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Long-term cost-effectiveness of screening strategies for hearing loss

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Abstract—Routine hearing screening can identify patients who are motivated to seek out and adhere to treatment, but little information exists on the cost-effectiveness of hearing screening in a general population of older veterans. We compared the cost-effectiveness of three screening strategies (tone-emitting otoscope, hearing handicap questionnaire, and both together) against no screening (control group) in 2,251 older veterans. The effectiveness measure for each group was the proportion of hearing aid use 1 year after screening. The audiology cost measure included costs of hearing loss screening and audiology care for 1 year after screening. Incremental cost-effectiveness was the audiology cost of additional hearing aid use for each screening group compared with the control group. The mean total audiology cost per patient was $77.04, $122.70, $121.37, and $157.08 for the control, otoscope, questionnaire, and dual screening groups, respectively. The tone-emitting otoscope appears to be the most cost-effective approach for hearing loss screening, with a significant increase in hearing aid use 1 year after screening (2.8%) and an insignificant incremental cost-effectiveness of $1,439.00 per additional hearing aid user compared with the control group. For this population of older veterans, screening for hearing loss with the tone-emitting otoscope is cost-effective.

Key words: audiology, aural rehabilitation, cost-effectiveness, healthcare cost, health services, hearing aid, hearing loss, hearing loss screening, preventive care, veterans.

INTRODUCTION

Hearing loss is one of the most common chronic conditions in older Americans [1–2]. The number of individuals with hearing impairment in the United States is estimated to be over 28 million [3]. The development of hearing loss is usually gradual and lacks acute symptoms, leaving the condition underdetected [4–5] and undertreated [6–7]. Thus, many patients with hearing loss do not seek treatment that can alleviate depression symptoms and diminish social isolation associated with this condition, ultimately improving quality of life [8–11]. The typical hearing aid user waits many years after the onset of hearing loss before seeking treatment. To alleviate the toll that hearing loss exacts on productivity, function, and quality of life, some authors have advocated routine hearing screening. Several screening tests can accurately detect hearing loss among

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Abbreviations: CES-D = Center for Epidemiologic Studies–Depression, DALC = Denver Acquisition and Logistics Center, DSS = Decision Support System, MCS = mental health component score, PCS = physical component score, SAI-WHAT = Screening for Auditory Impairment–Which Hearing Assessment Test, VA = Department of Veterans Affairs.

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elderly patients [12–14], and both the U.S. Preventive Service Task Force and the Canadian Task Force on Preventive Health Care have recommended routine screening of hearing loss in the elderly [15–16].

The Screening for Auditory Impairment–Which Hearing Assessment Test (SAI-WHAT) randomized trial evaluated the effectiveness of screening older outpatient veterans for hearing loss. The SAI-WHAT study compared three different screening strategies against no screening. The study showed that screening for hearing loss resulted in significantly more veterans who used hearing aids 1 year after screening, particularly if screened with a tone-emitting otoscope, compared with veterans who did not receive screening [17].

Information on the cost-effectiveness of hearing loss screening provides critical information for administrators and policy makers deciding to adopt a new screening strategy. No previous research has assessed costs or cost-effectiveness of hearing loss screening strategies. In this article, we assess the effect of the SAI-WHAT study screening strategies on utilization and costs of audiology care. We also examine the long-term cost-effectiveness of each of the SAI-WHAT study screening strategies.

METHODS

Screening Strategies

The SAI-WHAT study was a four-group, randomized trial, including three screening strategies and one control group without screening. The three screening groups consisted of a physiologic hearing test using a tone-emitting otoscope (AudioScope, Welch Allyn; Skaneateles Falls, New York); a validated, self-administered hearing handicap questionnaire; and both screening tools used together. A detailed description of the study design, baseline screening, and main outcomes has been published elsewhere [17–18].

Tone-Emitting Otoscope Screening

For the tone-emitting otoscope screening, the examiner held the unit to the participant's ear while the participant listened to tones emitted by the device. The screening was positive if the participant did not hear a 40 dB tone at 2,000 Hz in either ear [13,19–20]. Training required to use the device was negligible. Screening time was about 2 minutes.

