

Global hearing health care: new findings and perspectives



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In 2015, approximately half a billion people had disabling hearing loss, about 6·8% of the world's population. These numbers are substantially higher than estimates published before 2013, and point to the growing importance of hearing loss and global hearing health care. In this Review, we describe the burden of hearing loss and offer our and others' recommendations for halting and then reversing the continuing increases in this burden. Low-cost possibilities exist for prevention of hearing loss, as do unprecedented opportunities to reduce the generally high treatment costs. These possibilities and opportunities could and should be exploited. Additionally, a comprehensive worldwide initiative like VISION 2020 but for hearing could provide a focus for support and also enable and facilitate the increased efforts that are needed to reduce the burden. Success would produce major personal and societal gains, including gains that would help to fulfil the "healthy lives" and "disability inclusive" goals in the UN's new 2030 Agenda for Sustainable Development.

Introduction

Results from the most recent Global Burden of Disease (GBD) Studies¹⁻³ indicate a growing, and now alarmingly high, burden of hearing loss. Analyses of the results to enable direct comparisons across the studies show that hearing loss was the 11th leading cause of years lived with disability (YLDs) in 2010 and the fourth leading cause in both 2013 and 2015 (appendix pp 2-3). Moreover, the prevalence of disabling hearing loss is far greater today than in 1985 when the first estimates for all world regions were published.⁴ As noted in a recent editorial in *The Lancet*,⁵ hearing loss has become a major concern for global health.

In this Review we aim to provide the detailed information that decision makers need to position hearing loss optimally among health-care priorities; present best practices for hearing health care; indicate the many additional changing conditions for hearing health care worldwide; and offer our and others' recommendations for first halting the growth in the burden of hearing loss, and then reducing it.

Although awareness of hearing loss and its sequelae is increasing, prevention and treatment are still not regarded as urgent needs in many countries, especially in low-income and middle-income countries (LMICs) where scarce resources force difficult choices. Hearing loss has been and remains in some places the "invisible disability" that can all too easily be set aside in favour of attention to other health problems.⁶ And yet, new and earlier data indicate that the consequences of not allocating resources for at least targeted prevention and treatment of hearing loss are dire, both in personal and societal terms. Therefore, in this Review we also consider choices to maximise benefit-to-cost ratios for fixed budgets and for budgets that might be increased with changing priorities or the rapidly improving economies in many LMICs.

Global burden of hearing loss

Impact of losses in hearing

The reach of hearing loss extends far beyond sensory impairment.⁷⁻⁹ The absence or substantial attenuation of auditory input to the brain alters brain connectivity and

processing,⁸⁻¹² especially before about age 3 years⁹ and perhaps again after about age 60 years.^{13,14} Hearing loss in those early years precludes or delays the acquisition of spoken language.^{10,15} Children with severe or worse losses in hearing have lower literacy than do their normally hearing peers,¹⁶ and their educational attainments are greatly compromised.^{17,18} Most adults with disabling hearing loss have a sense of profound isolation (appendix p 4), and they typically withdraw from society and even family interactions.^{7,19-21} Furthermore, relations within couples are often severely tested when one person in the couple has normal

Search strategy and selection criteria

We searched the Cochrane Library, PubMed, and Embase for relevant and high-quality references (eg, references that reported results from worldwide surveys). The start dates for the searches were 2004, 1988, and 1973, respectively, and the end dates all were in September, 2014, with supplemental searches of PubMed up to Oct 8, 2016. For the Cochrane search, we used the following logical combination of search terms: ("hearing loss" OR "deafness" OR "hearing health" OR "hearing aids" OR "audiology" OR "otolaryngology" OR "cochlear implant") AND ("education" OR "research" OR "early detection") AND ("developing countries" OR "global health"). The same terms were used for the PubMed searches except for the term "developing countries". For Embase, we used a similar search strategy but substituted the appropriate Emtree terms. With one important exception (WHO's resolution WHA48.9 from 1995), we selected publications from the past 15 years with a high emphasis on publications from the past 3 years. We also searched the reference lists in the identified publications for further potentially relevant references, and we remained vigilant to new publications in the specialty journals in the fields indicated by the search terms and in the broad-audience journals such as *The Lancet* that frequently publish papers in the field of global health. Suggestions for additional references from outside world experts (see Acknowledgments) were incorporated into our set of selected references for careful study.

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See Online for appendix

Key messages

- Hearing loss is the fourth leading contributor to years lived with disability worldwide
- This so-called invisible disability nonetheless has enormous economic and personal consequences, particularly in low-income and middle-income countries (LMICs) where more than 80% of people with hearing loss live
- Prevention is the most cost-effective way to reduce the high and growing burden of hearing loss; primary prevention could reduce prevalence by 50% or more in some world regions
- Treatment costs can be reduced with changes in service provision and the rules for provision, with bulk purchases, and with disruptive and parsimonious designs of hearing aids and cochlear implants
- Cost-effectiveness analyses can inform resource allocations to maximise value for money and prioritise interventions
- A comprehensive global programme could, with adequate funding and other support, halt and then begin to reverse the presently unchecked growth in the burden of hearing loss
- Much more funding and further efforts are needed to reduce the burden of hearing loss
- Investments to improve hearing health care worldwide would be especially effective; few if any other investments of the same magnitude could produce greater reductions in the global burden of disease

hearing and the other a disabling hearing loss.^{20,22} Many people with hearing loss try to hide it, because it is commonly associated with ageing and low intelligence.¹⁹ The stigma or perceived stigma can impede treatment and greatly diminish self esteem and self efficacy.^{19,23,24} Coping with hearing loss is difficult at best; not surprisingly, psychological illnesses are more prevalent for individuals with hearing loss than for those in the general population.^{25–29} Opportunities for people with disabling hearing loss are restricted,^{30–32} and usually severely so, because of the aforementioned factors and a sharply reduced or no ability to communicate using spoken language. In high-income countries, for instance, adults with disabling hearing loss have twice the prevalence of unemployment and half the median income of their normally hearing peers.³¹

