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

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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 aged 50 years or older.

Data Sources: MEDLINE (1950 and July 2010) and the Cochrane Library (through the second quarter of 2010).

Study Selection: Randomized trials, controlled observational studies, and studies on diagnostic accuracy were selected.

Data Extraction: Investigators abstracted details about the patient population, study design, data analysis, follow-up, and results and assessed quality by using predefined criteria.

Data Synthesis: Evidence on benefits and harms of screening for and treatments of hearing loss was synthesized qualitatively. One large (2305 participants) randomized trial found that screening for hearing loss was associated with increased hearing aid use at 1 year, but screening was not associated with improvements in hearing-related function. Good-quality evidence suggests that common screening tests can help identify patients at higher risk for hearing loss. One good-quality randomized trial found that immediate hearing aids were effective compared with wait-list control in improving hearing-related quality of life 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.

Limitation: Non–English-language studies were excluded, and studies of diagnostic accuracy in high-prevalence specialty settings were included.

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

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Editor's Note: *As part of the U.S. Preventive Services Task Force's (USPSTF) ongoing commitment to clarity about its work and methods, the USPSTF is inviting public comment on all draft recommendation statements. The USPSTF's draft recommendation statement on screening adults aged 50 years or older for hearing loss will soon be available for public comment at* www.uspreventiveservicestaskforce.org/tfcomment.htm. *As a result, the recommendation on screening adults aged 50 years or older for hearing loss does not appear with this accompanying background review. Once finalized, the recommendation statement will reflect any changes made on the basis of the public comments received. A summary of these changes will be included in a new section of the final recommendation statement.*

The prevalence of hearing loss is 20% to 40% in adults aged 50 years or older and more than 80% for those aged 80 years or older (1–4). Hearing loss can affect quality of life and ability to function (5). Age-related hearing loss (presbycusis) is typically gradual, progressive, and bilateral (1). Other factors contributing to hearing loss in older adults 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) (6–8).

Older adults may not realize that they have hearing loss because it is 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 owing to comorbid conditions, such as cognitive impairment. Only 10% to 20% of older adults with hearing loss have ever used hearing aids (2, 9). Screening could identify people who could benefit from therapies for hearing loss.

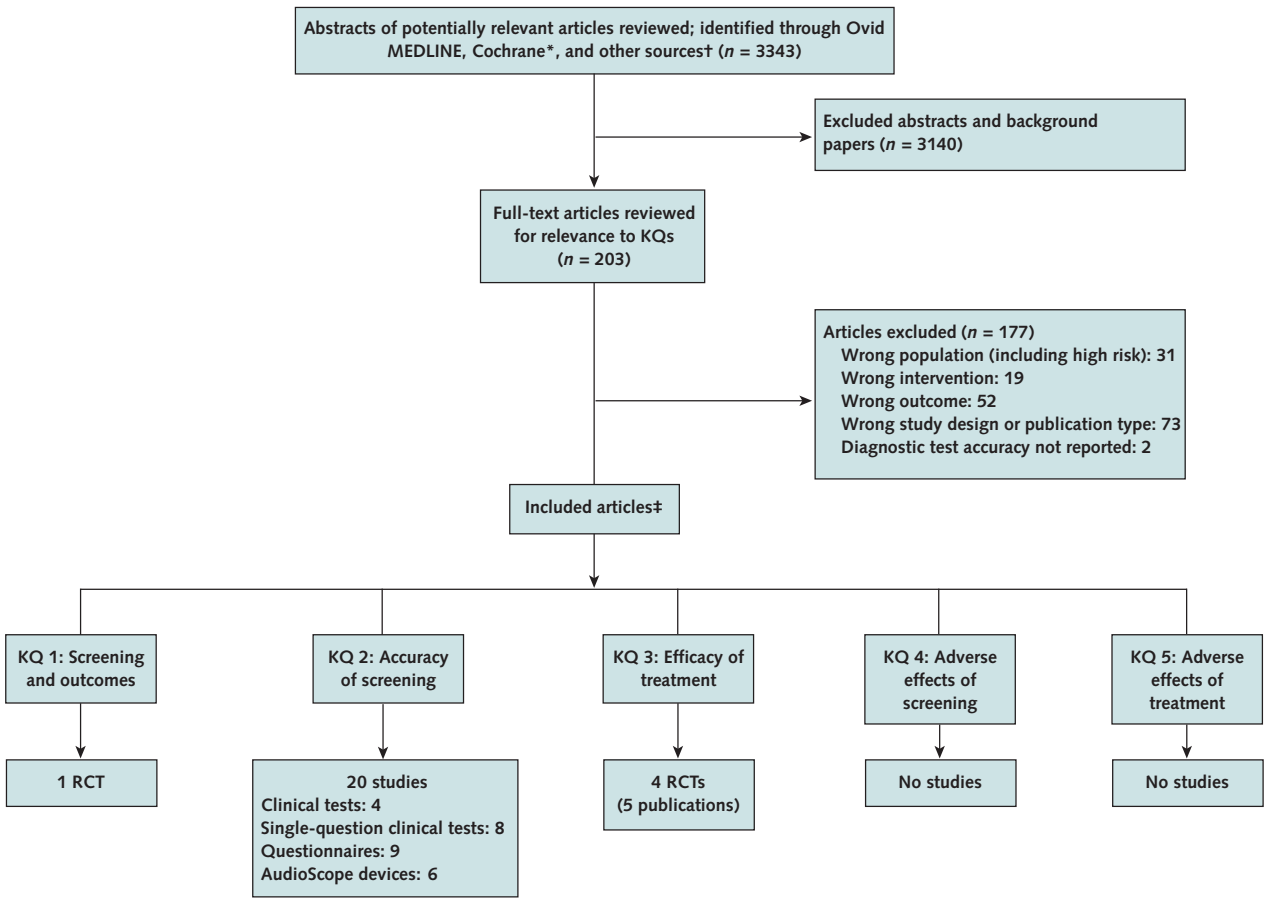
In 1996, the USPSTF issued a recommendation to screen adults aged 50 years or older for hearing loss (grade B recommendation) (10). In 2009, the USPSTF commissioned a new evidence review to update its recommendation. The purpose of this report is to systematically evaluate the current evidence on screening for hearing loss in adults aged 50 years or older in primary care settings. (The full evidence review [11] is available on the USPSTF Web site, www.uspreventiveservicestaskforce.org.) The key questions, analytic framework (**Appendix Figure**, available at www.annals.org), and scope of the report were developed in accordance with previously published USPSTF processes and methods (12–14). The key questions were:

1. Does screening of asymptomatic adults aged 50 years or older lead to improved health outcomes?

See also:

Web-Only
Appendix
Appendix Tables
Appendix Figure
Conversion of graphics into slides

Figure. **Summary of literature search and selection.**



KQ = key question; RCT = randomized, controlled trial.
* Cochrane databases include the Cochrane Central Register of Controlled Trials and the Cochrane Database of Systematic Reviews.
† Other sources include reference lists and suggestions by experts.
‡ Some articles are included for >1 KQ.

2. How accurate are the hearing-loss screening methods among older adults, including questionnaires, clinical techniques (whispered voice test), and hand-held audiometry?

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

4. What are the adverse effects of hearing-loss screening in adults aged 50 years or older?

5. What are the adverse effects of treatment of (screen-detected) hearing loss in adults aged 50 years or older?

Methods

Data Sources

We searched Ovid MEDLINE from 1950 to July 2010 and the Cochrane Database of Systematic Reviews and Central Register of Controlled Trials through the second quarter of 2010 to identify relevant articles. **Appendix Table 1** contains the full search strategy. (The **Appendix** and all appendix tables and appendix figures are available at www.annals.org.) We also reviewed reference lists of relevant articles.

Study Selection

The **Figure** shows the flow of studies from initial identification to final inclusion or exclusion. We selected studies pertaining to screening, diagnosis, and treatment of hearing loss in adults aged 50 years or older by using predefined inclusion and exclusion criteria. (For details on study selection, see **Appendix Table 2.**) Two reviewers evaluated each study to determine eligibility for inclusion. We restricted our review to published, English-language studies.

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.

Data Extraction and Quality Assessment

We abstracted details on patient population, study design, data analysis, follow-up, and results. One author abstracted data, and another verified the data. Two authors independently rated the internal validity of each study as

"good," "fair," or "poor" by using predefined criteria developed by the USPSTF (**Appendix Table 3**) (14, 15). We also evaluated the applicability of studies to primary care screening on the basis of whether patients were recruited from primary care settings, prevalence and severity of hearing loss, proportion of patients with perceived hearing loss, and access to hearing aids (such as availability of free hearing aids). We resolved discrepancies in quality ratings by discussion and consensus.

For diagnostic accuracy studies, we used the diagti procedure in Stata, version 10 (StataCorp, College Station, Texas), to calculate sensitivities, specificities, and likelihood ratios. For studies that reported diagnostic accuracy based on more than 1 definition of hearing loss, we estimated median values on the basis of the Ventry and Weinstein criteria (for >40-dB hearing loss), the Speech Frequency Pure-Tone Average criteria (for >25-dB hearing loss), or the definition most similar to those used by other relevant studies. We used the cci procedure in Stata to calculate diagnostic odds ratios with exact 95% CIs.

