The Cost-effectiveness of Hearing-Aid Fitting in the Netherlands

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Objective: To determine the cost-effectiveness of hearing-aid fitting.

Design: Cost-effectiveness analysis using a Markov model based on aggregate data and results from a prospective intervention study.

Setting: The cost-effectiveness study was based in the general community. The prospective study was hospital based, as 85% of the first-time hearing-aid users attend a hospital in the process of hearing-aid fitting.

Patients: The prospective intervention study included adult first-time hearing-aid users with no contraindications for hearing-aid use.

Intervention: The usual process of hearing-aid fitting in the Netherlands.

Main Outcome Measure: Costs per quality-adjusted life-year (QALY). The QALYs were based on EuroQol scores.

We included direct and indirect costs in the analysis.

Results: The mean improvement on the EuroQol measure was 0.03 (95% confidence interval [CI], −0.03 to 0.08), and on the hearing-specific visual analog scale, 0.27 (95% CI, 0.22-0.31). The base-case outcome based on the EuroQol was €15807/QALY (US $17072/QALY) (CI, €924-399/QALY to €3718/QALY).

Conclusions: On the basis of this base-case estimate, fitting of hearing aids is considered a cost-effective health care intervention. The CI indicates that the result is not unambiguously positive, probably because the EuroQol lacked sensitivity for the evaluation of hearing-aid fitting. Until now, no study has found an effect of hearing-aid fitting on generic quality of life. Therefore, measures are needed that are suitable for the evaluation of the effects of interventions for sensory disabilities, such as the fitting of hearing aids, on generic quality of life.


Hearing impairment is a very common condition, the onset of which is tightly coupled with aging. When defined as an average pure-tone hearing loss in the best ear of 35 dB or more at 1, 2, and 4 kHz, hearing impairment was found in 75% of the population older than 80 years.1 As the prevalence of hearing impairment increases rapidly with age, hearing impairment will be one of the most prevalent health problems in societies with aging populations. Hearing impairment has been associated with emotional, social, and communication dysfunction.2

Little information about the economic consequences of hearing impairment to society is available. In the United States, the lifetime costs of profound to severe hearing loss (defined as hearing thresholds of ≥70 dB averaged across the frequencies 0.5, 1, and 2 kHz) when onset is at older than 60 years were estimated to be on average US $43000.3 The use of hearing aids has been shown to improve social, emotional, and communication functions and to reduce depression.2 Although in most cases of sensorineural hearing impairment, a hearing aid is the only option for rehabilitation, only a few studies calculated the costs and effects associated with hearing-aid fitting.4,5 However, none of these studies focused on the societal costs and effects of hearing-aid fittings, and no study performed a cost-effectiveness analysis.

The objective of this study was to determine the cost-effectiveness of fitting hearing aids in adult hearing-impaired persons compared with that of not fitting them in the Netherlands. All costs are reported in Eurocurrency (€1=US $1.08, 1998 conversion rate). The results from
a prospective study of hearing-aid fitting in first-time users were combined with observational data to obtain a realistic view of the economic impact of hearing-aid fitting on society. All data were incorporated in a simulated cohort model of hearing disability in the population. The study results are reported in the following 2 cost-effectiveness ratios for hearing-aid fitting: costs per quality-adjusted life-year (QALY) and costs per hearing-related QALY (hearing-QALY). The latter is a combined measure of effect that is based on life expectancy and hearing-specific quality of life.

METHODS

MODEL OF HEARING-AID FITTING

The assessment of the effect of hearing-aid fitting on the quality of life of persons with hearing complaints requires the use of a dynamic modeling approach. People may have hearing complaints, may undergo the process of hearing-aid fitting, may become better or worse, may in time reapply for hearing aids, and so on. In a dynamic model, the population is divided among different health states; over time, persons move from one health state to another according to certain transition probabilities that can be assessed empirically. These models are often referred to as state-transition or Markov models. Markov models are particularly useful when modeling decision problems involving ongoing risk. We used cohort simulation to evaluate the model, i.e., a fixed number of persons per age group were followed up during their lifetime (Figure 1).