Hearing Handicap Questionnaire Screening

The hearing handicap questionnaire screening consisted of the self-administered Hearing Handicap Inventory for the Elderly, Screening Version. It assesses social and emotional hearing handicap [14,21], ranging from a no handicap score of 0 to a maximum handicap score of 40. A score of ≥10 was a positive screen. Hearing handicap questionnaire completion time was 5 minutes.

Dual Screening

The third screening strategy consisted of both the tone-emitting otoscope and the hearing handicap questionnaire. Together, they may assess complementary aspects of hearing loss [13,19]. The tone-emitting otoscope may identify those with mild hearing loss who may not have sufficient handicap to seek out and comply with treatment [19]. However, the hearing handicap questionnaire may identify motivated participants [12] but may miss those with only mild loss and miss early detection. We considered a positive screen for the tone-emitting otoscope or the hearing handicap questionnaire a positive screen for this dual screening strategy.

Study Sample

We recruited study participants from the general outpatient population at the Department of Veterans Affairs (VA) Puget Sound Health Care System from January 2002 through December 2003. The enrollment criteria included patients (1) aged ≥50 years and (2) eligible for no-charge, VA-issued hearing aids. Participants were not eligible if they (1) already used hearing aids; (2) had received a hearing evaluation in the 6 months prior to screening; or (3) could not complete any questionnaires, including hearing handicap, baseline, or follow-up questionnaire by mail 1 year after screening.

The study sample included 2,305 eligible participants randomized in blocks of 10 into the control and screening groups by using an unbalanced randomization strategy with a 2:1:1:1 ratio. The ratio was doubled in the control group to ensure sufficient power, given that we only expected 3 percent of these participants to be 1-year hearing aid users on the basis of pilot data. We excluded 54 participants who died during the study period. The final study sample consisted of 2,251 patients.

We informed participants who screened positive for hearing loss that they might have hearing loss and provided them with written instructions to contact the VA Puget Sound Health Care System audiology clinic for a hearing evaluation. We told participants who screened negative that they likely had no more than a mild hearing loss. We provided participants who screened negative, as well as participants who did not receive screening (control group), with information about how to contact the audiology clinic if they wanted an evaluation.

The study tracked audiology use and hearing aid dispensing for a study cohort of 2,251 participants for 1 year after screening. The effective measure was whether a participant used the hearing aid in the 12 months after screening, which we determined through a self-administered mail survey, electronic medical record review, or telephone interview.

Audiology Cost

We assessed the audiology cost from the VA payers' perspective, including care received in VA and non-VA facilities. The VA covered all costs, which included two components: cost of hearing loss screening and cost of audiology care after screening. We collected the data for use of audiology care during the study period. We also collected costs for screening and audiology care for 1 year after screening. These costs were actual VA costs that we obtained directly from the Decision Support System (DSS) database [22] and the Denver Acquisition and Logistics Center (DALC) database. The DSS database is the VA cost accounting system that contains the cost for each VA visit by veterans based on type of provider, materials and supplies used, length of time, and procedure codes for a specific visit. The DALC database contains the VA cost for each medical prosthetic device used in VA, including hearing aids and batteries.

We calculated the cost for hearing loss screening for participants in the three screening groups, including personnel time for conducting screening, equipment cost for the tone-emitting otoscope, and printing cost for the hearing handicap questionnaire. We calculated the personnel cost based on the full-time salary of a medical assistant, including fringe benefits. On average, the tone-emitting otoscope test took 2 minutes per participant and scoring the hearing handicap questionnaire took 1 minute per participant. We spread the equipment cost of $640.00, including one AudioScope ($450.00) and annual calibration of the AudioScope for 2 years ($85.00 per year), across the participants in the otoscope and dual screening groups. The printing cost for the 1-page hearing handicap questionnaire was $0.10 per participant in both the questionnaire and dual screening groups.

The cost of audiology care in the 12-month period after screening included audiology visits, hearing aids, and hearing aid batteries, including both VA and non-VA costs. We directly extracted the cost for each audiology visit in VA for our study cohort from the DSS database. We also directly extracted the costs for hearing aids and batteries used by the study cohort from the DALC database.