These problems have obvious implications for society. A principal driver for economic vitality is an educated and healthy workforce.^{33–35} Additionally, the proportions of jobs that depend on spoken communication or high literacy or both are high and are growing rapidly worldwide.³¹ Thus for multiple reasons, emphasis on prevention and treatment of hearing loss is appropriate at both the national and international levels.

A growing number of significant associations have been shown between hearing loss in older people (aged ~60 years and older) and various negative health outcomes,^{11,13,14,27,36} including associations between hearing loss and dementia.^{13,14} Indeed, the hazard ratio for developing dementia increases two, three, and five times with mild, moderate, and severe losses in hearing, respectively.¹⁴

Of course, association is not causation. If in the future hearing loss is identified as a contributing cause of

dementia, detection and treatment of hearing loss in middle-aged and older adults (aged ~40 years and older) will become even more important, given the ageing of the world's population, the high prevalence of hearing loss among older adults, the rapidly increasing prevalence of dementia, and the high personal and societal costs of dementia (appendix p 5).³⁷

Prevalence and YLDs

Hearing loss typically is assessed by the average of thresholds for hearing sinusoids at the frequencies of 0.5 kHz, 1 kHz, 2 kHz, and 4 kHz; the thresholds are measured as decibels (dB) relative to the thresholds of unimpaired hearing. Averages of 20–34 dB, 35–49 dB, 50–64 dB, 65–79 dB, 80–94 dB, and 95 or more dB are mild, moderate, moderately severe, severe, profound, and complete losses, respectively. Losses of 35 dB and greater are regarded as disabling losses, although even mild losses can affect function adversely.

The figure shows aspects of hearing loss worldwide with data from GBD 2015. Prevalences were adjusted in the study according to estimated uses of hearing aids in the included 195 countries and territories and in subnational and supranational regions. Prevalences (and thus YLDs) would be higher without the adjustments (appendix pp 6–9). Inputs for GBD 2015 were limited in many cases—eg, data from surveys of hearing loss were available from only 31 countries and some of those surveys were done before 2005. Prevalences for the other countries and for all territories were imputed from the available survey results using sophisticated models; Smith and colleagues³⁸ have advocated additional surveys to provide up-to-date information and greater geographical coverage.

In broad terms, the data from GBD 2015 show that prevalence is higher for men and boys than for women and girls; prevalence increases sharply from age 20 years to 64 years; YLDs increase from age 35 years to 64 years; prevalence declines exponentially with increasing severities of loss; YLDs are greatest for losses of 20–64 dB; prevalence has increased across the years from 1990 to 2015; and YLDs trended upwards during the same period. The 95% uncertainty intervals for the data are much larger for the YLDs than for the prevalence measures, most likely because the uncertainty intervals for the disability weights used in the calculations for the YLDs also are quite large (appendix p 14). The difference in YLDs from 1990 to 2015 is not significant, whereas the difference in the prevalences is highly significant. The departures from the monotonic growths in prevalence and YLDs beyond age 64 years are principally due to changes in the population with age. The populations decline beyond age 64 years and women live longer on average than men. Additionally, the category of ages starting at 80 years includes all ages older than 80 years, whereas the other categories include only 5 years. These three