Data Synthesis and Analysis

We assessed the overall strength of the body of evidence for each key question ("good," "fair," or "poor") by using methods developed by the USPSTF on the basis of the number, quality, and size of studies; consistency of results among studies; and directness of evidence (14). We did not quantitatively pool results on diagnostic accuracy because of differences across studies in populations evaluated, definitions of hearing loss, screening tests evaluated, and screening cutoffs applied. Instead, we created descriptive statistics with the median sensitivity, specificity, and likelihood ratios (16), as well as associated ranges. We chose the total range, rather than the

Table 1. **Randomized, Controlled Trials of Screening and Treatment**

Study, Year (Reference)	Country; Setting	Population	Main Outcomes	Quality Rating
Screening				
Yueh et al, 2010 (17)	US; VA primary care clinics	Mean age, 61 y 94% male Mean baseline hearing loss: NR	Screen with AudioScope vs. HHIE-S vs. both vs. usual care with no screening; results at 1 y: Hearing aid use: 6.3% vs. 4.1% vs. 7.4% vs. 3.3% ($P = 0.003$) ≥6-point improvement on the Inner EAR scale: 40% vs. 36% vs. 40% vs. 36% ($P = 0.39$)	Fair
Treatment				
Jerger et al, 1996 (18)	US; NR	Mean age, 74 y 63% male Mean pure-tone threshold: 37 dB* Mean baseline HHIE score: 30	Hearing aid vs. assistive listening device vs. both vs. no amplification; mean scores at 6 wk: HHIE: 25 vs. 27 vs. 26 vs. 28 ($P > 0.05$ for any intervention vs. no amplification) Mean 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 (19)	US; VA primary care clinic	Mean age, 72 y 99% male 97% white Mean better ear pure-tone threshold: 52 dB* Mean baseline HHIE score: 50	Immediate hearing aid vs. wait list; mean scores (mean difference in change from baseline) at 4 mo: HHIE: 15 vs. 51 (34 [95% CI, 27 to 41]; $P < 0.001$) QDS: 36 vs. 62 (24 [CI, 17 to 31]; $P < 0.001$) Short Portable Mental Status Questionnaire: 0.29 vs. 0.28 (0.28 [CI, 0.08 to 0.48]; $P = 0.008$) Geriatric Depression Scale: 2.6 vs. 3.8 (0.80 [CI, 0.09 to 1.5]; $P = 0.03$) Self-Evaluation of Life Function: 92 vs. 97 (1.9 [CI, –1.6 to 5.4]; $P = 0.27$)	Good
Tolson et al, 2002 (20)	UK; general practice clinic attendees	Mean age, 77 y 23% male Other baseline characteristics: NR	Hearing aid vs. no hearing aid; results at 6 mo: Data for Mini-Mental State Examination, Geriatric Depression Scale, Malaise Inventory (caregiver), Family Relationship Index, and 14-item caregiver's assessment of hearing difficulties not provided; text states that "depression scores were unchanged at the 6-month follow up" in the intervention group	Poor
Yueh et al, 2001 (21)	US; VA audiology clinic	Mean age, 68 y 100% male Race NR Mean pure-tone threshold: right ear, 33 dB; left ear, 32 dB Mean baseline HHIE 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 scores at 3 mo: HHIE: 4.4 vs. 2.2 Abbreviated Profile of Hearing Aid Benefit: 6.4 vs. 2.7 Revised QDS: 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 mo: HHIE: 31 vs. 17; $P < 0.05$ Abbreviated Profile of Hearing Aid Benefit: 16 vs. 7.7 Revised QDS: 0.84 vs. 0.70 Proportion reporting less social isolation: 10/16 (62%) vs. 2/14 (14%)	Fair

HHIE = Hearing Handicap Inventory for the Elderly; HHIE-S = Hearing Handicap Inventory for the Elderly—Screening Version; Inner EAR = Inner Effectiveness of Aural Rehabilitation; NR = not reported; QDS = Quantified Denver Scale; UK = United Kingdom; US = United States; VA = Veterans Affairs.
* Average hearing levels of 1000, 2000, and 4000 Hz.

Table 2. **Diagnostic Accuracy of Screening Tests for Hearing Loss**

Screening Test	Number of Studies (References)	Positive Likelihood Ratio	Negative Likelihood Ratio
>25-dB or >30-dB hearing loss			
Whispered voice	4 (23, 26, 31, 37)	Median, 5.1 (range, 2.3–7.4)	Median, 0.03 (range, 0.007–0.73)
Finger rub	1 (23)	10 (95% CI, 26–43)	0.75 (CI, 0.68–0.84)
Watch tick	1 (23)	70 (CI, 4.4–1120)	0.57 (CI, 0.46–0.66)
Single-question screening	6 (23, 25, 33, 34, 36, 38)	Median, 3.0 (range, 2.4–3.8)	Median, 0.40 (range, 0.33–0.82)
Screening questionnaire (HHIE-S*)	4 (30, 32, 33, 36)	Median, 3.5 (range, 2.4–11)	Median, 0.52 (range, 0.43–0.70)
Hand-held audiometric devices	2 (22, 32)	3.1 (CI not calculable) and 5.8 (CI, 3.4–9.8)	0.10 and 0.40 (CIs not calculable)
>40-dB hearing loss			
Single-question screening	3 (25, 28, 36)	Median, 2.5 (range, 2.1–3.1)	Median, 0.26 (range, 0.13–0.41)
Screening questionnaire (HHIE-S*)	5 (28, 30, 32, 36, 39)	Median, 3.1 (range, 2.1–4.5)	Median, 0.43 (range, 0.26–0.70)
Hand-held audiometric devices	3 (26, 30, 32)	Median, 3.4 (range, 1.7–4.9)	Median, 0.05 (range, 0.03–0.08)

HHIE-S = Hearing Handicap Inventory for the Elderly—Screening Version.
* Based on cutoff score >8.

interquartile range, because certain outcomes were reported by only a few studies and the summary range highlights the greater uncertainty in the estimates. Too few randomized trials of hearing loss treatments were available to perform meta-analysis.

Role of the Funding Source

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RESULTS

Key Question 1

Does screening of asymptomatic adults aged 50 years or older for hearing loss lead to improved health outcomes?

We identified 1 randomized trial (17) of screening for hearing loss (**Table 1** and **Appendix Table 4**). We rated the SAI-WHAT (Screening for Auditory Impairment—Which Hearing Assessment Test) trial as fair quality primarily because of high loss to follow-up and unclear blinding status of outcomes assessors. It compared 3 screening strategies (the AudioScope [Welch Allyn, Skaneateles Falls, New York], which is based on inability to hear a 40-dB tone at 2000 Hz in either ear; the Hearing Handicap Inventory for the Elderly—Screening Version [HHIE-S] [10 items; score ≥10; range, 0 to 40]; or the AudioScope plus the HHIE-S) with usual care without screening in 2305 predominantly male (94%) patients aged 50 years or older (mean age, 61 years) at a Veterans Affairs (VA) medical center. All enrollees were eligible to receive free, VA-issued hearing aids. About three quarters of patients reported perceived hearing loss at enrollment (on the basis of the question, "Do you think you have a hearing loss?").

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

The proportion of patients who had a minimum clinically important difference (≥6-point improvement on a 0- to 100-point scale) on the Inner Effectiveness of Aural Rehabilitation scale (a measure of hearing-related function), a secondary outcome of the trial, did not differ at 1 year (36% to 40% in the screened groups vs. 36% in the unscreened group; $P = 0.39$). Post hoc analyses also showed no differences in the proportion who had improvements in hearing-related function according to whether patients had perceived hearing loss, except in a subgroup that was also 65 years of age or older (54% in the AudioScope group, 34% in the HHIE-S group, 40% in the combined group, and 34% in the control group).

Key Question 2

How accurate are the hearing-loss screening methods among older adults, including questionnaires, clinical techniques (whispered voice test), and hand-held audiometry?

Twenty studies evaluated the diagnostic accuracy of various screening tests (**Appendix Table 5**) (22–41). Four studies evaluated clinical tests (23, 26, 31, 37), 8 evaluated single-question screening (23, 25, 28, 33, 34, 36, 38, 40), 9 evaluated a hearing questionnaire (28–30, 32, 33, 35, 36, 39, 41), and 6 evaluated a hand-held audiometric device (22, 24, 26, 27, 30, 32). Four studies were population-based (25, 28, 33, 36), 4 recruited patients from primary care or community-based settings (30, 32, 35, 41), and the remainder recruited

patients from specialty or other high-prevalence settings or evaluated nursing-home residents (24, 40).

We rated the quality of 7 studies as good (23, 25, 28, 30, 32, 33, 35) and the remainder as fair (**Appendix Table 6**, available at www.annals.org). The most common methodological shortcomings were failure to describe a representative spectrum of patients, failure to report interpretation of the reference standard blinded to results of the screening test, and failure to describe a random or consecutive series of patients. All studies except for 1 used pure-tone audiometry as the reference standard, and 4 studies used a portable audiometer instead of standard audiometry (24, 34, 38, 40). One study performed an audiometric examination but used an audiologist assessment as the reference standard (41). **Table 2** summarizes the main results on diagnostic accuracy.