For non-VA care, 23 participants sought audiology care from community audiologists. VA paid for the majority of these community audiology visits through the fee-basis care program. In rare instances, participants paid out-of-pocket for their audiology care. The study team contacted these community providers, identified by participants, to obtain the payment for audiology care provided. We adjusted all costs to 2004 dollars using the medical component of the consumer price index.

Effectiveness and Cost-Effectiveness Measures

Table 1 provides definitions of audiology cost, incremental cost, effectiveness of hearing loss screening, incremental effectiveness, cost-effectiveness, and incremental cost-effectiveness in this study. We calculated the audiology cost for each of the three screening groups and the control group. Incremental cost measures the additional audiology cost attributable to a hearing loss screening strategy and calculates the difference in the total audiology cost between a screening group and the control group.

The effectiveness measure for each group was the proportion of hearing aid use in 12 months after the screening, which was the main outcome measure from the SAI-WHAT study [17]. The incremental effectiveness was the difference in the proportion of hearing aid use between a screening group and the control group. Cost-effectiveness measures the cost per unit of hearing loss screening program effectiveness, in this case, the average annual audiology cost per hearing aid user for a hearing loss screening strategy. We calculated cost-effectiveness for each group by dividing the average cost of audiology care by the proportion of participants who used a hearing aid in the 12 months after screening.

Incremental cost-effectiveness is the ratio of the added cost of a hearing loss screening program to the added effectiveness above and beyond the level of care provided relative to the control group. We calculated the incremental cost-effectiveness measure by dividing the incremental cost by the incremental effectiveness between each screening group and the control group. Incremental cost-effectiveness estimates how much more

Table 1.
Definitions of measures used in study.

Term	Definition
Audiology Cost	Average direct and overhead costs to VA for providing hearing loss screening and audiology care after screening for three screening groups and one control group.
Incremental Cost	Mean audiology cost among participants in screening group minus mean audiology cost among participants in control group.
Effectiveness	Probability of hearing aid use in 12 months after screening for three screening groups and one control group.
Incremental Effectiveness	Probability of hearing aid use in 12 months after screening for each screening group minus probability of control group.
Cost-Effectiveness	Mean audiology cost divided by measure of hearing loss screening effectiveness for each screening group.
Incremental Cost-Effectiveness	Audiology cost of screening group minus cost of control group divided by measure of effectiveness of screening group minus measure of effectiveness of control group.

VA = Department of Veterans Affairs.

or less it would cost VA to obtain one additional hearing aid user with each screening strategy in comparison with the control group.

Analysis

We used logistic regressions to estimate screening effectiveness, i.e., the probability of hearing aid use 1 year after screening. We used a two-part model to estimate costs of hearing loss screening and audiology care during the same period, because a significant number of study participants were not screened and did not seek audiology care, thereby incurring no costs [23–24]. In the first part, we used a logistic regression to estimate the probability of having any healthcare costs of screening and audiology care. In the second part, we estimated the costs of hearing loss screening and audiology care (total cost) by using ordinary least square regressions with logarithmic cost. Because we used logarithmic cost, we retransformed the predicted cost by using Duan's smearing estimator [25]. Finally, we took into account the probability of incurring any healthcare cost (model part 1) in the estimation of the predicted cost for each participant.

We estimated confidence intervals for the incremental effectiveness in the probability of using a hearing aid, the incremental cost of audiology care, and the incremental cost-effectiveness (cost per additional hearing aid user) by bootstrapping with 1,000 replications [26–28]. We adjusted all regression analyses for baseline demographic characteristics including age, sex, race, number of years of education, the 36-Item Short Form Health Survey physical component score (PCS) and mental health component score (MCS) [29–31], and depression symptoms measured by the Center for Epidemiologic Studies–Depression (CES-D) scale, with a score of ≥16 out of 60 indicating the presence of depression [32].