The cohort ceased to exist when all members of the cohort group had died. The model ran with steps of 1 year, and during that year persons moved between the different health states, resulting in a new distribution of persons among the health states on the first day of the next year. The starting year of the model was 1995, and mortality figures were based on data from the Central Bureau of Statistics for that year. Future costs and benefits were discounted to their present value by a rate of 5%. Boas et al9 described the technical and methodological merits of dynamic modeling in the case of hearing-aid fitting more extensively.

The model distinguishes among the following 3 different groups of patients: those with hearing complaints without a hearing aid (non–hearing-aid users with hearing complaints), those with hearing complaints who are satisfied with their hearing aid (satisfied hearing-aid users), and those with hearing complaints who are dissatisfied with their hearing aid (dissatisfied hearing-aid users). From these health states, persons can enter the diagnostics-and-treatment phase (Figure 1). In the Netherlands, all patients must first consult their general practitioner (GP) for referral to an ear, nose, and throat (ENT) specialist or an audiological center (AC). Only ENT specialists and audiologists are entitled to prescribe hearing aids. The ACs offer multidisciplinary specialized help for the more serious or complicated cases. The actual hearing-aid fitting takes place at a hearing-aid dispenser. Once a satisfying hearing-aid fit is obtained, the patient returns to the ENT specialist or the AC for approval of the fitted hearing aid. The approval entitles the patient to (partial) reimbursement of the cost of the hearing aid.

STUDY POPULATION

A prospective study of hearing-aid fitting was performed at the ENT clinic of the University Hospital Maastricht, Maastricht, the Netherlands, in collaboration with the Hoesbroek Audiological Centre, Hoesbroek, the Netherlands. The medical ethics committee of the university hospital approved the study. Hearing-impaired persons 18 years and older were asked to enter the study when they received a prescription for a hearing aid from their ENT specialist or audiologist. Immediately after their written informed consent was obtained, the baseline measurement took place. This measurement consisted of pure-tone audiometry and a questionnaire. A hearing-aid dispenser then performed the hearing-aid fitting. After the trial period, when a satisfying fit of the hearing aid was obtained, the patient visited the ENT specialist or audiologist again, and the fit of the hearing aid was evaluated and eventually approved. The follow-up measurement was scheduled at 4 months after baseline at the ENT clinic or the AC.

From February 1, 1998, to March 31, 1999, 126 hearing-impaired persons entered the study. Of these, 28% attended the University Hospital Maastricht and 72% attended the AC. Forty-eight persons left the study owing to lack of a hearing aid that fit (n=17), death (n=2), illness (n=2), own request (n=15), and lost to follow-up for unverifiable reasons (n=12). Seventy-eight patients completed the third and final measurement (mean age, 69.1 years [range, 29-96 years]). The mean hearing loss was 47.4 dB at 1, 2, and 4 kHz in the best ear. The patients who left the study were somewhat younger (mean age, 65.5 years), and had somewhat better hearing (43.5 dB) than those who completed the study. Approximately half of the participants were male (42 [34%]), and 52 were married (67%). Sixty-two patients were fitted with a hearing aid behind the ear (79%). Of the remainder, 14 (18%) were fitted with an in-the-ear hearing aid and only 2 (3%) with an in-the-canal hearing aid.

QUALITY-OF-LIFE ASSESSMENT

Generic Quality of Life

To measure change in overall health-related quality of life, we used the EuroQol 5 Dimensions (EQ-5D).10 This generic measure consists of 5 questions concerned with the dimensions of
overall health status (mobility, self-care, daily activities, pain and complaints, and feeling), a question about health transition, and a visual analog scale (VAS). The answers on the VAS can be interpreted as patient scores. Dolan developed an algorithm to calculate population utilities from the patient data.

