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Cost-effectiveness of selected interventions for hearing impairment in Africa and Asia: A mathematical modelling approach

Key Words
Costs
Economic analysis
Cost-effectiveness
Hearing impairment
Deafness
Modelling

Abbreviations
ACER: Average cost-effectiveness ratio
CEA: Cost-effectiveness analysis
CHOICE: Choosing Interventions that are cost-effective
CMH: Commission on macroeconomics and health
COM: Chronic otitis and media
DALY: Disability-adjusted life year
ICER: Incremental cost-effectiveness ratio

Abstract
The purpose of this paper was to present estimates of costs and effects of selected interventions for hearing impairment in Africa and Asia. The method used mathematical simulation models on the basis of WHO burden of disease information, and WHO-CHOICE costing databases. Findings showed that in both regions, screening strategies for hearing impairment and delivery of hearing aids cost between I$1000 and I$1600 per DALY, with passive screening being the most efficient intervention. Active screening at schools and in the community are somewhat less cost-effective. In the treatment of chronic otitis media, aural toilet in combination with topical antibiotics costs is more efficient than aural toilet alone, and costs between I$11 and I$59 in both regions. The treatment of meningitis with ceftriaxone costs between I$55 and I$217 at low coverage levels, in both regions. In more absolute terms, the vast majority of all considered intervention strategies are cost-effective strategies according to international benchmarks, in both regions concerned. In conclusion, various strategies are economically attractive to reduce the disease burden of hearing impairment around the world.

Sumario
El propósito de este trabajo fue presentar información que estima los costos y efectos de intervenciones seleccionadas para los impedimentos auditivos en África y Asia. El método usó modelos de simulación matemática con base en la información de la WHO sobre el peso de las enfermedades y las bases de datos de costos WHOCHOICE. Los hallazgos mostraron que en ambas regiones, las estrategias de tamiz de impedimentos auditivos y la provisión de auxiliares auditivos cuesta entre I$1000 y I$1600 por DALY, siendo el tamiz pasivo la intervención más eficiente. El tamiz activo en las escuelas y en la comunidad tiene un costo-efectividad un tanto menor. En el tratamiento de la otitis media crónica, los costos de la higiene auricular en combinación con antibióticos tópicos es más eficiente que la higiene aislada, que van de I$11 a I$59 en ambas regiones. Los costos del tratamiento de la meningitis con cefriaxona fueron de entre I$55 y I$217, en niveles de baja cobertura en ambas regiones. En términos más absolutos, la amplia mayoría de todas las estrategias de intervención consideradas, en lo que concierne a las dos regiones, son costo-efectivas, de acuerdo con los patrones internacionales.

Throughout the world, hearing impairment is responsible for a major disease burden. In 2005, 278 million people worldwide had disabling hearing loss (Mathers et al, 2005; WHO, 2006). This includes 210 million people with adult-onset loss and 68 million people with child-onset loss, who together make up almost 4.3% of the world's population. It has been estimated that at least 50% of the burden of hearing loss, i.e. 33.3 million disability-adjusted life years (DALYs) could be prevented by primary, secondary, and tertiary preventive measures (Brobby, 1989; WHO, 1991). DALYs are a summary measure of population health, and can be used to express reductions in both mortality and morbidity as a result of interventions (Tan Torres et al, 2003).

Hearing loss is a chronic and often lifelong disability that, depending on the severity and frequencies affected, can cause profound damage to the development of speech, language, and cognitive skills in children, especially if commencing prelingually. That damage, in turn, may affect the child's progress in school and, later, his or her ability to obtain, keep, and perform an occupation. For all ages and for both sexes, it may cause difficulties with interpersonal communication and leads to significant individual social problems, especially isolation and stigmatization. All these difficulties are magnified in developing countries, where there are generally limited services, few trained staff members, and little awareness about how to deal with these difficulties (Cook et al, 2006).

In addition to its individual effects, hearing loss substantially affects social and economic development in communities and countries. Ruben (2000), taking into account rehabilitation, special education, and loss of employment, estimated the cost to the U.S. economy in 1999 of communication disorders (hearing, voice, speech, and language disorders) at between US$176 billion and US$212 billion. Hearing loss accounted for about one-third of the prevalence of these communication disorders.

Effective interventions to reduce hearing impairment or its consequences are manifold, and include neonatal, early-childhood and school-age screening, education, rehabilitation, noise

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conservation programmes, treatment of chronic otitis media (COM), surgical interventions, hearing aids, and cochlear implants. However, all the data on the costs and cost-effectiveness of interventions related to hearing loss come from developed countries, and it is not clear whether and how they relate to the costs that would be experienced in developing countries. Hence, the costs and effects of such programmes in developing counties are largely unknown.

Against this background, this paper evaluates, through mathematical modelling, the costs and effects of three sets of interventions targeting different types of hearing impairment. The first set of interventions relates to screening for hearing impairment and the provision of hearing aids. Hearing aids, fitted properly, are often proposed as an effective intervention to reduce the impact of hearing disorders for the vast majority of all people with moderate or severe hearing loss in developing countries (Arslan & Genovese, 1996). Globally about six million hearing aids are dispensed annually, but less than one million go to the developing world (WHO, 2004a,b). The second set of interventions relates to chronic otitis media (COM), as one of the most common causes of hearing impairment in developing countries, especially in children. The global burden of otitis media-induced hearing impairment equalled 277 000 DALYs in 2000, which is 0.83% of the total burden of hearing impairment. This burden of otitis media occurs overwhelmingly in the developing world, with developing countries experiencing 91% of the global burden (Smith & Mathers, 2006). Evidence suggests that antibiotics, or antiseptics, are more effective and cost-effective than ear toilet alone (WHO, 2004c) The third set of interventions relates to meningitis. The global burden of meningitis-induced hearing loss is 411 000 DALYs, which is equivalent to 1.2% of the total burden of child- and adult-onset hearing loss. This burden for meningitis occurs overwhelmingly in the developing world, with developing countries experiencing more than 96% of the disease burden (Smith & Mathers, 2006). Interventions targeting other types of hearing impairment (e.g. noise conservation and neonatal screening programmes) are not considered here because of lack of data on burden of disease and/or intervention effectiveness in a developing country context.

In this study, we evaluate costs and effects of these interventions for two major global regions using a generic measure of effectiveness and a standardized analytical approach. This analysis is designed to provide a broad assessment of the cost-effectiveness of screening for hearing impairment that covers various strategies in different settings, and that allows comparisons with recent cost-effectiveness analyses for other health care interventions—in sensory disorder control but also in other areas—that follow the same analytical approach (Baltussen et al, 2004, 2005; Hogan et al, 2005).