Whispered Voice, Finger Rub, and Watch Tick Tests

One good-quality (23) and 3 fair-quality (26, 31, 37) studies evaluated the whispered voice test at 2 feet for identifying hearing loss greater than 25 or 30 dB (**Appendix Table 7**). Likelihood ratio (LR) estimates varied, with a median positive LR of 5.1 (range, 2.3 to 7.4) and median negative LR of 0.03 (range, 0.007 to 0.73). The good-quality study reported the weakest LRs (positive LR, 2.3 [95% CI, 1.3 to 3.8]; neg-

Table 3. **Summary of Evidence**

Studies	Limitations	Consistency	Primary Care Applicability	Overall Quality Rating
KQ 1: Does screening of asymptomatic adults aged ≥50 y lead to improved health outcomes?				
1 RCT	One large (n = 2305), fair-quality trial of screening vs. no screening in a VA setting in patients with a high prevalence of perceived hearing loss. High loss to follow-up.	NA (1 study)	Low to moderate	Fair
Summary of findings: One trial found that screening with the HHIE-S, the AudioScope, or both was associated with greater hearing aid use at 1 y compared with no screening. Effects of screening on hearing aid use seemed 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 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 hearing-loss screening methods among older adults, including questionnaires, clinical techniques (whispered voice test), and hand-held audiometry?				
20 studies*	Most studies conducted in specialty or other high-prevalence settings. Differences between studies in how hearing loss defined and in screening cutoffs used.	Consistent	Moderate	Good
Summary of findings: For detection of >25- or >30-dB hearing loss, 4 studies (1 good-quality) found that the whispered voice test at 2 feet was associated with a median positive LR of 5.1 (range, 2.3–7.4) and median negative LR of 0.03 (range, 0.007–0.73). For detection of >25-dB hearing loss, 6 studies (4 good-quality) found that single-question screening was associated with a median positive LR of 3.0 (range, 2.4–3.8) and median negative LR of 0.40 (range, 0.33–0.82) and 4 good-quality studies found the HHIE-S (based on a cutoff score of >8) was associated with a median positive LR of 3.5 (range, 2.4–11) and median negative LR of 0.52 (range, 0.43–0.70). For detection of >40-dB hearing loss, 3 studies (2 good-quality) found the AudioScope (based on ability to hear tones between 500 and 4000 Hz at 40 dB) was associated with a median positive LR of 3.4 (range, 1.7–4.9) and median negative LR of 0.05 (range, 0.03–0.08).				
KQ 3: How efficacious is the treatment of (screen-detected) hearing loss, namely amplification, in improving health outcomes?				
4 RCTs	Only 1 good-quality trial of hearing aids vs. no hearing aids, conducted in a VA setting in patients eligible for free hearing aids.	Consistent	Low to moderate	Fair
Summary of findings: One good-quality RCT found that immediate hearing aids were 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 were 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 and 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 vs. no hearing aids reported outcomes very poorly.				
KQ 4: What are the adverse effects of hearing-loss screening in adults aged 50 years or older?				
No studies	No studies	NA	NA	NA
Summary of findings: No RCTs or controlled observational studies. Harms of hearing loss screening are unlikely to be greater than small or minimal due to the noninvasive nature of screening, confirmatory testing, and treatments.				
KQ 5: What are the adverse effects of treatment of (screen-detected) hearing loss in adults aged 50 years or older?				
No studies	No studies	NA	NA	NA
Summary of findings: No RCTs or controlled observational studies. Hearing aids are unlikely to be associated with serious harms, although there are reports of dermatitis, otitis externa, cerumen impaction, and other complications associated with their use.				

HHIE-S = Hearing Handicap Inventory for the Elderly—Screening Version; KQ = key question; LR = likelihood ratio; NA = not applicable; RCT = randomized, controlled trial; VA = Veterans Affairs.
* Clinical test, 4 studies; single-question screening, 8 studies; questionnaires, 9 studies; and AudioScope devices, 6 studies.

ative LR, 0.73 [CI, 0.61 to 0.87]) (22). One fair-quality study found inability to hear a whispered voice at 6 inches (positive LR, 72 [CI, 4.6 to 1140]) or a conversation voice at 2 feet (positive LR, 46 [CI, 2.9 to 740]) to be more useful than inability to hear a whispered voice at 2 feet (positive LR, 5.7 [CI, 3.1 to 11]) for identifying hearing loss, but estimates were imprecise and overlapped (30). Normal results with the first 2 tests were less useful than the whispered voice test at 2 feet for identifying persons without hearing loss (negative LRs, 0.27 [CI, 0.19 to 0.39] and 0.53 [CI, 0.43 to 0.66], respectively, vs. 0.008 [CI 0.0005 to 0.13]).

The good-quality study also evaluated the accuracy of the finger rub and watch tick tests at 6 inches for detecting hearing loss greater than 25 dB (23). Compared with the whispered voice test, inability to hear a finger rub or watch tick was more useful for identifying hearing loss (positive LR, 10 [CI, 26 to 43] and 70 [CI, 4.4 to 1120], respectively); normal results were similarly useful for identifying persons without hearing loss (negative LR, 0.75 [CI, 0.68 to 0.84] and 0.57 [CI, 0.46 to 0.66]).

Single-Question Screening

Five good-quality (23, 25, 28, 33, 36) and 3 fair-quality (34, 38, 40) studies evaluated a single screening question about perceived hearing difficulties (**Appendix Table 8**). For detection of hearing loss greater than 25 dB, 6 studies found that a positive response to a single question increased the likelihood of hearing loss (median positive LR, 3.0 [range, 2.4 to 3.8]) (23, 25, 33, 36, 38). Usefulness of a negative response varied (median negative LR, 0.40 [range, 0.33 to 0.82]). For detection of hearing loss greater than 40 dB, 3 good-quality studies found a median positive LR of 2.5 (range, 2.1 to 3.1) and median negative LR of 0.26 (range, 0.13 to 0.41) (25, 28, 36). One fair-quality study of nursing home residents reported a weaker positive LR (1.4 [CI, 1.2 to 1.8]) and similar negative LR (0.61 [CI, 0.43 to 0.87) compared with studies of community-dwelling older adults (40).

Screening Questionnaires

Five good-quality (28, 30, 32, 33, 36) and 3 fair-quality (35, 39, 41) studies evaluated the HHIE-S, and 1 fair-quality study evaluated the American Academy of Otolaryngology—Head and Neck Surgery 5-minute hearing test (29) (**Appendix Table 9**).

On the basis of an HHIE-S cutoff score greater than 8, 4 good-quality studies reported a median positive LR of 3.5 (range, 2.4 to 11) and negative LR of 0.52 (range, 0.43 to 0.70) for detection of hearing loss greater than 25 dB (30, 32, 33, 36). One fair-quality study reported a somewhat lower positive LR and similar negative LR (2.3 and 0.38, respectively [CIs not calculable]) based on an audiologist evaluation reference standard rather than audiometry (41). Studies on the accuracy of HHIE-S cutoff scores greater than 8 for identifying hearing loss greater than 40 dB reported similar likelihood ratios (28, 30, 32, 36, 39). Changing the HHIE-S threshold from greater than 8 to greater than 24 increased the positive LR for identification of hearing loss greater than 40 dB from 3.1 to 10 and increased the negative LR from 0.37 to 0.77 in 1 good-quality study (30) but had little effect on LR estimates in another good-quality study (32).

One fair-quality study found that the 5-minute hearing test had positive LRs ranging from 1.1 to 9.9 and negative LRs ranging from 0.47 to 0.76 for detection of hearing loss greater than 25 dB, depending on the cutoff score evaluated (29).

Hand-Held Audiometric Devices

Two good-quality (30, 32) and 4 fair-quality (22, 24, 26, 27) studies evaluated the AudioScope hand-held audiometric device (**Appendix Table 10**). The frequencies and intensities of the tones tested with the AudioScope varied. For detection of hearing loss greater than 25 dB (based on Speech Frequency Pure-Tone Average criteria), 1 good-quality study found that the AudioScope (based on the ability to hear a 2000-Hz tone at 40 dB) had a positive LR of 5.8 (CI, 3.4 to 9.8) and a negative LR of 0.40 (CI not calculable) (32). For detection of hearing loss greater than 30 dB, a fair-quality study found that the AudioScope (based on ability to hear 500-, 1000-, 2000-, and 4000-Hz tones at 25 dB) had a positive LR of 3.1 and a negative LR of 0.10 (CIs not calculable) (22). For detection of hearing loss greater than 40 dB, 3 studies of community-dwelling older adults found that the AudioScope (based on ability to hear tones between 500 and 4000 Hz at 40 dB) had a median positive LR of 3.4 (range, 1.7 to 4.9) and median negative LR of 0.05 (range, 0.03 to 0.08) (26, 30, 32). One fair-quality study of nursing-home residents found that the AudioScope (based on failure to hear a 1000- or 2000-Hz tone in both ears) was associated with a much weaker positive LR (1.3 [CI, 1.0 to 1.5]) but similar negative LR (0.08 [CI, 0.01 to 0.61]) (24).

Direct Comparisons of Different Types of Screening Tests

Six good-quality studies directly compared the diagnostic accuracy of different screening tests (23, 28, 30, 32, 33, 36). One study found that the whispered voice test and single-question screening had similar positive LRs (2.3 [CI, 1.3 to 3.8] and 2.5 [CI, 1.0 to 5.9], respectively) and negative LRs (0.73 [CI, 0.61 to 0.87] and 0.82 [CI, 0.68 to 0.99]), but the watch tick and finger rub tests had substantially stronger positive LRs (70 [CI, 4.4 to 1120] and 10 [CI, 2.6 to 43], respectively) and similar negative LRs (0.57 [CI, 0.49 to 0.66] and 0.75 [CI, 0.68 to 0.84]) (23). Three studies showed a consistent tradeoff with the HHIE-S compared with single-question screening, with somewhat stronger positive and weaker negative LRs (23, 28, 33, 36). Two studies found that normal results on AudioScope were generally associated with stronger negative LRs (0.05 and 0.24) compared with the HHIE-S (0.37 and 0.76), although LR estimates varied de-

pending on the HHIE-S cutoff score evaluated and the criteria used to define hearing loss (30, 32).

