DYNAMIC MODELING IN MEDICAL TECHNOLOGY ASSESSMENT

Fitting Hearing Aids in The Netherlands

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Abstract

Objectives: The main objective of this article is to demonstrate the usefulness of dynamic modeling for an economic assessment of technology in health care. Specifically, this approach is applied to assess the impact of the use of hearing aids in Dutch health care.
Methods: The population is divided into different health classes between which, over time, transitions occur. Transition probabilities are derived from exogenous data. The transitions are associated with economic and societal costs and benefits. People who are satisfied with their hearing aids experience benefits. These benefits are expressed by quality-adjusted life-years (QALYs). Costs are made during transitions (mainly the fitting of hearing aids). A cohort analysis is carried out, starting with people in a particular age group. The starting point is a fixed number of people within this age group, who are followed during their whole lifetime.
Results: Costs per QALY ratios are calculated for two health programs. The Fitting Hearing Aid Program describes the present situation in the Netherlands; the Post-purchase Counseling Hearing Aid Program is a hypothetical addition to the first program, where an intervention based on a Dutch study is undertaken to improve satisfaction with hearing aids. Future benefits and costs are discounted at a rate of 5%.
Conclusions: The dynamic modeling approach provides a more realistic picture than a static approach. Particularly, the cost-effectiveness of the Fitting Hearing Aid Program is compared with the Post-purchase Counseling Hearing Aid Program.

Keywords: Hearing aids, Models, economic, Cohort studies, Cost benefit analysis

Assessment, from the economic and societal point of view, of the impact of applying medical technology in health care on the well-being of individuals by its very nature requires the use of dynamic modeling. People become ill, are treated with appropriate medical technology or interventions, may become better or worse after treatment, and so on. The total population can be divided into different health classes. Over time persons move from one health class to another according to certain transition probabilities that can be assessed empirically. These transitions may be associated with medical interventions or other factors. Economic and societal costs and benefits can be associated with these transitions, in terms of health and healthcare costs, but also, for instance, in terms of productivity losses and gains.

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This article presents a dynamic modeling approach that has been applied to the problem of hearing complaints and fitting hearing aids. Through this specific application, the wider objective of this article is to demonstrate the usefulness of dynamic modeling for the economic assessment of technology in health care.

Loss of hearing capacity (hearing impairment) is one of the most common chronic health problems in Western society, especially among the elderly. We define hearing impairment as a person having an average pure tone hearing loss of at least 35 decibels for 1, 2, and 4 kHz in the best ear. Chorus et al. (4) state that more than 10% of the Dutch population suffers from hearing impairment.

In the model for hearing complaints described in this article, the population is divided into those with and those without hearing complaints. People without complaints may start to suffer from the disability in accordance with their risk profile. On the basis of these risk profiles, incidences are generated each year. The group with hearing complaints is further divided into various subclasses between which transitions occur. Insofar as medical interventions or other healthcare programs bring about these transitions, there are associated costs and benefits.

The change in costs and benefits after fitting hearing aids was assessed in a Dutch study, which has been carried out by the Societal Impact of Hearing Impairment (SIHI) study group (7).[1] The study population consisted of individuals aged 18 years and older, living in the Netherlands, who visited the Ear, Nose and Throat (ENT) Clinic of Maastricht University Hospital or the Audiological Center Hoensbroeck and received a prescription for a hearing aid.

For an economic assessment, the costs and benefits of fitting hearing aids are considered from the societal viewpoint. Applying the model to the Dutch situation, the economic assessment concerns two interventions. The first intervention consists of a Fitting Hearing Aid (HA) program, which reflects the Dutch healthcare structure concerning fitting hearing aids. In the second intervention, a hypothetical Post-purchase Counseling Hearing Aid Program is carried out, aimed at decreasing the number of dissatisfied users of hearing aids. This program was not carried out in the Netherlands; therefore, its extra costs and effectiveness were based on other publications. The costs (of treatments) and the benefits (expressed in quality-adjusted life-years [QALYs]) of both interventions are computed by the model.

The paper aims at demonstrating the usefulness of dynamic modeling for an economic assessment of medical technology. This may support policy makers in government or insurance companies in making decisions on issues such as medical budget allocation and insurance packages. The application to hearing aid programs in the Netherlands in particular provides cost-effectiveness ratios that could be useful for decision makers.

DESCRIPTION OF THE MODEL

The total population is divided into several categories. People without hearing complaints are denoted as the HC^- population. Hearing complaints are defined as not being able to hear well in a group of at least three persons, as published in Chorus et al. (4). People between 15 and 100 years old with hearing complaints form the HC^+ population. The HC^+ population contains people without hearing aids (the HC^+HA^- population) and people with hearing aids (the HC^+HA^+ population). Between these populations, transitions take place. Furthermore, people leave the population due to mortality.

