An economic evaluation of screening 60- to 70-year-old adults for hearing loss

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ABSTRACT

Background Hearing loss is common among older adults and has consequences for sufferers, families and society, but there is substantial unmet need for intervention. Screening could expedite intervention and improve outcomes.

Methods We use Markov models to estimate the incremental cost-effectiveness ratio (ICER) of potential screening programmes compared with current provision (GP-referral), from a health service perspective. Alternative options are investigated through scenario analysis. One-way and probabilistic sensitivity analyses are undertaken.

Results All modelled screens are cost-effective and reduce unmet need for hearing aids. The most cost-effective option identified is a one-stage audiometric screen for bilateral hearing loss ≥30 dB hearing level (HL) at age 60, repeated at ages 65 and 70. This option has an ICER of £1461 compared to GP-referral and would mean an additional 15,437 adults benefiting from hearing intervention per 100,000 population aged 60. The cost-effectiveness acceptability curve shows that screening is more cost-effective than GP-referral provided a Quality Adjusted Life Year is valued at £2000 or more.

Conclusions Adult hearing screening would provide a cost-effective way to improve quality of life for older adults. We recommend piloting an audiometric screen offered to all adults age 60, 65 and 70 years to identify bilateral hearing loss of at least 30 dB HL.

Keywords cost effectiveness, ear disorders, screening

Background

Populations are ageing and older adults make an increasing contribution to society, yet uncorrected hearing loss is common over the age of 50 years, increasing in prevalence and severity with age. The consequences of uncorrected hearing loss can be significant for hearing-impaired individuals and their communication partners: difficulties are experienced at work, home and in social interaction; participation, independence and quality of life can become compromised.1,2 Adults commonly delay 10—15 years before seeking help for hearing difficulty3,4 and the most common reason is the belief that their hearing is not bad enough.5 Evidence shows hearing aids improve social functioning and quality of life even for mild hearing loss6,7 and long-term outcomes are better when they are obtained early.4

Current knowledge of age-related hearing loss does not allow for primary prevention, so secondary prevention of disability is proposed, through actively seeking cases who could benefit from intervention. For screening to be justified, the health problem should be important, its natural history should be understood and early intervention should lead to better outcomes.8 Age-related hearing loss is important due to high prevalence9 and negative consequences, the
progression of age-related hearing loss is well established and the benefits of early intervention are to reduce both the duration of disability and its severity in later life.

Previous work suggests adult hearing screening (AHS) should target 50–65 year olds, old enough for prevalence to justify screening but young enough to gain from early intervention.

The options assessed here are derived from a project reported in 2007. Davis et al. considered the acceptability, benefits and costs of early screening for hearing disability. They estimated prevalence of hearing problems and the use of hearing services and aids through reviewing routinely collected data and a survey of a sample of 55–74 year olds selected randomly. Some individuals newly identified as hearing impaired were invited to have a trial of hearing aids, where acceptability of aids and clinical effect were assessed. Following this, a controlled trial of various options for hearing screening was undertaken in two centres, with hearing and quality of life being the main outcomes assessed. They then went on to investigate the long-term outcomes for people fitted with hearing aids through a case–control study. Here they were interested in what proportion of people would continue using the aids they had been fitted with, what the predictors of longer term use were, and what the long-term benefit of hearing aids might be. They then went on to consider the clinical performance of different options for hearing screening and concluded that AHS is acceptable and beneficial to 55–74 year olds and that a screen offered to 60–70 year olds for bilateral hearing loss of at least 35 dB hearing level (HL) is most appropriate. The present study assesses the cost-effectiveness of this proposed screen and uses scenario analysis to investigate alternative screening strategies.