Specific Quality of Life

The sensitivity of the EQ-5D, as for virtually all generic measures, was perceived to be suboptimal for detecting changes in health-related quality of life after hearing-aid fitting. Therefore, the effect of hearing-aid fitting was also measured using a hearing-specific scale, a VAS that ranges from 0 (dead) to 1 (perfect sense of hearing). This hearing-specific VAS is part of a newly developed multiattribute questionnaire used to measure the effects of interventions for hearing impairment and disability on quality of life (Horst Zank, PhD, M.A.J., H.J.M.P., G.M.B., and L.J.C.A., unpublished data, January 2002).

PROBABILITIES

Non–Hearing-Aid Users

Among the Dutch population, approximately 11.4% have hearing complaints defined as “some difficulties” or “inability” to follow a conversation in a group of 3 or more persons. Of the population with hearing complaints, approximately 20% are fitted with hearing aids. On the basis of the results of an epidemiological field study, the population with hearing complaints but without hearing aids was subdivided in 5-year age groups for both sexes. From this, we calculated that 4.04% of the population aged 15 to younger than 60 years and 32.43% of the population 60 years and older have hearing complaints but no hearing aid. Of the population with hearing complaints who were younger than 60 years, 67% was male, compared with 50% in the general population younger than 60 years. Approximately 132,000 non–hearing-aid users 15 years and older contact their GP with hearing complaints for the first time each year (incidence, 9.2/1000 patients). On the basis of age-specific incidence data, we calculated the average transition probability of contacting the GP from the population of non–hearing-aid users with hearing complaints to be 4.28% for persons aged 15 to younger than 60 years and 16.44% for those 60 years and older.

Diagnostics-and-Treatment Phase

Of the persons who visit the GP because of hearing problems, 45% are not referred to an ENT specialist or an AC. When referred to the ENT specialist or the AC, 75% receive a prescription for a hearing aid. Eventually, somewhat more than 7% of all hearing-aid trials end without the purchase of a hearing aid. The probabilities of first seeing the GP and eventually having a hearing aid fitted are the same for men and women. All hearing-aid reapplicants (satisfied and dissatisfied) are assumed to go through all treatment stages and end up with a new hearing aid with a satisfying fit (Figure 1).

Satisfied and Dissatisfied Hearing-Aid Users

All patients who underwent first-time fitting with hearing aids entered the satisfied hearing-aid users population, since it was assumed that if the person was not satisfied with the fit of the hearing aid, no hearing aid would be purchased. We found that 11% of all hearing-aid users become dissatisfied with the hearing aid, expressed in use of the hearing aid for less than 4 h/d. Since this phenomenon seemed more prevalent in older persons, we assumed that of the inflow to the dissatisfied hearing-aid users population, the proportion of persons aged 15 to younger than 60 years was 10%, vs 90% of persons 60 years and older. This assumption resulted in transition probabilities of 6.08 and 12.16, respectively. Based on the study by Grootveld et al, 12% from the dissatisfied hearing-aid users were transferred to the non–hearing-aid users population annually, because they no longer used their hearing aids.

The average replacement time of the patients in the satisfied hearing-aid users population was calculated by correcting the annual number of hearing aids sold for the proportion of hearing aids sold to first-time hearing-aid users and for mortality in the population of satisfied hearing-aid users. We assumed that the average replacement time of irregularly used hearing aids was approximately double the replacement time of hearing aids used by satisfied patients.

Mortality

All populations were adjusted for mortality annually. Mortality rates were specific for age (5-year age groups) and sex.

COSTS

In this study, we considered costs from a societal point of view. Societal costs consist of the extra health care and non–health care costs (regardless of who pays for them) decreased by savings resulting from the possible gain in productivity related to the intervention. The direct health care costs included in the study were associated with consultations (GP, ENT specialist, or AC), diagnostics (audiometry), hearing-aid fitting, the hearing-aid instrument, and hearing-aid use (batteries and repair). Direct non–health care costs such as time spent and the costs of travel associated with the fitting of the hearing aid and its use were not quantified. Possible savings in terms of increased productivity were assessed in the prospective study of first-time fitting of hearing aids. The most recent price information was from 1998, so all costs were based on the 1998 price level. On July 1, 1998, €1.0 equaled US $1.08. Table 1 provides a summary of all cost input.