RESULTS

We found no significant differences in baseline participant characteristics across groups (**Table 2**). The mean age of the cohort was 60.6 years, 94.2 percent were male, and 74.9 percent identified themselves as white. The mean PCS and MCS were 35.7 and 42.8, respectively. More than half the cohort (53.4%) reported depression symptoms (CES-D scores ≥16).

Table 3 summarizes the screening outcomes. The dual screening group had the highest rate of positive screens for hearing loss (63.4%), followed by the questionnaire (58.8%) and otoscope (18.1%) groups ($p <$ 0.001). For the proportion of participants having an audiology visit, the dual screening group had the highest rate (27.1%), followed by the questionnaire group (23.2%), the otoscope group (14.5%), and the control group (11.4%) ($p < 0.001$). We observed a similar pattern for the number of audiology visits per participant across the four groups. The dual screening group had the highest number of visits per participant (0.42), followed by the questionnaire group (0.32), the otoscope group (0.29), and the control group (0.21) ($p < 0.001$).

For hearing aid use 1 year after screening, the dual screening group continued to have the highest percentage of individuals (7.5%), but the pattern shifted to favor the otoscope group with 6.4 percent of participants wearing

Table 2.
Patient characteristics at baseline.*

Characteristic	Control (*n* = 897)	Otoscope (*n* = 454)	Questionnaire (*n* = 449)	Dual Screening (*n* = 451)	Total (*N* = 2,251)
Age, yr (mean ± SD)	60.5 ± 9.0	60.4 ± 8.8	61.2 ± 9.0	60.5 ± 9.0	60.6 ± 8.9
Male (%)	92.6	95.4	95.0	95.6	94.2
Education, yr (mean ± SD)	14.0 ± 2.1	14.0 ± 2.1	13.9 ± 2.1	14.0 ± 2.1	14.0 ± 2.1
White (%)	74.1	77.8	73.9	74.7	74.9
SF-36 Score (mean ± SD)					
Physical Component	35.3 ± 11.1	36.1 ± 11.5	35.8 ± 11.6	35.9 ± 11.0	35.7 ± 11.3
Mental Health Component	42.7 ± 14.4	42.3 ± 14.9	43.3 ± 14.9	43.0 ± 14.4	42.8 ± 14.5
Depression Symptoms (%)†	53.2	55.2	52.5	52.8	53.4

*With exception of age, characteristics were self-reported.
†Center for Epidemiologic Studies–Depression scale scores ≥16 out of 60.
SD = standard deviation, SF-36 = 36-Item Short Form Health Survey.

Table 3.
Effectiveness of hearing loss screening, unadjusted.

Effectiveness	Control (*n* = 897)	Otoscope (*n* = 454)	Questionnaire (*n* = 449)	Dual Screening (*n* = 451)	*p*-Value*
Screened Positive For Hearing Loss (%)	—	18.1	58.8	63.4	<0.001
Having an Audiology Visit (%)	11.4	14.5	23.2†	27.1†	<0.001
No. of Audiology Visits per Participant (mean ± SD)	0.21 ± 0.76	0.29 ± 0.88	0.32‡ ± 0.68	0.42† ± 0.86	<0.001
Using Hearing Aid 1 Year After Screening (%)	3.3	6.4‡	4.1	7.5†	0.003

*Based on analysis of variance test of equality across four groups.
†Significance level compared with control group, $p < 0.001$.
‡Significance level compared with control group, $p < 0.01$.
SD = standard deviation.

hearing aids compared with 4.1 and 3.3 percent for the questionnaire and control groups, respectively ($p < 0.01$). For head-to-head comparisons, the results indicate statistically significant differences in hearing aid use 1 year after screening between the control and otoscope groups ($p < 0.001$) and between the control and dual screening groups ($p < 0.01$), but no significant difference between the questionnaire and control groups.