Methods

Overview of cost-effectiveness analysis (CEA)

CEA in health aims to inform policymakers on the economic attractiveness (or returns on investment) of interventions to reduce disease-related mortality and morbidity. The validity and relevance of CEA in health has been discussed extensively in western countries (Drummond et al, 2005), and recently Singer (2008) called for a broader application of CEA in developing countries. By assessing costs and effectiveness of an intervention, a 'value for money' estimate is provided. The cost-effectiveness of a given intervention is typically expressed as costs per unit of effectiveness, with costs measured in monetary terms and effectiveness measured in health metrics terms. Health metrics measure the impact of an intervention on the quality of life (morbidity) and length of life (mortality) of a population and express this as a single number such as a Quality Adjusted Life Year (QALY) or DALY (for more information on DALY, please read Tan Torres et al, 2003). Interventions with an attractive cost-effectiveness ratio (e.g. low cost per DALY) are said to be eligible for implementation, at least in economic terms.

CEA can be undertaken in many ways, and there have been several attempts to develop methodological guidelines to make results more comparable. WHO has developed a standardized set of methods and tools that can be used to analyse the societal costs and effectiveness of current and possible new interventions simultaneously (Tan Torres et al, 2005), named WHO-CHOICE. The program is designed to provide regularly updated databases on the costs and effects of a full range of promotive, preventive, curative, and rehabilitative health interventions (Hutubessy et al, 2003).

Regions analysed

Most countries do not have the capacity to evaluate all potential interventions aimed at improving given health indicators at the national and sub-national level, and global estimates are too general and of little use to any specific country. Countries may however benefit from regional evaluations of data, where data of countries with similar settings are pooled. The present analyses drew on a comprehensive examination of 14 world sub-regions defined by geographic proximity and epidemiology according to WHO classification. This paper only presents results for two regions selected on the basis of their diverse epidemiological patterns. The two sub-regions are the African sub-region with high rates of adult and very high rates of child mortality (Afr-E), and the South-East Asian sub-region with high rates of adult and child mortality (Sear-D). A full list of sub-regions and included countries is available on the WHO-CHOICE website (www.who.int/choice).

Epidemiology of hearing impairment

According to WHO classification, levels of hearing impairment comprise mild (26–40 decibel hearing level, dBHL), moderate (41–60 dBHL), severe (61–80 dBHL), and profound (81 dBHL or greater) (WHO, 1991). The term *deafness* denotes profound hearing impairment (WHO, 1991; WHO, 1997). Disabling hearing impairment in adults is defined as a permanent unaided hearing threshold level for the better ear of 41 dB or greater. Disabling hearing impairment in children under the age of 15 years is defined as a permanent, unaided hearing threshold level for the better ear of 31 dB or greater (WHO, 1991; WHO, 1997).

WHO has recently estimated the burden of disease of hearing impairment (defined as moderate or worse hearing loss in the better ear) for both adult-onset hearing loss and child-onset hearing loss (Smith & Mathers, 2006). Numbers with childhood-onset hearing loss are also included among sequelae of other diseases (for example, infectious diseases such as meningitis, otitis media, and congenital conditions). This paper concentrates on adult- and child-onset hearing loss, and child-onset hearing

Table 1. The prevalence and incidence of child- and adult-onset hearing loss (per 1000)*

	Afr-E				*Sear-D*			
	Male		*Female*		*Male*		*Female*	
Age	*prev.*	*inc.*	*prev*	*inc*	*prev.*	*inc.*	*prev*	*inc*
0–4	17.64	5.55	19.44	6.12	7.68	2.42	7.69	2.42
5–14	36.88	0.74	40.65	0.81	16.07	0.32	16.08	0.32
15–29	39.10	0.62	41.08	0.28	16.15	0.16	15.98	0.03
30–44	57.83	1.94	56.53	2.03	35.88	3.04	33.14	3.45
45–59	90.34	2.61	91.76	2.99	115.17	8.19	114.99	7.47
60–69	145.00	8.36	141.99	5.72	252.40	14.27	246.62	13.91
70–79	240.83	10.17	202.41	6.82	393.59	13.89	383.49	13.97
80+	324.92	7.79	261.73	4.85	513.62	9.40	502.82	9.22

*Source: Smith & Mathers (2006), and Mathers et al (2005). Incidence rates of age groups 0–4 and 5–14 are based on our own estimates, using DISMOD software (Barendregt et al, 2003).

loss due to meningitis and otitis media. Tables 1–3 provide the detailed information on their epidemiology.

Interventions

The analyses distinguish between interventions targeting various types of hearing impairment. For screening and provision of hearing aids, this includes passive screening (defined here as the absence of any specific population-based strategy, and including treatment of only those people who present themselves at health centres seeking care for hearing impairment), and active screening of school children and adults at different time intervals (defined here as a population-based strategy to identify people eligible for hearing aids). For chronic otitis media, this includes aural toilet alone, and in combination with topical antibiotics. For meningitis, this includes antibiotic treatment. The interventions are described in detail in Appendix A, B, and C.

Estimating population health effects

We used the population model PopMod (Lauer et al, 2003) to estimate the effects of the above interventions on population health in the regions considered. Population health is expressed as the number of Healthy Years Lived (HYL), and differences in HYL as DALYs averted as a result of the intervention. The model divides the population of interest into three health states: hearing impaired, healthy, and dead, on the basis of the epidemiological patterns described above.

Population health is dependent upon the proportion of people in each health state, as well as the health state valuation that is associated with the health state (the health state valuations for untreated and treated moderate hearing loss are respectively 0.88 and 0.96, and for untreated and treated severe and profound hearing loss are respectively 0.667 and 0.88) (Mathers et al, 2002). The proportion of individuals in the different states is dependent on parameters such as prevalence, incidence, and remission, and is similarly modelled for both the 'no-intervention' scenario and the situation in which people are screened and/or treated. Given the very low coverage of screening and provision of hearing aids in developing countries, we assume that the current situation describes the 'no intervention' scenario. The 'no intervention' scenario assumes a hearing impairment remission rate of zero. Differences in population health estimates between the baseline and intervention scenario were considered a measure of intervention effectiveness, expressed in DALYs. The specific models for the three types of hearing impairment are described in Appendix A, B, and C.

