.1)	0.26 (0.14-0.47)	12 (5.3-30)	Good
Gates et al, 2003[47]	Do you have a hearing problem now?	>40 dB hearing loss at 1000 or 2000 Hz in both ears or >40 dB hearing loss at 1000 and 2000 Hz in one ear	0.71 (0.63-0.78)	0.72 (0.67-0.76)	2.5 (2.1-3.0)	0.41 (0.31-0.53)	6.2 (4.0-9.6)	Good
Sindhusake et al, 2001[45]	Do you feel you have hearing loss?	>40 dB hearing loss at 500-4000 Hz	0.93 (0.89-0.96)	0.56 (0.54-0.58)	2.1 (2.0-2.3)	0.13 (0.08-0.20)	17 (10-28)	Good
		Total	**0.81 (0.71-0.93)**	**0.72 (0.56-0.74)**	**2.5 (2.1-3.1)**	**0.26 (0.13-0.41)**	**--**	--
Sindhusake et al, 2001[45]	Do you feel you have hearing loss?	>60 dB hearing loss at 500-4000 Hz	1.0 (0.92-1.0)	0.50 (0.48-0.52)	2.0 (1.9-2.1)	0.02 (0.001-0.34)	91 (5.6-1480)	Good
Nursing home-dwelling older adults								
Voeks et al, 1993[55]	Do you have trouble hearing?	>25 dB hearing loss at 500, 1000, 2000, and 4000 Hz in better ear	0.69 (0.60-0.78)	0.51 (0.40-0.61)	1.4 (1.1-1.8)	0.61 (0.43-0.87)	2.3 (1.2-4.3)	Fair

*Not included in the total estimate in order to avoid double counting a sample.

Table 4. Screening Questionnaires

Study, Year	Screening test, Definition of a positive screening exam	Definition of a case	Sensitivity (range)	Specificity (range)	Positive likelihood ratio (95% CI)	Negative likelihood ratio (95% CI)	Diagnostic odds ratio (95% CI)	Quality score
Lichtenstein et al, 1988[46]	HHIE-S Score >8	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.66 (0.54-0.77)	0.79 (0.70-0.86)	3.2 (2.1-4.7)	0.43 (0.30-0.60)	7.4 (3.6-16)	Good
McBride et al, 1994[22]	HHIE-S Score >8	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.58 (0.45-0.70)	0.76 (0.69-0.84)	2.4 (1.6-3.5)	0.55*	4.4*	Good
Sever et al, 1989[53]	HHIE-S Score >8	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.71 (0.48-0.89)	NR	NC	NC	ND	Fair
Lichtenstein et al, 1988[46]	HHIE-S Score >8	HFPTA: ≥25 dB hearing loss at 1000, 2000, and 4000 Hz in better ear	0.53 (0.43-0.63)†	0.84 (0.74-0.91)†	3.3 (1.9-5.8)†	0.56 (0.44-0.70)†	6.0 (2.8-14)	Good
McBride et al, 1994[22]	HHIE-S Score >8	HFPTA: ≥25 dB hearing loss at 1000, 2000, and 4000 Hz in better ear	0.48 (0.39-0.58)†	0.86 (0.79-0.94)†	3.6 (2.0-6.6)†	0.60*†	5.7*	Good
Nondahl et al, 1998[44]; Wiley et al, 2000[69]	HHIE-S Score >8	>25 dB hearing loss at 500, 1000, 2000, and 4000 Hz in either ear	0.32 (0.29-0.35)	0.97 (0.95-0.98)	10.7 (6.8-17)	0.70 (0.67-0.73)	15 (9.4-26)	Good
Sindhusake et al, 2001[45]	HHIE-S Score >8	>25 dB hearing loss at 500, 1000, 2000, and 4000 Hz	0.58 (0.54-0.62)	0.85 (0.83-0.87)	3.9 (3.3-4.5)	0.49 (0.45-0.54)	7.8 (6.2-10)	Good
		Total	**0.58 (0.32-0.66)**	**0.82 (0.76-0.97)**	**3.5 (2.4-11)**	**0.52 (0.43-0.70)**	**--**	--
Weinstein, 1986[56]	HHIE-S Score >8	Audiologist recommendation for evaluation	0.74*	0.68*	2.3*	0.38*	6.1*	Fair
Gates et al, 2003[47]	HHIE-S Score >8	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in one ear	0.36 (0.28-0.44)	0.92 (0.89-0.94)	4.5 (3.0-6.7)	0.70 (0.61-0.79)	6.5 (3.8-11)	Good
Lichtenstein et al, 1988[46]	HHIE-S Score >8	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in one ear	0.72 (0.58-0.83)	0.77 (0.68-0.84)	3.1 (2.2-4.4)	0.37 (0.24-0.57)	8.4 (3.8-19)	Good
McBride et al, 1994[22]	HHIE-S Score >8	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in one ear	0.63 (0.49-0.76)	0.75 (0.68-0.82)	2.5 (1.8-3.6)	0.49*	5.1*	Good
Sever et al, 1989[53]	HHIE-S Score >8	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in one ear	0.81 (0.54-0.96)	NR	NC	NC	ND	Fair
Sindhusake et al, 2001[45]	HHIE-S Score >8	>40 dB hearing loss at 500, 1000, 2000, and 4000 Hz	0.80 (0.74-0.85)	0.76 (0.74-0.78)	3.3 (3.0-3.7)	0.26 (0.20-0.34)	13 (8.9-18)	Good
Ventry & Weinstein, 1983[9]	HHIE-S Score >8	>40 dB hearing loss at 1000 or 2000 Hz in both ears	0.72 (0.56-0.85)	0.66 (0.52-0.77)	2.1 (1.4-3.1)	0.43 (0.26-0.71)	4.9 (1.9-13)	Fair
		Total	**0.72 (0.36-0.81)**	**0.76 (0.66-0.92)**	**3.1 (2.1-4.5)**	**0.43 (0.26-0.70)**	**--**	**--**

Table 4. Screening Questionnaires

Study, Year	Screening test, Definition of a positive screening exam	Definition of a case	Sensitivity (range)	Specificity (range)	Positive likelihood ratio (95% CI)	Negative likelihood ratio (95% CI)	Diagnostic odds ratio (95% CI)	Quality score
McBride et al, 1994[22]	HHIE-S Score >24	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.36 (0.23-0.48)	0.87 (0.81-0.93)	2.8 (1.6-5.0)	0.74*	3.8*	Good
McBride et al, 1994[22]	HHIE-S Score >24	HFPTA: ≥25 dB hearing loss at 1000, 2000, and 4000 Hz in better ear	0.29 (0.20-0.37)	0.93 (0.88-0.99)	4.3 (1.7-10)	0.76*	5.4*	Good
		Total	**0.32 (0.29-0.36)**	**0.90 (0.87-0.93)**	**3.5 (2.8-4.3)**	**0.75 (0.74-0.76)**	**--**	**--**
Lichtenstein et al, 1988[46]	HHIE-S Score >24	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in one ear	0.25 (0.14-0.38)	0.98 (0.93-1.0)	10.2 (3.0-34.0)	0.77 (0.66-0.90)	13 (3.3-75)	Good
McBride et al, 1994[22]	HHIE-S Score >24	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in one ear	0.42 (0.28-0.56)	0.88 (0.82-0.93)	3.4 (1.9-5.9)	0.66*	5.3*	Good
		Total	**0.32 (0.25-0.42)**	**0.93 (0.88-0.98)**	**5.9 (3.4-10.2)**	**0.71 (0.66-0.77)**	**--**	--
Sindhusake et al, 2001[45]	HHIE-S Score >8	>60 dB hearing loss at 500, 1000, 2000, and 4000 Hz	1.0 (0.90-1.0)	0.70 (0.68-0.72)	3.3 (3.0-3.6)	0.02 (0.001-0.31)	165 (10-2700)	Good
Weinstein, 1986[56]	HHIE-S Score >10	Audiologist recommendation for evaluation	0.65*	0.83*	3.8*	0.42*	9.0*	Fair
Koike et al, 1994[51]	5-Minute Hearing Test Various cutoffs	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	10: 0.90* 15: 0.80* 25: 0.90* 30: 0.74* 35: 0.51* 40: 0.26*	10: 0.20* 15: 0.55* 25: 0.54* 30: 0.72* 35: 0.87* 40: 0.97*	10: 1.1* 15: 1.8* 25: 2.0* 30: 2.6* 35: 4.0* 40: 9.9*	10: 0.47* 15: 0.36* 25: 0.18* 30: 0.36* 35: 0.56* 40: 0.76*	10: 2.3* 15: 5.0* 25: 11* 30: 7.2* 35: 7.1* 40: 13*	Fair

*Confidence interval not calculable.
†Not included in total estimates in order to avoid double counting a sample.

Abbreviations: HFPTA = High Frequency Pure-Tone Average; HHIE-S = Hearing Handicap Inventory for the Elderly-Screening; NC = not calcuable; ND = not dichotomized; NR = not reported; SFPTA = Speech Frequency Pure-Tone Average; V&W = Ventry and Weinstein criteria.

Table 5. Handheld Audiometric Devices

Study, Year	Definition of a positive screening exam	Definition of a case	Sensitivity (range)	Specificity (range)	Positive likelihood ratio (95% CI)	Negative likelihood ratio (95% CI)	Diagnostic odds ratio (95% CI)	Quality score
Community-dwelling older adults								
Eekhof et al, 1996[40]	Failure to hear 40 dB at 500, 1000, 2000, or 4000 Hz using AudioScope	>40 dB hearing loss	1.0 (0.91-1.0)	0.42 (0.31-0.54)	1.7 (1.4-2.1)	0.03 (0.002-0.45)	61 (3.6-102)	Fair
Lichtenstein et al, 1988[46]	Failure to hear 40 dB at 500, 1000, 2000, or 4000 Hz using AudioScope	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in one ear	0.94 (0.84-0.99)	0.72 (0.63-0.80)	3.4 (2.5-4.5)	0.08 (0.03-0.24)	43 (12-220)	Good
McBride et al, 1994[22]	Failure to hear 40 dB at 2000 Hz in better ear using AudioScope	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in one ear	0.96 (0.90-1.00)	0.80 (0.74-0.87)	4.9 (3.4-6.8)	0.05*	98*	Good
		Total	**0.96 (0.94-1.0)**	**0.72 (0.42-0.89)**	**3.4 (1.7-4.9)**	**0.05 (0.03-0.08)**	**--**	**--**
McBride et al, 1994[22]	Failure to hear 40 dB at 2000 Hz in better ear using AudioScope	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.64 (0.52-0.77)	0.89 (0.83-0.94)	5.8 (3.4-9.8)	0.40*	14*	Good
McBride et al, 1994[22]	Failure to hear 40 dB at 2000 Hz in better ear using AudioScope	HFPTA: ≥25 dB hearing loss at 1000, 2000, and 4000 Hz in better ear	0.71 (0.63-0.80)†	0.91 (0.84-0.97)†	7.5 (3.7-15)†	0.32*†	23*	Good
Bienvenue et al, 1985[48]	Failure to hear 25 dB at 500, 1000, 2000, or 4000 Hz using AudioScope	≥30 dB hearing loss at 500, 1000, 2000, and 4000 Hz	0.93*	0.70*	3.1*	0.10*	31*	Fair
Frank and Petersen, 1987[50]	Failure to hear 40 dB at 500, 1000, 2000, 4000 Hz	≥45 dB hearing loss at 500, 1000, 2000, and 4000 Hz	Age 50-59: 0.90* 60-69: 0.89 70-79: 0.85 80-89: 0.86 90-96: 0.86	Age 50-59: 0.94* 60-69: 0.90 70-79: 0.90 80-89: 0.89 90-96: 0.90	Age 50-59: 16* 60-69: 9.2* 70-79: 8.7* 80-89: 8.1* 90-96: 9.1*	Age 50-59: 0.11* 60-69: 0.12* 70-79: 0.17* 80-89: 0.16* 90-96: 0.15*	Age 50-59:140* 60-69: 77* 70-79: 51* 80-89: 51* 90-96: 61*	Fair
Chronic care facility-dwelling older adults								
Ciurlia-Guy et al, 1993[49]	Failure to hear 40 dB at 1000 or 2000 Hz in either ear	>40 dB hearing loss at 1000 or 2000 Hz in either ear	0.98 (0.91-1.0)	0.21 (0.08-0.41)	1.3 (1.0-1.5)	0.08 (0.01-0.61)	16 (1.8-76)	Fair

*Confidence interval not calculable.
†Not included in total estimates in order to avoid double counting a sample.

Abbreviations: HFPTA = High Frequency Pure-Tone Average; SFPTA = Speech Frequency Pure-Tone Average; V&W = Ventry and Weinstein criteria.

Table 6. Diagnostic Accuracy of Screening Tests for Hearing Loss

Screening test	Number of studies, References	Positive likelihood ratio	Negative likelihood ratio
>25 or >30 dB hearing loss			
Whispered voice test	Four[39-42]	Median: 5.1 Range: 2.3-7.4	Median: 0.03 Range: 0.007-0.73
Finger rub test	One[39]	10 (95% CI, 2.6-43)	0.75 (95% CI, 0.68-0.84)
Watch tick test	One[39]	70 (95% CI, 4.4-1120)	0.57 (95% CI, 0.49-0.66)
Single-question screening	Six[39, 43-45, 52, 54]	Median: 3.0 Range: 2.4-3.8	Median: 0.40 Range: 0.33-0.82
Screening questionnaire (Hearing Handicap in the Elderly-Screening*)	Four[22, 44-46]	Median: 3.5 Range: 2.4-11	Median: 0.52 Range: 0.43-0.70
Handheld audiometric devices	Two[22, 48]	3.1 (95% CI not calculable) 5.8 (95% CI, 3.4-9.8)	0.10 (95% CI not calcuable) 0.40 (95% CI not calculable)
>40 dB hearing loss			
Single-question screening	Three[43, 45, 47]	Median: 2.5 Range: 2.1-3.1	Median: 0.26 Range: 0.13-0.41
Screening questionnaire (Hearing Handicap in the Elderly-Screening*)	Five[9, 22, 45-47]	Median: 3.1 Range: 2.1-4.5	Median: 0.43 Range: 0.26-0.70
Handheld audiometric devices	Three[22, 40, 46]	Median: 3.4 Range: 1.7-4.9	Median: 0.05 Range: 0.03-0.08

*Based on cutoff score of >8.

Abbreviation: CI = confidence interval.