The cost for hearing loss screening was very low (**Table 4**). The screening cost per participant was $1.31, $0.74, and $2.06 for the otoscope, questionnaire, and dual screening groups, respectively. The mean cost per participant for audiology visits was $57.54, $62.79, $87.92, and $39.62 for the otoscope, questionnaire, dual screening, and control groups, respectively ($p < 0.001$). The mean cost per participant for hearing aids and batteries was $63.85, $57.84, $67.10, and $37.43 for the same groups ($p = 0.07$), respectively. In total, the dual screening group had the highest mean total audiology cost per participant ($157.08), followed by the otoscope ($122.70), questionnaire ($121.37), and control ($77.04) groups ($p < 0.01$). For head-to-head comparisons in the total audiology cost per participant, each of the screening groups were significantly different compared with the control group ($p = 0.03$ for the otoscope vs control groups, $p < 0.05$ for the questionnaire vs control groups, and $p < 0.001$ for the dual screening vs control groups).

Table 5 presents the 1-year adjusted cost-effectiveness analyses. For incremental effectiveness (difference in the proportion of hearing aid use 1 year after screening), the otoscope and dual screening groups were significantly greater than the control group, with 2.78 and 4.16 percent (both $p < 0.05$), respectively, and no significant difference (0.60%) between the questionnaire and control groups. On the incremental cost and incremental cost-effectiveness measures, we found the same pattern of significance. For incremental costs (difference in the total audiology cost per participant), the dual screening group ($67.00) was significantly higher than the control group ($p < 0.05$), while the otoscope ($40.00) and questionnaire ($30.00)

Table 4.
Cost of audiology care per patient, unadjusted.*

Cost Measure	Control (*n* = 897)	Otoscope (*n* = 454)	Questionnaire (*n* = 449)	Dual Screening (*n* = 451)	*p*-Value†
Screening ($)	0.00	1.31	0.74	2.06	—
Audiology Visits, $ (mean ± SD)	39.62 ± 152.40	57.54 ± 178.40	62.79‡ ± 153.30	87.92§ ± 205.00	<0.001
Hearing Aids and Batteries, $ (mean ± SD)	37.43 ± 206.10	63.85¶ ± 261.30	57.84 ± 239.50	67.10¶ ± 233.20	0.07
Total Cost, $ (mean ± SD)	77.04 ± 325.90	122.70¶ ± 406.40	121.37¶ ± 362.80	157.08§ ± 412.10	<0.01

*Includes cost of screening and audiology cost for 1 year after screening.
†Based on analysis of variance test of equality across four groups.
‡Significance level compared with control group, $p < 0.01$.
§Significance level compared with control group, $p < 0.001$.
¶Significance level compared with control group, $p < 0.05$.
SD = standard deviation.

Table 5.
Cost-effectiveness of hearing loss screening, adjusted.*

Group	Incremental Effectiveness (%)†	Incremental Cost ($)	Incremental Cost-Effectiveness ($)‡
Otoscope vs Control			
Mean	2.78	40.00	1,439.00
95% CI	0.60, 5.10	–3.00, 87.00	–440.00, 4,068.00
Questionnaire vs Control			
Mean	0.60	30.00	5,000.00
95% CI	–1.30, 2.60	–9.00, 72.00	–27,255.00, 32,854.00
Dual Screening vs Control			
Mean	4.16	67.00	1,611.00
95% CI	1.60, 6.60	23.00, 112.00	872.00, 3,568.00

*Analysis conducted using two-part models and adjusted for age, sex, race, education, SF-36 PCS and MCS, and depression symptoms and includes cost of screening and audiology cost for 1 year after screening.
†Additional proportion of participants with long-term hearing aid use at 1 year follow up after screening compared with control group.
‡Additional cost per gaining an additional hearing aid user compared with control group.
CI = confidence interval, MCS = mental health component score, PCS = physical component score, SF-36 = 36-Item Short Form Health Survey.

groups were not significantly higher than the control group. Similarly, incremental cost-effectiveness (cost per additional hearing aid user) was significantly different from zero for the dual screening group at $1,611.00 ($p < 0.05$) compared with the control group, while it was not significantly different from zero for the otoscope ($1,439.00) and questionnaire ($5,000.00) groups compared with the control group.