Key Question 3

How efficacious is the treatment of (screen-detected) hearing loss, namely amplification, in improving health outcomes?

We identified 4 RCTs on treatment of hearing loss (**Table 1**) (18–21). We rated the quality for 1 trial as good (19), 2 as fair (18, 21), and 1 as poor (20) (**Appendix Table 4**). Shortcomings of the fair-quality trials included potentially important baseline differences between groups and failure to describe intention-to-treat analysis (21) and failure to describe randomization or allocation concealment methods or loss to follow-up (18). The poor-quality trial did not describe allocation concealment, use of intention-to-treat analysis, or loss to follow-up and reported outcomes incompletely (20). All of the trials had characteristics that could limit generalizability to screening in primary care, including recruitment of mostly white male veterans (19, 21), restriction to patients eligible for free hearing aids (21), inclusion of patients referred for suspected hearing problems (19), enrollment of dependent older adults (20), and inclusion of patients using hearing aids (18).

The good-quality RCT ($n = 194$) randomly assigned veterans (mean age, 72 years) to immediate hearing aids or wait-list control for 4 months (19). About two thirds of patients were enrolled from a primary care setting on the basis of a positive AudioScope screening result for hearing loss greater than 40 dB. The others were referred to the trial because of suspected hearing problems. Mean pure-tone threshold was 52 dB and was similar among screening-detected and referred patients. Mean baseline HHIE score was about 50 (25 items; range, 0 to 100), indicating severe effects on hearing-related quality of life and function (42).

At 4 months, HHIE or Quantified Denver Scale (QDS) (a measure of perceived communication difficulties) scores did not change from baseline in the control group. In the hearing aid group, the 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 (CI, 27 to 41) on the HHIE and 24 (CI, 17 to 31) on the QDS. Results were similar in the subgroup of screening-detected patients. Statistically significant but small (<1 point) effects on the Geriatric Depression Scale (0- to 15-point scale) and Short Portable Mental Status Questionnaire (0- to 10-point scale) scores were also observed in the hearing aid group, but baseline scores indicated only mild depression or cognitive dysfunction. A follow-up study found that improvements in HHIE and QDS scores were sustained in the hearing aid group through 12 months (43).

A second, fair-quality trial ($n = 64$) enrolled veterans (mean age, 68 years) with less severe hearing loss (mean pure-tone threshold of 32 dB) (21). Patients eligible for free VA-issued hearing aids ($n = 30$) were randomly assigned to a standard nondirectional ($n = 14$) or a programmable, directional digital hearing aid ($n = 16$). Those ineligible for free hearing aids were randomly assigned to no treatment ($n = 15$) or an assistive listening device ($n = 15$). Baseline differences across the intervention groups in Abbreviated Profile of Hearing Aid Benefit (APHAB) score (0- to 100-point scale) were statistically significant (range, 38 to 52; $P = 0.04$) and were likely to be clinically significant for baseline HHIE scores (range, 28 to 50).

At 3-month follow-up, trivial improvements from baseline on HHIE scores occurred in the no-treatment and assistive listening device groups (mean change, 2.2 and 4.4 points, respectively), but both types of hearing aids were associated with clinically significant improvements (mean, 17 and 31 points with standard and programmable hearing aids, respectively). Changes in APHAB scores were small in the assistive listening device and no-treatment groups (6 and 3 points, respectively), with no change in Revised QDS scores. Although both hearing aid groups had greater improvements in hearing-related outcomes than the no-treatment and assistive listening device groups, these were baseline differences between groups, and results are subject to additional confounding because patients were randomly assigned separately on the basis of 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 of 37 dB and mean HHIE score of 30) found no clear differences between hearing aids, an assistive listening device, or both and no amplification on HHIE scores and other measures of function or quality of life (18). A poor-quality trial ($n = 133$) found that older adults who were randomly assigned to hearing aids did not experience improvement in Geriatric Depression Scale scores at 6 months and did not report results in adults randomly assigned to no hearing aids (20).

Key Question 4

What are the adverse effects of hearing-loss screening in adults aged 50 years or older?

No randomized trials or controlled observational studies evaluated potential harms (such as anxiety, labeling, or other psychosocial effects) associated with screening for hearing loss.

Key Question 5

What are the adverse effects of treatment of (screen-detected) hearing loss in adults aged 50 years or older?

Harms were not reported in any trial of hearing aids, and we identified no controlled observational studies on potential harms. Adverse effects described in case reports include dermatitis, accidental retention of molds, cerumen impaction, otitis externa, or associated middle ear problems (44–46).

Discussion

Table 3 summarizes the results of this evidence synthesis by key question. The SAI-WHAT trial is the only study that compared screening with no screening (17). Although hearing aid use was higher after 1 year with screening, the likelihood of a clinically important improvement

in hearing-related function did not differ. Hearing aid use at 1 year was less than 10% in all groups in the trial, and the trial was not powered to assess improvements in hearing-related function. The trial also restricted enrollment to veterans who were 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.

Good evidence suggests that common screening tests are useful for identifying patients at higher risk for hearing loss. A challenge in understanding diagnostic accuracy is that studies used different thresholds and criteria to define hearing loss. The clinical relevance of detecting mild (25 to 40 dB) hearing loss as it pertains to effectiveness of screening is also uncertain, because the only trial showing benefits of hearing aids enrolled patients with screening-detected hearing loss greater than 40 dB (19). Relatively simple tests, such as the whispered voice test at 2 feet or single-question screening, regarding perceived hearing loss seem to be nearly as accurate as a more detailed hearing loss questionnaire or a hand-held audiometric device. A negative screening result based on a hand-held audiometric device may be particularly useful for ruling out hearing loss greater than 40 dB. The choice of which screening test to use may depend in part on cost or convenience. For the whispered voice test, an important consideration is the need for standardized and consistent administration. Although the finger rub and the watch tick tests may be easier to standardize, both were evaluated in only 1 study (23).

Our conclusions regarding diagnostic accuracy are generally in accord with another recent systematic review (7). It estimated stronger likelihood ratios for the whispered voice test, largely because it was conducted before the publication of a recent good-quality study (23) that reported substantially weaker estimates. The other review also pooled LR estimates, included studies (5, 47, 48) that analyzed the same populations reported in other studies (33, 37), included studies that we considered to be less applicable to U.S. primary care settings (49, 50), and did not include studies that we deemed relevant (28, 34).

Evidence on the efficacy of treatments of screening-detected hearing loss is limited. One good-quality RCT found that hearing aids resulted in near-normalization of hearing-related quality of life in a subgroup of patients identified by screening, based on hearing loss greater than 40 dB using a hand-held audiometric device (19). Because the trial was conducted in a VA medical center and almost exclusively enrolled white men, its generalizability to other settings may be limited. Two fair-quality RCTs found no clear differences in hearing-related quality-of-life outcomes between amplification and no treatment in patients with milder baseline hearing loss (18, 21).

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 detection of hearing loss greater than 25 dB ranged from 5% to 41% (25, 28, 30, 33, 36). However, harms of screening are probably minimal because screening tests and the reference standard (audiometric testing) are noninvasive, and hearing aids are not known to be associated with serious adverse events. No study has tested the hypothesis that hearing aid use might lead to further deterioration in patients with severe to profound hearing loss due to the increased amplification required (51).

Our evidence review has limitations. First, evidence was very limited for benefits and harms of screening for and treatments of hearing loss, making it difficult to reach strong conclusions. We excluded non–English-language studies, which could introduce language bias, although we identified no relevant non–English-language studies in literature searches or when reviewing reference lists. Finally, many studies evaluated diagnostic accuracy of screening tests in populations recruited from specialty settings, which could limit their generalizability to primary care settings (14).

Hearing loss is very common in older adults. 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 to help define optimal screening test thresholds and methods. Because the effectiveness of any hearing screening strategy will depend on how likely persons 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 treatments (including more effective treatments or increased usability of hearing aids) after screening.