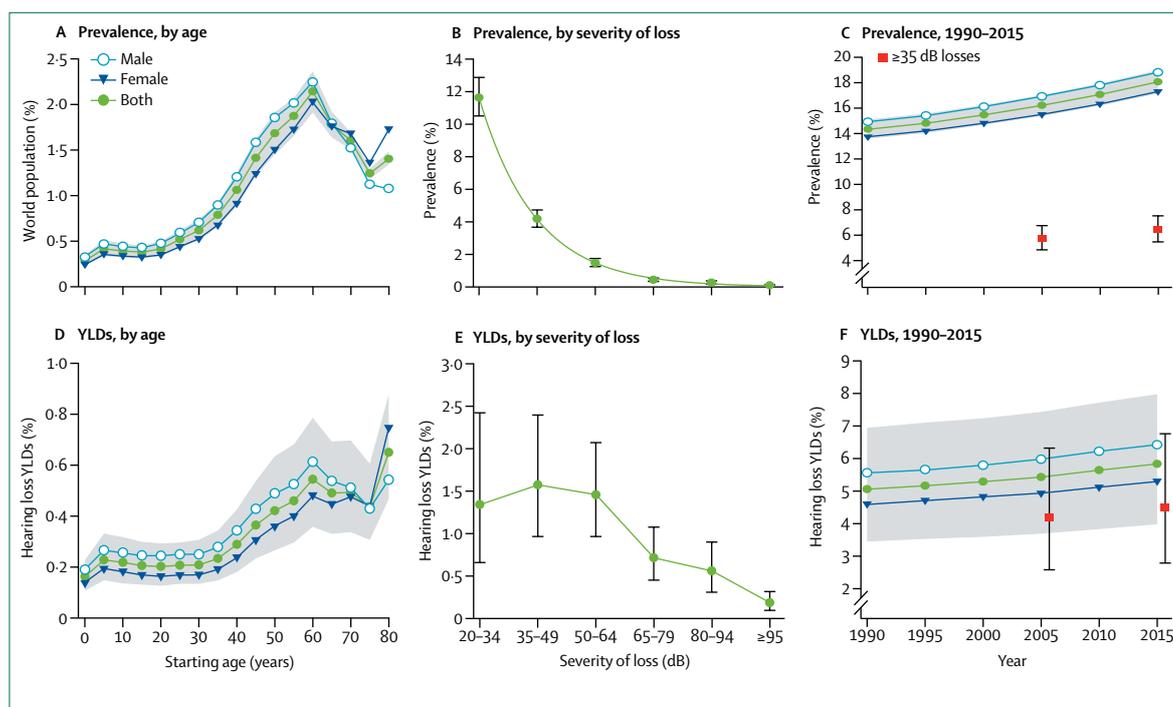


Figure: Aspects of hearing loss as shown by findings from GBD 2015

Prevalence of hearing loss for the world population according to age (A) severity of loss in dB (B), and year (C). Years lived with disability (YLDs) due to hearing loss as the percentage of YLDs due to all causes, according to age (D), severity of loss in dB (E), and year (F). Ages are recorded in 5-year ranges, except ages older than 80 years, which are grouped into one. Data are for losses of 20 dB or greater in hearing; in C and F, data for losses of 35 dB or greater (both sexes combined) also are shown. Data in B, C, E, and F are for all ages. Data are for 2015, except in C and F, in which data for additional years also are shown. Data in C are fit by a decaying exponential ($r > 0.99$, $p < 0.0001$). Grey shading and black bars show 95% uncertainty intervals.

factors together contribute strongly to the patterns seen in the left two graphs in the figure.

Central estimates of prevalence (ie, the junctures of the upper and lower uncertainty intervals) for both sexes combined increased from 14.33% to 18.06% of the world's population for all hearing loss (≥ 20 dB losses) from 1990 to 2015 (figure C). Furthermore, the estimates for disabling hearing loss increased from 5.73% in 2005 to 6.42% in 2015. For 2015, those percentages are equivalent to 1.33 billion people for all hearing loss and 473 million people with disabling hearing loss. Without the adjustments for estimated uses of hearing aids, these numbers would increase to about 1.34 billion and 498 million, respectively (appendix pp 6–9). Estimates published in 2013 from another study³⁹ are even higher—eg, the estimated prevalence of disabling hearing loss for individuals aged 5 years or older is 554 million. That adjustments for hearing aids were not used in the study could partly explain the higher numbers.

The YLDs that are due to hearing loss are high (figure F). In 2015 for both sexes combined, the central estimate of YLDs due to all hearing loss was 5.83% of the total YLDs due to all causes that year. Similarly, the central estimate of YLDs due to disabling hearing loss was 4.49% of the total. These high percentages indicate again and emphatically the (perhaps surprising) importance and burden of hearing loss as a global health concern.

Data for the years before 2015 were calculated in GBD 2015 with the then-current methods, disability weights, and survey results. The values from previous GBD studies are different, and in some cases markedly so, reflecting differences among the studies in inputs and methods. For example, the YLDs for all hearing loss reported in GBD 2010 were 2.57% of all YLDs, whereas the YLDs for all hearing loss reported for 2010 in GBD 2015 were 5.64% of the total.

In addition to the variations shown in the figure, prevalence and YLDs vary according to economic and sociodemographic indicators for different countries and regions (appendix pp 10–12). The data suggest that a high emphasis on prevention and treatment of childhood hearing loss would be most effective in reducing the burden of hearing loss in countries in the lower tiers of economic prosperity and sociodemographic indices, whereas special attention to adults would be most effective in the upper-tier countries.

The change in the rankings of YLDs due to hearing loss (from 11th in GBD 2010 to fourth in GBD 2013 and GBD 2015) is largely attributable to the updated disability weights first used in the GBD 2013.² The updates reflect an increasing appreciation of the importance of hearing loss for gauging overall health and wellbeing (appendix pp 13–14).