To transfer from the HC^+HA^- population to the HC^+HA^+ population, people undergo the process of being fitted for a hearing aid. These potential first-time users of hearing aids are temporarily situated in the transition phase, which consists of several stages. Also, members from the HC^+HA^+ population, to whom a new hearing aid is fitted (in the Netherlands mostly after a period of 5 to 6 years) are considered to be in the transition phase. This group is denoted as reapplicants. When leaving the transition phase, all reapplicants return to the HC^+HA^+ population (apart from mortality). Potential first-time users also go to this population (and become first-time users) or return to the HC^+HA^- population, depending on what happens during the several stages of the transition phase.

The model assumes that the process of developing hearing complaints is irreversible, although in reality a small number of persons in the HC^+ population may return to the HC^- population. This may be the result of an operation or due to the fact that the hearing-related complaints are not caused by hearing loss after all.

The HC^+HA^+ population is subdivided in a satisfied and a dissatisfied population. We assume that a dissatisfied attitude toward hearing aid use is more prevalent in first-time users than in reapplicants (2). In the end, dissatisfied people may not use their hearing aids at all and return to the HC^+HA^- population.

At the beginning of each year the transition phase is assumed to be empty. Transitions are supposed to take place during the year.

In the model costs are made in the transition phase, while benefits are experienced by people in the HC^+HA^+ population. However, as explained earlier, not all people in this population are satisfied with their hearing aid. To count the benefits, we only take satisfied people into consideration.

The model has been implemented in a computer program, which enables analysis by simulating changes in the present situation. This program is structured in such a way that two types of studies can be carried out, namely, a population study and a cohort study.

1. *Population study*: A population study involves the whole population. Starting with a distribution of the total population over all subgroups, the evolution of these groups is calculated over a certain period of time using exogenous transition probabilities. Societal costs and benefits for the whole population as well as the evolutions of the different populations are obtained by aggregation over the subgroups.
2. *Cohort study*: A cohort study deals with people in a particular age group. The starting point is a fixed number of people of the HC^+HA^- population within this age group, who are followed during their whole lifetime without addition of people to the initial group. This means that the cohort group will not be replenished with births and will cease to exist when all the members of the cohort group have died.

The economic analysis in this article is based on the cohort study. Therefore, we continue with a more detailed description of this latter approach.

The starting point is the subgroup of the population consisting of people with hearing complaints but without hearing aids, denoted by HC^+HA^-. This group is divided in different age groups. Each age group is represented by a subgroup, a *cohort*. This cohort should be representative for its age group, for instance, with respect to the male/female ratio. This approach enables us to make comparisons between different age groups and to draw conclusions for specific age groups.

At the starting year (e.g., 1995 in the Dutch situation) all cohorts are homogeneous in the sense that all members are without hearing aids. After a while this situation has changed: some members will have been fitted with a hearing aid. Initially, the number of people with hearing aids will grow until it reaches a certain maximum. In the end the number of people with hearing aids as well as the number of people without hearing aids will drop to zero due to mortality. The model follows this process in time steps of 1 year. Thus, the members of each cohort move between the several health classes as described above, according to transition probabilities. Once all transition probabilities are known, the distribution of the cohort over the various groups at the end of the year can be computed, and this process can be continued until the whole cohort has vanished due to mortality.

Some transition probabilities depend on sex and age. Therefore, the model distinguishes between male and female subgroups. We assume that the age differences within a cohort are small enough to consider these subgroups as being homogeneous with respect to transition probabilities. The probabilities are derived from exogenous data, such as the number of incidences reported in literature studies. The mortality figures are based on life tables for men and women.

As mentioned, the model can also be used to carry out a population study. The transition probabilities used in both types of studies should match. In particular, the results of the population study can be (and were) used to calibrate these probabilities. Also, the male/female ratio in the different cohorts can be based on the population study.

The costs are incurred during the transition phase. The model calculates costs as the total volume of treatments multiplied by unit cost (price per treatment) by considering the treatment profiles of fitting hearing aids.

Benefits are experienced by the satisfied people in the HC^+HA^+ group and are expressed in terms of a utility. The increase of health utility on the EuroQol, as measured by the SIHI study group (7), amounts to 0.02 utilities per person per year on a scale from 0 to 1. The benefits are computed by counting the total number of satisfied users in a certain year, multiplying by 0.02, and adding over the years. Thus, the benefits are expressed in QALYs. The comparison of costs and benefits results in a ratio of costs per QALY outcome. Costs and benefits are discounted to their present values.