Table 7. Summary of Evidence

Number of studies, Overall quality rating	Limitations	Consistency	Primary care applicability	Summary of findings
KQ 1. Does screening for hearing loss in asymptomatic adults ages 50 years and older lead to improved health outcomes?				
1 RCT Overall quality: Fair	One large (n=2305), fair-quality trial of screening versus no screening in a VA setting in patients with a high prevalence of perceived hearing loss. High loss to follow-up.	N/A (1 study)	Low-moderate	One trial found that screening with HHIE-S, AudioScope, or both was associated with greater hearing aid use at 1 year compared with no screening. Effects of screening on hearing aid use appeared to be limited to patients with perceived hearing loss at baseline. Screening was not associated with any differences in hearing-related quality of life compared with no screening. Because 3/4 of patients enrolled in the trial reported perceived hearing loss and all patients were eligible to receive free hearing aids, results are likely to be most generalizable to high-prevalence settings in which the cost of hearing aids is not a barrier.
KQ 2. How accurate are the methods for hearing loss screening in older adults?				
20 studies total 4 Clinical test 8 Single question 9 Questionnaires 6 AudioScope Overall quality: Good	Most studies conducted in specialty or other high-prevalence settings. Differences between studies in how hearing loss was defined and in screening cutoffs used.	Consistent	Moderate	For detection of >25 or >30 dB hearing loss, four studies (one good-quality) found that the whispered voice test at 2 feet was associated with a median PLR of 5.1 (range, 2.3 to 7.4) and median NLR of 0.03 (range, 0.007 to 0.73). For detection of >25 dB hearing loss, six studies (four good-quality) found that a single question screening was associated with a median PLR of 3.0 (range, 2.4 to 3.8) and median NLR of 0.40 (range, 0.33 to 0.82), and four good-quality studies found that the HHIE-S (based on a cutoff score of 8) was associated with a median PLR of 3.5 (range, 2.4 to 11) and median NLR of 0.52 (range, 0.43 to 0.70). For detection of >40 dB hearing loss, three studies (two good-quality) found that the AudioScope (based on ability to hear tones between 500 and 4000 Hz at 40 dB) was associated with a median PLR of 3.4 (range, 1.7 to 4.9) and median NLR of 0.05 (range, 0.03 to 0.08).
KQ 3. How efficacious is the treatment of screening-detected hearing loss in improving health outcomes?				
4 RCTs Overall quality: Fair	Only one good-quality trial of hearing aids versus no hearing aids, conducted in a VA setting in patients eligible for free hearing aids.	Consistent	Low-moderate	One good-quality RCT found that immediate hearing aid use was associated with moderate improvements in hearing-specific quality of life and communication difficulties compared with wait-list control in veterans with hearing loss >40 dB who are eligible for free hearing aids. A smaller, fair-quality RCT found no clear difference between an assistive listening device and no treatment in veterans ineligible for free hearing aids. Another fair-quality RCT found no difference between a hearing aid, an assistive listening device, or both compared with no amplification in a subgroup of patients not using hearing aids at enrollment with mild baseline hearing loss and hearing-related handicap. A fourth RCT of hearing aids versus no hearing aids reported outcomes very poorly.
KQ 4. What are the adverse effects of screening for hearing loss in adults ages 50 years and older?				
No studies	No studies	N/A	N/A	No RCTs or controlled observational studies were found. Harms of hearing loss screening are unlikely to be greater than small or minimal due to the non-invasive nature of screening, confirmatory testing, and treatments.

Table 7. Summary of Evidence

Number of studies, Overall quality rating	Limitations	Consistency	Primary care applicability	Summary of findings
KQ 5. What are the adverse effects of treatment of screening-detected hearing loss in adults ages 50 years and older?				
No studies	No studies	N/A	N/A	No RCTs or controlled observational studies were found. Hearing aids are unlikely to be associated with serious harms, though there are reports of dermatitis, otitis externa, cerumen impaction, and other complications associated with their use.

Abbreviations: HHIE-S = Hearing Handicap Inventory for the Elderly-Screening; KQ = key question; N/A = not applicable; NLR = negative likelihood ratio; PLR = positive likelihood ratio; RCT = randomized controlled trial; VA = U.S. Department of Veteran Affairs.

Appendix A1. Literature Search Strategies

Overall

Database: Cochrane Database of Systematic Reviews

1 (hearing and adult$).mp. [mp=title, short title, abstract, full text, keywords, caption text]
2 1 not (neonat$ or pregnan$ or infant or child or pediatri$).mp. [mp=title, short title, abstract, full text, keywords, caption text]
3 limit 2 to full systematic reviews

Key Question 1. Screening and Outcomes

Databases: Ovid MEDLINE; Cochrane Central Register of Controlled Trials

1 Hearing Disorders/
2 Hearing Loss/
3 Hearing Loss, Mixed Conductive-Sensorineural/
4 Hearing Loss, Sensorineural/
5 PRESBYCUSIS/
6 or/1-5
7 mass screening/
8 screen$.mp.
9 7 or 8
10 6 and 9
11 (clinical trial or controlled clinical trial or multicenter study or randomized controlled trial).pt.
12 Comparative Study/
13 Follow-Up Studies/
14 (prospectiv$ or retrospectiv$ or baseline or cohort or consecutive$ or compar$).tw.
15 10 and (or/11-14)
16 limit 15 to ("adult (19 to 44 years)" or "middle age (45 to 64 years)" or "all aged (65 and over)")

Key Question 2. Accuracy of Screening

Databases: Ovid MEDLINE; Cochrane Central Register of Controlled Trials

1 Hearing Disorders/
2 Hearing Loss/
3 Hearing Loss, Mixed Conductive-Sensorineural/
4 Hearing Loss, Sensorineural/
5 PRESBYCUSIS/
6 presbyacusis.mp.
7 or/1-6
8 Mass Screening/
9 screen$.ti,ab,hw.
10 8 or 9
11 7 and 10
12 Hearing Tests/
13 Audiometry/ or Audiometry, Pure-Tone/
14 12 or 13
15 "Sensitivity and Specificity"/
16 "Predictive Value of Tests"/
17 ROC Curve/

18 accuracy.ti,ab.
19 specificit$.ti,ab.
20 predictive value.ti,ab.
21 or/15-20
22 (11 or 14) and 21
23 audioscop$.ti,ab.
24 hhie$.mp. or hearing handicap inventory.ti,ab. [mp=title, original title, abstract, name of substance word, subject heading word]
25 23 or 24
26 22 or 25
27 limit 26 to humans
28 limit 27 to ("adult (19 to 44 years)" or "middle age (45 to 64 years)" or "all aged (65 and over)")

Key Question 3. Overall Treatment

Databases: Ovid MEDLINE; Cochrane Central Register of Controlled Trials

1 Hearing Aids/
2 hearing aid$.ti,ab.
3 1 or 2
4 treatment outcome/
5 Treatment Failure/
6 health outcome$.ti,ab.
7 "Outcome Assessment (Health Care)"/
8 functional status.ti,ab.
9 Health Status/
10 Health Status Indicators/
11 health status.ti,ab.
12 "Quality of Life"/
13 quality of life.ti,ab.
14 qol.ti,ab.
15 depression/
16 Depressive Disorder/
17 Mood Disorders/
18 depression.ti,ab.
19 Social Isolation/
20 Loneliness/
21 Social Alienation/
22 social$ isolat$.ti,ab.
23 Communication/
24 (improv$ adj4 communicat$).ti,ab.
25 Cognition/
26 cognitive function$.ti,ab.
27 or/4-26
28 3 and 27
29 limit 28 to ("adult (19 to 44 years)" or "middle age (45 to 64 years)" or "all aged (65 and over)")

Key Question 4. Adverse Effects of Screening

Database: Ovid MEDLINE

1 Hearing Disorders/
2 Hearing Loss/
3 Hearing Loss, Mixed Conductive-Sensorineural/
4 Hearing Loss, Sensorineural/
5 Presbycusis/
6 presbyacusis.mp.
7 age related hearing loss.mp.
8 Hearing Loss, Noise-Induced/
9 or/1-8
10 Mass Screening/
11 screen$.ti,ab.
12 10 or 11
13 9 and 12
14 ((advers$ adj3 effect$) or harm$ or contraindicat$).mp.
15 ae.fs.
16 exp Diagnostic Errors/
17 (overtest$ or overdiagnos$ or over-test$ or over-diagnos$).mp.
18 (false$ adj2 (result$ or positiv$ or negativ$)).mp.
19 (observer$ adj3 bias$).mp.
20 (diagnos$ adj3 (error$ or mistak$ or incorrect$)).mp.
21 or/14-20
22 13 and 21
23 limit 22 to ("middle aged (45 plus years)" or "all aged (65 and over)" or "aged (80 and over)")

Key Question 5. Adverse Effects of Treatment

Database: Ovid MEDLINE

1 Hearing Aids/ or hearing aid$.mp.
2 Cochlear Implants/
3 1 not 2
4 Hearing Loss/th [Therapy]
5 3 or 4
6 adverse effect$.mp.
7 (ae or co).fs.
8 (safety or harm$).mp.
9 or/6-8
10 5 and 9
11 limit 10 to ("middle age (45 to 64 years)" or "all aged (65 and over)")

Appendix A1. Literature Search Strategies

KEYWORD SEARCHES

Tuning Fork

Databases: Cochrane Central Register of Controlled Trials; Cochrane Database of Systematic Reviews

1 (whisper$ adj5 (test$ or screen$ or measur$)).mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
2 (tuning adj3 fork$).mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]

Tuning Fork

Database: Ovid MEDLINE

1 (whisper$ adj5 (test$ or screen$ or measur$)).mp. [mp=title, original title, abstract, name of substance word, subject heading word]
2 (tuning adj3 fork$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]
3 exp Hearing/
4 exp Hearing Disorders/
5 exp Hearing Tests/
6 or/3-5
7 2 and 6
8 1 and 7

Whisper Test

Databases: Cochrane Central Register of Controlled Trials; Cochrane Database of Systematic Reviews

1 (whisper$ adj5 (test$ or screen$ or measur$)).mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
2 (tuning adj3 fork$).mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]

Whisper Test

Database: Ovid MEDLINE

1 (whisper$ adj5 (test$ or screen$ or measur$)).mp. [mp=title, original title, abstract, name of substance word, subject heading word]
2 (tuning adj3 fork$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]
3 exp Hearing/
4 exp Hearing Disorders/
5 exp Hearing Tests/
6 or/3-5
7 2 and 6
8 1 and 7

Appendix A2. Inclusion and Exclusion Criteria

All Key Questions

Ages/population:

Include: Adults ages 50 years or older without diagnosed hearing loss; comorbid conditions of depression and cognitive dysfunction. Also include nursing home populations

Exclude: Adults younger than age 50 years; previously diagnosed hearing loss; current hearing aid users (within the last 6 months)

Disease:

Include: Sensorineural hearing loss, presbycusis

Exclude: Conductive hearing loss, congenital hearing loss, sudden hearing loss, hearing loss due to recent noise or occupational exposure

Languages:

Include: Full text published in English

Settings:

Include: Studies performed in settings generalizable to primary care

Exclude: Countries with populations not similar to the United States

Key Question 1 (Screening and Outcomes)

Interventions/diagnostic tests:

Include: Screening tests used, available, or feasible in primary care settings, including whispered voice, finger rub, watch tick, single question regarding perceived hearing loss, hearing loss questionnaire, and portable audiometer

Exclude: Screening tests not used or available in primary care settings (e.g., audiometric testing), Rinne and Weber tests (used to distinguish sensorineural from conductive hearing loss, not to screen persons for hearing loss)

Outcomes:

Include: Hearing-related quality of life and function (e.g., emotional and social function, communication, and cognitive function)

Exclude: Outcomes related to hearing aid performance and efficacy (e.g., speech intelligibility and quality of the listening experience)

Study designs:

Include: Randomized controlled trials and controlled observational studies

Appendix A2. Inclusion and Exclusion Criteria

Key Question 2 (Accuracy of Screening Methods and Testing)

Interventions/diagnostic tests:

Include: See Key Question 1

Exclude: Audiometric testing, except as reference standard

Outcomes:

Include: Sensitivity, specificity, positive and negative predictive values, positive and negative likelihood ratios, diagnostic odds ratios

Study designs:

Include: Cross-sectional or cohort studies of primary care, community-based, or specialty settings

Exclude: Case control studies (e.g., 50 selected patients with hearing loss vs. 50 selected patients without hearing loss)

Key Question 3 (Effectiveness of Amplification Treatment)

Interventions/treatments:

Include: Amplification with hearing aids or assistive listening devices

Exclude: Nutritional pharmaceuticals, hearing rehabilitation

Outcomes:

Include: Health-related quality of life (e.g., emotional and social function, communication, and cognitive function)

Exclude: Outcomes related to hearing aid performance and efficacy (e.g., speech intelligibility and quality of the listening experience)

Study designs:

Include: Randomized controlled trials and controlled observational studies

Key Question 4 (Harms of Screening) and 5 (Harms of Treatment)

Interventions/diagnostic tests:

See Key Question 1

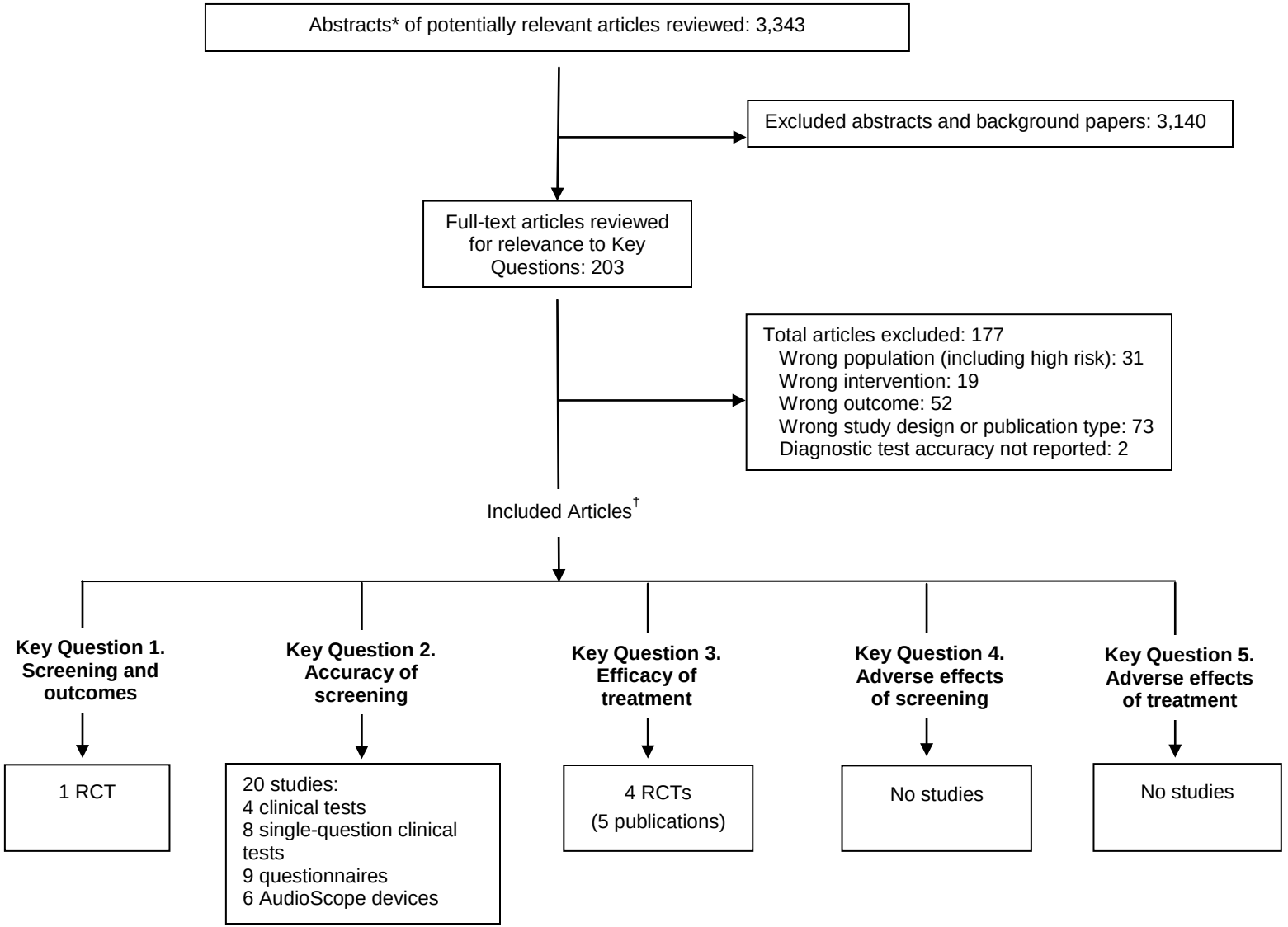
Outcomes:

Include: False-positives, labeling, anxiety, any other significant harms

Study designs:

Include: Randomized controlled trials and controlled observational studies

Appendix A3. Literature Flow Diagram



*Abstracts were identified through the Cochrane Central Register of Controlled Trials, the Cochrane Database of Systematic Reviews, Ovid MEDLINE, and other sources, including reference lists and suggestions by experts.
†Some articles are included for more than one Key Question.

Abbreviation: RCT = randomized controlled trial.

Appendix A4. Excluded Studies

Wrong Population:

Ahn JH, Lee HS, Kim YJ, et al. Comparing pure-tone audiometry and auditory steady state response for the measurement of hearing loss. *Otolaryngol Head Neck Surg*. 2007;136(6):966-971.

Andelin LC, Alessi CA, Aronow HU. Reliability of screening for sensory impairment in depressed versus nondepressed older adults. *J Am Geriatr Soc*. 1995;43(6):684-687.

Barbara M, Bandiera G, Serra B, et al. Digital hearing aids for high-frequency sensorineural hearing loss: preliminary experience with the RetroX device. *Acta Otolaryngol*. 2005;125(7):693-696.

Bille M, Jensen AM, Kjaerbol E, et al. Clinical study of a digital vs an analogue hearing aid. *Scand Audiol*. 1999;28(2):127-135.

Bosman AJ, Hol MK, Snik AF, et al. Bone-anchored hearing aids in unilateral inner ear deafness. *Acta Otolaryngol*. 2003;123(2):258-260.

Chao TK, Chen TH. Distortion product otoacoustic emissions as a prognostic factor for idiopathic sudden sensorineural hearing loss. *Audiol Neurootol*. 2006;11(5):331-338.

Cienkowski KM, McHugh MS, McHugo GJ, et al. A computer method for assessing satisfaction with hearing aids. *Int J Audiol*. 2006;45(7):393-399.

Cohen SM, Labadie RF, Dietrich MS, et al. Quality of life in hearing-impaired adults: the role of cochlear implants and hearing aids. *Otolaryngol Head Neck Surg*. 2004;131(4):413-422.

Cohen SM, Turley R. Coprevalence and impact of dysphonia and hearing loss in the elderly. *Laryngoscope.* 2009;119(9):1870-1873.

De Silva ML, McLaughlin MT, Rodrigues EJ, et al. A mini-mental status examination for the hearing impaired. *Age Ageing*. 2008;37(5):593-595.

Del Bo L, Ambrosetti U. Hearing aids for the treatment of tinnitus. *Prog Brain Res*. 2007;166:341-345.

Dias de Freitas C, Costa M. Hearing aid fitting process in users fitted in a federal public institution, part II: self-assessment questionnaire results. *Braz J Otorhinolaryngol*. 2007;73(5):660-670.

Fellinger J, Holzinger D, Gerich J, et al. Mental distress and quality of life in the hard of hearing. *Acta Psychiatr Scand*. 2007;115(3):243-245.

Folmer RL, Carroll JR. Long-term effectiveness of ear-level devices for tinnitus. *Otolaryngol Head Neck Surg*. 2006;134(1):132-137.

Freyaldenhoven MC, Nabelek AK, Tampas JW. Relationship between acceptable noise level and the abbreviated profile of hearing aid benefit. *J Speech Lang Hear Res*. 2008;51(1):136-146.

Gilhome Herbst KR, Meredith R, Stephens SD. Implications of hearing impairment for elderly people in London and in Wales. *Acta Otolaryngol Suppl.*1990;476:209-214.

Gordon-Salant S, Lantz J, Fitzgibbons P. Age effects on measures of hearing disability. *Ear Hear*. 1994;15(3):262-265.

Hill SL 3rd, Marcus A, Digges EN, et al. Assessment of patient satisfaction with various configurations of digital CROS and BiCROS hearing aids. *Ear Nose Throat J*. 2006;85(7):427-430.

Hol MK, Snik AF, Mylanus EA, et al. Long-term results of bone-anchored hearing aid recipients who had previously used air-conduction hearing aids. *Arch Otolaryngol Head Neck Surg*. 2005;131(4):321-325.

Jespersen CT, Groth J, Kiessling J, et al. The occlusion effect in unilateral versus bilateral hearing aids. *J Am Acad Audiol*. 2006;17(10):763-773.
Jupiter T, Palagonia CL. The Hearing Handicap Inventory for the Elderly screening version adapted for use with elderly Chinese American individuals. *Am J Audiol*. 2001;10(2):99-103.
Karlsmose B, Lauritzen T, Engberg M, et al. A randomised controlled trial of screening for adult hearing loss during preventive health checks. *Br J Gen Pract*. 2001;51(466):351-355.
Lopez-Vazquez M, Orozco JA, Jimenez G, et al. Spanish hearing impairment inventory for the elderly. *Int J Audiol*. 2002;41(4):221-230.
Mendel LL. Objective and subjective hearing aid assessment outcomes. *Am J Audiol*. 2007;16(2):118-129.
Metselaar M, Maat B, Krijnen P, Verschuure H, Dreschler WA, Feenstra L. Self-reported disability and handicap after hearing-aid fitting and benefit of hearing aids: comparison of fitting procedures, degree of hearing loss, experience with hearing aids and uni- and bilateral fittings. *Eur Arch Otorhinolaryngol.* 2009;266(6):907-917.
Okamoto M, Nakanishi N, Tatara K. Self-reported hearing difficulty and hearing impairment in Japanese people living in a community. *Int J Audiol.* 2004;43(1):54-59.
Palmer CV, Bentler R, Mueller HG. Amplification with digital noise reduction and the perception of annoying and aversive sounds. *Trends Amplif*. 2006;10(2):95-104.
Saunders GH, Forsline A. The Performance-Perceptual Test (PPT) and its relationship to aided reported handicap and hearing aid satisfaction. *Ear Hear*. 2006;27(3):229-242.
Smith MF, Nathan RG, Wayner DS, et al. Comparative validity of two hearing loss screening questionnaires. *J Fam Pract.* 1992;35(4):411-416.
Surr RK, Kolb JA, Cord MT, et al. Tinnitus Handicap Inventory (THI) as a hearing aid outcome measure. *J Am Acad Audiol*. 1999;10(9):489-495.
Uhlmann RF, Rees TS, Psaty BM, et al. Validity and reliability of auditory screening tests in demented and non-demented older adults. *J Gen Intern Med.* 1989;4(2):90-96.

Wrong Intervention:

Andersson G. Decreased use of hearing aids following training in hearing tactics. *Percept Mot Skills*. 1998;87(2):703-706.
Andersson G, Green M, Melin L. Behavioural hearing tactics: a controlled trial of a short treatment programme. *Behav Res Ther*. 1997;35(6):523-530.
Andersson G, Melin L, Scott B, et al. Behavioral counselling for subjects with acquired hearing loss: a new approach to hearing tactics. *Scand Audiol.* 1994;23(4):249-256.
Badran K, Bunstone D, Arya AK, et al. Patient satisfaction with the bone-anchored hearing aid: a 14-year experience. *Otol Neurotol*. 2006;27(5):659-666.
Blackmore KJ, Kernohan MD, Davison T, et al. Bone-anchored hearing aid modified with directional microphone: do patients benefit? *J Laryngol Otol*. 2007;121(9):822-825.
Calviti KC, Pereira LD. Sensitivity, specificity and predictive values of hearing loss to different audiometric mean values. *Braz J Otorhinolaryngol.* 2009;75(6):794-800.
Chaiklin JB. A descending LOT-Bekesy screening test for functional hearing loss. *J Speech Hear Disord*. 1990;55(1):67-74.
Chang HP, Ho CY, Chou P. The factors associated with a self-perceived hearing handicap in elderly people with hearing impairment—results from a community-based study. *Ear Hear.* 2009;30(5):576-583.

Chisolm TH, Noe CM, McArdle R, et al. Evidence for the use of hearing assistive technology by adults: the role of the FM system. *Trends Amplif*. 2007;11(2):73-89.
Collins MP, Souza PE, Liu CF, Heagerty PJ, Amtmann D, Yueh B. Hearing Aid Effectiveness After Aural Rehabilitation-Individual Versus Group (HEARING) trial: RCT design and baseline characteristics. *BMC Health Serv Res.* 2009;9:233.
Culling JF, Zhao F, Stephens D. The viability of speech-in-noise audiometric screening using domestic audio equipment. *Int J Audiol*. 2005;44(12):691-700.
Doshi J, Karagama Y, Buckley D, et al. Observational study of bone-anchored hearing aid infection rates using different post-operative dressings. *J Laryngol Otol*. 2006;120(10):842-844.
Ellison JC, Keefe DH. Audiometric predictions using stimulus-frequency otoacoustic emissions and middle ear measurements. *Ear Hear*. 2005;26(5):487-503.
Ho AT, Hildreth AJ, Lindsey L. Computer-assisted audiometry versus manual audiometry. *Otol Neurotol.* 2009;30(7):876-883.
House JW, Kutz JW Jr. Bone-anchored hearing aids: Incidence and management of postoperative complications. *Otol Neurotol*. 2007;28(2):213-217.
Johnson CE, Danhauer JL, Reith AC, et al. A systematic review of the nonacoustic benefits of bone-anchored hearing aids. *Ear Hear*. 2006;27(6):703-713.
Lesner SA. Candidacy and management of assistive listening devices: special needs of the elderly. *Int J Audiol*. 2003;42(Suppl 2):S68-S76.
Luntz M, Yehudai N, Shpak T. Hearing progress and fluctuations in bimodal-binaural hearing users (unilateral cochlear implants and contralateral hearing aid). *Acta Otolaryngol*. 2007;127(10):1045-1050.
Wazen JJ, Spitzer J, Ghossaini SN, et al. Results of the bone-anchored hearing aid in unilateral hearing loss. *Laryngoscope*. 2001;111(6):955-958.

Wrong Outcome:

Ahmad N, Etheridge C, Farrington M, et al. Prospective study of the microbiological flora of hearing aid moulds and the efficacy of current cleaning techniques. *J Laryngol Otol.* 2007;121(2):110-113.
Allen NH, Burns A, Newton V, et al. The effects of improving hearing in dementia. *Age Ageing*. 2003;32(2):189-193.
Barton GR, Bankart J, Davis AC, et al. Comparing utility scores before and after hearing-aid provision: results according to the EQ-5D, HUI3 and SF-6D. *Appl Health Econ Health Policy.* 2004;3(2):103-105.
Bentler R, Palmer C, Mueller HG. Evaluation of a second-order directional microphone hearing aid, I: speech perception outcomes. *J Am Acad Audiol*. 2006;17(3):179-189.
Blamey PJ, Fiket HJ, Steele BR. Improving speech intelligibility in background noise with an adaptive directional microphone. *J Am Acad Audiol*. 2006;17(7):519-530.
Brooks DN, Hallam RS, Mellor PA. The effects on significant others of providing a hearing aid to the hearing-impaired partner. *Br J Audiol*. 2001;35(3):165-171.
Burk MH, Humes LE, Amos NE, et al. Effect of training on word-recognition performance in noise for young normal-hearing and older hearing-impaired listeners. *Ear Hear*. 2006;27(3):263-278.

Appendix A4. Excluded Studies

Chang WH, Tseng HC, Chao TK, et al. Measurement of hearing aid outcome in the elderly: comparison between young and old elderly. *Otolaryngol Head Neck Surg*. 2008;138(6):730-734.

Chisolm TH, Abrams HB, McArdle R. Short- and long-term outcomes of adult audiological rehabilitation. *Ear Hear*. 2004;25(5):464-477.

Cilento BW, Norton SJ, Gates GA. The effects of aging and hearing loss on distortion product otoacoustic emissions. *Otolaryngol Head Neck Surg*. 2003;129(4):382-389.

Compton-Conley CL, Neuman AC, Killion MC, et al. Performance of directional microphones for hearing aids: real-world versus simulation. *J Am Acad Audiol*. 2004;15(6):440-455.

Cord MT, Leek MR, Walden BE. Speech recognition ability in noise and its relationship to perceived hearing aid benefit. *J Am Acad Audiol*. 2000;11(9):475-483.

Danhauer JL, Celani KE, Johnson CE. Use of a hearing and balance screening survey with local primary care physicians. *Am J Audiol*. 2008;17(1):3-13.

Davies JE, John DG, Stephens SD. Intermediate hearing tests as predictors of hearing aid acceptance. *Clin Otolaryngol*. 1991;16(1):76-83.

Davis A, Stephens D, Rayment A, et al. Hearing impairments in middle age: the Acceptability, Benefit and Cost of Detection (ABCD). *Br J Audiol*. 1992;26(1):1-14.