	Primary prevention	Secondary prevention	Tertiary prevention
Prenatal			
Rubella	Immunisation of girls	Early detection of hearing loss with universal or at least targeted screening; if possible, prompt intervention for the identified cases	Hearing aids, cochlear implants, or assistive listening devices or strategies according to severity of hearing loss; hearing rehabilitation; teach sign language to otherwise untreated children or children whose losses remain severe or worse after treatment with a hearing aid or cochlear implant; other special education for children who need it
Syphilis	Health education; treatment of the mother	As for rubella	As for rubella
Toxoplasmosis	As for syphilis	As for rubella	As for rubella
HIV infection	Health education; treatment	As for rubella	As for rubella
Iodine deficiency	Nutrition; diet supplementation	As for rubella	As for rubella
Hypertension	Health education	As for rubella	As for rubella
Ototoxicity	Avoidance or careful regulation of use	As for rubella	As for rubella
Genetic; family history of deafness	Health education; counselling; avoidance of consanguinity	As for rubella	As for rubella
Congenital anomalies	None	Surgery when warranted	As for rubella
Perinatal or neonatal			
Preterm; low birth weight	Nutrition; antenatal care	Early detection of hearing loss with universal or at least targeted screening; if possible, prompt intervention for the identified cases	Hearing aids, cochlear implants, or assistive listening devices or strategies according to severity of hearing loss; hearing rehabilitation; teach sign language to otherwise untreated children or children whose losses remain severe or worse after treatment with a hearing aid or cochlear implant; other special education for children who need it
Birth trauma; hypoxia	Improved birth practice	As for preterm	As for preterm
<i>Herpes simplex</i> infection	Timely caesarean section	As for preterm	As for preterm
Cytomegalovirus infection	Promotion of personal hygiene; health education	As for preterm	As for preterm
Severe jaundice	Detection of at-risk groups; screening for G6PD deficiency and blood group compatibility	As for preterm	As for preterm
Exposure to excessive incubator noise	Avoidance or reduction of the noise	As for preterm	As for preterm
Neonatal through adulthood			
Ototoxicity	Use of ototoxic drugs only when there are no alternatives and only for serious conditions	Systematic monitoring of serum levels and hearing during and after administrations of ototoxic drugs; alter therapeutic course if possible when losses in hearing are detected	Hearing aids, cochlear implants, or assistive listening devices or strategies according to severity of hearing loss; hearing rehabilitation; teach sign language to otherwise untreated children or children whose losses remain severe or worse after treatment with a hearing aid or cochlear implant; other special education for children who need it
Childhood through adulthood			
Impacted cerumen or foreign body	Promotion of good hygiene; avoidance of earbuds	Early recognition of disease and associated hearing loss; removal of cerumen or foreign body	None
Exposure to damagingly loud sounds (noise exposure)	See appendix pp 15–16	Early detection and prompt management of disabling hearing loss	Hearing aids, cochlear implants, or assistive listening devices or strategies according to severity of hearing loss; hearing rehabilitation; teach sign language to otherwise untreated children or children whose losses remain severe or worse after treatment with a hearing aid or cochlear implant; other special education for children who need it
Trauma	Health education; prevention with use of helmets and seat belts	Surgery	For permanent losses, hearing aids, cochlear implants, or assistive listening devices or strategies according to severity of hearing loss and if the cochlear nerve is intact; hearing rehabilitation; teach sign language if losses remain severe or worse after treatment with a hearing aid or cochlear implant; other special education for children who need it
Sudden hearing loss, Menière's disease, or immune-mediated hearing loss	None	None	Low-salt diet; drug therapies; surgery as indicated; treat hearing loss as for exposure to damaging loud sounds

(Table 1 continues on next page)

	Primary prevention	Secondary prevention	Tertiary prevention
(Continued from previous page)			
Childhood			
Acute or chronic otitis media	Promotion of personal hygiene and of better nutrition, breastfeeding, and living conditions; better management of upper respiratory tract infections	Early recognition of disease and associated hearing loss; prompt treatment with antibiotics or surgery or both as indicated, and continued follow up	Access to ear surgery; hearing aids, cochlear implants, or assistive listening devices or strategies according to severity of hearing loss; hearing rehabilitation; teach sign language to otherwise untreated children or to children whose losses remain severe or worse after treatment with a hearing aid or cochlear implant; other special education for children who need it
Measles and mumps	Immunisation	As for otitis media	Hearing aids, cochlear implants, or assistive listening devices or strategies according to severity of hearing loss; hearing rehabilitation; teach sign language to otherwise untreated children or children whose losses remain severe or worse after treatment with a hearing aid or cochlear implant; other special education for children who need it
Cerebral malaria	Vector reduction; prophylaxis	As for otitis media	As for measles and mumps
Meningitis	Immunisation; prophylaxis	As for otitis media	As for measles and mumps
Adulthood			
Encephalitis; meningitis	Immunisation; prophylaxis	Early recognition of disease; prompt treatment and continued follow-up	Hearing aids, cochlear implants, or assistive listening devices or strategies according to severity of hearing loss; hearing rehabilitation; teach sign language if losses remain severe or worse after treatment with a hearing aid or cochlear implant
Ototoxicity	Avoidance of ototoxic drugs, solvents, and industrial chemicals	Systematic monitoring of serum concentrations and hearing during and after administrations of ototoxic drugs or exposures to ototoxic solvents or other industrial chemicals	As for encephalitis and meningitis
Chronic otitis media	Health education; primary care	Surgery as appropriate to treat underlying medical condition and hearing loss	As for encephalitis and meningitis
Presbycusis	Avoidance of exacerbating factors such as ototoxicity and exposure to damagingly loud sounds	Periodic screening for hearing loss in elderly persons; prompt treatment for persons with disabling losses	Hearing aids, cochlear implants, or assistive listening devices or strategies according to severity of hearing loss; encouragement to seek prompt treatment for hearing loss to mitigate documented consequences of hearing loss in adults
Otosclerosis	None	Surgery	As for encephalitis and meningitis
Adapted from Olusanya and colleagues, ⁴ with further inputs from Smith ⁴² and WHO's Primary Ear and Hearing Care Training Resource. ⁴³ Primary, secondary, and tertiary preventions are defined in the text. Outcomes from treatments can be improved in many cases with patient-centred and family-oriented models of care. ⁴⁴ G6PD=glucose-6-phosphate dehydrogenase.			
Table 1: Primary, secondary, and tertiary prevention of hearing loss by age group and potential cause			