GP Consultation

In 1998, the costs per GP consultation were on average €16.26. Only the costs of the GP consultations related to the referral to the ENT specialist or AC were counted. This number was estimated at 1.5 consultations per person, and the costs of GP consultations related to fitting of hearing aids were €24.40.

ENT Clinic

In the Netherlands, 83% of all hearing-aid fittings are performed through an ENT clinic. The costs per ENT consultation in 1998 were on average €28.26 (based on a low-estimate, non-university hospital). During the process of hearing-aid fitting, the ENT specialist was visited once for diagnosis of the hearing impairment and prescription of a hearing aid and once for the approval of the fitted hearing aid. At both consultations in the ENT clinic, tone and speech audiometry was performed to diagnose hearing impairment and evaluate the fitted hearing aid. The costs of the audiometry were based on weighted averages of the charges for voluntary and compulsory insurance. In 1998, the costs for tone audiometry were €29.55 and those for speech audiometry were €63.65. The total costs of the ENT clinic amount to €242.92 per each successful hearing-aid fitting (€121.46 per consultation). We assumed that after a negative result of a trial at the hearing-aid dispenser, only 50% of the persons would consult the ENT specialist afterward, and that no audiometry would...
be performed at this consultation. The costs of the follow-up at the ENT clinic after a negative trial result amounted to €28.26.

**Audiology Center**

Of all hearing-aid fittings, 15% are performed through an AC. The charge for the AC was €216 in 1998. For this amount, audiometry and an extensive counseling and rehabilitation program (when indicated) are performed.

**Hearing-Aid Dispenser**

We assumed that every person who receives a prescription sees a dispenser. The costs of a negative trial result at the hearing-aid dispenser were estimated to amount to the dispenser's fee in the price of a hearing aid (39%).