DeStefano AL, Gates GA, Heard-Costa N, et al. Genomewide linkage analysis to presbycusis in the Framingham Heart Study. *Arch Otolaryngol Head Neck Surg*. 2003;129(3):285-289.

Dhar S, Humes LE, Calandruccio L, et al. Predictability of speech-in-noise performance from real ear measures of directional hearing aids. *Ear Hear*. 2004;25(2):147-158.

Durvasula VS, Patel H, Mahendran S, et al. Bone anchored hearing aids: a second fixture reduces auditory deprivation in Cambridge. *Eur Arch Otorhinolaryngol*. 2007;264(9):991-994.

Eekhof J, De Bock G, Schaapveld K, et al. Effects of screening for disorders among the elderly: an intervention study in general practice. *Fam Pract*. 2000;17(4):329-333.

Gianopoulos I, Stephens D. Opting for two hearing aids: a predictor of long-term use among adult patients fitted after screening. *Int J Audiol*. 2002;41(8):518-526.

Gopinath B, McMahon CM, Rochtchina E, Mitchell P. Dizziness and vertigo in an older population: the Blue Mountains prospective cross-sectional study. *Clin Otolaryngol.* 2009;34(6):552-556.

Haskell GB, Noffsinger D, Larson VD, et al. Subjective measures of hearing aid benefit in the NIDCD/VA clinical trial. *Ear Hear*. 2002;23(4):301-307.

Horwitz AR, Ahlstrom JB, Dubno JR. Factors affecting the benefits of high-frequency amplification. *J Speech Lang Hear Res*. 2008;51(3):798-813.

Hough DA, Matthews P, Hough JV. Bone conduction implants for amplification: comparison of results. *Ear Nose Throat J*. 1997;76(12):857.

Humes LE, Wilson DL. An examination of changes in hearing-aid performance and benefit in the elderly over a 3-year period of hearing-aid use. *J Speech Lang Hear Res*. 2003;46(1):137-145.

Hurley RM. Onset of auditory deprivation. *J Am Acad Audiol*. 1999;10(10):529-534.

Jauhiainen T. Progression of sensorineural hearing impairment in aided and unaided ears. *Scand Audiol Suppl*. 2001;(52):28-31.

Johnson CE, Danhauer JL, Koch LL, et al. Hearing and balance screening and referrals for Medicare patients: a national survey of primary care physicians. *J Am Acad Audiol*. 2008;19(2):171-190.

Appendix A4. Excluded Studies

Jupiter T. Screening for hearing loss in the elderly using distortion product otoacoustic emissions, pure tones, and a self-assessment tool. *Am J Audiol.* 2009;18(2):99-107.

Koopman J, Davey E, Thomas N, et al. How should hearing screening tests be offered? *Int J Audiol*. 2008;47(5):230-237.

Kramer SE, Allessie GH, Dondorp AW, et al. A home education program for older adults with hearing impairment and their significant others: a randomized trial evaluating short- and long-term effects. *Int J Audiol*. 2005;44(5):255-264.

Lapsley Miller JA, Marshall L, Heller LM. A longitudinal study of changes in evoked otoacoustic emissions and pure-tone thresholds as measured in a hearing conservation program. *Int J Audiol*. 2004;43(6):307-322.

Larson VD, Williams DW, Henderson WG, et al. A multi-center, double blind clinical trial comparing benefit from three commonly used hearing aid circuits. *Ear Hear*. 2002;23(4):269-276.

Larson VD, Williams DW, Henderson WG, et al; NIDCD/VA Hearing Aid Clinical Trial Group. Efficacy of 3 commonly used hearing aid circuits: a crossover trial. *JAMA.* 2000;284(14):1806-1813.

Lee LW, Geddes ER. Perception of microphone noise in hearing instruments. *J Acoust Soc Am*. 1998;104(6):3364-3367.

Lunner T, Sundewall-Thoren E. Interactions between cognition, compression, and listening conditions: effects on speech-in-noise performance in a two-channel hearing aid. *J Am Acad Audiol*. 2007;18(7):604-617.

Magnusson L, Karlsson M, Ringdahl A, et al. Comparison of calculated, measured and self-assessed intelligibility of speech in noise for hearing-aid users. *Scand Audiol*. 2001;30(3):160-171.

Manwaring N, Jones MM, Wang JJ, et al. Mitochondrial DNA haplogroups and age-related hearing loss. *Arch Otolaryngol Head Neck Surg*. 2007;133(9):929-933.

McMahon CM, Kifley A, Rochtchina E, et al. The contribution of family history to hearing loss in an older population. *Ear Hear*. 2008;29(4):578-584.

Meister H, Lausberg I, Kiessling J, et al. Identifying the needs of elderly, hearing-impaired persons: the importance and utility of hearing aid attributes. *Eur Arch Otorhinolaryngol*. 2002;259(10):531-534.

Moore AA, Siu A, Partridge JM, et al. A randomized trial of office-based screening for common problems in older persons. *Am J Med*. 1997;102(4):371-378.

Moore BC, Stone MA, Alcantara JI. Comparison of the electroacoustic characteristics of five hearing aids. *Br J Audiol*. 2001;35(5):307-325.

Munro KJ, Patel RK. Are clinical measurements of uncomfortable loudness levels a valid indicator of real-world auditory discomfort? *Br J Audiol*. 1998;32(5):287-293.

Noble W, Gatehouse S. Effects of bilateral versus unilateral hearing aid fitting on abilities measured by the Speech, Spatial, and Qualities of Hearing Scale (SSQ). *Int J Audiol*. 2006;45(3):172-181.

Schow RL, Smedley TC, Longhurst TM. Self-assessment and impairment in adult/elderly hearing screening—recent data and new perspectives. *Ear Hear*. 1990;11(5 Suppl):17S-27S.

Smits C, Kapteyn TS, Houtgast T. Development and validation of an automatic speech-in-noise screening test by telephone. *Int J Audiol*. 2004;43(1):15-28.

Souza PE, Boike KT, Witherell K, et al. Prediction of speech recognition from audibility in older listeners with hearing loss: effects of age, amplification, and background noise. *J Am Acad Audiol*. 2007;18(1):54-65.
Souza PE, Yueh B, Sarubbi M, et al. Fitting hearing aids with the Articulation Index: impact on hearing aid effectiveness. *J Rehabil Res Dev*. 2000;37(4):473-481.
Takahashi G, Martinez CD, Beamer S, et al. Subjective measures of hearing aid benefit and satisfaction in the NIDCD/VA follow-up study. *J Am Acad Audiol*. 2007;18(4):323-349.
Torres-Russotto D, Landau WM, Harding GW, et al. Calibrated Finger Rub Auditory Screening Test (CALFRAST). *Neurology*. 2009;72(18):1595-1600.
Vestergaard MD. Self-report outcome in new hearing-aid users: longitudinal trends and relationships between subjective measures of benefit and satisfaction. *Int J Audiol*. 2006;45(7):382-392.
Wu HY, Chin JJ, Tong HMH. Screening for hearing impairment in a cohort of elderly patients attending a hospital geriatric medicine service. *Singapore Med J*. 2004;45(2):79-84.

Wrong Study Design or Publication Type:

Abrams HB, Hnath-Chisolm T, Guerreiro SM, et al. The effects of intervention strategy on self-perception of hearing handicap. *Ear Hear*. 1992;13(5):371-377.
Appollonio I, Carabellese C, Frattola L, et al. Effects of sensory aids on the quality of life and mortality of elderly people: a multivariate analysis. *Age Ageing*. 1996;25(2):89-96.
Appollonio I, Carabellese C, Magni E, et al. Sensory impairments and mortality in an elderly community population: a six-year follow-up study. *Age Ageing*. 1995;24(1):30-36.
Bagai A, Thavendiranathan P, Detsky A. Does this patient have hearing impairment? *JAMA*. 2006;295(4):416-428.
Blanchet C, Pommie C, Mondain M, et al. Pure-tone threshold description of an elderly French screened population. *Otol Neurotol*. 2008;29(4):432-440.
Bratt GW, Rosenfeld MA, Williams DW. NIDCD/VA hearing aid clinical trial and follow-up: background. *J Am Acad Audiol*. 2007;18(4):274-281.
Brickley GJ, Cleaver VC, Bailey S. An evaluation of a group follow-up scheme for new NHS hearing aid users. *Br J Audiol.* 1996;30(5):307-312.
Bromwich MA, Parsa V, Lanthier N, et al. Active noise reduction audiometry: a prospective analysis of a new approach to noise management in audiometric testing. *Laryngoscope*. 2008;118(1):104-109.
Brooks DN. Some factors influencing choice of type of hearing aid in the UK: behind-the-ear or in-the-ear. *Br J Audiol.* 1994;28(2):91-98.
Brooks DN, Hallam RS. Attitudes to hearing difficulty and hearing aids and the outcome of audiological rehabilitation. *Br J Audiol.* 1998;32(4):217-226.
Browning GG, Swan IR, Chew KK. Clinical role of informal tests of hearing. *J Laryngol Otol.* 1989;103(1):7-11.
Bunnag C, Prasansuk S, Nakorn AN, et al. Ear diseases and hearing in the Thai elderly population, part I: a comparative study of the accuracy of diagnosis and treatment by general practitioners vs ENT specialists. *J Med Assoc Thai*. 2002;85(5):521-531.
Cacciatore F, Napoli C, Abete P, et al. Quality of life determinants and hearing function in an elderly population: Osservatorio Geriatrico Campano Study Group. *Gerontology*. 1999;45(6):323-328.

Appendix A4. Excluded Studies

Cherry R, Rubinstein A. The long-term effect of early telephone intervention on hearing aid success. *Scand Audiol.*1995;24(4):243-246.

Cook JA, Hawkins DB. Hearing loss and hearing aid treatment options. *Mayo Clin Proc*. 2006;81(2):234-237.

Cook JA, Hawkins DB. Outcome measurement for patients receiving hearing aid services. *Laryngoscope*. 2007;117(4):610-613.

Coren S, Hakstian AR. The development and cross-validation of a self-report inventory to assess pure-tone threshold hearing sensitivity. *J Speech Hear Res*. 1992;35(4):921-928.

Cox RM, Alexander GC, Gray GA. Personality, hearing problems, and amplification characteristics: contributions to self-report hearing aid outcomes. *Ear Hear*. 2007;28(2):141-162.

Davis A. Population study of the ability to benefit from amplification and the provision of a hearing aid in 55–74-year-old first-time hearing aid users. *Int J Audiol*. 2003;42(Suppl 2):S39-S52.

Dobie RA. The burdens of age-related and occupational noise-induced hearing loss in the United States. *Ear Hear*. 2008;29(4):565-577.

Erber NP. Use of hearing aids by older people: influence of non-auditory factors (vision, manual dexterity). *Int J Audiol*. 2003;42(Suppl 2):S21-S25.

Hands S. Hearing loss in over-65s: is routine questionnaire screening worthwhile? *J Laryngol Otol*. 2000;114(9):661-666.

Henrichsen J, Noring E, Christensen B, et al. In-the-ear hearing aids: the use and benefit in the elderly hearing-impaired. *Scand Audiol.* 1988;17(4):209-212.

Hickson L. Rehabilitation approaches to promote successful unilateral and bilateral fittings and avoid inappropriate prescription. *Int J Audiol*. 2006;45(Suppl 1):S72-S77.

Hickson L, Worrall L. Beyond hearing aid fitting: improving communication for older adults. *Int J Audiol Suppl.*2003;42(Suppl 2):S84-S91.

Hildesheimer M, Muchnik C. Cooperation of hearing-impaired elderly subjects for participation in a hearing screening program. *Audiology*. 1992;31(4):222-227.

Holcomb SS, Punch JL. Multimedia hearing handicap inventory: reliability and clinical utility. *Am J Audiol*. 2006;15(1):3-13.

Humes LE. Factors underlying the speech-recognition performance of elderly hearing-aid wearers. *J Acoust Soc Am*. 2002;112(3 Pt 1):1112-1132.

Humes LE. The contributions of audibility and cognitive factors to the benefit provided by amplified speech to older adults. *J Am Acad Audiol*. 2007;18(7):590-603.

Humes LE, Garner CB, Wilson DL, et al. Hearing-aid outcome measured following one month of hearing aid use by the elderly. *J Speech Lang Hear Res*. 2001;44(3):469-486.

Humes LE, Halling D, Coughlin M. Reliability and stability of various hearing-aid outcome measures in a group of elderly hearing-aid wearers. *J Speech Hear Res*. 1996;39(5):923-935.

Humes LE, Wilson DL. A comparison of single-channel linear amplification and two-channel wide-dynamic-range-compression amplification by means of an independent-group design. *Am J Audiol*. 2004;13(1):39-53.

Humes LE, Wilson DL, Barlow NN, et al. Changes in hearing-aid benefit following 1 or 2 years of hearing-aid use by older adults. *J Speech Lang Hear Res*. 2002;45(4):772-782.

Ivory PJ, Hendricks BL, Van Vliet D, Beyer CM, Abrams HB. Short-term hearing aid benefit in a large group. *Trends Amplif.* 2009;13(4):260-280.

Appendix A4. Excluded Studies

Iwai H, Baba S, Omae M, et al. Maintenance of systemic immune functions prevents accelerated presbycusis. *Brain Res*. 2008;1208:8-16.

Jerram JC, Purdy SC. Technology, expectations, and adjustment to hearing loss: predictors of hearing aid outcome. *J Am Acad Audiol.* 2001;12(2):64-79.

Joore MA, Brunenberg DE, Chenault MN, et al. Societal effects of hearing aid fitting among the moderately hearing impaired. *Int J Audiol*. 2003;42(3):152-160.

Joore M, Brunenberg D, Zank H, et al. Development of a questionnaire to measure hearing-related health state preferences framed in an overall health perspective. *Int J Technol Assess Health Care*. 2002;18(3):528-539.

Joore MA, Potjewijd J, Timmerman AA, et al. Response shift in the measurement of quality of life in hearing impaired adults after hearing aid fitting. *Qual Life Res*. 2002;11(4):299-307.

Kaneko K, Shoji K, Kojima H, et al. Nonlinear digital hearing aid with near-instantaneous amplitude compression. *Eur Arch Otorhinolaryngol*. 2001;258(10):523-528.

Kricos PB. Audiologic management of older adults with hearing loss and compromised cognitive/psychoacoustic auditory processing capabilities. *Trends Amplif*. 2006;10(1):1-28.

Kricos PB. Hearing assistive technology considerations for older individuals with dual sensory loss. *Trends Amplif*. 2007;11(4):273-279.

Lamden KH, St Leger AS, Raveglia J. Hearing aids: value for money and health gain. *J Public Health Med.*1995;17(4):445-449.