Reducing the burden Prevention and treatment

According to WHO, approximately 50% of hearing loss could be prevented and most of the remainder could be treated effectively.³⁰ Thus, the potential for reducing the burden of hearing loss is high, especially with attention to LMICs, where more than 80% of people with disabling hearing loss live.⁴⁰

WHO and the World Bank have categorised prevention in three tiers: primary prevention to avert an adverse health condition; secondary prevention to detect a condition at an early stage and to treat it promptly; and tertiary prevention to reduce the impact of an established condition and to restore function to the maximum extent possible.⁴¹ (Full restorations are generally not possible with present treatments.) These tiers for hearing loss are shown in table 1; many of the actions listed for primary prevention are strikingly inexpensive and effective (eg, immunisation to prevent rubella), and are thus good first targets for reducing the burden of hearing loss.

WHO has been at the vanguard of prevention and treatment of hearing loss in LMICs since the mid 90s, and of its many reports and publications (appendix pp 19–20) is The Primary Ear and Hearing Care Training Resource,⁴³ which provides four exceptionally clear manuals covering topics from basic to advanced care.

Prevention is generally better than treatment of a condition, is usually less expensive, and often can be implemented at the community level.⁴⁵ Foremost among preventable causes are otitis media, maternal rubella, other infectious diseases, problems at birth, overuse of ototoxic drugs, consanguinity, and exposure to damagingly loud sounds. Strategies for prevention are presented in table 1, the WHO publications, and other sources.^{4,32,46} A preventable cause of growing concern is exposure to damagingly loud sounds (appendix pp 15–16).^{47–49} Hearing loss caused by these sounds often is called noise-induced hearing loss, but that is a misnomer since noise to one person can be a sublime sound to another. Unfortunately, damagingly loud sounds abound in populated world regions. For example,

personal audio players are ubiquitous, and the sounds they present via earbuds just 2–3 cm away from the eardrum can easily exceed safe limits.

Secondary and tertiary interventions are generally more expensive than primary prevention but are becoming more feasible in many LMICs owing to their improving economies.^{34,50} Thus, the scope of considerations by decision makers can be expanded to reduce the burden of hearing loss further. A leading possibility for such reduction is universal screening for hearing loss among newborn babies,⁵¹ which has been highly effective in high-income countries in the identification of serious problems when they can be best treated.^{52,53} Screening programmes exist in or are being developed for some LMICs as well,⁵¹ but much more could be done. Obstacles include the expense and the fact that in many low-income countries most births are in places other than hospitals.^{51,54} These obstacles might be overcome by reducing the expense with efficient use of personnel and equipment in high-throughput settings and with screening in community centres instead of hospitals. Olusanya and colleagues⁵⁵ have shown, for instance, that screening in community immunisation clinics can be inexpensive (<US\$8 per baby even in a low-throughput setting) and just as effective as screening in hospitals.

The principal treatments for hearing loss at present are hearing aids for mild-to-severe losses and cochlear implants for severe-to-complete losses (see table 1 for additional treatments). Hearing aids and cochlear implants are expensive, especially cochlear implants, but costs can be reduced with new models for provision and with parsimonious and disruptive designs of these devices, as described later in this Review.

Maximising value for money

Decision makers want to squeeze the most out of their budgets and choose the most cost-effective additions when budgets can be increased or in making the case for an increase. Of course, other factors also influence resource allocations—eg, ensuring equity of care across a population.

Cost-effectiveness analysis (CEA) can provide the cost and cost-effectiveness inputs to the decisions.⁵⁶ The results can indicate whether an addition to an existing mix of interventions would be very cost-effective, cost-effective, or not cost-effective. Alternatively, the results can indicate the mix that would produce the greatest health benefit for a given budget. Additionally, this latter type of analysis, called generalised CEA,⁵⁶ indicates the most cost-effective order for interventions that could be added with increases in the budget. Changes in an existing mix as suggested by CEA results can produce substantial gains in value for money.⁵⁷

CEAs have been done to evaluate interventions for hearing loss in LMICs: treatments of chronic otitis media with aural toilet plus topical antibiotics, and of meningitis

with ceftriaxone, were very cost-effective in sets of countries in sub-Saharan Africa and southeast Asia as of 2005;^{58,59} cochlear implants were cost-effective in Nicaragua, Nigeria, and South Africa but not in Kenya, Uganda, Rwanda, and Malawi as of 2012;^{60,61} cochlear implants were very cost-effective in three Latin American countries, cost-effective in another three, and marginally cost-effective in Guatemala as of 2015;⁶² and programmes for screening for hearing loss and follow-up with hearing aids or other treatments as appropriate were shown to be cost-effective as of various years from 2005 to 2009 in five of eight provinces in China, China as a whole, the Tamil Nadu state in India, India as a whole, and the sets of countries in Africa and southeast Asia.^{58,59,63–66} Most of these analyses used the WHO-CHOICE method and tools^{56,67} and the remainder used decision-tree approaches.⁶⁸ More analyses are needed to provide updated information and to include additional countries, multi-country regions, and regions within large countries with substantial inter-regional differences. Indeed, conditions can vary widely across countries and among regions, and the most pertinent results can only be obtained with analyses for geographical areas with little or no variation in conditions (eg, fairly constant costs for interventions, a uniform economy, and a uniform health-care infrastructure). Additionally, conditions can change with time—eg, reductions in costs for interventions and improvements in economies.