Following standardized WHO-CHOICE cost-effectiveness analysis, all interventions were evaluated for a period of ten years, and benefits (i.e. improved hearing and health state

Table 2. The prevalence and incidence of otitis media induced hearing impairment (per 1000)*

	Afr-E				*Sear-D*			
	Male		*Female*		*Male*		*Female*	
Age	*prev.*	*inc.*	*prev*	*inc*	*prev.*	*inc.*	*prev*	*inc*
0–4	0.048	0.020	0.048	0.020	0.049	0.020	0.049	0.020
5–14	0.199	0.020	0.199	0.020	0.200	0.020	0.200	0.020
15–29	0.300	0.000	0.300	0.000	0.299	0.000	0.299	0.000
30–44	0.300	0.000	0.300	0.000	0.299	0.000	0.299	0.000
45–59	0.300	0.000	0.300	0.000	0.299	0.000	0.299	0.000
60–69	0.300	0.000	0.300	0.000	0.299	0.000	0.299	0.000
70–79	0.300	0.000	0.300	0.000	0.299	0.000	0.299	0.000
80+	0.300	0.000	0.300	0.000	0.299	0.000	0.299	0.000

* Source: World Health Organization. Burden of disease estimates 2004. Provided on demand.

Table 3. The prevalence and incidence of meningitis-induced hearing impairment (per 1000)*

	Afr-E				*Sear-D*			
	Male		*Female*		*Male*		*Female*	
Age	*Prev.*	*Inc.*	*Prev.*	*Inc.*	*Prev.*	*Inc.*	*Prev.*	*Inc.*
0–4	0.217	0.087	0.217	0.087	0.315	0.126	0.315	0.126
5–14	0.477	0.007	0.477	0.007	0.692	0.011	0.692	0.011
15–29	0.559	0.003	0.559	0.003	0.812	0.005	0.812	0.005
30–44	0.559	0.003	0.559	0.003	0.812	0.005	0.812	0.005
45–59	0.650	0.005	0.650	0.005	0.944	0.008	0.944	0.008
60–69	0.769	0.011	0.769	0.011	1.117	0.015	1.117	0.015
70–79	0.769	0.011	0.769	0.011	1.117	0.015	1.117	0.015
80+	0.769	0.011	0.769	0.011	1.117	0.015	1.117	0.015

* Source: World Health Organization. Burden of disease estimates 2004. Provided on demand.

valuation following the intervention) were included to the extent they took place within this period. Following this standardized approach, it was assumed that interventions were performed optimally, i.e. no under- or over-treatment at the highest efficiency level (Tan Torres et al, 2003).

Estimating costs

Costs covered in this analysis include programme-level costs associated with running the intervention, such as administration and training, and patient-level costs such as primary care visits. These costs were based on a standard ingredients approach developed by WHO-CHOICE to facilitate costing of interventions (Johns et al, 2003). The following components were thus included, (specific cost inputs for the three types of hearing impairment are described in Appendix A, B and C)

Firstly, programme-level costs relate to the resource inputs used in the production of an intervention at a level above that of the patient or providing facility, such as central planning and administration functions, supervision, and training. Estimated quantities of resources required for central planning and administration at national, provincial and district levels were based on a series of evaluations made by WHO-CHOICE costing experts in the different sub-regions and validated against the literature (categories of resource input included personnel, training, materials and supplies, media, transport, maintenance, utilities, and capital) (Tan Torres et al, 2003). Secondly, patient-level costs relate to resource inputs used in the provision of a given health-care intervention. Thirdly, unit costs relate to the prices of programme-level and patient-level resource inputs, such as the salaries of central administrators, the capital costs of offices and furniture, the cost per in- and out-patient visit, or the cost of drugs or hearing aids. Data were obtained from a review of literature and supplemented by primary data from several countries, or based on international catalogue prices for e.g. operation supplies and equipment (Tan Torres et al, 2003). For a full overview of all unit costs, see the WHO-CHOICE website (www.who.int/choice).

Costs are reported in international dollars to facilitate more meaningful comparisons for countries with different purchasing power within a region (Tan Torres et al, 2003). International dollars can be expressed in US dollars (US$), by multiplying them by the conversion factor (1/[official exchange rate/purchasing power parity exchange rate]). An example is given in the Discussion section of this paper. The base year is 2000. More details on health facility unit cost estimates are reported in Adam et al (2003) whereas a description on the programme cost estimates, including the costing of various coverage levels as well as the scaling-up of costs to the level of WHO sub-regions, can be found in Johns et al (2003).

Estimating cost-effectiveness

Average cost-effectiveness ratios (ACERs) are calculated for each screening strategy by combining the information on the total costs with information on the total health effects in terms of DALYs averted. All costs and effects are discounted at 3%, following standardized WHO-CHOICE analysis (Tan Torres et al, 2003). Using a standard approach, we identified the set of interventions a region should purchase to maximize health gain for different budget levels. The order in which interventions would be purchased is called an expansion path and is based on the incremental costs and health effects of each intervention compared to the last intervention purchased within each set of mutually exclusive interventions. The incremental cost-effectiveness ratios (ICER) for those interventions are calculated by dividing the incremental costs by the incremental health effects.

The Commission on Macroeconomics and Health defined interventions that have a cost-effectiveness ratio of less than three times the gross domestic product (GDP) per capita as cost-effective (WHO Commission on Macroeconomics and Health, 2001). Based on this, three broad categories are defined here. Interventions that gain each year of healthy life (e.g. DALY averted) at a cost less than the GDP per capita are defined as very cost-effective. Those averting each DALY at a cost between one and three times GDP per capita are cost-effective, and the remainder are not cost-effective. Both univariate and multivariate sensitivity analyses were performed on key parameters to determine the robustness of model results.