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References

1. **Cruickshanks KJ, Wiley TL, Tweed TS, Klein BE, Klein R, Mares-Perlman JA, et al.** Prevalence of hearing loss in older adults in Beaver Dam, Wisconsin. The Epidemiology of Hearing Loss Study. Am J Epidemiol. 1998;148:879-86. [PMID: 9801018]

2. **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;11:247-56. [PMID: 2210098]
3. **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;46:1008-11. [PMID: 9706892]
4. **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;87:440-2. [PMID: 9096550]
5. **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;43:661-8. [PMID: 14570962]
6. **Gates GA, Mills JH.** Presbycusis. Lancet. 2005;366:1111-20. [PMID: 16182900]
7. **Bagai A, Thavendiranathan P, Detsky AS.** Does this patient have hearing impairment? JAMA. 2006;295:416-28. [PMID: 16434632]
8. **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; 29:578-84. [PMID: 18469720]
9. **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;46:1075-8. [PMID: 9736098]
10. **U.S. Preventive Services Task Force.** Screening for hearing impairment in older adults. Rockville, MD; Agency for Healthcare Research and Quality; 1996. Accessed at www.ahrq.gov/CLINIC/uspstf/uspshear.htm on 16 April 2010.
11. **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; 2010.
12. **Barton MB, Miller T, Wolff T, Petitti D, LeFevre M, Sawaya G, et al; U.S. Preventive Services Task Force.** How to read the new recommendation statement: methods update from the U.S. Preventive Services Task Force. Ann Intern Med. 2007;147:123-7. [PMID: 17576997]
13. **Guirguis-Blake J, Calonge N, Miller T, Siu A, Teutsch S, Whitlock E; U.S. Preventive Services Task Force.** Current processes of the U.S. Preventive Services Task Force: refining evidence-based recommendation development. Ann Intern Med. 2007;147:117-22. [PMID: 17576998]
14. **Harris RP, Helfand M, Woolf SH, Lohr KN, Mulrow CD, Teutsch SM, et al; Methods Work Group, Third US Preventive Services Task Force.** Current methods of the US Preventive Services Task Force: a review of the process. Am J Prev Med. 2001;20:21-35. [PMID: 11306229]
15. **Leeflang MM, Deeks JJ, Gatsonis C, Bossuyt PM; Cochrane Diagnostic Test Accuracy Working Group.** Systematic reviews of diagnostic test accuracy. Ann Intern Med. 2008;149:889-97. [PMID: 19075208]
16. **Deeks JJ, Altman DG.** Diagnostic tests 4: likelihood ratios. BMJ. 2004;329: 168-9. [PMID: 15258077]
17. **Yueh B, Collins MP, Souza PE, Boyko EJ, Loovis CF, Heagerty PJ, 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;58:427-34. [PMID: 20398111]
18. **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;17:490-504. [PMID: 8979037]
19. **Mulrow CD, Aguilar C, Endicott JE, Tuley MR, Velez R, Charlip WS, et al.** Quality-of-life changes and hearing impairment. A randomized trial. Ann Intern Med. 1990;113:188-94. [PMID: 2197909]
20. **Tolson D, Swan I, Knussen C.** Hearing disability: a source of distress for older people and carers. Br J Nurs. 2002;11:1021-5. [PMID: 12181509]
21. **Yueh B, Souza PE, McDowell JA, Collins MP, Loovis CF, Hedrick SC, et al.** Randomized trial of amplification strategies. Arch Otolaryngol Head Neck Surg. 2001;127:1197-204. [PMID: 11587599]
22. **Bienvenue GR, Michael PL, Chaffinch JC, Zeigler J.** The AudioScope: a clinical tool for otoscopic and audiometric examination. Ear Hear. 1985;6:251-4. [PMID: 4054439]
23. **Boatman DF, Miglioretti DL, Eberwein C, Alidoost M, Reich SG.** How accurate are bedside hearing tests? Neurology. 2007;68:1311-4. [PMID: 17438223]
24. **Ciurlia-Guy E, Cashman M, Lewsen B.** Identifying hearing loss and hearing handicap among chronic care elderly people. Gerontologist. 1993;33:644-9. [PMID: 8225009]
25. **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; 134:704-8. [PMID: 1951276]
26. **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;46:473-4. [PMID: 8949327]
27. **Frank T, Petersen DR.** Accuracy of a 40 dB HL Audioscope and audiometer screening for adults. Ear Hear. 1987;8:180-3. [PMID: 3609515]
28. **Gates GA, Murphy M, Rees TS, Fraher A.** Screening for handicapping hearing loss in the elderly. J Fam Pract. 2003;52:56-62. [PMID: 12540314]
29. **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;111:625-32. [PMID: 7970802]
30. **Lichtenstein MJ, Bess FH, Logan SA.** Validation of screening tools for identifying hearing-impaired elderly in primary care. JAMA. 1988;259:2875-8. [PMID: 3285039]
31. **Macphee GJ, Crowther JA, McAlpine CH.** A simple screening test for hearing impairment in elderly patients. Age Ageing. 1988;17:347-51. [PMID: 3068972]
32. **McBride WS, Mulrow CD, Aguilar C, Tuley MR.** Methods for screening for hearing loss in older adults. Am J Med Sci. 1994;307:40-2. [PMID: 8291505]
33. **Nondahl DM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein R, Klein BE.** Accuracy of self-reported hearing loss. Audiology. 1998;37:295-301. [PMID: 9776206]
34. **Rawool VW, Keihl JM.** Perception of hearing status, communication, and hearing aids among socially active older individuals. J Otolaryngol Head Neck Surg. 2008;37:27-42. [PMID: 18479626]
35. **Sever JC Jr, Harry DA, Rittenhouse TS.** Using a self-assessment questionnaire to identify probable hearing loss among older adults. Percept Mot Skills. 1989;69:511-4. [PMID: 2813000]
36. **Sindhusake D, Mitchell P, Smith W, Golding M, Newall P, Hartley D, et al.** Validation of self-reported hearing loss. The Blue Mountains Hearing Study. Int J Epidemiol. 2001;30:1371-8. [PMID: 11821349]
37. **Swan IR, Browning GG.** The whispered voice as a screening test for hearing impairment. J R Coll Gen Pract. 1985;35:197. [PMID: 3989786]
38. **Torre P, Moyer CJ, Haro NR.** The accuracy of self-reported hearing loss in older Latino-American adults. Int J Audiol. 2006;45:559-62. [PMID: 17062497]
39. **Ventry IM, Weinstein BE.** Identification of elderly people with hearing problems. ASHA. 1983;25:37-42. [PMID: 6626295]
40. **Voeks SK, Gallagher CM, Langer EH, Drinka PJ.** Self-reported hearing difficulty and audiometric thresholds in nursing home residents. J Fam Pract. 1993;36:54-8. [PMID: 8419504]
41. **Weinstein BE.** Validity of a screening protocol for identifying elderly people with hearing problems. ASHA. 1986;28:41-5. [PMID: 3718608]
42. **Ventry IM, Weinstein BE.** The hearing handicap inventory for the elderly: a new tool. Ear Hear. 1982;3:128-34. [PMID: 7095321]
43. **Mulrow CD, Tuley MR, Aguilar C.** Sustained benefits of hearing aids. J Speech Hear Res. 1992;35:1402-5. [PMID: 1494282]
44. **Kohan D, Sorin A, Marra S, Gottlieb M, Hoffman R.** Surgical management of complications after hearing aid fitting. Laryngoscope. 2004;114:317-22. [PMID: 14755211]
45. **Lear JT, Sandhu G, English JS.** Hearing aid dermatitis: a study in 20 consecutive patients. Contact Dermatitis. 1998;38:212. [PMID: 9565294]
46. **Sood A, Taylor JS.** Allergic contact dermatitis from hearing aid materials. Dermatitis. 2004;15:48-50. [PMID: 15573649]
47. **Browning GG, Swan IR, Chew KK.** Clinical role of informal tests of hearing. J Laryngol Otol. 1989;103:7-11. [PMID: 2646384]
48. **Wiley TL, Cruickshanks KJ, Nondahl DM, Tweed TS.** Self-reported hearing handicap and audiometric measures in older adults. J Am Acad Audiol. 2000;11:67-75. [PMID: 10685672]
49. **Abyad A.** Screening for hearing loss in the elderly. Geriatrics Today. 2004;7:43-5.
50. **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;45:79-84. [PMID: 14985847]
51. **Macrae JH.** Prediction of deterioration in hearing due to hearing aid use. J Speech Hear Res. 1991;34:661-70. [PMID: 2072691]
52. **Clark JG.** Uses and abuses of hearing loss classification. ASHA. 1981;23:493-500. [PMID: 7052898]
53. **Goldstein DP.** Hearing impairment, hearing aids and audiology. ASHA. 1984;26:24-35, 38. [PMID: 6487402]

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Obtaining of funding: R. Chou.
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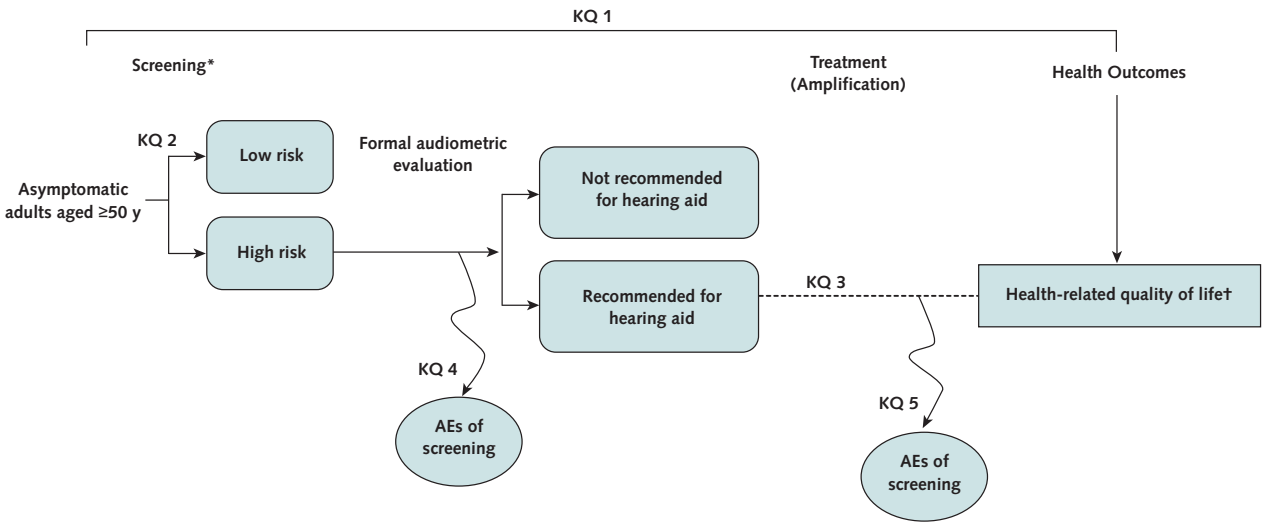
Collection and assembly of data: R. Chou, T. Dana, C. Bougatsos, C. Fleming, T. Beil.