A generalised CEA that includes a broad spectrum of possible interventions for prevention and treatment of hearing loss has yet to be done for any country or region.⁶⁹ As noted previously, the results from such analyses could identify opportunities for increasing cost efficiencies. CEAs require considerable expertise and data gathering. Fortunately, help if needed is available from the WHO-CHOICE team⁶⁷ and can also be requested from experts at universities.

Capacity building and education

Hearing health-care professionals are in short supply in most LMICs.⁷⁰ Impediments to increasing or even maintaining the supply include inadequate funding for education of these professionals, migration of trained professionals to high-income countries (the so-called brain drain), low compensation, and lack of a career path for hearing health-care professionals other than physicians. A higher priority for hearing loss among the health-care priorities for a country could address at least to some extent each of these impediments. For example, career paths for audiologists and speech and language professionals could be established at low costs by ministers of health for countries where the paths do not already exist.

The brain-drain problem is a general one and thus has been considered extensively.^{41,71–73} Some of the strategies developed for stemming the drain are presented in the appendix p 21. A reverse brain drain also is possible, in which a native trained in another country returns home

to provide services there. Many physicians have taken this path, which is highly beneficial to the home countries and should be encouraged, such as through help in defraying the costs for studies abroad. Additionally, such help could be provided for individuals wishing to become audiologists or speech and language professionals.

Nonetheless, the best education in high-income countries might not be the best education in LMICs for increasing hearing health-care capacity. In high-income countries, specialty training is emphasised.⁷⁴ In LMICs, a broader range of training could be better, to enable the teamwork and task shifting that is needed to maximise care with a small number of professionals.^{73,74} Also, training to enable nurses and other caregivers in communities to shoulder the load for primary prevention would greatly extend the reach of hearing health-care professionals;^{45,73} the WHO manuals⁴³ could be used in the training.

Marshalling international resources

The high and growing burden of hearing loss should be a compelling argument for international collaboration and assistance. Even before the present burden, WHO and non-governmental organisations (NGOs) such as CBM⁷⁵ have been working for decades to improve hearing health care, primarily in LMICs. Additionally, hearing health-care professionals—mainly from high-income countries—have travelled to LMICs to provide training and services for free (eg, help in capacity building).

Although these efforts have been wonderful—and have been managed by supremely talented and dedicated people—to date the efforts have not measurably slowed the growth in the burden. More is needed, both in personnel and funding. Also, a new global initiative dedicated to reducing the burden could help enable and then facilitate such greater efforts, as discussed later in this Review.

Fortunately, further factors favour the needed additional funding: the shift in emphasis towards non-communicable diseases and injuries by prominent funding agencies and NGOs;^{34,76} the fact that five of the 17 goals in the UN's 2030 Agenda for Sustainable Development⁷⁷ are “disability inclusive” goals; and the rights of disabled people to receive the best available health care and education, and to participate as fully as possible in society, as asserted repeatedly and forcefully by the UN^{77–79} and as mandated in the laws for many countries.^{41,79} Additionally, rock musicians, baby boomers, and others in positions to help have become keenly interested in hearing loss and its consequences. A focus for support from these various potential sources could increase the overall funding tremendously; at present there are many targets for support, which is confusing, and directing money to any one of the targets might not produce much of an effect at the global level (so far, it has not).

Reducing treatment costs

The present costs are high but could be reduced through innovations in technology, new models for provision, and more competition. The high cost of hearing aids is a problem even in the USA where the average price of bilateral devices exceeds \$4700,^{80,81} which is prohibitive for many potential users. High prices are even further beyond the reach of potential users in LMICs or their governments. Possibilities for dramatic reductions in cost include allowing people to use personal amplification devices rather than hearing aids for remediation of mild-to-moderate losses; elimination of prescription and fitting by an audiologist for routine cases (eg, for the mild-to-moderate losses); purchase and distribution of hearing aids in large quantities; and revision of regulatory requirements to allow more competition and comparison shopping for hearing aids.⁸⁰ The US President's Council of Advisors on Science and Technology (PCAST) advocated these changes in a letter to President Obama⁸⁰ and envisions a time when hearing aids can be purchased over the counter like reading glasses at similarly low costs and low risks to health. Many of the same findings and recommendations are presented in a report by the US National Academies of Sciences, Engineering, and Medicine.⁸² The report was released in early June, 2016, approximately 7 months after the letter from PCAST, and the report greatly extends the information presented in the letter. Although the report focuses on the US situation, its content has important global implications.⁵

An additional possibility for reducing costs that is presented in both the report and the letter is disruptive technology, such as use of smartphones or mobile phones for remediation of hearing loss in addition to their many other functions.^{80,83} Indeed, downloadable applications for smartphones allow users to test their hearing, can implement a wide variety of hearing aid algorithms, and can automatically adjust sound processing for the best hearing across different acoustic environments.^{80,83} These devices are now common in all world regions. Moreover, the devices and their earpieces are fashionable, which could reduce or even eliminate the stigma of using a visible aid to improve hearing.^{80,84} Complex cases would require professional oversight as before, but the cost of the aids, and their fitting and maintenance, still could be much lower. Also, the complex cases constitute less than 15% of the total number of cases (figure B). Use of consumer electronics for remediation of hearing loss would be a boon everywhere, but especially in LMICs. Intense competition drives the prices of consumer electronics to the lowest possible points; smartphones can access the internet and have vastly greater processing capabilities than existing hearing aids.