Laplante-Levesque A, Pichora-Fuller MK, Gagne JP. Providing an internet-based audiological counseling programme to new hearing aid users: a qualitative study. *Int J Audiol*. 2006;45(12):697-706.

Lewis MS, Valente M, Horn JE, et al. The effect of hearing aids and frequency modulation technology on results from the communication profile for the hearing impaired. *J Am Acad Audiol*. 2005;16(4):250-261.

Martin M. International technical standards: whose problem is it? *Int J Audiol*. 2002;41:371-373.

McBride C, Mulrow CD, Tuley MR. Screening tests for hearing loss in the elderly. *Clin Res*. 1990;38(2):707A.

McLeod B, Upfold L, Broadbent C. An investigation of the applicability of the inventory, satisfaction with amplification in daily life, at 2 weeks post hearing aid fitting. *Ear Hear*. 2001;22(4):342-347.

McPherson B, Wong ET. Effectiveness of an affordable hearing aid with elderly persons. *Disabil Rehabil*. 2005;27(11):601-609.

Metz MJ, Nilsson MJ. The Words-In-Noise (WIN) test with multitalker babble and speech-spectrum noise maskers. *J Am Acad Audiol*. 2007;18(8):718.

Munro KJ, Lutman ME. Self-reported outcome in new hearing aid users over a 24-week post-fitting period. *Int J Audiol*. 2004;43(10):555-562.

Nabelek AK. Acceptable noise level: a clinical measure for predicting hearing aid outcome. *J Am Acad Audiol*. 2006;17(9):624-625.

Newman CW, Jacobson GP, Hug GA, et al. Practical method for quantifying hearing aid benefit in older adults. *J Am Acad Audiol*. 1991;2(2):70-75.

Noffsinger D, Haskell GB, Larson VD, et al. Quality rating test of hearing aid benefit in the NIDCD/VA clinical trial. *Ear Hear*. 2002;23(4):291-300.

Ohlemiller KK. Age-related hearing loss: the status of Schuknecht's typology. *Curr Opin Otolaryngol Head Neck Surg*. 2004;12(5):439-443.

Palmer CV, Adams SW, Bourgeois M, et al. Reduction in caregiver-identified problem behaviors in patients with Alzheimer disease post-hearing-aid fitting. *J Speech Lang Hear Res*. 1999;42(2):312-328.

Parving A, Philip B. Use and benefit of hearing aids in the tenth decade—and beyond. *Audiology*. 1991;30(2):61-69.

Philibert B, Collet L, Vesson JF, et al. Auditory rehabilitation effects on speech lateralization in hearing-impaired listeners. *Acta Otolaryngol*. 2003;123(2):172-175.

Saunders GH, Forsline A, Fausti SA. The performance-perceptual test and its relationship to unaided reported handicap. *Ear Hear*. 2004;25(2):117-126.

Saunders GH, Jutai JW. Hearing specific and generic measures of the psychosocial impact of hearing aids. *J Am Acad Audiol.* 2004;15(3):238-248.

Schum DJ. Responses of elderly hearing aid users on the hearing aid performance inventory. *J Am Acad Audiol.* 1992;3(5):308-314.

Schum DJ. Perceived hearing aid benefit in relation to perceived needs. *J Am Acad Audiol.*1999;10(1):40-45.

Someya S, Yamasoba T, Weindruch R, et al. Caloric restriction suppresses apoptotic cell death in the mammalian cochlea and leads to prevention of presbycusis. *Neurobiol Aging*. 2007;28(10):1613-1622.

Sood A, Taylor JS. Allergic contact dermatitis from hearing aid materials. *Dermatitis*. 2004;15(1):48-50.

Taylor KS. Self-perceived and audiometric evaluations of hearing aid benefit in the elderly. *Ear Hear*. 1993;14(6):390-394.

Tesch-Romer C. Psychological effects of hearing aid use in older adults. *J Gerontol B Psychol Sci Soc Sci*. 1997;52(3):127-138.

van Hooren SA, Anteunis LJ, Valentijn SA, et al. Does cognitive function in older adults with hearing impairment improve by hearing aid use? *Int J Audiol*. 2005;44(5):265-271.

Vikram KB, Naseeruddin K. Combined tuning fork tests in hearing loss: explorative clinical study of the patterns. *J Otolaryngol*. 2004;33(4):227-234.

Ward JA, Lord SR, Williams P, et al. Hearing impairment and hearing aid use in women over 65 years of age: cross-sectional study of women in a large urban community. *Med J Aust.* 1993;159(6):382-384.

Wazen JJ, Caruso M, Tjellstrom A. Long-term results with the titanium bone-anchored hearing aid: the U.S. experience. *Am J Otol*. 1998;19(6):737-741.

Weinstein BE. Age-related hearing loss: how to screen for it, and when to intervene. *Geriatrics*. 1994;49(8):40-45.

Weinstein BE. The quantification of hearing aid benefit in the elderly: the role of self-assessment measures. *Acta Otolaryngol Suppl*. 1990;476:257-261.

Yamasoba T, Someya S, Yamada C, et al. Role of mitochondrial dysfunction and mitochondrial DNA mutations in age-related hearing loss. *Hear Res*. 2007;226(1-2):185-193.

Diagnostic Test Accuracy Not Reported:

Matthews LJ, Lee FS, Mills JH, et al. Audiometric and subjective assessment of hearing handicap. *Arch Otolaryngol Head Neck Surg*. 1990;116(11):1325-1330.

Pugh KC, Crandell CC. Hearing loss, hearing handicap, and functional health status between African American and Caucasian American seniors. *J Am Acad Audiol*. 2002;13(9):493-502.

Diagnostic Accuracy Studies

Criteria:

- Screening test relevant, available for primary care, adequately described
- Study uses a credible reference standard, performed regardless of test results
- Reference standard interpreted independently of screening test
- Handles indeterminate results in a reasonable manner
- Spectrum of patients included in study
- Sample size
- Administration of reliable screening test
- Random or consecutive selection of patients[35]
- Screening cutoff pre-determined[35]
- All patients undergo the reference standard[35]

Definition of ratings based on above criteria:

Good: Evaluates relevant available screening test; uses a credible reference standard; interprets reference standard independently of screening test; reliability of test assessed; has few or handles indeterminate results in a reasonable manner; includes large number (more than 100) of broad-spectrum patients with and without disease; study attempts to enroll a random or consecutive sample of patients who meet inclusion criteria[35]; screening cutoffs are pre-stated.[35]

Fair: Evaluates relevant available screening test; uses reasonable although not best standard; interprets reference standard independent of screening test; moderate sample size (50 to 100 subjects) and a "medium" spectrum of patients (i.e., applicable to most screening settings).

Poor: Has important limitations, such as uses inappropriate reference standard; screening test improperly administered; biased ascertainment of reference standard; very small sample size of very narrow selected spectrum of patients.

Randomized Controlled Trials (RCTs) and Cohort Studies

Criteria:

- Initial assembly of comparable groups: RCTs—adequate randomization, including concealment and whether potential confounders were distributed equally among groups; cohort studies—consideration of potential confounders with either restriction or measurement for adjustment in the analysis; consideration of inception cohorts
- Maintenance of comparable groups (includes attrition, cross-over, adherence, contamination)
- Important differential loss to follow-up or overall high loss to follow-up
- Measurements are equal, reliable, and valid (includes masking of outcome assessment)
- Clear definition of interventions
- Important outcomes considered
- Analysis: adjustment for potential confounders for cohort studies, or intention-to-treat analysis for RCTs; for cluster RCTs, correction for correlation coefficient

Definition of ratings based on above criteria:

Good: Meets all criteria; comparable groups are assembled initially and maintained throughout the study (follow-up at least 80 percent); reliable and valid measurement instruments are used and applied equally to the groups; interventions are spelled out clearly; important outcomes are considered; appropriate attention to confounders in analysis.

Fair: Studies are graded "fair" if any or all of the following problems occur, without the important limitations noted in the "poor" category below: generally comparable groups are assembled initially but some question remains whether some (although not major) differences occurred in follow-up; measurement instruments are acceptable (although not the best) and generally applied equally; some but not all important outcomes are considered; some but not all potential confounders are accounted for.

Poor: Studies are graded "poor" if any of the following major limitations exists: groups assembled initially are not close to being comparable or maintained throughout the study; unreliable or invalid measurement instruments are used or not applied at all equally among groups (including not masking outcome assessment); key confounders are given little or no attention.

Case Control Studies

Criteria:

- Accurate ascertainment of cases
- Non-biased selection of cases/controls with exclusion criteria applied equally to both
- Response rate
- Diagnostic testing procedures applied equally to each group
- Measurement of exposure accurate and applied equally to each group
- Appropriate attention to potential confounding variable

Definition of ratings based on criteria above:

Good: Appropriate ascertainment of cases and non-biased selection of case and control participants; exclusion criteria applied equally to cases and controls; response rate equal to or greater than 80 percent; diagnostic procedures and measurements accurate and applied equally to cases and controls; appropriate attention to confounding variables.

Fair: Recent; relevant; without major apparent selection or diagnostic work-up bias but with response rate less than 80 percent or attention to some but not all important confounding variables.

Poor: Major selection or diagnostic work-up biases; response rates less than 50 percent or inattention to confounding variables.

Appendix A6. Expert Reviewers of the Draft Report

Karen J. Cruickshanks, PhD
Professor, University of Wisconsin-Madison School of Medicine and Public Health, Ophthalmology and Visual Sciences and Population Health Sciences

Linda Kinsinger, MD, MPH
Chief Consultant, Preventive Medicine, Veterans Health Administration, National Center for Health Promotion and Disease Prevention

Paul Shekelle, MD, PhD
Director, Southern California Evidence-Based Practice Center, RAND Corporation; Professor of Medicine, University of California, Los Angeles School of Medicine; Staff physician, Veterans Affairs Medical Center

Daniel A. Sklare, PhD
Research Training Officer, National Institute on Deafness and Other Communication Disorders, National Institutes of Health**,** Division of Scientific Programs

Appendix B1. Randomized Controlled Trials of Screening and Treatment Evidence Table

Study, Year	Purpose of study	Study design	Inclusion criteria	Exclusion criteria	# Screened/ eligible/enrolled	Subject age, Sex, Diagnosis	Country & Setting
Screening							
Yueh et al, 2010[36]	To evaluate effect of hearing screening on long-term hearing outcomes in a population of older veterans	Unblinded randomized trial	Outpatients seeking general medical care from VA Puget Sound Health Care System (Seattle and Tacoma) between Jan 2002 and Dec 2003; age ≥50 yrs; eligible to receive audiology services (must have 10-100% disability rating for any medical condition or any disability rating for a hearing-related condition)	Previous use of hearing aid; hearing evaluation in prior 6 months; unable to complete questionnaire; unwilling to follow-up by mail 1 year after screening	NR/NR/2314 2305 after post-randomization exclusions	Mean age: 61 yrs Sex: 94% male Mean baseline hearing loss: NR	US VA primary care clinic
Treatment							
Jerger et al, 1996[58]	To assess impact of personal amplification systems on quality of life in elderly persons and compare conventional hearing aids with assistive listening devices	Cross-over	Age >60 yrs; hearing loss >15 dB in both ears; normal middle ear status; average score ≤3 on self-report physical health scale; score ≥24 on Mini Mental State Exam; no history of neurologic or psychiatric disorder	NR	NR/NR/180	Mean age: 74.3 yrs (range, 60-96 yrs) Sex: 63% male Mean pre-tone threshold: 37 dB Mean baseline HHIE-S score: 30 (New users only)	US Setting NR

Study, Year	Sponsor	Measures	Intervention Type	Results	Duration of follow-up	Loss to follow-up	Adverse events & withdrawals	Quality Score
Screening								
Yueh et al, 2010[36]	VHA	*Screening* Tone-emitting otoscope; HHIE-S; and both otoscope and HHIE-S *Hearing-related function* Effectiveness of Aural Rehabilitation Scale; single-question test (Do you think you have a hearing problem?) *Primary outcome measure* Single-question test (Do you use your hearing aids?)	4 screening arms: Otoscope only (n=463) Questionnaire only (n=462) Otoscope and questionnaire (n=460) No screening (n=929)	*Screening w/AudioScope vs. HHIE-S vs. both vs. no screening, results at 1 year* Hearing aid use: 29/462 (6.3%) vs. 19/461 (4.1%) vs. 34/459 (7.4%) vs. 30/923 (3.3%); p=0.003 >6 point improvement on the Inner Effectiveness of Aural Rehabilitation scale: 146/361 (40%) vs. 125/346 (36%) vs. 141/355 (40%) vs. 252/700 (36%); p=0.39 Screening was not associated with any statistically significant differences in hearing-related quality of life compared with no screening (reported in text; no data)	1 year	High overall loss to follow-up (23.1%)	NR	Fair
Treatment								
Jerger et al, 1996[58]	National Institute on Aging	HHIE-S; Speech Perception in Noise Test; Brief Symptom Inventory: Social Activity Scale, Life Satisfaction in the Elderly Scale, Affect Balance Scale	n=80 for each intervention (cross-over) Hearing aid vs. assistive listening device vs. both vs. none	*Hearing aid vs. assistive listening device vs. both vs. none, mean scores at 6 weeks* HHIE-S: 25 vs. 27 vs. 26 vs. 28 (p>0.05) Speech Perception in Noise: 53% vs. 75% vs. 71% vs. 42% (p<0.05) Brief Symptom Inventory: no differences between interventions (data NR)	6 weeks	NR	NR	Fair

Appendix B1. Randomized Controlled Trials of Screening and Treatment Evidence Table

Study, Year	Purpose of study	Study design	Inclusion criteria	Exclusion criteria	# Screened/ eligible/enrolled	Subject age, Sex, Diagnosis	Country & Setting
Mulrow et al, 1990[13]	To assess whether hearing aids improve quality of life in elderly persons with hearing loss	Unblinded RCT	Age >64 yrs; attending general medicine clinic between June 1987 and June 1988	Already using a hearing aid; severe comorbidity including terminal cancer, hepatic encephalopathy, and end-stage pulmonary disease; requiring home oxygen therapy; residence >100 miles from clinic	771/587/194*	Mean age: 72 yrs Sex: 99% male Race: 97% white Mean pure-tone threshold, better ear: 52 dB† Mean baseline HHIE-S score: 50	US VA primary care clinic
Tolson et al, 2002[59]	To determine if hearing aid use makes a difference in mood, perception of wellbeing in patients and caregivers, caregiver stress, and familial relationships	Unblinded RCT	NR	NR	356/NR/133	Mean age: 76.6 yrs Sex: 23% male Other baseline characteristics: NR	UK General practice clinic