THE DUTCH SITUATION

The model was then applied to fitting hearing aids in the Dutch healthcare system. The general model is presented as a patient flow model. This means that the hearing complaint phenomenon is modeled in the same way as the development of the disease and the course of treatment. Consequently, the patient model has the form of a flow diagram. Figure 1 shows the patient flow model. As mentioned, the starting point in Figure 1 is a fixed number of people, denoted by HC^+HA^-. The patient flow model distinguishes three treatment stages in the process of fitting hearing aids, representing usual care in the Netherlands. The three stages are: a) a general practitioner stage (GP stage); b) a referral stage to the ear-nose-throat specialist or an audiological center (ENT/AC stage); and c) a fitting hearing aid stage (dispenser stage). The different stages in the model are marked as decision points that relate to the choice of treatment route that is made by the professional or by the patient himself.

For first-time users, the dispenser stage results in a trial period of 6 weeks at minimum, which includes learning about the use of hearing aids and assistive listening devices. Consultation of the prescriber after the trial period may result either in the purchase of the hearing aid or in a negative trial (that is, a well-informed decision not to take a hearing aid when it does provide little or no benefit). At this early stage of the model, precounseling resulting in negative trials reduces noncompliance, mostly in first-time users since reapplicants are already more experienced (5).

The treatment stages represent paths through which the various patient flows can pass. By following the patient flows through these routes, it is possible to determine the annual number of medical treatments, and thus also the costs of treatment, since costs are the product of number of treatments and unit cost.

As calculated by the SIHI study group (7), the unit costs of the GP, ENT specialist, and AC amount to Euro 26.63, Euro 107, and Euro 212, respectively. In the Netherlands 85% of the hearing aids are fitted at an ENT clinic and 15% at an AC. Therefore, the weighted unit cost of ENT and AC equals Euro 123. The average purchase cost of a monaural hearing aid and binaural aids amounts to Euro 864 and Euro 1,728, respectively. According to the

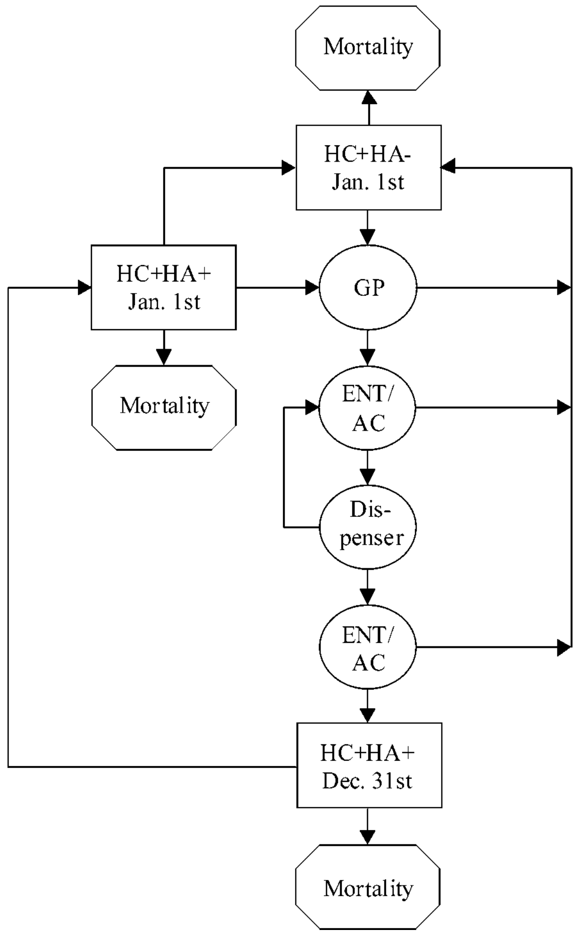

Figure 1. Patient flow model of hearing aids in the Dutch healthcare system.

market study of the Dutch Association of Hearing Aid Dispensers (8), 25% of sales are binaural fittings. Therefore, the weighted unit cost of monaural and binaural hearing aids is Euro 1,080.

The most recent data for calibrating the parameters in the computer program mainly refer to the period from 1993–97. The starting year in the computer program is 1995. This year is chosen because the computer program uses demographic forecasts of the Central Bureau of Statistics (3), based on 1995.