For cochlear implants, smart choices in design and greater competition also can produce large reductions in cost. For example, the recent development in China of a low-cost cochlear implant device with state-of-the-art performance⁸⁵ is a major step forward for service

provision in middle-income countries and perhaps in some low-income countries as well. Among the six African countries included in the CEA study by Emmett and colleagues,⁶⁰ for instance, the lower price would allow cochlear implants to become cost-effective in Kenya (a low-income country at the time of the study and now a lower-middle-income country) and very cost-effective in South Africa (an upper-middle-income country). Further progress in this direction is eminently feasible and might be achieved with parsimonious designs that are as simple as possible without degrading performance.⁸⁶

Additionally, assessment of hearing loss and fitting hearing aids and cochlear implants remotely via internet

connections and the appropriate equipment and personnel at each end has the potential to augment tremendously the impact of hearing health-care professionals,^{83,87} particularly for coverage of large geographical areas. Where the connections exist, such telemedicine could reduce costs and partly relieve the pressure to increase the professional workforce. However, for LMICs where connections or reliable connections are not yet available,⁸⁸ telemedicine is not an option. Fortunately, the number of countries without connections is shrinking and, if that trend continues as expected, absence of good internet access will become increasingly uncommon.⁸⁸

Suggested responses	
Leadership and governance	
Policy or strategy implementation	
Poor awareness of global burden of hearing loss and its economic impact	Mention that hearing loss is now the fourth leading cause worldwide of years lived with disability; produce data on country-specific prevalence of disabling hearing loss and its cost to society; explain the educational, psychological, and social consequences of disabling hearing loss; describe effects of disabling hearing loss on employment and its association with cognitive decline and dementia
No public health policy in relation to hearing loss; poor policy implementation	Develop or update national HHC policies within the context of primary care and other health priorities for the country; engage with other initiatives to enhance neonatal care and child health; ensure dissemination of policies and guidelines to health facilities
Lack of professional leadership	Develop national and regional champions for HHC; create promotion pathways for HHC professionals other than physicians (who generally already have such pathways); create further promotion pathways for physicians to encourage them to continue as practising physicians rather than moving into management
Neonatal hearing screening not in country operational plans	Encourage integrated approach, linking hearing screening to other initiatives to promote neonatal health and disability-free survival (such as widespread immunisation programmes); ensure screening is matched by accessible treatments for the identified cases of disabling hearing loss
No governance framework; no enforceability of contracts; potential for corrupt practices	Encourage improved stewardship, accountability, and service audit; engage community leaders and civic organisations in service delivery
No legislation relating to exposures to damagingly loud sounds	Raise awareness that the exposures are the single most preventable cause of hearing loss and tinnitus; highlight the needs for personal protection and noise-reduction strategies in the workplace; describe the highly deleterious effects and growing prevalence of recreational sources of damagingly loud sounds (eg, from entertainment venues and personal audio players); indicate that military personnel are at especially high risk due to the extreme intensities of sounds in their environments; encourage legislation with appropriate enforcement, regulation, and inspection
Political support and coordination	
Ineffective coordination among health, education, and social care, and between primary and secondary care	Strengthen coordination mechanisms; assign named individuals at the ministry of health and at the state and district levels with responsibility for HHC
Failure to recognise rights of people with disabilities	Highlight UN Convention on the Rights of Persons with Disabilities, ⁷⁶ including the right to health care without discrimination
Discrimination against individuals with disabling hearing loss, including discrimination that impedes or prevents full access to health care and education	Legislation and education against stigmatisation of these individuals; extend concept of disability access to social participation by individuals with disabling hearing loss; build awareness of the links among hearing health, human rights, and social justice
Lack of public-private partnerships	Create policies that favour informed public-private partnerships to address gaps in service provision
Restricted communication, geographical access, and transport infrastructure	Ensure that national policies promote access to health care by rural populations; empower and train primary care workers to deliver hearing services; increase the number of HHC professionals through task-shifting and training community workers; use automated audiometry and internet-based fitting of hearing aids and cochlear implants
Health financing	
Coverage of financing schemes	
Low coverage of health financing schemes and high out-of-pocket expenses	Expansion of health insurance to minimise out-of-pocket expenses (eg, for hearing aids, cochlear implants, and batteries)
Funding or budget allocation	
No budget line for neonatal hearing screening	Advocate inclusion of hearing screening for newborn babies as part of free national health insurance
High lifetime cost of hearing prostheses	Provide affordable hearing aids with appropriate infrastructure near to client or via telemedicine

(Table 2 continues on next page)