Results

Screening for hearing impairment in combination with the provision of hearing aids

Table 4 shows the number of individuals fitted with hearing aids, costs, health effects, and cost effectiveness of the different screening strategies in both regions considered (here, screening strategies refer always to screening in combination with the

Table 4. Cost, health effects and cost-effectiveness of screening and provision of hearing aids

Intervention	Number of people treated (mln)*	Costs (mln I$)				Effectiveness (mln DALYs averted)	Cost-effectiveness	
		Patient	Programme	Training	Total		ACER (I$ per DALY saved)	ICER (I$ per DALY saved)
Afr-E								
Screening at primary school	2.55	851.36	68.12	0.84	920.32	0.58	1,581	Dominated
Screening at secondary school	0.94	347.29	68.12	0.84	416.25	0.31	1,347	1,347
Screening at prim. and second. school	3.36	1179.09	68.12	0.84	1248.05	0.87	1,428	1,472
Screening in community, every 5 years	8.96	3434.16	68.12	0.84	3503.12	2.95	1,186	1,244
Screening in community, every 10 years	5.28	1887.82	68.12	0.84	1956.78	1.64	1,191	Dominated
Passive screening	2.39	667.08	24.69	0.00	691.77	0.07	998	998
Sear-D								
Screening at primary school	3.44	982.38	101.81	2.28	1086.47	0.83	1,315	Dominated
Screening at secondary school	1.77	557.55	101.81	2.28	661.64	0.61	1,079	1,079
Screening at prim. and second. school	4.93	1503.41	101.81	2.28	1607.50	1.40	1,148	1,201
Screening in community, every 5 years	45.77	15336.80	101.81	2.28	15440.89	11.92	1,295	1,343
Screening in community, every 10 years	26.90	8448.74	101.81	2.28	8552.83	6.62	1,292	Dominated
Passive screening	8.13	2057.86	35.45	0.00	2093.31	1.99	1,053	1,053

*In total over a period of 10 years. Some people have been treated early in this period and thus benefit longer, whereas others were treated later in the period, and thus benefit shorter.

provision of hearing aids to eligible individuals). The number of individuals fitted varies between regions and screening strategies, and depends on population size, prevalence of hearing impairment, and the attendance (e.g. school enrolment rates). In both regions, screening of primary school children leads to the treatment of a higher number of children compared to screening of secondary school children, e.g. 8.5 million vs. 3.5 million children in Afr-E. Screening of adults in the community every five years leads to the treatment of almost double the number treated compared to screening every ten years (e.g. 37 million vs. 21 million in Afr-E). In case of passive screening, assumed to cover 15% of the population over ten years, nine million individuals are treated in Afr-E.

Screening costs vary between regions and screening strategies, and depend on the number of individuals screened, the number of individuals treated, and regional price levels. In both regions, screening at secondary schools is less costly compared to screening at primary schools. Screening in the community every five years is almost double the costs of screening the same group every ten years. Costs per individual treated range between strategies, e.g. between I$290 (passive screening) and I$444 (screening at secondary school) in Afr-E (not in Table).

Health effects also vary between regions and screening strategies, primarily depending on the number of individuals treated, and therefore following the same pattern as described above. In both regions, screening at primary school yields more health effects than screening at secondary school. Screening in the community every five years yields almost double the health effects compared to screening the same group every ten years. Health effects per child treated are highest for screening at secondary school compared to screening at primary school (0.33 vs. 0.23 DALY) and this difference is mainly due to the concept of age-weighting in which older children receive higher weights than younger children (not in Table).

The expansion path shows the order in which interventions should be introduced according to their cost effectiveness. In both regions, passive screening is the most cost-effective intervention, with the cost per DALY averted ranging from I$998 per DALY averted in Afr-E to I$1053 per DALY averted in Sear-D. Costs of all screening interventions range between I$1079 and I$1472 per DALY in the two regions. At community level, screening every five years is slightly most cost-effective than screening every 10 years. Screening at secondary schools only is slightly more cost-effective than at primary schools only. Alternative model assumptions on the calculation of DALYs (without discounting and/ or age weighing), catchment area per primary health-care workers, and ratio of false positives to true positives do affect cost-effectiveness results, but only in the margin (Table A3). The exception is the assumption on the useful life of hearing aids, which when halved from four to two years, almost doubles the cost-effectiveness ratio.

Treatment of chronic otitis media (COM)

Table 5 shows the number of children treated for COM, costs, effects, and cost effectiveness of the different treatment strategies in both regions considered. The number of children treated varies between regions and treatment strategies, and depends on population size, prevalence of COM, and the effectiveness of the treatment strategy. For example, the number of children treated with aural toilet alone versus aural toilet and topical antibiotics

Table 5. Cost, health effects, and cost-effectiveness of interventions targeting COM-related hearing loss

			Costs (I$)				*Effectiveness (DALYs averted)*	*Cost-effectiveness*	
	Intervention	*Number of people treated in ten-year period*	*Patient*	*Programme*	*Training*	*Total*		*ACER (I$ per DALY saved)*	*ICER (I$ per DALY saved)*
Afr-E	Aural toilet 50%	336 620	1 513 613	390 608	0	1 904 221	135 585	14	Dominated
	Aural toilet 80%	538 592	2 617 965	390 608	0	3 008 572	182 058	17	Dominated
	Aural toilet 95%	639 578	3 707 196	390 608	0	4 097 804	199 391	21	Dominated
	Aural toilet and topical antibiotics 50%	221 138	2 272 314	390 608	0	2 662 922	215 181	12	12
	Aural toilet and topical antibiotics 80%	353 820	3 214 363	390 608	0	3 604 970	256 567	14	23
	Aural toilet and topical antibiotics 95%	420 162	3 969 504	390 608	0	4 360 112	269 350	16	59
Sear-D	Aural toilet 50%	943 733	4 272 389	862 121	0	5 134 510	443 385	12	Dominated
	Aural toilet 80%	1 509 972	5 993 253	862 121	0	6 855 374	595 047	12	Dominated
	Aural toilet 95%	1 793 092	7 092 590	862 121	0	7 954 711	651 552	2	Dominated
	Aural toilet and topical antibiotics 50%	619 715	6 643 112	862 121	0	7 505 233	702 999	11	11
	Aural toilet and topical antibiotics 80%	991 544	8 414 410	862 121	0	9 276 531	837 682	11	13
	Aural toilet and topical antibiotics 95%	1 177 459	9 298 138	862 121	0	10 160 259	879 229	12	21

(both at 50% coverage) is 337 000 versus 221 000; the latter treatment is more effective, and thus reduces the number of children who may need treatment in future years.

Treatment costs vary between regions and treatment strategies, and depend on the number of children treated, and regional price levels. In both regions, aural toilet alone is costing less than when combined with topical antibiotics (e.g. I$1 904 000 versus I$2 663 000 in Afr-E, at 50% coverage level). Costs per individual treated range between strategies, e.g. between I$7 (aural toilet alone) and I$10 (aural toilet and topical antibiotics) in Afr-E (not in Table).

Health effects also vary between regions and screening strategies, primarily depending on the effectiveness of the treatment strategies. In both regions, aural toilet alone yields less health effects than when combined with topical antibiotics (e.g. 136 000 vs. 215 000 DALYs averted in Afr-E, at 50% coverage level). Health effects per child treated follow the same pattern (0.40 versus 0.79 DALY averted per child treated in Afr-E, at 50% coverage level (not in Table).