**Methods**

**The intervention**

The screening programme recommended by Davis et al. would identify adults with hearing levels of 35 dB or worse in both ears averaged over the frequencies 0.5, 1, 2 and 4 kHz. Screening would be offered at age 60 and repeated at 65 and 70 years, but not beyond since evidence suggests that the mean age of GP-referral is 74 years and therefore the main benefits of expediting intervention are only available before this age. All adults aged 60, 65 or 70 except those already under the care of an audiology service (i.e. those who already have a hearing aid) would be eligible to participate, and it is anticipated that GP records would be used to identify and invite the eligible cohort. Two variations on the screening programme are modelled: a one-stage audiometric screen to which all eligible adults would be invited and a two-stage screen involving a postal questionnaire sent to all eligible adults followed by invitation to audiometric screen for those who fail the questionnaire screen. The audiometric screen involves a 3 kHz pure tone presented twice to each ear at 35 dB HL by a standard clinical audiometer; a pass is achieved if any of the tones are heard in either ear. The two-stage screen involves a single question (‘Do you have difficulty with your hearing?’) followed by an audiometric screen for those who fail (i.e. answer ‘yes’). These screening tests were identified by Davis et al. as having the best test properties among a range of one- and two-stage combinations trialled. Those who fail the screen would be offered audiological assessment where pure tone audiometry (PTA; assumed to be the gold standard test) would be performed. If a hearing loss is confirmed, one or two hearing aids would be offered; the model accounts for the fact that some would decline and some who accept would not use the hearing aid(s) in the longer term. The comparator intervention is the existing GP-referral service. This requires adults to request an appointment with their GP and for their GP to refer for audiological assessment, where PTA is performed.

**Modelling approach**

The study concerns adults with acquired sensorineural hearing loss who may benefit from hearing aids. An NHS perspective is taken for costs and the outcome measure used is the Quality Adjusted Life Year (QALY). The time horizon is age 60–85 years, based on average cohort life-expectancy of 87 years for males and females in England and Wales who were aged 60 in 2008 rounded to the nearest 5 years to fit the model cycle. As the cohort ages, the model accounts for the increasing likelihood of hearing reaching the threshold level for intervention, but the natural history progression of hearing beyond the level where intervention is offered is not modelled because there is no evidence to support different estimates of utility gain for people with different degrees of hearing loss. A discount rate of 3.5% is used for costs and benefits, consistent with guidelines from the National Institute for Health and Clinical Excellence.

A Markov state-transition model provides the analytical framework. A cycle-length of 5 years is used because repeat screening at 5-yearly intervals is considered appropriate given the rate of progression of hearing loss. A cohort of 100 000 adults aged 60 from the general population is modelled for each screening scenario and the current GP-referral service. The models were developed in Microsoft Excel 2003.
Model inputs

Extensive literature searches were conducted to inform estimates for each input parameter (see Supplementary data Appendix A for search strategy). Table 1 shows parameter values and sources of evidence. Costs are estimated for a steady-state service; set-up costs are not included. Cost estimates are based on the UK 2009/10 Adult Hearing Services Indicative Tariff except for costs of screening which are based on estimates from the work of Davis et al. A full list of parameter and cost values for all models is given in Supplementary data Appendix B and a list of assumptions is given in Supplementary data Appendix C.

Model outputs

At the end of each cycle, cohort members reach one of the four possible outcome states: No hearing aid (eligible for screening), New hearing aid owner (acquired hearing aid in current cycle), Existing hearing aid owner (acquired hearing aid in any previous cycle) and Died. Figure 1 illustrates the possible transitions between states.

There are a number of different routes to each outcome state, each with a unique set of costs and benefits, summarized in Supplementary Table S1.

Model analysis

Costs and benefits associated with each outcome scenario are multiplied by the number of cases and summed over the time horizon of the model; discount factors are applied at the end of each cycle.

Uncertainty

To incorporate parameter uncertainty, we adopted a probabilistic sensitivity analysis approach. Each variable was taken as a random draw from an appropriate distribution with a mean value equal to the mean of that parameter. Where available, uncertainty was taken from the 95% confidence interval of data from the literature (see Table 1). Cost data were estimated assuming a confidence interval of ±20% of the base case value. Since base case estimates for the screening test itself are low (£8 for one-stage screen, £13 for two-stage screen), a small absolute change in costs would represent a larger percentage of the base case, therefore we assess the impact of screening tests costing ±50% of base case. Ten thousand simulations were run for each model. In addition, we ran a series of one-way sensitivity analyses, where one parameter is varied at a time to indicate which parameters the model results are most sensitive to.