We applied the model to simulate two health programs:

1. The Fitting Hearing Aid (HA) Program reflects the present situation in the Netherlands concerning the fitting of hearing aids. Data and assumptions used in this program are based as much as possible on the present situation. Transition probabilities and costs are assumed to be constant over time.
2. The Post-purchase Counseling HA Program is a hypothetical addition to the Fitting HA Program, where further counseling after hearing aid purchase is undertaken to promote effective use of hearing aids. The program results in a reduction of the number of first-time users who become dissatisfied. As postpurchase counseling is not usual care, it should be regarded as an extra effort. The extra costs and its effectiveness are derived from a study by Ward et al. (9). The costs of extra effort have a linear relation with the number of first-time users. The unit cost is calculated as Euro 37 per first-time user. The effect is that there will be 36% fewer transfers from the satisfied to the dissatisfied HC^{+} group.

The applied method is a cost-utility analysis, which is a special form of a cost-effectiveness analysis. Costs and health effects are linked, resulting in costs per QALY ratios.

The cumulative extra costs and cumulative improvement in quality of life are considered in terms of their present value. In order to make future costs and QALYs comparable to the present ones, the cohort study discounts the future costs and benefits to their present value at a discount rate of 5%.

We performed a cohort analysis for both health programs. Figure 2 presents the costs in Euro per QALY ratio of a cohort of men and women for each age group. The costs per QALY ratios in the younger age groups are more favorable than in the older age groups. Though the younger groups generate more costs, they also generate more QALYs, both as a result of a longer life expectancy in comparison with the senior age groups. Moreover, in the senior age groups, the decrease of the costs is less when compared with the decrease of the QALYs, as a result of which the costs per QALY ratio increases.

As Figure 2 shows, the ratios for the Post-purchase Counseling HA Program are lower than for the Fitting HA Program. The Post-purchase Counseling HA Program generates both more costs and more benefits, since compared with the Fitting HA Program more people stay in the satisfied HC^+ group. An additional cost factor is formed by the counseling costs themselves. As the increase of costs is more than compensated by the increase of benefits, the cost per QALY ratios are better for the Post-purchase Counseling HA Program.

People in the HC^+HA^- population are on average 62 years old, as calculated by the SIHI study group. For this reason we consider the age group of 60–64 years old as an example. For this age group, the costs per QALY ratio is Euro 21,154 Euro per QALY in the Fitting HA Program and Euro 18,046 per QALY in the Post-purchase Counseling HA Program.

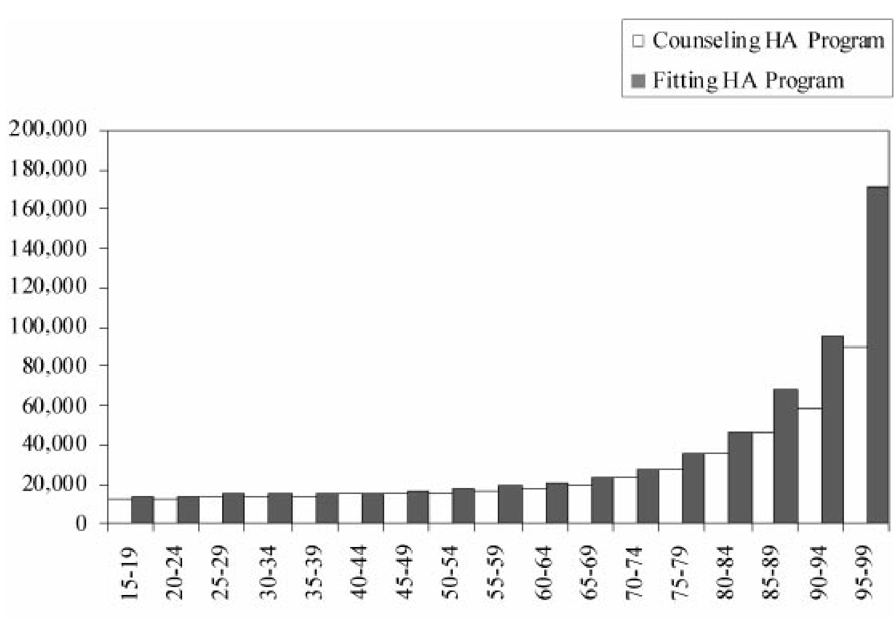

Figure 2. Costs in Euro per QALY ratio of the Fitting HA Program and the Post-purchase Counseling HA Program in a cohort study.

DISCUSSION

The main results are the costs per QALY ratios of two hearing aid programs discounted at 5%, performed in a cohort of men and women for each age group. In the age group of 60–64 years old, the costs per QALY ratios of the Fitting HA Program and the Post-purchase Counseling HA Program amount to Euro 21,154 and Euro 18,046 per QALY, respectively. Moreover, the results show that fitting hearing aids in younger age groups is more cost-effective than in older age groups.