In both regions, the expansion path shows that aural toilet alone in combination with topical antibiotics is most cost-effective, with the cost per DALY averted ranging from I$11 per DALY averted in Sear-D to I$12 per DALY averted in Afr-E, at 50% coverage level. If more resources are available, increasing coverage costs less than I$20 (Afro-E) to I$59 (Sear-D) per DALY averted.

Treatment of meningitis

Table 6 shows the number of children treated for meningitis, costs, effects, and cost effectiveness of the different treatment strategies in both regions considered. The number of individuals treated varies between regions and treatment strategies, and depends on population size, prevalence of meningitis, and geographic coverage level. Treatment costs vary between regions and treatment strategies, and mainly depend on the number of individuals treated (i.e. geographic coverage level), and regional price levels. In both regions, ceftriaxione is costing less at the 50% coverage level than at a higher coverage level. Costs per individual treated range between regions, e.g. between I$15 in Afro-E and I$16 Sear-D at 50% coverage level (not in Table).

Health effects also vary between regions and coverage levels. Treatment saves around 1 million DALYs in Afro-E, and 5.6 million DALYs in Sear-D (coverage level of 50%). Health effects per treated individual are higher in Sear-D (0.23 DALY) than in Afro-E (0.08) (not in Table). The expansion path shows the order in which interventions should be introduced according to their cost effectiveness. In both regions, treatment at 50% coverage is most cost-effective, with the cost per DALY averted ranging from I$55 per DALY averted in Sear-D to I$217 per DALY averted in Afr-E. Cost per DALY increases for higher coverage levels (up to I$3066 and I$244 per DALY, in respectively Afro-E and Sear-D).

In more absolute terms, all interventions in the three considered sets are cost-effective strategies according to CMH classification, in both regions concerned For example, Afr-E has a GDP per capita of I$1576 (http://www.who.int/choice/costs/CER_levels/en/index.html), and the cost-effectiveness of the vast majority of interventions is very well below the one-time GDP per capita level.

Discussion

Hearing impairment causes a major disease burden among children around the world, and this study has shown that various intervention strategies are economically attractive interventions to reduce this disease burden.

Among the three sets of interventions considered, screening for hearing impairment and the provision of hearing aids is most important in terms of its potential to reduce the burden of disease of hearing impairment. Analysis shows that passive screening is most cost-effective, and is the preferred option in case of limited budgets. When more resources would become available, active screening strategies would also be efficient investments, and given their similar cost-effectiveness results, it is difficult to derive recommendations on the order of implementation of the different screening strategies concerned at schools, or in the community. Overall, with a cost of around I$1000 per DALY averted, all interventions can be considered cost-effective according to CMH standards (WHO Commission on Macroeconomics and Health, 2001). Results are similar to those reported in a study on school-based screening in China (Baltussen et al, 2008). As a result, all interventions can be considered economically attractive, and should—on the basis of economic grounds—be considered for implementation.

Table 6. Cost, health effects and cost-effectiveness of interventions targeting meningitis

		Costs (mln) I$)					*Cost-effectiveness*	
Intervention	*Number of people treated in ten-year period (mln)*	*Patient*	*Programme*	*Training*	*Total*	*Effectiveness (DALYs averted)*	*ACER (I$ per DALY saved)*	*ICER (I$ per DALY saved)*
Afr-E								
Ceftriaxione 50%	13,51	188,06	32,99	0	221,05	1,02	217	217
Ceftriaxione 80%	15,1	252,75	32,99	0	285,75	1,09	263	959
Ceftriaxione 95%	15,69	324,04	32,99	0	357,03	1,11	322	3,066
Sear-D								
Ceftriaxione 50%	19,72	272,46	39,74	0	312,2	5,59	56	56
Ceftriaxione 80%	21,91	305,55	39,74	0	345,29	5,92	58	100
Ceftriaxione 95%	22,71	333,6	39,74	0	373,34	6,04	62	244

COM causes less than 1% of the total burden of hearing impairment. The most efficient option for the treatment of COM to reduce hearing impairment is aural toilet in combination with topical antibiotics, with cost per DALY ranging between I$11 and I$59 in both regions. These interventions can be considered cost-effective. Our analysis only included the impact of treatment on hearing impairment, which constitutes 19% of the total burden of otitis media. As a result, we are likely to have underestimated the economic attractiveness of treatment of COM in improving the health status of individuals beyond hearing impairment.

Meningitis causes little more than 1% of the total burden of hearing impairment. Treatment with ceftriaxone is a cost-effective intervention, with cost per DALY between I$55 and I$959 per DALY in both regions (except for treatment at 95% coverage level in Afr-E). Also here, our analysis only included the impact of treatment on hearing impairment, which constitutes 7% of the total burden of meningitis. As a result, we are likely to have underestimated the economic attractiveness of treatment of meningitis in improving the health status of individuals beyond hearing impairment.

A number of observations should be taken into account when interpreting the results. First, the interventions considered only comprise a small selection of all possible intervention options in hearing impairment control. Other interventions, e.g. education, rehabilitation and noise conservation programmes, neonatal screening, surgical interventions, and cochlear implants are not evaluated here because of lack of data on burden of disease and/or intervention effectiveness in a developing country context. Policy makers should be aware of this, and should not limit their choice of interventions to those included in this analysis. Second, in the absence of strong evidence on the association between hearing impairment and excess mortality, and following the WHO burden of disease study on this (Mathers et al, 2005; Smith & Mathers, 2006), we assumed no case-fatality related to hearing impairment. This may have underestimated the resulting health effects. Third, we modelled COM assuming that all individuals who failed treatment would present themselves again for the same treatment. The result is that, in our analysis, relatively many more individuals receive treatment for aural toilet (which is less effective) compared to aural toilet in combination with topical antibiotics (which is more effective) (102 000 versus 65 000 individuals in Afr-E). It is not known whether this reflects reality. Fourth, our analysis estimates health effects in terms of DALYs averted, and the use of this summary measure of population health includes the concept of age-weighing in which health gains for older children receive higher weights than those for younger children. This seems not in line with the importance of early detection during the first 12–18 months of life to avoid hearing loss during the critical period of language development. However, sensitivity analyses showed that presenting results without age-weighing does not change study conclusions. Fifth, we evaluated the use of neomycin-polymyxin-steroid (nps) otic drops as topical antibiotics in the treatment of COM. A recent trial evaluated the use of ciprofloxacin, which turned out to have a comparable effectiveness (59% vs. 58% for nps) but comes at a higher cost (Macfadyen et al, 2005). Detailed economic analysis can show which treatment is more efficient. Sixth, we carried out analyses for geographic coverage levels as high as 95%, which may not be achievable in reality. However, these levels are standardized WHO-CHOICE coverage levels, and provide a standard for comparison for costs and effects between different disease programmes (including those that can be delivered at those high coverage levels). Seventh, sensitivity analysis on screening and provision of hearing aids showed that alternative study assumptions did, in general, not have a large impact on study results. The exception was the assumption on the useful life of hearing aids which, when changed from four to two years, almost doubles the cost-effectiveness ratios. The interventions can still be classified as cost-effectiveness according to CMH thresholds (WHO Commission on Macroeconomics and Health, 2001). Eighth, some of our cost estimates on the screening and provision of hearing aids are based on resource inputs obtained from a study in China (but with price levels adjusted to the regions under study). However, sensitivity analysis revealed that alternative assumptions did not change study conclusions.