### Table 1. Model Input Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base-Case Estimate</th>
<th>Range of Estimate</th>
<th>Source (Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter for non−hearing-aid users with hearing complaints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual probability to visit GP for hearing-related complaints, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;60 y</td>
<td>4.3</td>
<td>2.1 to 8.6</td>
<td>Chorus et al13 (1995)</td>
</tr>
<tr>
<td>≥60 y</td>
<td>16.4</td>
<td>8.2 to 32.9</td>
<td>Chorus et al13 (1995)</td>
</tr>
<tr>
<td>Diagnostics-and-treatment phase, %</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Annual probability to be referred by GP</td>
<td>54.5</td>
<td>40 to 70</td>
<td>Abutan et al1 (1993)</td>
</tr>
<tr>
<td>Annual probability to receive prescription for an HA</td>
<td>75.0</td>
<td>62.5 to 87.5</td>
<td>Streukens and Leenen16 (1996)</td>
</tr>
<tr>
<td>Annual probability of negative trial result at dispenser</td>
<td>7.4</td>
<td>3.7 to 11</td>
<td>Streukens and Leenen16 (1996)</td>
</tr>
<tr>
<td>Satisfied and dissatisfied hearing-aid users</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual probability to become satisfied HA user, %</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>&lt;60 y</td>
<td>6.1</td>
<td>0 to 12</td>
<td>Chorus et al13 (1995)</td>
</tr>
<tr>
<td>≥60 y</td>
<td>12.2</td>
<td>12 to 24</td>
<td>Chorus et al13 (1995)</td>
</tr>
<tr>
<td>Time to hearing-aid replacement, y</td>
<td>12.0</td>
<td>...</td>
<td>Grootveld et al18 (1989)</td>
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<tr>
<td>Satisfied HA user</td>
<td>8.2</td>
<td>4.1 to 12.4</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>Dissatisfied HA user</td>
<td>15.0</td>
<td>7.5 to 22.5</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>Mortality, annual age- and gender-specific mortality</td>
<td>5-y Age categories</td>
<td>...</td>
<td>CBS13 (1994)</td>
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<tr>
<td>Gain in generic quality of life</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Patient score on the EQ-5D VAS</td>
<td>0.02</td>
<td>−0.02 to 0.05†</td>
<td>This study</td>
</tr>
<tr>
<td>Population utility estimate EQ-5D</td>
<td>0.03</td>
<td>−0.03 to 0.08†</td>
<td>This study</td>
</tr>
<tr>
<td>Gain in hearing-specific quality of life, patient score on the hearing-specific VAS</td>
<td>0.27</td>
<td>0.22 to 0.31†</td>
<td>This study</td>
</tr>
<tr>
<td>Costs</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>GP consultations, €</td>
<td>24.40</td>
<td>...</td>
<td>Oostenbrink et al13 (2000)</td>
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<tr>
<td>ENT clinic, €</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First consultation</td>
<td>121.46</td>
<td>121.46 to 177.99</td>
<td>Oostenbrink et al13 (2000);‡</td>
</tr>
<tr>
<td>Follow-up consultation after successful trial at the dispenser</td>
<td>121.46</td>
<td>121.46 to 177.99</td>
<td>Oostenbrink et al13 (2000);‡</td>
</tr>
<tr>
<td>Follow-up consultation after negative trial result at the dispenser</td>
<td>28.26</td>
<td>28.26 to 84.79</td>
<td>Oostenbrink et al13 (2000);‡</td>
</tr>
<tr>
<td>Audiological center, €</td>
<td>216.09</td>
<td>...</td>
<td>Charge information</td>
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<tr>
<td>Ratio hearing-aid fittings through ENT clinic/AC, €</td>
<td>5/15</td>
<td>...</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>HA, €</td>
<td>670.69</td>
<td>350 to 1000</td>
<td>Mot and Meulenbeck22 (1997)</td>
</tr>
<tr>
<td>Proportion binaural fittings, %</td>
<td>25</td>
<td>10 to 50</td>
<td>Streukens and Leenen16 (1996)</td>
</tr>
<tr>
<td>Dispenser negative trial per HA, €</td>
<td>261.69</td>
<td>137 to 390</td>
<td>Mot and Meulenbeck22 (1997), Ziekenfondsraad (1994);‡</td>
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<td>HA battery costs for satisfied HA users, €</td>
<td>34.31</td>
<td>...</td>
<td>Consumers' information, Verlare21 (1985)</td>
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<tr>
<td>HA battery costs for dissatisfied HA users, €</td>
<td>10.04</td>
<td>...</td>
<td>Consumers' information, Verlare21 (1985)</td>
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<tr>
<td>HA repair costs for satisfied HA users, €</td>
<td>18.75</td>
<td>9.80 to 28.00</td>
<td>NVAB information§</td>
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<tr>
<td>HA repair costs for dissatisfied HA users, €</td>
<td>9.38</td>
<td>4.90 to 14.00</td>
<td>NVAB information§</td>
</tr>
<tr>
<td>Savings as a result of reduced productivity loss, €</td>
<td>0.00</td>
<td>...</td>
<td>This study</td>
</tr>
</tbody>
</table>

Abbreviations: AC, audiological center; CBS, Central Bureau of Statistics; ENT, ear, nose, and throat specialist; EQ-5D, EuroQol 5 Dimensions; GP, general practitioner; HA, hearing aid; NVAB, Nederlandse Vereniging van Audiciens Bedrijven (Dutch Association of Hearing Aid Dispensers); VAS, visual analog scale.

*Ellipses indicate data not available.
†Range indicates 95% confidence interval.
‡Indicates charge information.
§H. Streukens, oral communication, 1999.