Appendix: Additional Details on Study Selection

The target sample was persons aged 50 years or older who were evaluated in primary care settings and did not have diagnosed hearing loss, 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). Reference criteria for hearing loss vary but generally define hearing loss as decreased tonal perception on pure-tone audiometric testing at frequencies between 500 and 4000 Hz, the most important for speech processing (38, 51, 52). Mild hearing loss is frequently considered the inability to hear tones within this range at 25 dB or less and moderate hearing loss as inability to hear them at 40 dB or less. Although hearing problems can occur despite normal tonal perception (2), hearing loss is generally defined on the basis of pure-tone audiometric testing because the primary treatment is signal amplification. For screening tests, we focused on clinical tests (detection of a whispered voice, finger rub, or watch tick), a single question (for example, "Do you have difficulty with your hearing?), questionnaires (for example, the HHIE-S, a 10-item self-administered questionnaire) (31, 38), and hand-held audiometric devices (for example, AudioScope, a portable instrument consisting of an otoscope with a built-in audiometer). The purpose of all screening tests is to identify people 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. 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 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).

Appendix Figure. **Analytic framework and key questions.**



Key Questions

1. **Does screening of asymptomatic adults aged 50 years or older lead to improved health outcomes?**
2. **How accurate are the hearing-loss screening methods among older adults, including questionnaires, clinical techniques (whispered voice test), and hand-held audiometry?**
3. **How efficacious is the treatment of (screen-detected) hearing loss, namely amplification, in improving health outcomes?**
4. **What are the adverse effects of hearing-loss screening in adults aged 50 years or older?**
5. **What are the adverse effects of treatment of (screen-detected) hearing loss in adults aged 50 years or older?**

AE = adverse effect; KQ = key question.
* 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.

Appendix Table 1. 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)")

Continued on following page

Appendix Table 1—Continued

Keyword searches

Tuning fork 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]

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

Whispered voice 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]

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 Table 2. Inclusion and Exclusion Criteria

KQ	Inclusion Criteria	Exclusion Criteria
All KQs		
Ages and population	Adults ≥50 y without diagnosed hearing loss; comorbid conditions of depression and cognitive dysfunction; also included nursing home populations	Adults <50 y with previously diagnosed hearing loss; current hearing aid users (within the past 6 mo)
Disease	Sensorineural hearing loss, presbycusis	Conductive hearing loss, congenital hearing loss, sudden hearing loss, hearing loss due to recent noise or occupational exposure
Languages	Full text published in English	–
Settings	Studies performed in settings generalizable to primary care	Countries with populations not similar to the United States
KQ 1 (screening and outcomes)		
Interventions or diagnostic tests	Screening tests used, available, or feasible in primary care settings, including whispered voice test, finger rub test, watch tick test, single-question screening regarding perceived hearing loss, hearing loss questionnaire, and portable audiometer	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	Hearing-related quality of life and function (e.g., emotional and social function, communication, and cognitive function)	Outcomes related to hearing aid performance and efficacy (e.g., speech intelligibility and quality of the listening experience)
Study designs	RCTs and controlled observational studies	–
KQ 2 (accuracy of screening methods and testing)		
Interventions or diagnostic tests	See KQ 1	Audiometric testing, except as reference standard
Outcomes	Sensitivity, specificity, positive and negative predictive values, positive and negative likelihood ratios, diagnostic odds ratios	–
Study designs	Cross-sectional or cohort studies of primary care, community-based, or specialty settings	Case–control studies (e.g., 50 selected patients with hearing loss vs. 50 selected patients without hearing loss)
KQ 3 (effectiveness of amplification treatment for screen-detected hearing loss)		
Interventions or treatments	Amplification with hearing aids or assistive listening devices	Nutritional pharmaceuticals, hearing rehabilitation
Outcomes	Health-related quality of life (e.g., emotional and social function, communication, and cognitive function)	Outcomes related to hearing aid performance and efficacy (e.g., speech intelligibility and quality of the listening experience)
Study designs	RCTs and controlled observational studies	–
KQs 4 (harms of screening) and 5 (harms of treatment)		
Interventions or diagnostic tests	See KQ 1	See KQ 1
Outcomes	False-positive results, labeling, anxiety, any other significant harms	–
Study designs	RCTs and controlled observational studies	–

KQ = key question; RCT = randomized, controlled trial.

Appendix Table 3. U.S. Preventive Services Task Force Quality Rating Criteria for RCTs and Observational Studies*

Diagnostic accuracy studies

Criteria:

- Screening test relevant, available for primary care, and 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 (15)
- Screening cutoff predetermined (15)
- All patients undergo the reference standard (15)

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 (>100) of broad-spectrum patients with and without disease; study attempts to enroll a random or consecutive sample of patients who meet inclusion criteria (15); screening cutoffs prestated (15).
- 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 participants) and a "medium" spectrum of patients (i.e., applicable to most screening settings).
- Poor: Has important limitation, 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.

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, crossovers, adherence, contamination)
- Important differential loss to follow-up or overall high loss to follow-up
- Measurements: 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 ≥80%); reliable and valid measurement instruments are used and applied equally to the groups; interventions are spelled out clearly; important outcomes are considered; and appropriate attention to confounders in analysis.
- Fair: Studies will be 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; and some but not all potential confounders are accounted for.
- Poor: Studies will be 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); and key confounders are given little or no attention.

Case–control studies

Criteria:

- Accurate ascertainment of cases
- Nonbiased selection of case patients or control participants, 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 nonbiased selection of case patients and control participants; exclusion criteria applied equally to case patients and control participants; response rate ≥80%; diagnostic procedures and measurements accurate and applied equally to case patients and control participants; and appropriate attention to confounding variables.
- Fair: Recent, relevant, without major apparent selection or diagnostic work-up bias but with response rate <80% or attention to some but not all important confounding variables.
- Poor: Major selection or diagnostic work-up biases, response rates <50%, or inattention to confounding variables.

RCT = randomized, controlled trial.

* Data from references 14 and 15.

Appendix Table 4. Quality Ratings for Trials of Screening and Treatment

Study, Year (Reference)	Randomization	Allocation Concealed	Groups Similar at Baseline	Eligibility Criteria Specified	Blinding			Intention-to-Treat Analysis	Reporting of Attrition and Contamination	Differential or Overall High Loss to Follow-up or Incomplete Follow-up	Funding Source	External Validity	Quality Rating
					Patients	Providers	Outcome Assessors or Data Analysts						
Screening													
Yueh et al, 2010 (17)	Described as randomized, method not reported	Yes	Yes	Yes	Not applicable	Not applicable	Cannot tell	Yes	Yes	High overall loss to follow-up	Veterans Health Administration	Mean age, 61 y (SD, 9) 94% male 75% white Mean hearing loss: NR	Fair
Treatment													
Jerger et al, 1996 (18)	Described as randomized, method not reported	Cannot tell	Cannot tell	Yes	Not applicable	Not applicable	Cannot tell	Yes	No	Cannot tell	National Institute on Aging	Mean age, 74.3 y (range, 60–96 y) 63% male Mean pure-tone threshold: 37 dB (new users group only)	Fair
Mulrow et al, 1990 (19)	Described as randomized, method not reported	Yes	Yes	Yes	Not applicable	Not applicable	Cannot tell	Yes	Yes	No	Robert Wood Johnson Foundation; Milbank Scholar Program; ACP Teaching and Research Scholar Award	Mean age, 72 y (SD, 6) 99% male 97% white Mean pure-tone hearing in the better ear: 52 dB (SD, 8)*	Good
Tolson et al, 2002 (20)	Yes	Cannot tell	Yes	No	Not applicable	Not applicable	Cannot tell	Cannot tell	No	Cannot tell	NR	Mean age, 76.6 y 77% female Other baseline characteistics: NR	Poor
Yueh et al, 2001 (21)	Described as randomized, method not reported	Yes	No	Yes	Not applicable	Not applicable	Cannot tell	Cannot tell	None	No	Career Development Award CD-98318, Department of Veterans Affairs	Mean age, 68.5 y (range, 50–86 y) 100% male Race: NR Mean pure-tone hearing: right ear, 32.8 dB (SD, 5.6); left ear, 32.3 dB (SD, 5.7)	Fair

ACP = American College of Physicians; NR = not reported.
* Average of 1000-, 2000-, and 4000-Hz hearing levels.