Study, Year	Sponsor	Measures	Intervention Type	Results	Duration of follow-up	Loss to follow-up	Adverse events & withdrawals	Quality Score
Mulrow et al, 1990[13]	Robert Wood Johnson Foundation; Milbank Scholar Program; ACP Teaching and Research Scholar Award	HHIE-S; Quantified Denver Scale; Short Portable Mental Status Questionnaire; Geriatric Depression Scale; Self Evaluation of Life Function	Immediate hearing aid use (n=95) vs. wait list (n=99)	*Immediate hearing aid use vs. wait list, mean scores at 4 months (mean difference in change from baseline)* HHIE-S: 15 vs. 51 (34 [95% CI, 27 to 41]; p<0.001) Quantified Denver Scale: 36 vs. 62 (24 [95% CI, 17 to 31]; p<0.001) Short Portable Mental Status Questionnaire: 0.29 vs. 0.28 (0.28 [95% CI, 0.08 to 0.48]; p=0.008) Geriatric Depression Scale: 2.6 vs. 3.8 (0.80 [95% CI, 0.09 to 1.5]; p=0.03) Self Evaluation of Life Function: 92 vs. 97 (1.9 [95% CI, -1.6 to 5.4]; p=0.27)	4 months	At 4 months: 6/194 (3%)	NR	Good
Tolson et al, 2002[59]	NR	Mini Mental Status Examination; Geriatric Depression Scale, Malaise Inventory (caregiver); Family Relationship Index; 14-item caregiver's assessment of hearing difficulties	Hearing aid (n=63) vs. no hearing aid (n=70)	NR; authors state “depression scores were unchanged at the 6-month follow-up” in the intervention group	6 months	NR	NR	Poor

Appendix B1. Randomized Controlled Trials of Screening and Treatment Evidence Table

Study, Year	Purpose of study	Study design	Inclusion criteria	Exclusion criteria	# Screened/ eligible/enrolled	Subject age, Sex, Diagnosis	Country & Setting
Yueh et al, 2001[57]	To compare the effectiveness of a non-programmable hearing aid with a programmable hearing aid	Unblinded RCT	Age >50 yrs; seeking diagnostic or hearing aid evaluation	Asymmetric or conductive hearing loss; loss other than mild to moderately severe; upsloping hearing loss of ≥5 dB per octave between 500 and 3000 Hz; poor word recognition scores; atypical cause of sensorineural hearing loss; prior hearing aid use; poor cognitive function; poor manual dexterity	NR/NR/64	Mean age: 68.5 yrs Sex: 100% male Race: NR Mean pure-tone threshold, right ear: 33 dB Mean pure-tone threshold, left ear: 32 dB Mean baseline HHIE-S score: 28 vs. 35 (assistive listening device vs. no treatment); 50 vs. 36 (programmable vs. standard hearing aid)	US VA audiology clinic

Study, Year	Sponsor	Measures	Intervention Type	Results	Duration of follow-up	Loss to follow-up	Adverse events & withdrawals	Quality Score
Yueh et al, 2001[57]	Career Development Award; VA	HHIE-S; Abbreviated Profile of Hearing Aid Benefit; Revised Quantified Denver Scale; social isolation	Programmable hearing aid (n=16) vs. standard (non-programmable) hearing aid (n=14) and assistive listening device (n=15) vs. no treatment (n=15)	*Assistive listening device vs. no treatment, mean scores at 3 months* HHIE-S: 4.4 vs. 2.2 Abbreviated Profile of Hearing Aid Benefit: 6.4 vs. 2.7 Revised Quantified Denver Scale: 0.03 vs. -0.05 Proportion reporting less social isolation: 0/15 (0%) vs. 0/15 (0%) *Programmable hearing aid vs. standard hearing aid, results at 3 months* HHIE-S: 31 vs. 17 (p<0.05) Abbreviated Profile of Hearing Aid Benefit: 16 vs. 7.7 Revised Quantified Denver Scale: 0.84 vs. 0.70 Proportion reporting less social isolation: 10/16 (62%) vs. 2/14 (14%)	3 months	4/64 (6%)	NR	Fair

*Includes 72 subjects referred from other clinics.
†Average at 1000, 2000, and 4000 Hz.
‡p=0.05.

Abbreviations: # = number; ACP = American College of Physicians; CI = confidence interval; HHIE-S = Hearing Handicap Inventory In the Elderly-Screening; NR = not reported; RCT = randomized controlled trial; UK = United Kingdom; US = United States; VA = Department of Veterans Affairs; VHA = Veterans Health Administration.

Appendix B2. Quality Ratings for Trials of Screening and Treatment

Study, Year	Random assignment	Allocation concealed	Groups similar at baseline	Eligibility criteria specified	Patient blinding	Provider blinding	Outcome assessor or data analyst blinding	Intention-to-treat analysis
Screening								
Yueh et al, 2010[36]	Described as randomized, method NR	Yes	Yes	Yes	N/A	N/A	Cannot tell	Yes
Treatment								
Jerger et al, 1996[58]	Described as randomized, method NR	Cannot tell	Cannot tell	Yes	N/A	N/A	Cannot tell	Yes
Mulrow et al, 1990[13]	Described as randomized, method NR	Yes	Yes	Yes	N/A	N/A	Cannot tell	Yes
Tolson et al, 2002[59]	Yes	Cannot tell	Yes	No	N/A	N/A	Cannot tell	Cannot tell
Yueh et al, 2001[57]	Described as randomized, method NR	Yes	No	Yes	N/A	N/A	Cannot tell	Cannot tell

Study, Year	Reporting of attrition, contamination	Differential loss to follow-up, overall high loss to follow-up, or incomplete follow-up	Funding source	External validity	Quality score
Screening					
Yueh et al, 2010[36]	Yes	High overall loss to follow-up	Veterans Health Administration	Mean age: 61 years (SD, 9) Sex: 94% male Race: 75% white Mean hearing loss: NR	Fair
Treatment					
Jerger et al, 1996[58]	No	Cannot tell	National Institute on Aging	Mean age: 74.3 years (range, 60-96) Sex: 63% male Mean pure-tone threshold: 37 dB**	Fair
Mulrow et al, 1990[13]	Yes	No	Robert Wood Johnson Foundation; Milbank Scholar Program; ACP Teaching and Research Scholar Award	Mean age: 72 years (SD, 6) Sex: 99% male Race: 97% white Mean pure-tone threshold, better ear: 52 dB (SD, 8)*	Good
Tolson et al, 2002[59]	No	Cannot tell	Not reported	Mean age: 76.6 years Sex: 77% female Other baseline characteristics: NR	Poor
Yueh et al, 2001[57]	No	No	Career Development Award, Department of Veterans Affairs	Mean age: 68.5 years (range, 50-86) Sex: 100% male Race: NR Mean pure-tone threshold, right ear: 32.8 dB (SD, 5.6) Mean pure-tone threshold, left ear: 32.3 (SD, 5.7)	Fair

*Average of 1000, 2000, and 4000 Hz hearing levels.
**New users group only.

Abbreviations: ACP = American College of Physicians; N/A = not applicable; NR = not reported; SD = standard deviation.

Appendix B3. Whispered Voice, Watch Tick, and Finger Rub Clinical Tests Evidence Table

Study, Year	Screening test	Reference standard	Type of study	Setting	Screener	Age of enrollees	N	Proportion with hearing loss	Definition of a positive screening exam
Boatman et al, 2007[39]	Whispered voice at 2 feet	Pure-tone audiometry	Cross-sectional	Movement disorders clinic (patients or family)	Neurologist	50-88 years	107 (214 ears)	Hearing loss >25 dB: 63% (135/214)	Inability to repeat 2 or more words from two 3-word combinations
	Watch tick at 6 inches								No response to 2 or more of 6 presentations of watch tick
	Finger rub at 6 inches								No response to 2 or more of 6 finger rubs
Eekhof et al,1996[40]	Whispered voice at 2 feet	Pure-tone audiometry	Cross-sectional	Otolaryngology clinic	NR	≥55 years (mean age NR)	62 (124 ears)	Hearing loss >30 dB: 59% (73/124) Hearing loss >40 dB: 33% (41/124)	Inability to repeat 2 or more combinations correctly
Macphee et al,1988[41]	Whispered voice at 2 feet	Pure-tone audiometry	Cross-sectional	Acute rehabilitation wards	Geriatrician and otolaryngologist	Mean age 81 years (range, 66 to 96)	62 (124 ears)	Hearing loss >30dB: 61% (38/62)	Inability to repeat 1 triplet set of numbers correctly or 50% of 4 sets of triplet numbers
	Whispered voice at 6 inches								Inability to repeat 1 triplet set of numbers correctly or 50% of 4 sets of triplet numbers
	Conversation voice at 2 feet								Inability to repeat 1 triplet set of numbers correctly or 50% of 4 sets of triplet numbers
Swan et al, 1985[42]	Whispered voice at 2 feet	Pure-tone audiometry	Cross-sectional	Audiology clinic	NR	Mean age 57 years	101 (202 ears)	Hearing loss >30 dB: 43% (87/202)	Unable to repeat at least 3 out of 6 letters or numerals correctly

Study, Year	Definition of a case	Subjects	Proportion un-examinable by screening test	Analysis of screening failures	Proportion who underwent reference standard	Sensitivity (range)	Specificity (range)	Positive likelihood ratio (95% CI)	Negative likelihood ratio (95% CI)
Boatman et al, 2007[39]	>25 dB hearing loss at 500 Hz	Age: 66 years Sex: 51% female	Appears to be none	NA	100% (214/214 ears)	0.40 (0.32-0.49)	0.82 (0.72-0.90)	2.3 (1.3-3.8)	0.73 (0.61-0.87)
	>25 dB hearing loss at 1000 Hz					0.44 (0.35-0.53)	1.0 (0.95-1.0)	70 (4.4-1120)	0.57 (0.49-0.66)
	>25 dB hearing loss at 2000 Hz					0.27 (0.19-0.35)	0.98 (0.91-1.0)	10 (2.6-43)	0.75 (0.68-0.84)
Eekhof et al,1996[40]	>30 dB hearing loss in either ear (frequency NR)	Age: ≥55 years (mean NR) Sex: NR	Appears to be none	NA	100% (124/124 ears)	0.90 (0.81-0.96)	0.80 (0.67-0.90)	4.6 (2.6-8.1)	0.12 (0.06-0.24)
Macphee et al,1988[41]	>30 dB hearing loss at 500 Hz	Mean age: 81 years Sex: 69% female	Appears to be none	NA	100% (124/124 ears)	1.0 (0.95-1.0)	0.83 (0.70-0.93)	5.7 (3.1-10.6)	0.008 (0.0005-0.13)
	>30 dB hearing loss at 1000 Hz					0.74 (0.62-0.83)	1.0 (0.93-1.0)	72 (4.6-1140)	0.27 (0.19-0.39)
	>30 dB hearing loss at 2000 Hz					0.47 (0.36-0.59)	1.0 (0.93-1.0)	46 (2.9-740)	0.53 (0.43-0.66)
Swan et al, 1985[42]	>30 dB hearing loss at 500, 1000, and 2000 Hz	Mean age: 57 years Sex: NR	Appears to be none	NA	100% (202/202 ears)	1.0 (0.96-1.0)	0.87 (0.79-0.93)	7.4 (4.7-12)	0.007 (0.0005-0.10)

Appendix B3. Whispered Voice, Watch Tick, and Finger Rub Clinical Tests Evidence Table

Study, Year	Positive predictive value	Negative predictive value	Diagnostic odds ratio	Quality score
Boatman et al, 2007[39]	0.79 (0.68-0.88)	0.45 (0.36-0.53)	3.1 (1.5-6.6)	Good
	1.0 (0.94-1.0)	0.51 (0.43-0.59)	120 (7.5-2040)	
	0.95 (0.82-0.99)	0.44 (0.36-0.51)	14 (3.4-120)	
Eekhof et al, 1996[40]	0.87 (0.77-0.94)	0.85 (0.72-0.94)	39 (12-130)	Fair
Macphee et al,1988[41]	0.91 (0.82-0.96)	1.0 (0.91-1.0)	730 (41-12,950)	Fair
	1.0 (0.94-1.0)	0.71 (0.58-0.81)	270 (16-4540)	
	1.0 (0.90-1.0)	0.55 (0.44-0.65)	87 (5.2-1470)	
Swan et al, 1985[42]	0.85 (0.77-0.92)	1.0 (0.96-1.0)	1140 (70-19,240)	Fair

Abbreviations: CI = confidence interval; N = number of enrollees; NA = not applicable; NR = not reported.