The reduction of the dissatisfied HC^+ population is important for the results of the Post-purchase Counseling HA Program. The assumption of 36% for this parameter based on a study of Ward et al. (9) is confirmed by Kapteyn et al. (6). The latter authors demonstrate that the noneffective use of hearing aids is reduced by almost a third (0.27), from 37% to 27%, which leads to a cost per QALY ratio of Euro 18,770 per QALY.

In the model, sensitivity analysis was performed using different data in order to test the sensitivity of the outcomes. If the sensitivity analysis of such manipulations produces large fluctuations in the outcomes, greater caution is necessary when using the results.

The outcome of the sensitivity analysis is measured in costs per QALY ratio for the age groups of 60–64 years old. In the Fitting HA Program, the costs per QALY are Euro 21,154 per QALY. By manipulating some data of the Fitting HA Program, the following results are obtained:

- An increase of 25% in the average prices of a monaural hearing aid from Euro 860 to 1,080 results in Euro 25,570 per QALY;
- A 100% increase in the overall percentage of binaural fittings from 25% to 50% results in Euro 24,687 per QALY; and
- A 100% increase in the health utility from 2% to 4% results in Euro 10,577 per QALY.

We conclude that the costs per QALY ratio are very sensitive to both changes in the price of HA and (not surprisingly) change in the health utility outcome, and are less sensitive to a change in the number of binaural fittings.

In the results so far, the cohorts consist of males and females. An analysis for male only and female only cohorts was also carried out. This gives an indication about the sensitivity of the model for the male/female ratios in the cohorts. For all-male cohorts, the costs per QALY ratios are between 0% and 22% higher than for mixed cohorts. For female cohorts, these figures are between 0% and 11% lower. These statements hold both for the Fitting HA Program and for the Post-purchase Counseling HA Program. This is explained by the higher mortality rates for men.

The model considers costs from a societal point of view. Societal costs consist of the extra health services costs, including the portion of costs not covered by insurance, decreased by savings in the loss of productive output to the community, insofar as both types of cost are due to an intervention. However, little information is available about absence from work, loss of efficiency, or loss of personal time and/or increase of traveling costs due to hearing impairment. Therefore, these indirect costs were not used in the cost calculations.

The results are obtained by a dynamic modeling approach that enables an economic assessment of the potential benefits of a technology in health care from the societal perspective, on the basis of patient flows. Compared to a more static approach, in which patients are followed only during the time path the intervention has taken place, the dynamic approach as advocated in this paper provides a more realistic picture and enables the adaptation of the model parameters to changes over time.

POLICY IMPLICATIONS

The policy implications of the Post-purchase Counseling HA Program are that nonuse of hearing aids results in noneffective use of time and money, both for clients and the healthcare system. There is evidence that hearing impairment is associated with a number of adverse effects (such as social isolation, cognitive dysfunction, loss of quality of life, and independence) that can be alleviated with appropriate hearing aid use. Therefore, cost-effective efforts to improve the effectiveness of hearing aid provision should be encouraged.

The dynamic approach is of particular interest for policy planning with a view on cost-effectiveness. Decision makers may compare the costs per QALY ratios of the hearing aid programs with the costs per QALY ratio of other interventions.

NOTE

[1]The study has been carried out by the Societal Impact of Hearing Impairment (SIHI) study group, including: Audiological Center Hoensbroeck, represented by D. J. E. J. Pans, MSc, clinical audiologist; Department of Otorhinolaryngology, Head and Neck Surgery, Maastricht University Hospital, represented by L. J. C. Anteunis, PhD, clinical physicist audiologist, and M. N. Chenault, statistical analyst; Department of Clinical Epidemiology and Medical Technology Assessment, Maastricht University Hospital, represented by M. A. Joore, MSc, health administrator; Department of Quantitative Economics, Maastricht University, represented by Prof. H. J. M. Peters, PhD, J. van der Stel, PhD, and H. Zank, PhD, per 1.05.1999 affiliated with the School of Economic Studies, The University of Manchester, Manchester, UK; Health Center Neerbeek, represented by Y. D. van Leeuwen, PhD, general practitioner; and Maastricht Health Economics Research and Consultancy Agency, represented by G. M. Boas, PhD, health economist, and D. E. M. Brunenberg, MSc, health administrator, per 1.09.1999 in service of the Department of Clinical Epidemiology and Medical Technology Assessment, Maastricht University Hospital.

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