Scenario analysis

Although Davis et al. recommend screening adults age 60–70 years, they found that screening was acceptable from 55 years. Screening younger adults has the potential to widen the audience and extend the duration of benefit, although this may be counter-balanced by lower levels of uptake and usage. Models were constructed to investigate the impact on cost-effectiveness of starting screening at age 55 (Scenario 1). Both one-stage and two-stage strategies were modelled. Parameter estimates for Scenario 1 models are the same as for base case models (see Table 1) with the addition of values for prevalence of 35 dB HL hearing loss at age 55 (base case 7.8%, lower value for sensitivity analysis 6.4%, upper value 9.5%) and prevalence of hearing aid ownership at age 55 (base case 6.6%, lower value for sensitivity analysis 2.0%, upper value 8.0%).

Work by Stephens et al. found that the better-ear-average hearing loss of adults accepting hearing aids after screening was 30 dB HL. As with a screen from age 55 years, a screen that targets milder hearing loss has the potential to widen the audience and extend the duration of benefit. Models were constructed to investigate the impact on cost-effectiveness of screening for bilateral hearing loss of 30 dB HL or worse (Scenario 2). Both one-stage and two-stage strategies were modelled. Parameter estimates for Scenario 2 models are the same as for base case models (see Table 1) except where shown in Supplementary Table S2.

Results

Table 2 shows results for the GP-referral service and the proposed screening programmes. Incremental cost-effectiveness ratios (ICERs) are shown for non-dominated options. An option is dominated if there is an alternative which is both cheaper and more effective. Alternatively, an option that is not strictly dominated can be eliminated if there is a hypothetical combination of two other options that would dominate it, referred to as extended dominance.

One-way sensitivity analysis shows that the results are sensitive to the estimate of utility from hearing aids. Within the modelled range of utility values, the cost of screening and GP-referral varied by around £1200 per QALY.