In the Netherlands, a market study of the average purchase costs of a hearing aid found an average price of €636.00 in 1995. This price was corrected for price differences from 1995 to 1998 using the Dutch health care price index figures, resulting in an average price of €671.00 in 1998. According to the market study of the Dutch Association of Hearing Aid Dispensers, 25% of all sales are binaural fittings, in which case the costs are doubled. Costs resulting from the use of hearing aids were costs of batteries and repair. The average yearly costs of batteries were

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estimates at €34.31 for satisfied users and €10.04 for dissatisfied users (available at the Web site for the NVVS [Nederlandse Vereniging Voor Slechthorenden (Dutch Association for the Hard of Hearing)], http://www.nvvs.nl). On average, behind-the-ear hearing aids were repaired 1.2 times per 5 years and in-the-ear hearing aids, 1.9 times per 5 years. The average costs per repair were estimated at €68.18. Based on the ratio of behind-the-ear-in-the-ear hearing aids (75:25), the average yearly repair costs per hearing aid were estimated at €18.75.

**Productivity Loss**

Only 10 persons in the prospective hearing-aid fitting study (12.8%) performed paid labor. This finding seemed normal after we considered the age distribution of a population of adult first-time hearing-aid applicants. They did not report any absence from work due to hearing impairment or other health problems. Based on these results, in this population of moderately hearing-impaired first-time hearing-aid users, no costs result from productivity loss due to not being fitted with hearing aids. As a consequence, no savings result from a possible gain in productivity after a hearing-aid fitting.

**COST/QALY CALCULATION**

We assumed that only satisfied hearing-aid users would experience a gain in quality of life as a result of fitting of a hearing aid. The total amount of QALYs gained was computed by counting the total number of satisfied users in a certain year, multiplied by the change in the population utility estimate from the EQ-5D, and added across the total life expectancy. Age-specific cost/QALY ratios were calculated by dividing the total amount of costs by the total amount of QALYs gained in the specific age category. To calculate the overall cost/QALY ratio, the distribution of persons across the age categories should match the distribution of persons eligible for a hearing aid (persons with hearing complaints) at the population level. Otherwise, the average cost/QALY ratio might not be representative at the population level, and thus not suited for decision making. Therefore, the number of persons in each age group reflected the age-specific prevalence of hearing complaints. We then calculated the overall cost/QALY outcome by dividing the sum of costs by the sum of QALYs. In the calculation of the costs/hearing-QALY outcome, we used the gain on the hearing-specific VAS.

**ANALYSIS**

We used descriptive statistics to describe the characteristics of the study population. The results of the EQ-5D (the VAS and population utility estimate) and the hearing-specific VAS are reported as mean±SD. We compared the scores before and after fitting of the hearing aids on the EQ-5D and the hearing-VAS by means of the paired-samples *t* test when normally distributed or the Wilcoxon signed rank test when not normally distributed. We used the 95% confidence interval of the changes in the EQ-5D population utility estimate and hearing-VAS score, with the highest and lowest estimates of the costs to construct cost-effectiveness confidence boxes on the cost-effectiveness plane to present the confidence limits of the estimates of the cost/QALY and cost/hearing-QALY outcomes. The cost-effectiveness plane is a coordinate system with the incremental costs on the y-axis and the incremental effects on the x-axis and is often used to show the outcomes of cost-effectiveness studies. The 4 quadrants represent the 4 possible outcomes of incremental costs and health effects of a new health intervention. Univariate sensitivity analysis was performed to test the robustness of the cost/QALY outcomes for variation in single-model input variables.

**RESULTS**

**QUALITY-OF-LIFE OUTCOMES**

The average scores on the hearing-VAS showed a substantial and highly statistically significant improvement after hearing-aid fitting (0.27 [95% confidence interval, 0.22-0.30]; *P* < .001, paired *t* test), whereas the result on the EQ-5D VAS (patient preferences) and the EQ-5D population utility estimate showed only a small and nonstatistically significant gain in quality of life (0.02 and 0.03, respectively) (Table 1).