Study results are expressed in terms of international dollars (I$), and can be converted to US dollars (US$) using a conversion factor. For example, for Tanzania, this conversion factor equals 0.45 for the year 2000, and the cost-effectiveness of screening at secondary school can hence be considered as either I$1347 per DALY averted, or US$613 per DALY averted (Tan Torres et al, 2003).

This study has made available crude estimates of costs and effects of interventions in hearing-impairment control at the world sub-regional level; more detailed estimates can only be made when analyses are contextualised at the country level, taking into account the local socio-economic, epidemiologic, and behavioural situation (Hutubessy et al, 2003). However, considering the conservative study assumptions and the robustness of study conclusions towards changes in these assumptions, we believe that the interventions considered, i.e. screening for hearing impairment in combination with the provision of hearing aids, and treatment of meningitis and COM, remain economically attractive in all regions in the world.

Conclusion

Various intervention strategies are economically attractive to reduce the disease burden of hearing impairment around the world.

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Appendix A

Screening and provision of hearing aids

Background

Sensorineural hearing loss is the most common type of hearing loss, and results from damage to the cochlea or the auditory nerve. Common causes include advanced age, and noise exposure. This type of hearing problem is usually permanent and requires rehabilitation, such as with a hearing aid.

Epidemiology

Table 1 summarizes the burden of adult onset hearing loss due to ageing and noise exposure (excluding hearing loss due to congenital causes, infectious diseases, other diseases or injury). Prevalence and incidence data are based on WHO burden of disease data (Mathers et al, 2005; Smith & Mathers, 2006). Incidence rates of age groups 0–4 and 5–14 are based on own models, using DISMOD software (Barendregt et al, 2003).

Interventions

We analysed screening of school children, and hereby differentiate between screening of school children at primary school (at primary school entry, all five year olds, every year), and at secondary school (at secondary school entry, all 11 year olds, every year): the incidence and prevalence of these age-groups is identical, but the primary school enrolment rate is higher. This will render screening at primary school more effective, and thus more cost-effective. In addition, we analysed screening of adults (15 years and older) in the community, and hereby differentiate between screening with 5-year intervals and 10-year intervals: although the use of the shorter intervals improves identification of hearing disorders, it also increases costs, and it is therefore not clear which strategy is most cost-effective. Also we analysed passive screening of children and adults in the community.

This leads to the identification of six alternative screening strategies:

1. Active screening of primary school children (age 5 years), at one-year interval;
2. Active screening of secondary school children (age 11 years), at one-year interval;
3. Active screening of both primary and secondary school children (ages 5 and 11), at one-year interval;
4. Active screening of adults of 15 years and older in the community, at five-years interval;
5. Active screening of adults of 15 years and older in the community, at ten-years interval;
6. Passive screening of children and adults in the community. We assumed that 15% of all eligible people present themselves over the period of ten years.

All screening strategies are combined with the provision of hearing aids for eligible people. Interventions 1, 2, and 3 are mutually exclusive, as well as interventions 4 and 5.

Screening and delivery model

Screening for hearing impairment and delivery of hearing aids can take different shapes. Following the WHO guidelines for hearing aids and services in developing countries (WHO 2004a), we assumed that the target population (here the school children and the community, respectively) is screened by trained primary health workers. Trained primary health workers are primary health workers who have received an initial three-week training course in the community followed by supervision, networking, and refresher courses (WHO 2004a). We assumed that one screening team (consisting of a trained primary health worker, accompanied by a driver) can annually screen 50 000 school children/adults (depending on the intervention under study). In the sensitivity analysis, we assumed one primary health-care worker per 25 000 children. The costs of screening an individual in the community are assumed equal to those of screening one school child.

Eligible individuals are then referred to the secondary level hospital for further consultation, according to a set protocol. At the first visit, individuals receive a physical and a hearing examination. Individuals are referred in cases where disorders are not treatable with hearing aids. If eligible for hearing aids, an ear mould is taken. In a second visit, the hearing aid is fitted. The individual is followed up during two visits at, respectively, three weeks and three months. We assumed that all consultations are carried out by audiologists, and ear moulds are taken and prepared by an ear mould technician. Resource utilization patterns of the outpatient visits, the audiologist, ear mould technician, hearing aids, related material and equipment costs for mould taking and making, and of two follow-up visits are based on data collected in China (Baltussen et al, 2008). We assumed that the hearing aids have a useful life of four years, after which the individual goes through the same procedure (minus the screening) to fit the next hearing aid (in the sensitivity analysis, we assumed a useful life of respectively two and six years).

We assumed an arbitrary number of one false-positive individual for each true-positive individual (in the sensitivity analysis, we assumed a false-positive rate of two) (personal communication, A. Smith). The false-positive individuals receive a first consultation including hearing tests.

We assumed supervision, monitoring, and evaluation activities of the school by the national and province level (labelled program costs). Training costs are an important component of the screening program, and we assumed to train each primary health-care worker for one day (Adam et al, 2003).

Costs

Table A1 provides the detailed inputs for the screening and treatment costs per patient fitted with a hearing aid for the screening program in the community (every 10 years). Program and training costs are based on WHO-CHOICE standardized templates (Johns et al, 2003). Unit costs for non-traded goods are based on the WHO-CHOICE costing database. Unit costs for traded goods are based on costs as observed in China (Baltussen et al, 2008), and are converted into I$ using the official exchange rate.