Results from probabilistic sensitivity analysis are plotted for the GP-referral service and one-stage screen for bilateral hearing loss ≥35 dB HL from age 60 (Fig 2). The two-stage programme is not shown since this is eliminated by extended dominance. Provided a QALY is valued at £2000 or more, the screening programme is more cost-effective than GP-referral. Above willingness-to-pay around £12 000, we can be 95% confident that screening is cost-effective.
Table 1 Parameter values and costs for base case models (GP-referral, one- and two-stage screening programmes for 35 dB HL from age 60 years)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Base case</th>
<th>Sensitivity analysis range (lower)</th>
<th>Sensitivity analysis range (upper)</th>
<th>Distribution</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence of bilateral hearing loss ≥35 dB HL</td>
<td>Varies from 11.3% (age 60) to 63.5% (age 80)</td>
<td>Varies from 10.7% (age 60) to 46.6% (age 80)</td>
<td>Varies from 14.4% (age 60) to 70.3% (age 80)</td>
<td>Beta</td>
<td>From Davis(^9)</td>
</tr>
<tr>
<td>Bilateral hearing loss ≥35 dB HL and already own hearing aid</td>
<td>Varies from 6.9% (age 60) to 13.4% (age 80)</td>
<td>Varies from 1% (age 60) to 7.9% (age 80)</td>
<td>Varies from 8% (age 60) to 22% (age 80)</td>
<td>Beta</td>
<td>From Stephens et al.(^3) and Davis et al.(^4,9,12,16)</td>
</tr>
<tr>
<td>Accept one-stage screen</td>
<td>86%</td>
<td>72%</td>
<td>99%</td>
<td>Beta</td>
<td>Includes those who passively decline by non-response and non-attendance</td>
</tr>
<tr>
<td>Accept two-stage screen</td>
<td>56%</td>
<td>40%</td>
<td>87%</td>
<td>Beta</td>
<td>From Davis et al.(^4,12) and Wilson et al.(^17)</td>
</tr>
<tr>
<td>One-stage screen sensitivity and specificity</td>
<td>Sensitivity 87.4% Specificity 89.1%</td>
<td>Sensitivity 78.7% Specificity 88%</td>
<td>Sensitivity 96.1% Specificity 90.2%</td>
<td>Beta</td>
<td>From Davis et al.(^4)</td>
</tr>
<tr>
<td>Two-stage screen sensitivity and specificity</td>
<td>Sensitivity 84.2% Specificity 90.7%</td>
<td>Sensitivity 75.8% Specificity 91.6%</td>
<td>Sensitivity 92.6% Specificity 89.8%</td>
<td>Beta</td>
<td>From Davis et al.(^4)</td>
</tr>
<tr>
<td>Accept offer of hearing aid</td>
<td>66%</td>
<td>46%</td>
<td>86%</td>
<td>Beta</td>
<td>From Davis et al.(^4,12) and Wilson et al.(^17)</td>
</tr>
<tr>
<td>Utility gain from hearing aid</td>
<td>0.068</td>
<td>0.035</td>
<td>0.105</td>
<td>Beta</td>
<td>From Barton et al.(^18) and Davis et al.(^4)</td>
</tr>
<tr>
<td>Probability of using hearing aid in first 5 years</td>
<td>90%</td>
<td>80%</td>
<td>100%</td>
<td>Beta</td>
<td>From Davis et al.(^12)</td>
</tr>
<tr>
<td>Probability of using hearing aid beyond first 5 years—screen cases</td>
<td>62%</td>
<td>46%</td>
<td>77%</td>
<td>Beta</td>
<td>From Davis et al.(^4)</td>
</tr>
<tr>
<td>Probability of using hearing aid beyond first 5 years—GP-referral cases</td>
<td>81%</td>
<td>49%</td>
<td>97%</td>
<td>Beta</td>
<td>From Davis et al.(^4)</td>
</tr>
<tr>
<td>Cost of one-stage screen</td>
<td>£8</td>
<td>£4</td>
<td>£12</td>
<td>Gamma left</td>
<td>Assumed those who use hearing aid beyond the first 5-years continue for the rest of their life</td>
</tr>
<tr>
<td>Cost of two-stage screen</td>
<td>£13</td>
<td>£7</td>
<td>£20</td>
<td>Gamma left</td>
<td>From Davis et al.(^4)</td>
</tr>
<tr>
<td>Accept two hearing aids—screen cases</td>
<td>95%</td>
<td>75%</td>
<td>100%</td>
<td>Beta</td>
<td>From Stephens et al.(^3) and Davis et al.(^4)</td>
</tr>
<tr>
<td>Accept two hearing aids—GP-referral cases</td>
<td>80%</td>
<td>60%</td>
<td>100%</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>Cost of single hearing aid and ear mould</td>
<td>£122</td>
<td>£98</td>
<td>£146</td>
<td>Gamma left</td>
<td>Taken from UK NHS 2009/10 Adult Hearing Services Indicative Tariff</td>
</tr>
<tr>
<td>Cost of audiological assessment</td>
<td>£57</td>
<td>£46</td>
<td>£68</td>
<td>Gamma left</td>
<td></td>
</tr>
<tr>
<td>Cost of hearing aid fitting appointment</td>
<td>£69</td>
<td>£55</td>
<td>£83</td>
<td>Gamma left</td>
<td></td>
</tr>
<tr>
<td>Cost of follow-up appointment</td>
<td>£49</td>
<td>£39</td>
<td>£59</td>
<td>Gamma left</td>
<td></td>
</tr>
<tr>
<td>Cost of hearing aid repair</td>
<td>£26</td>
<td>£21</td>
<td>£31</td>
<td>Gamma left</td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>Varies with age</td>
<td></td>
<td>N/A</td>
<td></td>
<td>Taken from Government Actuary’s Department. Interim Life Tables, 2004–2006</td>
</tr>
</tbody>
</table>

*See Supplementary data Appendix B for all parameter and cost values.
Results for scenario analyses are reported in Supplementary Tables S3 and S4.