Appendix B4. Single Screening Question Evidence Table

Study, Year	Screening question	Reference standard	Type of study	Setting	Screener	Age of enrollees	N	Proportion with hearing loss	Subjects	Proportion unexaminable by screening test
Community-Dwelling Older Adults										
Boatman et al, 2007[39]	Do you think you have difficulty hearing?	Pure-tone audiometry	Cross-sectional	Patients and family from movement disorders clinic	Neurologist Reference test: audiologist	50-88 years	107	Hearing loss >25 dB: 24%	Ages 50-64: 37% Ages 65-74: 49% Ages >74: 14% Sex: 49% male	NR
Clark et al, 1991[43]	Would you say that you have any difficulty hearing?	Pure-tone audiometry	Cross-sectional	Population from an osteoporosis study	NR Reference test: audiologist	60-85 years	267	Hearing loss >40 dB: 18% Hearing loss >25 dB: 45%	Age: NR Sex: 100% female	NR
Gates et al, 2003[47]	Do you have a hearing problem now?	Pure-tone audiometry	Cross-sectional	Subset of Framingham cohort	Self-administered questionnaire with audiologist review	>70 years	546	Hearing loss >40 dB (V&W): 27%	Mean age: 78.3 (±4.1) Sex: 36% male	7% (due to time, fatigue, malaise)

Study, Year	Analysis of screening failures	Proportion who underwent reference standard	Definition of a case	Sensitivity	Specificity	Positive likelihood ratio	Negative likelihood ratio	Positive predictive value	Negative predictive value	Diagnostic odds ratio	Quality score
Community-Dwelling Older Adults											
Boatman et al, 2007[39]	None	100%	>25 dB hearing loss at 500, 1000, 2000, or 4000 Hz in either ear	0.27 (0.16-0.41)	0.89 (0.78-0.96)	2.5 (1.0-5.9)	0.82 (0.68-0.99)	0.70 (0.46-0.88)	0.56 (0.45-0.67)	3.0 (0.96-10)	Good
Clark et al, 1991[43]	None	99% (267/290)	≥25 dB hearing loss at 1000 and 2000 Hz in better ear	0.66 (0.55-0.75)	0.80 (0.74-0.86)	3.3 (2.4-4.6)	0.43 (0.32-0.58)	0.63 (0.52-0.73)	0.82 (0.76-0.88)	7.7 (4.2-14)	Good
			≥25 dB hearing loss at 1000, 2000, 3000, and 4000 Hz in better ear	0.56 (0.47-0.65)	0.82 (0.75-0.88)	3.1 (2.1-4.5)	0.53 (0.43-0.67)	0.71 (0.61-0.80)	0.70 (0.63-0.77)	5.8 (3.2-10)	
			>40 dB hearing loss at 1000 and 2000 Hz in worse ear	0.81 (0.67-0.91)	0.74 (0.68-0.80)	3.1 (2.4-4.1)	0.26 (0.14-0.47)	0.40 (0.30-0.51)	0.95 (0.90-0.98)	12 (5.3-30)	
Gates et al, 2003[47]	None	93% (672/723)	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears or >40 dB hearing loss at 1000 and 2000 Hz in one ear	0.71 (0.63-0.78)	0.72 (0.67-0.76)	2.5 (2.1-3.0)	0.41 (0.31-0.53)	0.48 (0.41-0.55)	0.87 (0.83-0.90)	6.2 (4.0-9.6)	Good

Appendix B4. Single Screening Question Evidence Table

Study, Year	Screening question	Reference standard	Type of study	Setting	Screener	Age of enrollees	N	Proportion with hearing loss	Subjects	Proportion unexaminable by screening test
Nondahl et al, 1998[44] Wiley et al, 2000[69]	Do you feel you have hearing loss?	Pure-tone audiometry	Cross-sectional	Subset of Beaver Dam Eye Study	NR	48-92 years	3342	Hearing loss >25 dB: 32%	Age: 65.8 years Sex: 42.3% male	6.0% did not respond or answered "I don't know"
Rawool et al, 2008[52]	Do you think you have hearing loss?	Pure-tone audiometry (portable audiometer)	Cross-sectional	Volunteer active community dwelling	Researcher	≥65 years	30	Hearing loss >25 dB: 63%	Age: 77.5 years Sex: 26.7% male	NR
Sindhusake et al, 2001[45]	Do you feel you have hearing loss?	Pure-tone audiometry	Cross-sectional	Subset of Blue Mountain Eye Study	NR Reference test: audiologist	55-99 years	1931	Hearing loss >25 dB: 39% Hearing loss >40 dB: 14% Hearing loss >60 dB: 2%	Age 55-64: 29.8% Age 65-74: 41.1% Age 75-84: 24% Age ≥85: 5.1% Sex: 42.6% male	3.6% did not answer or answered "don't know"
Torre et al, 2006[54]	Do you feel you have hearing loss? English and Spanish)	Pure-tone audiometry (portable audiometer)	Cross-sectional	Referred from physicians or medical staff	NR	42-88 years	59	Hearing loss >25 dB: 63%	Mean age: 62.3 years Sex: 45.8% male	None

Study, Year	Analysis of screening failures	Proportion who underwent reference standard	Definition of a case	Sensitivity	Specificity	Positive likelihood ratio	Negative likelihood ratio	Positive predictive value	Negative predictive value	Diagnostic odds ratio	Quality score
Nondahl et al, 1998[44] Wiley et al, 2000[69]	None	89% (3342/3753); 1701 were ages 65-92 years	>25 dB hearing loss at 500, 1000, 2000, and 4000 Hz in either ear	0.67 (0.64-0.70)	0.80 (0.77-0.83)	3.4 (2.8-4.0)	0.41 (0.38-0.45)	0.86 (0.84-0.88)	0.57 (0.53-0.60)	8.1 (6.4-10)	Good
Rawool et al, 2008[52]	None	100%	≥25 dB hearing loss at 500, 1000, 2000, 3000, and 4000 Hz in better ear	0.68 (0.43-0.87)	0.81 (0.48-0.98)	3.8 (1.0-13.7)	0.39 (0.19-0.79)	0.87 (0.60-0.98)	0.60 (0.32-0.84)	9.8 (1.3-110)	Fair
Sindhusake et al, 2001[45]	None	96% (1931/2015)	>25 dB hearing loss at 500-4000 Hz	0.78 (0.75-0.81)	0.67 (0.64-0.70)	2.4 (2.2-2.6)	0.33 (0.29-0.38)	0.61 (0.58-0.64)	0.82 (0.80-0.85)	7.2 (5.8-8.9)	Good
			>40 dB hearing loss at 500-4000 Hz	0.93 (0.89-0.96)	0.56 (0.54-0.58)	2.1 (2.0-2.3)	0.13 (0.08-0.20)	0.25 (0.23-0.28)	0.98 (0.97-0.99)	17 (10-28)	
			>60 dB hearing loss at 500-4000 Hz	1.0 (0.92-1.0)	0.50 (0.48-0.52)	2.0 (1.9-2.1)	0.02 (0.001-0.34)	0.05 (0.03-0.06)	1.0 (1.0-1.0)	91 (5.6-1480)	
Torre et al, 2006[54]	NA	100% (32/32) all were ages 60 and older	≥25 dB hearing loss at 500, 1000, 2000, and 4000 Hz in worse ear	0.76 (0.59-0.88)	0.73 (0.50-0.89)	2.8 (1.4-5.6)	0.33 (0.18-0.62)	0.82 (0.66-0.93)	0.64 (0.43-0.82)	8.3 (2.2-33)	Fair

Appendix B4. Single Screening Question Evidence Table

Study, Year	Screening question	Reference standard	Type of study	Setting	Screener	Age of enrollees	N	Proportion with hearing loss	Subjects	Proportion unexaminable by screening test
Nursing Home-Dwelling Older Adults										
Voeks et al, 1993[55]	Do you have trouble hearing?	Pure-tone audiometry (portable audiometer)	Cross-sectional	New admissions to nursing home	NR	NR	198	Hearing loss >25 dB: 54%	Mean age: 72.4 years (±11.4) Sex: 80% male	17% (41/239) did not have reliable audiometric responses

Study, Year	Analysis of screening failures	Proportion who underwent reference standard	Definition of a case	Sensitivity	Specificity	Positive likelihood ratio	Negative likelihood ratio	Positive predictive value	Negative predictive value	Diagnostic odds ratio	Quality score
Nursing Home-Dwelling Older Adults											
Voeks et al, 1993[55]	>50% of those with unreliable results gave verbal indication of some hearing dysfunction	84% (198/239)	>25 dB hearing loss at 500, 1000, 2000, and 4000 Hz in better ear	0.69 (0.60-0.78)	0.51 (0.40-0.61)	1.4 (1.1-1.8)	0.61 (0.43-0.87)	0.62 (0.53-0.71)	0.58 (0.47-0.69)	2.3 (1.2-4.3)	Fair

Abbreviations: N = number of enrollees; NR = not reported; V&W = Ventry & Weinstein criteria.

Appendix B5. Hearing Questionnaires Evidence Table

Study, Year	Screening test	Reference standard	Type of study	Setting	Screener	Age of enrollees	N	Proportion with hearing loss	Definition of a positive screening exam	Subjects	Proportion unexaminable by screening test
Community-Dwelling											
Gates et al, 2003[47]	HHIE-S	Pure-tone thresholds	Cross-sectional	Subset of Framingham cohort	Self-administered questionnaire with audiologist review	>70 years	546	Hearing loss >40 dB (V&W criteria): 27%	Score >8 on HHIE-S	Mean age: 78.3 yrs (±4.1) Sex: 36% male	7% (51/723) due to time, fatigue, malaise
Lichtenstein et al, 1988[46]	HHIE-S	Pure-tone thresholds	Cross-sectional	Internal medicine clinic	Self-administered HHIE-S Reference test: unknown	>65 years	178	Hearing loss >40 dB (V&W criteria): 30%	Score >8 on HHIE-S	Age: 74.2 yrs ±6.4 Sex: 37.1% male Race: 77.5% white	13% (36/284)
								Hearing loss >40 dB (V&W criteria): 30%	Score >24 on HHIE-S		
								Hearing loss >25 dB (SFPTA criteria): 38%	Score >8 on HHIE-S		
								Hearing loss >25 dB (HFPTA criteria): 58%	Score >8 on HHIE-S		
McBride et al, 1994[22]	HHIE-S	Pure-tone thresholds	Cross-sectional	Community health clinic; VA Medical Center	Trained researcher	>60 years	185	Not reported	Score >8 on HHIE-S; Score >24 on HHIE-S	Mean age: 70 yrs (±5.0) Sex: 69% male SES: 8 mean yrs of school	6.1% (13/212)
Nondahl et al, 1998[44] Wiley et al, 2000[69]	HHIE-S	Pure-tone thresholds	Cross-sectional	Subset of Beaver Dam Eye Study	Unknown	48-92 years	3471	Hearing loss >25 dB: 32%	Score >8 on HHIE-S	Age: 65.8 years Sex: 42.3% male	2.4% did not complete all questions and were excluded
Sever et al, 1989[53]	HHIE-S	Pure-tone thresholds	Cross-sectional	Audiology clinic	Unknown	60-84 years	59	Hearing loss >25 dB (SFPTA criteria): 36% Hearing loss >40 dB (V&W criteria): 27%	Score 0-8, 10-24, or 26-40 on HHIE-S	Age: Not reported Sex: Not reported	Not reported
Sindhusake et al, 2001[45]	HHIE-S	Pure-tone thresholds	Cross-sectional	Subset of Blue Mountain Eye Study	Screening test: unknown Reference test: audiologist	55-99 years	1807	Hearing loss >25 dB: 39% Hearing loss >40 dB: 13% Hearing loss >60 dB: 2%	Score >8 on HHIE-S	Age 55-64: 29.8% Age 65-74: 41.1% Age 75-84: 24.0% Age ≥85: 5.1% Sex: 42.6% male	9.8% did not complete all questions and were excluded
Ventry & Weinstein, 1983[9]	HHIE-S	Pure-tone thresholds	Cross-sectional	Community volunteers	Unknown	≥65 years	104	Hearing loss >40 dB: 51%	Score >8 on HHIE-S	Age: Not reported Sex: Not reported	Not reported
Weinstein, 1986[56]	HHIE-S	Pure-tone thresholds	Cross-sectional	Senior citizen centers	Unknown	62-91 years	106	Not reported	Score >8 on HHIE-S; Score >10 on HHIE-S	Age: 76 yrs (±6.9) Sex: 42.3% male	Not reported
Koike et al, 1994[51]	FMHT	Pure-tone thresholds	Cross-sectional	Audiology clinic	Unknown	>55 years	70	Not reported	Various cutoff scores on the FMHT	Age: 69.1 yrs (±8.39) Sex: 56% male	Not reported

Appendix B5. Hearing Questionnaires Evidence Table

Study, Year	Analysis of screening failures	Proportion who underwent reference test	Definition of a case	Sensitivity	Specificity	Positive likelihood ratio	Negative likelihood ratio	Positive predictive value	Negative predictive value	Diagnostic odds ratio	Quality score
Community-Dwelling											
Gates et al, 2003[47]	None	100% (672/672)	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in one ear	0.36 (0.28-0.44)	0.92 (0.89-0.94)	4.5 (3.0-6.7)	0.70 (0.61-0.79)	0.62 (0.51-0.73)	0.80 (0.76-0.83)	6.5 (3.8-11)	Good
Lichtenstein et al, 1988[46]	None	100% (178/178)	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in one ear	0.72 (0.58-0.83)	0.77 (0.68-0.84)	3.1 (2.2-4.4)	0.37 (0.24-0.57)	0.57 (0.44-0.69)	0.87 (0.79-0.92)	8.4 (3.8-19)	Good
			V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in one ear	0.25 (0.14-0.38)	0.98 (0.93-1.0)	10.2 (3.0-34.0)	0.77 (0.66-0.90)	0.81 (0.54-0.96)	0.75 (0.68-0.82)	13 (3.3-75)	
			SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.66 (0.54-0.77)	0.79 (0.70-0.86)	3.2 (2.1-4.7)	0.43 (0.30-0.60)	0.66 (0.54-0.77)	0.79 (0.70-0.86)	7.4 (3.6-16)	
			HFPTA: ≥25 dB hearing loss at 1000, 2000, and 4000 Hz in better ear	0.53 (0.43-0.63)	0.84 (0.74-0.91)	3.3 (1.9-5.8)	0.56 (0.44-0.70)	0.82 (0.71-0.90)	0.57 (0.47-0.66)	6.0 (2.8-14)	
McBride et al, 1994[22]	Not applicable	100%	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.58 (0.45-0.70)	0.76 (0.69-0.84)	2.4 (1.6-3.5)*	0.55*	Not calculable	Not calculable	4.4*	Good
			HFPTA: ≥25 dB hearing loss at 1000, 2000, and 4000 Hz in better ear	0.48 (0.39-0.58)	0.86 (0.79-0.94)	3.6 (2.0-6.6)*	0.60*	Not calculable	Not calculable	5.7*	
			V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in one ear	0.63 (0.49-0.76)	0.75 (0.68-0.82)	2.5 (1.8-3.6)*	0.49*	Not calculable	Not calculable	5.1*	
			SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.36 (0.23-0.48)	0.87 (0.81-0.93)	2.8 (1.6-5.0)*	0.74*	Not calculable	Not calculable	3.8*	
			HFPTA: ≥25 dB hearing loss at 1000, 2000, and 4000 Hz in better ear	0.29 (0.20-0.37)	0.93 (0.88-0.99)	4.3 (1.7-10)*	0.76*	Not calculable	Not calculable	5.4*	
			V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in one ear	0.42 (0.28-0.56)	0.88 (0.82-0.93)	3.4 (1.9-5.9)*	0.66*	Not calculable	Not calculable	5.3*	
Nondahl et al, 1998[44] Wiley et al, 2000[69]	None	100% (1725/1725 for ages 65-92 yrs)	>25 dB hearing loss at 500, 1000, 2000, and 4000 Hz in either ear	0.32 (0.29-0.35)	0.97 (0.95-0.98)	10.7 (6.8-17.1)	0.70 (0.67-0.73)	0.95 (0.93-0.97)	0.44 (0.41-0.46)	15 (9.4-26)	Good