**COST OUTCOMES**

The average costs of fitting hearing aids in a population of persons with hearing complaints amount to €781 (base-case estimate, discounted). Of this amount, 60% is spent on hearing aids, 16% on hearing-aid batteries and repair, and 14% on direct health care costs (GP, ENT clinic, and AC). Based on the highest estimates for all cost variables, the average incremental costs amount to €1.197, and based on the lowest estimates, the average incremental costs amount to €490.

**COST/QALY OUTCOMES**

Based on the average outcome per patient of the EQ-5D population utility estimate (mean utility gain, 0.03) as a result of fitting of hearing aids in the total population with hearing complaints, on average 0.05 QALYs are gained. The cost/QALY outcome ranges from €11984 in the youngest to €34902 in the oldest groups. The increase with age is due to increasing mortality during the life span of a hearing aid in older groups. As a result, the outcomes are also slightly less beneficiary for male compared with female hearing-aid users in the groups older than 50 years. The average cost/QALY outcome amounts to €15807/QALY. This outcome is considered a base-case estimate.

When using the patient scores on the EQ-5D VAS, an average of 0.03 QALYs were gained per person. The cost/QALY outcome ranged from €17996 in the group aged 15 to 19 years to €52502 in the group aged 95 to 99 years (average, €23745/QALY).

Based on the average gain in hearing-related quality of life, 0.44 hearing-QALYs were gained. The costs/hearing-QALY outcomes ranged from €1333 in the youngest group to €3889 in the oldest group. The overall costs/hearing-QALY ratio amounts to €1759 (Figure 2).

The QALYs gained using the lower (−0.03) and upper (0.08) limits of the 95% CI of the average incremental population utility combined with the highest and lowest incremental cost estimates result in worst- and best-case scenarios. The cost/QALY outcome in the worst-case scenario amounts to €24339 per QALY lost, and the cost/QALY outcome in the best-case scenario amounts to €3718 per QALY gained. Based on these outcomes, a confidence box was constructed around the base-case cost/QALY outcome.
The highest and lowest incremental cost estimates and the lower and upper bound of the QALYs gained using the increase in hearing-related quality of life are used to construct a confidence box for the cost/hearing-QALY outcome. In the worst-case scenario in this hearing-specific perspective, the costs are £3305 per hearing-QALY gained; in the best-case scenario, the costs are £959 per hearing-QALY gained (Figure 3).

SENSITIVITY ANALYSIS

The base-case outcome (£15807/QALY, based on the average incremental population utility of 0.03) is used as input in the univariate sensitivity analysis. Change in quality of life had by far the most impact on the cost/QALY outcome. When we varied the utility gain from −0.03 to 0.08, the cost/QALY ranged from £15807 to £5936.