When all modelled screening scenarios are considered together, all are eliminated by extended dominance except for a one-stage screen for bilateral hearing loss of at least 30 dB HL from age 60 years. This is the most cost-effective option, with an ICER of £1461 compared with GP-referral. Interventions with ICER estimates up to £20 000–£30 000 (approximately £25 000–£35 000 or $30 000–$45 000 in June 2010) are considered acceptable in the UK. The model for this screen indicates that a total of 32 506 out of a cohort of 100 000 adults would be fitted with hearing aids over the time horizon considered, 15 437 more than are estimated to be fitted via GP-referral (17 069).

### Discussion

**Main finding of this study**

Our study shows that screening adults aged 60–70 years for bilateral hearing loss of at least 35 dB HL, as proposed by Davis et al., is cost-effective. A one-stage audiometric screen is more cost-effective than a two-stage strategy (questionnaire followed by audiometric screen). Among the screening strategies considered in this study, the most cost-effective option is an audiometric screen for bilateral hearing loss of at least 30 dB HL, starting at age 60 and repeated at 65 and 70 years. This strategy has an ICER of £1461 in

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**Table 2** Base case model results (GP-referral and screens for 35 dB HL from 60 years)

<table>
<thead>
<tr>
<th></th>
<th>QALY gain</th>
<th>Total cost</th>
<th>Incremental QALY</th>
<th>Incremental cost</th>
<th>ICER</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP referral</td>
<td>10 048</td>
<td>£13 176 794</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-stage screen for 35 dB HL from 60 years</td>
<td>13 768</td>
<td>£20 088 732</td>
<td>3720</td>
<td>£6 911 938</td>
<td>Eliminated by extended dominance</td>
</tr>
<tr>
<td>One-stage screen for 35 dB HL from 60 years</td>
<td>14 957</td>
<td>£21 947 434</td>
<td>4909</td>
<td>£8 770 640</td>
<td>£1787</td>
</tr>
</tbody>
</table>

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**Fig. 1** Transition between the Markov outcome states.

**Fig. 2** Cost effectiveness acceptability curve showing change in the probability of cost-effectiveness as the value of a QALY changes.
relation to the current GP-referral service. Sensitivity analysis shows that screening is expected to be more cost-effective than GP-referral where a QALY is valued at more than £2000; there is less than 5% risk of screening exceeding an acceptable cost provided a QALY is valued at £12 000 or more.

Gains are greatest for the modelled one-stage strategies, due to high predicted attendance and good screen test properties. This finding applies only to the scenarios modelled and alternative two-stage strategies should not be ruled out, provided good screen take-up and sensitivity are expected. Benefit is greatest for programmes targeting BEA ≥30 dB HL, due to higher prevalence and only slightly lower predicted acceptance of intervention compared with targeting BEA ≥35 dB HL.

**What is already known on this topic**

Davis et al. present a preliminary economic evaluation as part of a study of the acceptability, benefits and costs of AHS. They estimate that a QALY generated from AHS would cost £800–£1000. However, this estimate is based only on an additional 9 years of costs and benefits (on the assumption that screening brings intervention forward from 74 to 65 years, on average), and does not compare the costs and benefits of screening with the costs and benefits of existing services. The authors recommend that more detailed modelling and formal quantification of uncertainty are required.

**What this study adds**

This is the first study to model the potential cost-effectiveness of screening compared with services currently offered to hearing-impaired adults. It contributes evidence that screening adults for hearing loss is likely to cost around £1500 per QALY and estimates the expected cost per QALY under different assumptions about the age at first screen, target level of hearing loss and type of screening programme. The screens that are expected to offer best value use a one-stage audiometric strategy, start at age 60, and target a bilateral hearing loss of at least 30 dB HL.

**Limitations**

The best available evidence was used to inform parameter estimates but for some parameters the evidence is limited. There is insufficient evidence to support an estimate of utility that varies with the characteristics of the hearing aid user (e.g. degree of loss, age). Moreover, it is likely that utility varies with a complex interaction of factors including some which cannot easily be modelled, such as other aspects of health and personal circumstances.