Appendix B5. Hearing Questionnaires Evidence Table

Study, Year	Analysis of screening failures	Proportion who underwent reference test	Definition of a case	Sensitivity	Specificity	Positive likelihood ratio	Negative likelihood ratio	Positive predictive value	Negative predictive value	Diagnostic odds ratio	Quality score
Sever et al, 1989[53]	None	100%	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.71 (0.48-0.89) for HHIE-S score >8	Not reported	Not calculable	Not calculable	HHIE-S 0-8: 0.43* HHIE-S 10-24: 1.81* HHIE-S 26-40: 3.02*	Not dichotomized	Not dichotomized	Fair
			V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in one ear	0.81 (0.54-0.96) for HHIE-S score >8	Not reported	Not calculable	Not calculable	HHIE-S 0-8: 0.29* HHIE-S 10-24: 1.80* HHIE-S 26-40: 5.37*	Not dichotomized	Not dichotomized	
Sindhusake et al, 2001[45]	None	100% (1807/1807)	>25 dB hearing loss at 500, 1000, 2000, and 4000 Hz	0.58 (0.54-0.62)	0.85 (0.83-0.87)	3.9 (3.3-4.5)	0.49 (0.45-0.54)	0.71 (0.67-0.75)	0.76 (0.74-0.78)	7.8 (6.2-10)	Good
			>40 dB hearing loss at 500, 1000, 2000, and 4000 Hz	0.80 (0.74-0.85)	0.76 (0.74-0.78)	3.3 (3.0-3.7)	0.26 (0.20-0.34)	0.33 (0.29-0.37)	0.96 (0.95-0.97)	13 (8.9-18)	
			>60 dB hearing loss at 500, 1000, 2000, and 4000 Hz	1.0 (0.90-1.0)	0.70 (0.68-0.72)	3.3 (3.0-3.6)	0.02 (0.001-0.31)	0.06 (0.04-0.08)	1.0 (1.0-1.0)	165 (10-2700)	
Ventry & Weinstein, 1983[9]	None	100%	>40 dB hearing loss at 1000 or 2000 Hz in both ears	0.72 (0.56-0.85)	0.66 (0.52-0.77)	2.1 (1.4-3.1)	0.43 (0.26-0.71)	0.60 (0.45-0.73)	0.77 (0.63-0.88)	4.9 (1.9-13)	Fair
Weinstein, 1986[56]	None	100%	Audiologist recommendation for evaluation	0.74*	0.68*	2.3*	0.38*	Not calculable	Not calculable	6.1*	Fair
				0.65*	0.83*	3.8*	0.42*	Not calculable	Not calculable	9.0*	
Koike et al, 1994[51]	None	100%	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	10: 0.90* 15: 0.80* 25: 0.90* 30: 0.74* 35: 0.51* 40: 0.26*	10: 0.20* 15: 0.55* 25: 0.54* 30: 0.72* 35: 0.87* 40: 0.97*	10: 1.1* 15: 1.8* 25: 2.0* 30: 2.6* 35: 4.0* 40: 9.9*	10: 0.47* 15: 0.36* 25: 0.18* 30: 0.36* 35: 0.56* 40: 0.76*	Not calculable	Not calculable	10: 2.3* 15: 5.0* 25: 11* 30: 7.2* 35: 7.1* 40: 13*	Fair

*Confidence interval not calculable.

Abbreviations: FMHT = Five-Minute Hearing Test; HFPTA = High Frequency Pure-Tone Average; HHIE-S = Hearing Handicap Inventory for the Elderly-Screening; SES = socioeconomic status; SFPTA = Speech Frequency Pure-Tone Average; V&W = Ventry & Weinstein criteria.

Appendix B6. Handheld Audiometric Devices Evidence Table

Study, Year	Screening test	Reference standard	Type of study	Setting	Screener	Age of enrollees	N	Proportion with hearing loss	Definition of a positive screening exam	Subjects	Recruitment sources
Community-Dwelling											
Bienvenue et al, 1985[48]	AudioScope	Pure-tone audiometry	Cross-sectional	Speech and hearing clinics	NR	51-81 yrs	30	NR	Failure to hear 25 dB at 500, 1000, 2000, and 4000 Hz	Age: 51-81 yrs Sex: NR	Speech and hearing clinics
Eekhof et al, 1996[40]	AudioScope	Pure-tone audiometry	Cross-sectional	Otolaryngology clinic	NR	≥55 yrs	62 (124 ears)	Hearing loss >30 dB: 59% (73/124) Hearing loss >40 dB: 33% (41/124)	Failure to hear 40 dB at 500, 1000, 2000, and 4000 Hz using AudioScope	Age: ≥55 yrs Sex: NR	Outpatient ENT clinic
Frank and Petersen, 1987[50]	AudioScope	Pure-tone audiometry	Cross-sectional	Speech and hearing clinic; Rehab center	AudioScope: audiologist or speech pathologist; Reference test: audiologist	50-96 yrs	405 (688 ears)	NR	Failure to hear 40 dB at 500, 1000, 2000, and 4000 Hz	Age: 50-96 yrs Sex: NR	Speech and hearing clinics; rehab center; senior citizen groups
Lichtenstein et al, 1988[46]	AudioScope	Pure-tone audiometry	Cross-sectional	Internal medicine clinic	AudioScope: internist; Reference test: NR	>65 yrs	178	Hearing loss >40 dB: 30% at 40 dB	Failure to hear 40 dB at 500, 1000, 2000, or 4000 Hz	Age: 74.2 yrs Sex: 37.1% male Race: 77.5% white	6 internal medicine clinics
McBride et al, 1994[22]	AudioScope	Pure-tone audiometry	Cross-sectional	Community health clinic; VA Medical Center	Trained researcher	>60 yrs	185	NR	Failure to hear 40 dB at 2000 Hz in better ear	Mean age: 70 yrs (±5.0) Sex: 69% male SES: 8 mean yrs of school	Community health clinic; VA Medical Center
Chronic Care Facility-Dwelling Older Adults											
Ciurlia-Guy et al, 1993[49]	AudioScope	Pure-tone audiometry	Cross-sectional	VA chronic care facilities	AudioScope: research assistant; Reference test: audiologist	60-99 yrs	99	Hearing loss >40 dB: 69%	Failure to hear 40 dB at 1000 or 2000 Hz in either ear	Age: 79 yrs (±9.98) Sex: 88% male	VA chronic care facility

Appendix B6. Handheld Audiometric Devices Evidence Table

Study, Year	Proportion un-examinable by screening test	Analysis of screening failures	Proportion screened who under-went reference standard	Definition of a case	Sensitivity	Specificity	Positive likelihood ratio	Negative likelihood ratio	Positive predictive value	Negative predictive value	Diagnostic odds ratio	Quality score
Community-Dwelling												
Bienvenue et al, 1985[48]	Appears to be none	NA	100%	≥30 dB hearing loss at 500, 1000, 2000,and 4000 Hz	0.93*	0.7*	3.1*	0.10*	Not calculable	Not calculable	31*	Fair
Eekhof et al, 1996[40]	Appears to be none	NA	100%	>40 dB hearing loss	1.0 (0.91-1.0)	0.42 (0.31-0.54)	1.7 (1.4-2.1)	0.03 (0.002-0.45)	0.46 (0.35-0.57)	1.0 (0.90-1.0)	61 (3.6-102)	
Frank and Petersen, 1987[50]	10% ears were not able to be screened	NA; rate of screening failure increased with age	100%	≥45 dB hearing loss at 500, 1000, 2000, and 4000 Hz	Age 50-59: 0.90* 60-69: 0.89 70-79: 0.85 80-89: 0.86 90-96: 0.86	Age 50-59: 0.94* 60-69: 0.90 70-79: 0.90 80-89: 0.89 90-96: 0.90	Age 50-59: 16* 60-69: 9.2* 70-79: 8.7* 80-89: 8.1* 90-96: 9.1*	Age 50-59: 0.11* 60-69: 0.12* 70-79: 0.17* 80-89: 0.16* 90-96: 0.15*	Not calculable	Not calculable	Age 50-59: 140* 60-69: 77* 70-79: 51* 80-89: 51* 90-96: 61*	Fair
Lichtenstein et al, 1988[46]	(25+7+16)/284 17% (due to stroke, dementia, or severe illness)	Not screened due to severe health conditions	100%	V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in 1 ear	0.94 (0.84-0.99)	0.72 (0.63-0.80)	3.4 (2.5-4.5)	0.08 (0.03-0.24)	0.59 (0.48-0.69)	0.97 (0.91-0.99)	43 (12-220)	Good
McBride et al, 1994[22]	6.1% (13/212)	NA	100%	SFPTA: ≥25 dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.64 (0.52-0.77)	0.89 (0.83-0.94)	5.8 (3.4-9.8)	0.40*	Not calculable	Not calculable	14*	Good
				HFPTA: ≥25 dB hearing loss at 1000, 2000 and 4000 Hz in better ear	0.71 (0.63-0.80)	0.91 (0.84-0.97)	7.5 (3.7-15)	0.32*	Not calculable	Not calculable	23*	
				V&W: >40 dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in 1 ear	0.96 (0.90-1.00)	0.80 (0.74-0.87)	4.9 (3.4-6.8)	0.05*	Not calculable	Not calculable	98*	
Chronic Care Facility-Dwelling Older Adults												
Ciurlia-Guy et al, 1993[49]	3.8% (4/104) didn't complete AudioScope screening	None	100% of those included	>40 dB hearing loss at 1000 or 2000 Hz in either ear	0.98 (0.91-1.0)	0.21 (0.08-0.41)	1.3 (1.0-1.5)	0.08 (0.01-0.61)	0.73 (0.62-0.82)	0.86 (0.42-1.0)	16 (1.8-76)	Fair

*Confidence interval not calculable.

Abbreviations: HFPTA = Hearing Frequency Pure-Tone Average; NA = not applicable; NR = not reported; SES = socioeconomic status; SFPTA = Speech Frequency Pure-Tone Average; V&W = Ventry & Weinstein criteria.

Appendix B7. Quality Ratings of Diagnostic Test Studies

Study, year	Representative spectrum	Random or consecutive sample	Screening test adequately described	Screening cutoffs predefined	Credible reference standard	Reference standard applied to all patients or a random subset
Bienvenue et al, 1985[48]	No	Cannot tell	Yes	Yes	Yes	Yes
Boatman et al, 2007[39]	High prevalence	Yes	Yes	Yes	Yes	Yes
Ciurlia-Guy et al, 1993[49]	High prevalence	Yes	Yes	Yes	Yes, portable audiometer	No (5/104)
Clark et al, 1991[43]	Yes	Yes	Yes	Yes	Yes	Yes
Eekhof et al, 1996[40]	High prevalence	Yes	Yes	Yes	Yes	Yes
Frank and Petersen, 1987[50]	Yes	Cannot tell	Yes	Yes	Yes	Yes
Gates et al, 2003[47]	Yes	Yes	Yes	Yes	Yes	Yes
Koike et al, 1994[51]	No	Cannot tell	Yes	No	Yes	Yes
Lichtenstein et al, 1988[46]	Yes	Yes	Yes	Yes	Yes	Yes
Macphee et al,1988[41]	High prevalence	Cannot tell	Yes	Yes	Yes	Yes
McBride et al, 1994[22]	Yes	Yes	Yes	Yes	Yes	Yes
Nondahl et al, 1998[44]	Yes	Yes	Yes	Yes	Yes	Yes
Rawool et al, 2008[52]	High prevalence	No	Yes	Yes	Yes, portable audiometer	Yes
Sever et al,1989[53]	Yes	Cannot tell	Yes	Yes	Yes	Yes
Sindhusake et al, 2001[45]	Yes	Yes	Yes	Yes	Yes	Yes
Swan et al,1985[42]	No	Yes	Yes	Yes	Yes	Yes
Torre et al, 2006[54]	High prevalence (63%)	No	Yes	Yes	Yes, portable audiometer	Yes
Ventry and Weinstein, 1983[9]	Cannot tell	Cannot tell	Yes	Yes	Yes	Yes
Voeks et al, 1993[55]	High prevelance (54%)	Yes	Yes	Yes	Yes, portable audiometer	Yes
Weinstein, 1986[56]	Yes	No	Yes	No	No	Yes

Appendix B7. Quality Ratings of Diagnostic Test Studies

Study, year	Same reference standard applied to all patients	Reference standard and screening examination interpreted independently	High rate of uninterpretable results or non-compliance with screening	Analysis includes patients with uninterpretable results or non-compliance	Quality score
Bienvenue et al, 1985[48]	Yes	Cannot tell	No	Not applicable	Fair
Boatman et al, 2007[39]	Yes	Yes	No	Not applicable	Good
Ciurlia-Guy et al, 1993[49]	Yes	Yes	No	No	Fair
Clark et al, 1991[43]	Yes	Cannot tell	No	No	Good
Eekhof et al, 1996[40]	Yes	Cannot tell	No	Not applicable	Fair
Frank and Petersen, 1987[50]	Yes	Yes	Yes	No	Fair
Gates et al, 2003[47]	Yes	No	No	No	Good
Koike et al, 1994[51]	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Lichtenstein et al, 1988[46]	Yes	Cannot tell	No	No	Good
Macphee et al,1988[41]	Yes	Yes	No	Not applicable	Fair
McBride et al, 1994[22]	Yes	Cannot tell	No	NA	Good
Nondahl et al, 1998[44]	Yes	Cannot tell	No	No	Good
Rawool et al, 2008[52]	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Sever et al,1989[53]	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Sindhusake et al, 2001[45]	Yes	Cannot tell	Yes	No	Good
Swan et al,1985[42]	Yes	Cannot tell	No	Not applicable	Fair
Torre et al, 2006[54]	Yes	Cannot tell	No	Not applicable	Fair
Ventry and Weinstein, 1983[9]	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Voeks et al, 1993[55]	Yes	Cannot tell	Yes	Yes	Fair
Weinstein, 1986[56]	Yes	Yes	Cannot tell	Cannot tell	Fair

Appendix C. Measures of Quality of Life or Function

Hearing-Related Quality of Life or Function[13,57]

Test	Description
Abbreviated Profile of Hearing Aid Benefit (APHAB)	24-item questionnaire Measures self-rated communication function Score 0-100; 4 subscales
Hearing Handicap Inventory for the Elderly-Screening Version (HHIE-S)	25-item questionnaire Measures emotional/ social impact of hearing loss Score 0-100
Quantified Denver Scale of Communication Function (QDS)	25-item questionnaire Measures self-reported communication function Score 0-100; 4 subscales
Revised Quantified Denver Scale of Communication Function (RQDS)	5-item questionnaire Measures self-rated communication function Score 1-5

General Quality of Life or Function

Test	Description
Geriatric Depression Scale (GDS)	30-item questionnaire Measures self-perceived depression in the elderly Score 0-30
Self-Evaluation of Life Function (SELF)	54-item questionnaire Measures self-reported physical, emotional, and social function Score 54-216
Short Portable Mental Status Questionnaire (SPMSQ)	10-item questionnaire Measures function related to psychiatric issues Score 0-10