Appendix Table 5. Studies on Diagnostic Accuracy of Screening Tests

Study, Year (Reference)	Screening Test: Definition of a Positive Result	Reference Standard: Definition of a Case	Setting	Sample Size	Participants	Proportion With Hearing Loss	Quality Rating
Bienvenue et al, 1985 (22)	AudioScope: failure to hear 25 dB at 500, 1000, 2000, or 4000 Hz	Pure-tone audiometry: ≥30-dB hearing loss at 500, 1000, 2000, and 4000 Hz	Speech and hearing clinics	30	Age: 51–81 y (mean NR) Sex: NR	NR	Fair
Boatman et al, 2007 (23)	Whispered voice at 2 ft: inability to repeat ≥2 words from two 3-word combinations Watch tick at 6 in: no response to ≥2 of 6 presentations of watch tick Finger rub at 6 in: no response to ≥2 of 6 finger rubs Single question: Do you think you have difficulty hearing?	Pure-tone audiometry: >25-dB hearing loss at 500, 1000, and 2000 Hz	Movement disorders clinic (patients or family members)	107 (214 ears)	Age: mean, 66 y Sex: 49% male	Hearing loss >25 dB: 63%	Good
Ciurlia-Guy et al, 1993 (24)	AudioScope: failure to hear 40 dB at 1000 or 2000 Hz in either ear	Pure-tone audiometry: >40-dB hearing loss at 1000 or 2000 Hz in either ear	Veterans Affairs chronic care facilities	99	Age: 79 y Sex: 88% male	Hearing loss >40 dB: 69%	Fair
Clark et al, 1991 (25)	Single question: Would you say that you have any difficulty hearing?	Pure-tone audiometry: ≥25-dB hearing loss at 1000 Hz, and 2000 Hz in better ear; ≥25-dB hearing loss at 1000, 2000, 3000, and 4000 Hz in better ear; or >40-dB hearing loss at 1000 Hz, 2000 Hz in worse ear	Population from an osteoporosis study	267	Age: mean NR Sex: 100% female	Hearing loss >25 dB: 45%; >40 dB: 18%	Good
Eekhof et al, 1996 (26)	Whispered voice at 2 ft: inability to repeat ≥2 combinations correctly AudioScope: failure to hear 40 dB at 500, 1000, 2000, or 4000 Hz	Pure-tone audiometry: >30-dB hearing loss in either ear (Hz not reported)	Otolaryngology clinic	62 (124 ears)	Age: ≥55 y (mean NR) Sex: NR	Hearing loss >30 dB: 59%; >40 dB: 33%	Fair
Frank and Petersen, 1987 (27)	AudioScope: failure to hear 40 dB at 500, 1000, 2000, or 4000 Hz	Pure-tone audiometry: ≥45-dB hearing loss at 500, 1000, 2000, or 4000 Hz	Speech and hearing clinic; rehabilitation center	405 (688 ears)	Age: 50–96 y (mean NR) Sex: NR	NR	Fair
Gates et al, 2003 (28)	HHIE-S: score >8 Single question: Do you have a hearing problem now?	Pure-tone thresholds: >40-dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in 1 ear (Ventry and Weinstein [39])	Subset of Framingham cohort	546	Age: mean, 78 y Sex: 36% male	Hearing loss >40 dB: 27% (Ventry and Weinstein [39])	Good
Koike et al, 1994 (29)	5-minute hearing test: various cutoffs	Pure-tone thresholds: ≥25-dB hearing loss at 500, 1000, and 2000 Hz in better ear (SFPTA criteria)	Audiology clinic	70	Age: mean, 69 y Sex: 56% male	NR	Fair
Lichtenstein et al, 1988 (30)	HHIE-S: score >8 or >24 AudioScope: failure to hear 40 dB at 500, 1000, 2000, or 4000 Hz	Pure-tone thresholds:≥25-dB hearing loss at 500, 1000, and 2000 Hz in better ear (SFPTA); ≥25-dB hearing loss at 1000, 2000, and 4000 Hz in better ear (HFPTA); or >40-dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in 1 ear (Ventry and Weinstein [39])	Internal medicine clinic	178	Age: mean, 74 y Sex: 37% male	Hearing loss >40 dB: 30% (Ventry and Weinstein [39]); >25 dB: 38% (SFPTA) and 58% (HFPTA)	Good
Macphee et al, 1988 (31)	Whispered voice at 2 ft: inability to repeat 1 triplet set of numbers correctly, or 50% of 4 triplet sets of numbers Whispered voice at 6 in: inability to repeat 1 triplet set of numbers correctly, or 50% of 4 triplet sets of numbers Conversation voice at 2 ft: inability to repeat 1 triplet set of numbers correctly, or 50% of 4 triplet sets of numbers	Pure-tone audiometry: >30-dB hearing loss at 500, 1000, and 2000 Hz	Acute rehabilitation wards	62 (124 ears)	Age: mean, 81 y Sex: 69% female	Hearing loss >30 dB: 61% (38/62)	Fair

Continued on following page

Appendix Table 5—Continued

Study, Year (Reference)	Screening Test: Definition of a Positive Result	Reference Standard: Definition of a Case	Setting	Sample Size	Participants	Proportion With Hearing Loss	Quality Rating
McBride et al, 1994 (32)	HHIE-S: score >8 or >24 AudioScope: failure to hear 40 dB at 2000 Hz in better ear	Pure-tone thresholds: ≥25-dB hearing loss at 500, 1000, and 2000 Hz in better ear (SFPTA); >40-dB hearing loss at 1000 or 2000 Hz in both ears; 1000 and 2000 Hz in 1 ear (Ventry and Weinstein [39])	Community health clinic; Veterans Affairs medical center	185	Age: mean, 70 y Sex: 69% male	NR	Good
Nondahl et al, 1998 (33); Wiley et al, 2000 (48)	HHIE-S: score >8 Single question: Do you feel you have hearing loss?	Pure-tone thresholds: >25-dB hearing loss at 500, 1000, 2000, and 4000 Hz in either ear	Subset of Beaver Dam Eye Study	3471	Age: mean, 66 y Sex: 42% male	Hearing loss >25 dB: 32%	Good
Rawool and Keihl, 2008 (34)	Single question: Do you think you have a hearing loss?	Pure-tone audiometry (portable audiometer): ≥25-dB hearing loss at 500, 1000, 2000, 3000, and 4000 Hz in better ear	Active, community-dwelling volunteer	30	Age: 78 y Sex: 27% male	Hearing loss >25 dB: 63%	Fair
Sever et al, 1989 (35)	HHIE-S: score of 0–8, 10–24, or 26–40	Pure-tone thresholds: ≥25-dB hearing loss at 500, 1000, and 2000 Hz in better ear (SFPTA); >40-dB hearing loss at 1000 or 2000 Hz in both ears; or 1000 and 2000 Hz in 1 ear (Ventry and Weinstein [39])	Audiology clinic	59	Age: mean NR Sex: NR	Hearing loss >25 dB: 36% (SFPTA); >40 dB: 27% (Ventry and Weinstein [39])	Fair
Sindhusake et al, 2001 (36)	HHIE-S: score >8 Single question: Do you feel you have hearing loss?	Pure-tone thresholds: >25-, >40-, or >60-dB hearing loss at 500, 1000, 2000, and 4000 Hz	Subset of Blue Mountain Eye Study	1807	Age: 55 to <65 y (30%); 65 to <85 y (65%) ≥85 y (5%) Sex: 43% male	Hearing loss >25 dB: 39%; >40 dB: 13%; >60 dB: 2%	Good
Swan and Browning, 1985 (37)	Whispered voice at 2 ft: unable to repeat ≥3 of 6 letters or numerals correctly	Pure-tone audiometry: >30-dB hearing loss at 500, 1000, and 2000 Hz	Audiology clinic	101 (202 ears)	Age: mean, 57 y Sex: NR	Hearing loss >30 dB: 43% (87/202)	Fair
Torre et al, 2006 (38)	Single question: Do you feel you have hearing loss? (*¿Usted siente que ha perdido su sentido de oido?*)	Pure-tone audiometry (portable audiometer): ≥25-dB hearing loss at 500, 1000, 2000, and 4000 Hz in poorer ear	Referred from physicians or medical staff	59	Age: mean, 62 y Sex: 46% male	Hearing loss >25 dB: 63%	Fair
Ventry and Weinstein, 1983 (39)	HHIE-S: score >8	Pure-tone thresholds: >40-dB hearing loss at 1000 or 2000 Hz in both ears	Community volunteers	104	Age: NR Sex: NR	Hearing loss >40 dB: 51%	Fair
Voeks et al, 1993 (40)	Single question: Do you have trouble hearing?	Pure-tone audiometry (portable audiometer): >25-dB hearing loss at 500, 1000, 2000, and 4000 Hz in better ear	New admissions to nursing home	198	Age: mean, 72 y Sex: 80% male	Hearing loss >25 dB: 54%	Fair
Weinstein, 1986 (41)	HHIE-S: score >8 or >10	Pure-tone audiometry: audiologist recommendation for evaluation	Senior citizen centers for initial screening	106	Age: mean, 76 y Sex: 42% male	NR	Fair

HFPTA = High-Frequency Pure-Tone Average; HHIE-S = Hearing Handicap Inventory for the Elderly—Screening Version; NR = not reported; SFPTA = Speech Frequency Pure-Tone Average.