The acceptability of hearing aids to the target population is an important concern and recognition of hearing difficulty is likely to be a significant factor. There is no evidence of acceptance rates among those who fail an audiometric screen but do not recognize hearing difficulty. The present study used estimates of 61 and 66% (for BEA ≥30 and 35 dB HL, respectively) for take-up of hearing aids after screening, based on studies by Davis et al. and Wilson et al. Additionally, it is not clear how many people would be screened then drop out of the process, this would lower the effective rate of uptake of hearing aids after screening. However, sensitivity analysis shows that even under a worse case estimate of 46% take-up (lower 95% confidence interval across the three studies), screening remains cost-effective, and this variable has a small effect on results within the modelled range.

It is worth noting that these studies predominantly prescribed analogue hearing aids and were carried out before open canal fittings were available. Preliminary evidence supports the expectation that open canal fittings will improve the acceptability of hearing aids to those with mild–moderate high-frequency hearing loss.

Similarly, evidence relating to long-term hearing aid use is scarce. The model estimates that 62% (sensitivity analysis range 46–77%) of those who accept hearing aids would continue to use them for longer than 5 years (based on Davis et al.). Gianopoulos et al. found only 43% of those who accepted hearing aids after screening were still using them 8–16 years later, but this sample were fitted using a more liberal criterion than assumed for the present study (worse ear average ≥30 dB HL) and they found that rejection of hearing aids could have been avoided by simple measures in the majority of cases and 71% were willing to try again. Tailoring interventions to individuals’ communication needs has the potential to achieve higher rates of long-term benefit, although models show that AHS is cost-effective even without further improvements.

Costs related to audiology appointments may be underestimated. For convenience, it is assumed that hearing aid users incur a full set of costs every 5 years, to fit with an appropriate screening cycle. However, recommended practice in the UK is for re-assessment every 3 years, although a proportion of patients requests this only after a significantly longer interval. This limitation applies to models of screening and GP-referral scenarios, so the comparison between the two approaches is expected to be secure. Costs of training additional personnel are not included in the analysis, but there are also likely to be economic gains that are not modelled and
cannot be quantified from currently available evidence, such as from prolonged productivity and independent living.

Hearing aids are assumed as the intervention in the current work because estimates of usage and utility gain are available in the literature. However, long-term benefit and cost-effectiveness is likely to be optimized by offering a broader programme of rehabilitation tailored to meet the needs of the individual.24,25 This may include elements of auditory and communication skills training, motivational counselling and environmental aids, as well as personal hearing aids when appropriate. Both costs and benefits of tailored communication rehabilitation are expected to be higher and evidence is needed to inform cost-effectiveness estimates.

The models used here are limited by the assumptions made by, and data available to, the investigators as all models are. Should a screening programme be introduced it will be necessary to conduct a contemporaneous evaluation (possibly in the form of a geographically localised pilot) to verify that the assumptions made here hold up.

Conclusions

Our study suggests that screening for bilateral hearing loss of at least 35 dB HL between the ages of 60 and 70 years, as proposed by Davis et al.,1 is likely to be cost-effective if the assumptions used when developing this model hold up on implementation. Moreover, it is expected to be more cost-effective than the current system of GP-referral if a QALY is valued above £2000. However, a more cost-effective screening option was identified through scenario analysis; a one-stage audiometric screen for bilateral hearing loss of at least 30 dB HL offered to adults aged 60, 65 and 70 years is the most cost-effective strategy modelled (ICER £1461 compared with GP-referral). The implementation of an AHS programme should be considered by policy-makers in the UK as a cost-effective way to reduce unmet need for hearing aids and improve quality of life among older adults. While the cost of such a programme would be low compared with the overall NHS budget, it is for policy-makers to consider the affordability of a screening programme in light of other commitments.

Supplementary data

Supplementary data are available at the Journal of Public Health online.

Conflict of interest

None declared.

References

18 Barton G, Bankart J, Davis A et al. Comparing utility scores before and after hearing aid provision: results according to the