DISCUSSION

This is the first study examining cost-effectiveness of hearing loss screening strategies in an adult population, and it provides the importation information needed by policy makers to determine whether their healthcare system can cope with implementing such a program [33]. The main results of the SAI-WHAT study show that out of three different methods, screening with the tone-emitting otoscope was an efficient and effective way to identify older veterans who would seek and adhere to hearing aid treatment [17]. The cost-effective analysis presented here suggests that the otoscope and dual screening groups are more cost-effective with significantly greater incremental cost-effectiveness than the control group. Further analysis shows that there was no statistical difference in cost-effectiveness between the otoscope and dual screening groups. From the practical point of view, the single-screening method approach (tone-emitting otoscope) is simpler and easier to implement than the dual screening approach (tone-emitting otoscope and hearing handicap questionnaire), giving a similar level of cost-effectiveness. Therefore, the tone-emitting otoscope is more efficient and the preferred screening strategy for hearing loss in this population and setting, consistent with earlier reports about general screening for hearing loss [13,19,21,34] and the recommendation by the Canadian Task Force on Preventive Health Care's screen with tone-emitting otoscope [35].

The SAI-WHAT study was designed to examine screening effectiveness rather than screening accuracy; therefore, we did not seek to obtain audiograms on all participants and screening test accuracy cannot be measured. However, the substantially higher percentage of participants who screened positive in the questionnaire group compared with the otoscope group, combined with a significant difference in 1-year hearing aid use between the otoscope and control groups but not the questionnaire and control groups, suggests that the questionnaire group produced many more false-positive results. The study results show that, compared with the control group, the incremental cost-effectiveness of the questionnaire group was not significantly different from zero. The questionnaire group was less efficient because it generated more audiology visits but fewer hearing aid users after 1 year. Therefore, screening with the hearing handicap questionnaire was the least preferred hearing loss screening approach among the three.

The study results suggest that, compared with the dual screening group, the otoscope group is the preferable approach, with a significant increase in the proportion of participants with long-term hearing aid use but no significant increase in cost. In addition, the tone-emitting otoscope is feasible and practical to incorporate into routine clinical care because it is easy to operate by medical assistant personnel with minimal additional training and administration time. The tone-emitting otoscope could be easily integrated into the patient check in and vital sign measurement process. Further, this study shows that the cost of the tone-emitting otoscope was very low, with an average of $1.31 per person screened. In combination with the strong evidence that treatment of hearing loss with hearing aids leads to substantial improvements in social and emotional function, communication function, and depression [9–11,34], this provides strong support for leadership to recommend implementation of routine hearing screening with the tone-emitting otoscope.

This cost-effectiveness study has several limitations. First, the study was only conducted in one audiology clinic and may not generalize to other VA audiology clinics with different sociodemographic populations. Second, the study participants were veterans and predominantly male, and the costs of hearing screening and audiology care were paid by the VA and not by the patient or a third-party insurer; therefore, the study results may not generalize to non-VA populations. Third, this study assessed the audiology cost from the VA payers' perspective, rather than from the societal perspective or participants' perspectives. Therefore, we did not include indirect costs to the participant, such as travel or time costs, in the analysis. Fourth, almost 75 percent of participants reported that they had some hearing loss and all participants were eligible for free hearing aids from VA. Both of these factors may affect willingness to screen and follow up with recommended therapies and likely affected cost analyses. Further, there was a potential increase in audiology visits and costs for paticipants who were randomized to the control group, because when asked, the study provided the audiology clinic information. Therefore, this analysis provides the lower-bound incremental cost-effectiveness estimates for all three screening strategies. Finally, this study did not conduct the cost-effective analyses based on quality-adjusted life years, because there are no validated measures for converting hearing-specific scales to generic health status scores or utility scores.

CONCLUSIONS

In summary, this study examined long-term cost-effectiveness of three hearing loss screening strategies among older veterans: tone-emitting otoscope, hearing handicap questionnaire, and a combination of both. The study shows that screening for hearing loss with the tone-emitting otoscope is both inexpensive and effective in terms of long-term hearing aid use and can potentially be integrated into routine clinical practice.

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Acquisition of data: C. F. Liu, M. P. Collins, B. Yueh.
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