Model design

The starting point of analysis is the WHO burden of disease data for child and adult-onset hearing impairment, as presented in Table 1. We then modelled the impact of screening through the remission rate, taking into account (1) geographic coverage of the intervention; (2) attendance for the intervention; and (3) compliance to wearing the hearing aid. Following WHO-CHOICE standards, we assumed a geographic coverage of 95% for all interventions. Attendance at schools was based on regional primary and secondary school enrolment rates, and at the community assumed to equal 70% (Table A2). Lack of compliance in use is a substantial problem everywhere among elderly and child users, including in developing countries (Furuta & Yoshino, 1998). We assumed, arbitrarily, a compliance rate of 70% of wearing hearing aids in a period of four years (personal communication, Dr. A. Smith). We assumed that hearing aids reduce the health state valuation to the next higher level (health state valuations are provided in the main text).

Appendix B

Chronic otitis media

Background

COM produces mild to moderate conductive hearing loss in more than 50% of cases (WHO, 2004c). This results from disruption of the eardrum and ossicles assembly (conductive hearing loss) or from hair cell damage by bacterial infection that has penetrated the inner ear (sensory hearing loss), or both (mixed hearing loss). Because of its long duration and greater severity compared with acute otitis media, and because most children need louder auditory stimuli than adults to perform optimally, COM in children is likely to inhibit language and cognitive development (WHO, 2004c).

Epidemiology

WHO has estimated the burden of disease of childhood-onset hearing loss as a sequelae of otitis media. The global burden of otitis media-induced hearing impairment equals 277 000 DALYs in 2000, which is two-thirds of the equivalent burden of hearing impairment from meningitis, 19% of the total burden of otitis media, and 0.83% of the total burden of hearing impairment. This burden of otitis media occurs overwhelmingly in the developing world, with developing countries experiencing 91% of the global burden (Smith & Mathers, 2006). Otitis media refers here to both acute and chronic otitis media. We assume here that all cases of hearing loss attributed to otitis media, stem from COM. Table 2 proves an overview of the incidence and prevalence of hearing loss from COM.

Interventions

A systematic review of randomized controlled trials in the Cochrane Library, and summarized elsewhere (WHO, 2004c) shows the results of the best available evidence with regard to the most appropriate management of COM. There is general agreement that aural toilet must be part of the standard medical treatment for COM. Cleaning the ear of mucoid discharge could reduce, even if temporarily, the quantity of infected material from the middle ear and could facilitate middle-ear penetration of topical antimicrobials. The addition of topical antibiotics to aural toilet was associated with a 57% rate of otorrhoea resolution, compared to 27% with aural toilet alone (WHO, 2004c). However, because of the limited extra costs associated with the use of topical antibiotics, it is not clear which intervention is most efficient.

For this reason, this study compares these two alternative management options for CSOM, and its impact on hearing impairment. The target group is children from 0–14 years. The following interventions are distinguished:

1. Aural toilet alone, 50% coverage
2. Aural toilet alone, 80% coverage
3. Aural toilet alone, 95% coverage
4. Aural toilet plus topical antibiotics, 50% coverage
5. Aural toilet plus topical antibiotics, 80% coverage
6. Aural toilet plus topical antibiotics, 95% coverage

Treatment and delivery model

We assumed that all interventions require one visit at a primary level health centre. In case of aural toilet alone, the child is provided ear wicking materials for two weeks. In case of topical antibiotics, the child is given one bottle of neomycin-polymyxin-steroid otic drops (US$2.50) (the drugs included in our analysis relate to the clinical trials on which the effectiveness data are based) (WHO, 2004c).

Model design

The starting point for the model is the incidence and prevalence rates as provided in Burden of Disease study (Mathers et al. 2005; Smith & Mathers 2006). Successful treatment for CSOM was modelled through the remission rate. The Cochrane review estimates that aural toilet results in 26 dry ears/100 patients treated. Aural toilet plus topical antibiotics results in 48–66 dry ears/100 patients treated (depending on the clinical study)—we assumed a result of 58 dry ears/100 patients treated in our analysis.

Costs

WHO estimated costs of aural toilet alone as US$0.30 per patient treated, and that of aural toilet plus topical antibiotics as US$0.30 + US$2.50 = US$2.80 per child treated (WHO 2004c, ERC 2008). We assumed limited administration costs at the national level, and no training costs (Johns et al, 2003).

Appendix C

Meningitis

Background

Meningitis remains a major public health challenge, especially in many African countries. Moderate and severe hearing impairment (with the same definition as used elsewhere in this paper) due to meningitis is included as one of the sequelae of meningitis in the WHO burden of disease estimates (Smith & Mathers 2006).

Epidemiology

The global burden of meningitis-induced hearing loss is 411 000 DALYs, which is 7.1% of the global burden for all sequelae of meningitis, and 12% of the total burden of child- and adult-onset hearing loss. This burden for meningitis occurs overwhelmingly in the developing world, with developing counties experiencing more than 96% of all the disease burden. By far the largest burden is in South-east Asia, followed by Africa and Latin America (Smith & Mathers 2006). Table 3 provides an overview of the incidence and prevalence of meningitis-induced hearing impairment

Interventions

WHO has defined recommendations for treatment of meningitis in Africa, in epidemic and non-epidemic situations (WHO, 2007). We define our interventions on the basis of these recommendations, for non-epidemic situations. Ideally, WHO writes, in a non-epidemic situation, lumbar puncture and laboratory identification of the bacteria in cerebrospinal fluid (CSF) should be done systematically to guide antibiotic treatment. However, WHO acknowledges that laboratory investigation of suspected meningitis cases is often unavailable, and treatment should be adapted to the most probable causative pathogen. This is the procedure we assume for the regions under study. Ceftriaxone is the recommended treatment for bacterial meningitis in many developed countries, and with the expiry of the patent, also for developing countries. We assume Ceftriaxone (100 mg/ kg/day – max 2 g, once daily for five days intramuscular injection) at US$2.70 per course (30).

1. Ceftriaxone, at 50% coverage level
2. Ceftriaxone, at 80% coverage level
3. Ceftriaxone, at 95% coverage level

The target group is the whole population with suspected meningitis, and coverage levels are achieved over a period of ten years. Following WHO recommendations (WHO 2007), we assume four visits at the primary health-care level (clinical assessment, and reassessment at 24 h, 36 h, and 48 h).