Appendix Table 6. Quality Ratings of Diagnostic Test Studies

Study, Year (Reference)	Representative Spectrum	Random or Consecutive Sample	Screening Test Adequately Described	Screening Cutoffs Predefined	Credible Reference Standard	Reference Standard Applied to and Analysis Includes All Patients or a Random Subset	Same Reference Standard Applied to All Patients	Reference Standard and Screening Examination Interpreted Independently	High Rate of Uninterpretable Results or Nonadherence to Screening Test	Analysis Includes Patients With Uninterpretable Results or Nonadherence	Quality Rating
Bienvenue et al, 1985 (22)	No	Cannot tell	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	NA	Fair
Boatman et al, 2007 (23)	High prevalence	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	NA	Good
Ciurlia-Guy et al, 1993 (24)	High prevalence	Yes	Yes	Yes	Yes, portable audiometer	No (5/104)	Yes	Yes	No	No	Fair
Clark et al, 1991 (25)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	No	Good
Eekhof et al, 1996 (26)	High prevalence	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	NA	Fair
Frank and Petersen, 1987 (27)	Yes	Cannot tell	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Fair
Gates et al, 2003 (28)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Good
Koike et al, 1994 (29)	No	Cannot tell	Yes	No	Yes	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Lichtenstein et al, 1988 (30)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	No	Good
Macphee et al, 1988 (31)	High prevalence	Cannot tell	Yes	Yes	Yes	Yes	Yes	Yes	No	NA	Fair
McBride et al, 1994 (32)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	NA	Good
Nondahl et al, 1998 (33); Wiley et al, 2000 (48)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	No	Good
Rawool and Keihl, 2008 (34)	High prevalence	No	Yes	Yes	Yes, portable audiometer	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Sever et al, 1989 (35)	Yes	Cannot tell	Yes	Yes	Yes	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Sindhusake et al, 2001 (36)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	No	Good
Swan and Browning, 1985 (37)	No	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	NA	Fair
Torre et al, 2006 (38)	High prevalence, 63%	No	Yes	Yes	Yes, portable audiometer	Yes	Yes	Cannot tell	No	NA	Fair
Ventry and Weinstein, 1983 (39)	Cannot tell	Cannot tell	Yes	Yes	Yes	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Voeks et al, 1993 (40)	High prevalence, 54%	Yes	Yes	Yes	Yes, portable audiometer	Yes	Yes	Cannot tell	Yes	Yes	Fair
Weinstein, 1986 (41)	Yes	No	Yes	No	No	Yes	Yes	Yes	Cannot tell	Cannot tell	Fair

NA = not applicable.

Appendix Table 7. Whispered Voice, Finger Rub, and Watch Tick Clinical Tests*

Study, Year (Reference)	Screening Test: Definition of a Positive Result	Definition of a Case	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds Ratio	Quality Rating
Boatman et al, 2007 (23)	Whispered voice at 2 ft: inability to repeat ≥2 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 (26)	Whispered voice at 2 ft: Inability to repeat ≥2 combinations correctly	>30-dB hearing loss in either ear (Hz not reported)	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 (31)	Whispered voice at 2 ft: inability to repeat 1 triplet set of numbers correctly, or 50% of 4 triplet sets of 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 (37)	Whispered voice at 2 ft: unable to repeat ≥3 of 6 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
Median (range)	Whispered voice at 2 ft	–	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 (31)	Whispered voice at 6 in: inability to repeat 1 triplet set of numbers correctly, or 50% of 4 triplet sets of 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 (31)	Conversation voice at 2 ft: inability to repeat 1 triplet set of numbers correctly, or 50% of 4 triplet sets of 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 (23)	Watch tick at 6 in: no response to ≥2 of 6 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 (23)	Finger rub at 6 in: no response to ≥2 of 6 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

* Values in parentheses are 95% CIs unless otherwise stated.

Appendix Table 8. Single-Question Screening*

Study, Year (Reference)	Screening Question	Definition of a Case	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds Ratio	Quality Rating
Community-dwelling older adults								
Boatman et al, 2007 (23)	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 (25)	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 (25)	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 (33); Wiley et al, 2000 (48)	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 and Keihl, 2008 (34)	Do you think you have a 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 (36)	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 (38)	Do you feel you have hearing loss? (*¿Usted siente que ha perdido su sentido de oido?*)	≥25-dB hearing loss at 500, 1000, 2000, and 4000 Hz in poorer 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
Median (range)	–	≥25-dB hearing loss	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 (25)	Would you say that you have any difficulty hearing?	>40-dB hearing loss at 1000 Hz; 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 (28)	Do you have a hearing problem now?	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 1 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 (36)	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
Median (range)	–	>40-dB hearing loss	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 (36)	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
Older adults in nursing homes								
Voeks et al, 1993 (40)	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

V & W = Ventry and Weinstein (39) criteria.
* Values in parentheses are 95% CIs unless otherwise stated.
† Not included when estimating median to avoid double counting of a sample.

Appendix Table 9. Screening Questionnaires*

Study, Year (Reference)	Screening Test: Definition of a Positive Result	Definition of a Case	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds Ratio	Quality Rating
Lichtenstein et al, 1988 (30)	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 (32)	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 (35)	HHIE-S: score >8	SFPTA: ≥25-dB hearing loss at 500, 1000, and 2000 Hz in better ear	0.71 (0.48–0.89)	Not reported	Not calculable	Not calculable	Not dichotomized	Fair
Lichtenstein et al, 1988 (30)	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 (32)	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 (33); Wiley et al, 2000 (48)	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)	11 (6.8–17)	0.70 (0.67–0.73)	15 (9.4–26)	Good
Sindhusake et al, 2001 (36)	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
Median (range)	HHIE-S: score >8	>25-dB hearing loss	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 (41)	HHIE-S: score >8	Audiologist recommendation for evaluation	0.74†	0.68†	2.3†	0.38†	6.1†	Fair
Gates et al, 2003 (28)	HHIE-S: score >8	V & W: >40-dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in 1 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 (30)	HHIE-S: score >8	V & W: >40-dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in 1 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 (32)	HHIE-S: score >8	V & W: >40-dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in 1 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 (35)	HHIE-S: score >8	V & W: >40-dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in 1 ear	0.81 (0.54–0.96)	Not reported	Not calculable	Not calculable	Not dichotomized	Fair
Sindhusake et al, 2001 (36)	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 and Weinstein, 1983 (39)	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
Median (range)	HHIE-S: score >8	>40-dB hearing loss	0.72 (0.36–0.81)	0.76 (0.66–0.92)	3.1 (2.1–4.5)	0.43 (0.26–0.70)	–	–
Sindhusake et al, 2001 (36)	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 (41)	HHIE-S: score >10	Audiologist recommendation for evaluation	0.65†	0.83†	3.8†	0.42†	9.0†	Fair
McBride et al, 1994 (32)	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 (32)	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
Median (range)	HHIE-S: score >24	>25-dB hearing loss	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 (30)	HHIE-S: score >24	V & W: >40-dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in 1 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

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Appendix Table 9—Continued

Study, Year (Reference)	Screening Test: Definition of a Positive Result	Definition of a Case	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds Ratio	Quality Rating
McBride et al, 1994 (32)	HHIE-S: score >24	V & W: >40-dB hearing loss at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in 1 ear	0.42 (0.28–0.56)	0.88 (0.82–0.93)	3.4 (1.9–5.9)	0.66†	5.3†	Good
Median (range)	HHIE-S: score >24	>40-dB hearing loss	0.32 (0.25–0.42)	0.93 (0.88-0.98)	5.9 (3.4–10.2)	0.71 (0.66–0.77)	–	–
Koike et al, 1994 (29)	FMHT: 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

FMHT = 5-minute hearing test; HFPTA = High-Frequency Pure-Tone Average; HHIE-S = Hearing Handicap Inventory for the Elderly—Screening Version; SFPTA = Speech Frequency Pure-Tone Average; V & W = Ventry and Weinstein (39) criteria.
* Values in parentheses are 95% CIs unless otherwise stated.
† 95% CI not calculable.
‡ Not included when estimating median to avoid double counting of a sample.

Appendix Table 10. Hand-Held Audiometric Devices*

Study, Year (Reference)	Definition of a Positive Result on Screening Test	Definition of a Case	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds Ratio	Quality Rating
Community-dwelling older adults								
McBride et al, 1994 (32)	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 (32)	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 (22)	Failure to hear 25 dB at 500, 1000, 2000, or 4000 Hz using AudioScope	≥30-dB hearing loss at 500, 1000, 2000, or 4000 Hz	0.93†	0.70†	3.1†	0.10†	31†	Fair
Eekhof et al, 1996 (26)	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 (30)	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 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)	43 (12–220)	Good
McBride et al, 1994 (32)	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 1 ear	0.96 (0.90–1.00)	0.80 (0.74–0.87)	4.9 (3.4–6.8)	0.05†	98†	Good
Median (range)	–	>40-dB hearing loss (3 studies)	0.96 (0.94–1.0)	0.72 (0.42–0.89)	3.4 (1.7–4.9)	0.05 (0.03–0.08)	–	–
Frank and Petersen, 1987 (27)	Failure to hear 40 dB at 500, 1000, 2000, or 4000 Hz	≥45-dB hearing loss at 500, 1000, 2000, or 4000 Hz	50–59 y: 0.90† 60–69 y: 0.89† 70–79 y: 0.85† 80–89 y: 0.86† 90–96 y: 0.86†	50–59 y: 0.94† 60–69 y: 0.90† 70–79 y: 0.90† 80–89 y: 0.89† 90–96 y: 0.90†	50–59 y: 16† 60–69 y: 9.2† 70–79 y: 8.7† 80–89 y: 8.1† 90–96 y: 9.1†	50–59 y: 0.11† 60–69: y 0.12† 70–79: y 0.17† 80–89 y: 0.16† 90–96 y: 0.15†	50–59 y: 140† 60–69 y: 77† 70–79 y: 51† 80–89 y: 51† 90–96 y: 61†	Fair
Older adults in chronic care facilities								
Ciurlia-Guy et al, 1993 (24)	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

HFPTA = High-Frequency Pure-Tone Average; SFPTA = Speech Frequency Pure-Tone Average; V & W = Ventry and Weinstein (39) criteria.
* Values in parentheses are 95% CIs unless otherwise stated.
† 95% CI not calculable.
‡ Not included when estimating median to avoid double counting of a sample.