When the price per hearing aid was varied from £350 to £1000, the cost/QALY outcome varied from £11 209 to £20 575. When the binaural fitting is changed from the base-case estimate of 25% to 10% and 50%, the outcome changes from £14 560/QALY to £17 948/QALY. When the replacement time of a hearing aid was halved and doubled, the outcome varied from £14 402/QALY to £20 175/QALY. Among the transition variables in the sensitivity analysis, becoming a dissatisfied hearing-aid user had the largest impact on the outcome. When the chance of becoming dissatisfied was halved and doubled, the outcome varied from £11 280/QALY to £20 283/QALY. The other transition variables in the sensitivity analysis have only little effect on the cost/QALY outcome (Table 2).
Given the base estimate of input variables, fitting of hearing aids costs society from €11,997/QALY in the youngest group to €35,001/QALY in the oldest group. The average outcome across all ages is €15,807/QALY. Laupacis et al found that the reimbursement of interventions costing less than CAN $20,000/QALY was generally never questioned (CAN $20,000/QALY). The base-case estimate of €15,807/QALY for fitting hearing aids is approximately CAN $20,000/QALY. Based on this outcome, fitting hearing aids could be considered a cost-effective health-care intervention. However, the effect of hearing-aid fitting on generic quality of life could not be determined unambiguously, since the 95% CI of the change in quality of life after fitting of the hearing aid, as measured by the EQ-5D, included zero. As a result, the confidence box around the cost/QALY outcome (Figure 2) clearly shows that we cannot rule out that not fitting hearing aids is more cost-effective than fitting them. The improvement on the hearing-VAS, however, was substantial and statistically significant. Therefore, we confirmed the effectiveness of hearing-related improvement of quality of life due to hearing aids. This finding could indicate that the EQ-5D lacked sensitivity for the purpose of this study. Although this seems highly likely, no study has been able to demonstrate an effect of fitting a hearing aid on generic quality of life using a measure suitable for use in cost-effectiveness analysis. Other prominent generic health status measures, like the 36-Item Short-Form Health Survey and the Health Utilities Index Mark II, would also have limitations for this purpose. The 36-Item Short-Form Health Survey contains very few items that could be influenced by the psychological, social, and emotional consequences of hearing impairment. According to the Health Utilities Index Mark II scoring formula, being deaf and blind generates the same amount of disutility as being only deaf or only blind, which is a counterintuitive outcome. Overall, health status measures are needed for the evaluation of the effect of interventions for sensory disabilities, such as hearing aids, on generic quality of life.

The hearing-specific VAS was used to determine the weights for the calculation of hearing-specific QALYs. This type of QALY could be useful as a measure of effectiveness in studies determining the incremental cost-effectiveness of binaural vs monaural fitting and among different types of hearing aids. For this purpose, a multiattribute preference-based questionnaire has been developed around the hearing-specific VAS (Horst Zank, PhD, M.A.J, H.J.M.P., G.M.B., and L.J.C.A., unpublished data, January 2002).

The cost-effectiveness of an intervention is only 1 criterion for inclusion in the basic package of social insurance. The necessity of treatment for the individual and the severity of the disease are also criteria for the inclusion of an intervention in the basic package. Hearing impairment is often trivialized as a normal aspect of aging and associated with stigmatized conditions such as mental disorders. This could lead to a lower perception of the severity of hearing impairment and the necessity of fitting a hearing aid than might be the case. Perhaps this has played a role in the decrease of the reimbursement for hearing aids in the Netherlands during the past few years. With the advancing technological possibilities of hearing aids and the related increase of the price of hearing aids, the amount of reimbursement might become a barrier to seeking of treatment by hearing-impaired persons.

The sensitivity analysis showed highly robust outcomes with respect to the major cost and transition variables. The variable that most substantially influenced the base-case estimate was the change in quality of life. The only other variables that influenced the costs/QALY outcome were the costs of the hearing aid and the probability of becoming a dissatisfied hearing-aid user. In the sensitivity analysis, we assumed that the price of the hearing aid would not influence the gain in health-related quality of life. In real life, more expensive (eg, digital) hearing aids might lead to a larger gain in health-related quality of life. In future research, the possible extra benefits of more ex-
pensive hearing aids, or binaural fitting, should be identified in terms of the incremental cost-effectiveness in well-defined patient categories. The probability of becoming a dissatisfied hearing-aid user also influenced the outcome quite substantially. Therefore, changes in the policy for fitting hearing aids that would increase the probability of becoming a dissatisfied hearing-aid user would considerably increase the amount of costs/QALY for fitting of hearing aids. For instance, screening for hearing impairment to fit more hearing-impaired persons with hearing aids could lead to an increase in the probability of becoming a dissatisfied user when the detected patients are not motivated to start using hearing aids. Cutting down on the professional quality and quantity of support for hearing-aid users might have a similar effect. On the other hand, extra counseling programs to keep hearing-aid users motivated are likely to improve the cost-effectiveness of hearing-aid fitting.

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