Model design

The starting point for the model is the incidence and prevalence rates for meningitis as a whole, as provided in the burden of disease study. Treatment of these cases may lead to the prevention of fewer cases of hearing impairment (as not every case of meningitis leads to hearing impairment). Successful treatment for CSOM was modelled through the remission rate. We assume Ceftriaxone to be 100% effective in the treatment of meningitis, and that the whole burden of meningitis-induced hearing impairment can thus be prevented by early treatment (taking into account coverage levels).

Costs

Costs of Ceftriaxone (100 mg/ kg/day: five days intramuscular injection) are US$2.70 per course (ERC, 2008). Costs of intramuscular injection are that of equipment (one syringe, one needle, one cotton ball), and equal US$0.35 (Adam et al, 2003). We assume four health-centre visits (at first level). We assume costs of administering the programme at national level, and supervision and monitoring and evaluation activities at the national and province level (Johns et al, 2003).

Table A1. Resource utilization, unit costs, and total costs of community-based screening program and fitting of hearing aids, Afro-E*

1. *Fixed costs*			
*Volume of mobile screening teams***			
One screening team per population	50,000		
Population of 15 years and older	94,174,925		
Required number of mobile screening teams	1,883		
Costs of mobile screening teams	Quantity	Unit costs (I$)	Costs (I$)
Trained primary health worker (FTE)	1	6106	6106
Driver (FTE)	1	4765	4765
Per diem trained primary health worker (per day)	240	76	18,246
Per diem driver (per day)	240	50	12,091
Portable audiometer	1	170	170
Otoscope	1	11	11
Transport costs (per day)***	240	5	1,138
Total cost per hearing team			42,526
Total fixed cost (a)			80,097,623
Average fixed costs			
Total cases treated			
Coverage (b)		95%	
Attendance (c)		70%	
Prevalence (d)		12,249,477	
Treated (e) = (b) x (c) x (d)		8,145,902	
Average fixed cost (f)		(a)/(e)	10
2. *Variable costs* Personnel (hours)****	*Quantity*	*Unit costs (I$)*	*Costs (I$)*
Audiologist (1st visit)	1.06	23,415	12.93
Audiologist (2nd visit)	0.70	23,415	8.54
Audiologist (3rd visit)	1.00	23,415	12.20
Audiologist (4th visit)	1.00	23,415	12.20
Ear mould technician (1st visit, taking mould)	0.73	8,806	3.35
Ear mould technician (making mould)	2.27	8,806	10.41
Ear mould technician (2nd visit, fitting mould)	0.15	8,806	0.69
Hearing test technician (1st visit)	0.73	8,806	3.35
Hearing test technician (2nd visit)	0.48	8,806	2.20
Hearing test technician (3rd visit)	0.50	8,806	2.29
Hearing test technician (4th visit)	0.50	8,806	2.29
Total (g)			70.44
Equipment			
Pure tone audiometer (per patient screened)	1	5.21	5.21
Equipment for taking mould	1	0.02	0.02
Equipment for making mould	1	13.34	13.34
Hearing aid	1	76.00	76.00
Computer and Hi-Pro software	1	1.85	1.85
Hearing test room	1	2.83	2.83
Total (h)			99.26
Materials			
Materials for taking mould impression	1	0.78	0.78
Materials for making mould	1	6.49	6.49
Battery provision	1	1.00	1.00
Battery provision at three months	1	1.00	1.00
Total (i)			9.26

Outpatient visits (hours)		*Costs*	
1st visit	1.06	15.01	15.91
2nd visit	0.70	15.01	10.50
3rd visit	1.00	15.01	15.01
4th visit	1.00	15.01	15.01
Total (j)			56
Ratio of false-positive to true-positive patients	1		
Average variable costs (k) *****	(g)+(h)+(i)+(j)	276	

* On the basis of a screening program every 10 years.
** Screening teams consists of a trained primary health worker and a driver
*** Assuming travelling a distance of 50 km per day
**** Unit costs are annual salaries
***** Including first consultation costs for false positive patients

Table A2. School enrolment rates*

Region	*Primary school*	*Secondary school*
Afr-E	63%	27%
Sear-D	77%	42%

* Weighted averages of country-specific rates, for most recent available years. Source: UNICEF (2008)

Table A3. Sensitivity analysis for analysis of screening and provision of hearing aids in Afr-E.

Intervention	*Costs (mln I$)* Total	*Effectiveness (mln DALYs averted)*	*Cost-effectiveness* ACER (I$ per DALY saved)	ICER (I$ per DALY saved)
Discounting, no age-weighing				
Screening at primary school	920.32	0.57	1,611	Dominated
Screening at secondary school	416.25	0.23	1,822	1,822
Screening at prim, and second, school	1248.05	0.79	1,588	1,491
Screening in community, every 5 years	3503.12	2.52	1,390	1,390
Screening in community, every 10 years	1956.78	1.40	1,394	Dominated
Passive screening	691.77	0.59	1,179	1,179
No discounting, no age-weiging				
Screening at primary school	920.32	0.71	1,296	Dominated
Screening at secondary school	416.25	0.28	1,474	1,474
Screening at prim, and second, school	1248.05	0.97	1,281	1,201
Screening in community, every 5 years	3503.12	3.09	1,133	1,243,122
Screening in community, every 10 years	1956.78	1.73	1,132	1,132
Passive screening	691.77	0.73	954	954
One trained primary health worker per 25,000 children				
Screening at primary school	920.77	0.58	1,582	Dominated
Screening at secondary school	416.43	0.31	1,347	1,347
Screening at prim, and second, school	1248.66	0.87	1,428	1,473
Screening in community, every 5 years	3503.55	2.95	1,186	1,186
Screening in community, every 10 years	1956.91	1.64	1,191	Dominated
Passive screening	691.77	0.07	998	998
Useful life of hearing aid two years				
Screening at primary school	1664.80	0.58	2,860	Dominated
Screening at secondary school	740.74	0.31	2,397	2,397
Screening at prim, and second, school	2265.58	0.87	2,592	2,698
Screening in community, every 5 years	6685.01	2.95	2,263	2,263
Screening in community, every 10 years	3675.74	1.64	2,236	Dominated
Passive screening	1295.86	0.07	1,869	1,869
Screeing ratio of false positive to true positive: two				
Screening at primary school	1065.67	0.58	1,831	Dominated
Screening at secondary school	496.34	0.31	1,606	1,606
Screening at prim, and second, school	1435.82	0.87	1,643	1,662
Screening in community, every 5 years	4025.85	2.95	1,363	1,363
Screening in community, every 10 years	2194.73	1.64	1,335	Dominated
Passive screening	667.08	0.07	962	962