Suggested responses	
(Continued from previous page)	
Health workforce	
Human resource planning	
Shortage of personnel; concentration of personnel in urban areas	Enhance professional careers to support staff retention and service provision in remote communities; seek voluntary agreements on migration of key staff, especially from rural areas; encourage actions to mitigate the brain drain from LMICs to high-income countries
Low staff pay and poor motivation	Increase pay, impose benchmarks and quality indicators, strengthen supervision, and introduce work incentives (productivity-based payments)
No career structure for HHC professionals (other than physicians) within the health-care system	Create viable career positions for HHC professionals to support interdisciplinary working; ensure acquisition of core competencies, including competencies for community-based workers
Poor skills and low competency	Promote accessible competency-based training at the local level; facilitate external mentoring
Essential medical products and technologies	
Audiological equipment	
Shortage of appropriate equipment and infrastructure for HHC	Consider automated audiometry or internet-based hearing assessment; adopt tele-audiology and tele-otoscopy to overcome gaps in service provision; adapt hearing aids with water-repellent coatings and materials for the tropics
Inadequate regulation of hearing aid provision; improper industry practices	Provide greater oversight by governing bodies of hearing aid and cochlear implant provisions; strengthen regulation through legal mechanisms
Hearing aid (and cochlear implant) supply severely restricted because of excessive cost	Encourage research and development of low-cost hearing prostheses; leverage smartphone technologies for use as hearing assistive devices; encourage manufacturers to meet WHO criteria for an affordable hearing aid; ⁹¹ support bulk commissioning to reduce cost and achieve equitable provision
Hearing aid batteries unaffordable or unobtainable	Consider rechargeable or solar-powered batteries if feasible and appropriate; buy batteries in bulk for distribution for free or at low cost to hearing aid and cochlear implant users
Ear surgery	
No otological equipment and infrastructure	Equip a small number of specialist centres for medical and surgical management of ear disease
Availability of commodities	
Inadequate management information systems	Establish functional logistic and supply chain management to district and health facility levels; streamline procurement procedures introducing penalties for non-compliance; use rapid-setting silicone for earmoulds
Logistics; management information systems	
Data collection, reporting, and monitoring	Incorporate service quality indicators in routine service delivery; include community-based data routinely in health management systems
Community ownership and partnership	
Community engagement and advocacy	
Lack of involvement because of restricted information materials and education	Provide information materials that are culturally and linguistically appropriate; use local, national, and social media to disseminate information
Insufficient community-based advocacy to drive establishment of hearing services	Involve community leaders in sensitisation meetings; highlight importance of timely ear care in children and adults; highlight importance of primary prevention
Stigmatisation of disabling hearing loss	Dispel myths about hearing loss—ie, a curse or a source of shame; promote a disability-inclusive culture and provide captioning, assistive listening devices, and other aids for individuals with a hearing impairment
Adapted from table 3 in Dickson and colleagues. ⁹⁰ Possible constraints are listed by health-system building blocks; the constraints are more common in low-income countries than middle-income or high-income countries. HHC=hearing health care. LMICs=low-income and middle-income countries.	
Table 2: Possible constraints in the provision of better hearing health care and suggested responses to them	

Centres of excellence for complex cases

In populous middle-income countries, or in large world regions, the creation of centres of excellence could drive down costs and improve care for complex cases, as has been the experience in high-income countries and in some middle-income countries—eg, with the creation and ongoing operation and growth of the Madras ENT Research Foundation (and hospital) in Chennai, India.⁸⁹ These centres bring together in one place the expertise needed for the complex cases and reduce costs through efficiencies of scale. Outreach can be provided with satellite facilities for local diagnosis and follow-up care along with

telemedicine links to the main facility. Other such centres exist in India and China, including centres within tertiary care hospitals; nonetheless, an immense unmet need exists in those two countries and elsewhere that could be at least ameliorated with additional centres and further increases in the capacities of the existing centres.

Responding to constraints

Table 2 shows possible constraints in the provision of better hearing health care and suggested responses. The constraints are common to many areas of health care, including barriers to reducing infant mortality and

improving neonatal and maternal care, and are especially challenging in low-income countries.⁹⁰ Fortunately, at least some of the constraints could be overcome with persistence and the appropriate actions.

A complementary perspective is presented by Tucci and colleagues,³² who suggested priorities for reducing the burden of hearing loss according to fiscal resources in low-income, middle-income, and high-income countries (appendix p 22).

Country-level engagement

The 1995 WHO resolution on prevention of hearing impairment⁹² called for focused action including the creation of national committees whose charge would be to prepare hearing health-care plans; supporting legislation to manage major causes of hearing loss including otitis media and overexposure to loud sounds; ensuring the highest possible coverage for immunisations to prevent hearing loss; establishing collaborations as needed to detect genetic predispositions to hearing loss and then to provide appropriate counselling; and making available to the public easily assimilated information about hearing loss and how to prevent it. Thus far, committees have been created in at least 24 countries.^{4,70} The groups represented in the committees typically include professional associations, academic institutions, organisations for disabled people, NGOs, and ministries of health, education, and social welfare.⁷⁰ The important point is that country-level engagement is central to the optimal provision of hearing health care, in that conditions can vary widely from country to country and in that most decisions are made at the national level. Additionally, active participation by many or all stakeholders can not only inform decisions but also promote buy in for implementing and sustaining them.

University participation

Physicians, scientists, and others at universities have been strongly involved in global hearing health care. Hopefully that involvement will grow and it certainly should be encouraged. However, a resource that has not been tapped yet for reducing the burden of hearing loss is the global health institutes, centres, and departments now in many universities worldwide.⁷⁶ These organisations have been a major force in globalisation and in improving global health through education, research, innovation, capacity building, technical support, and onsite help in dealing with emergencies such as the medical sequelae of natural disasters.⁷⁶ Partnerships with the organisations are characterised by reciprocity and mutual respect between the partners and typically include frequent exchanges of personnel to provide assistance and share and gain knowledge.^{72,76}

Global health organisations within universities could help reduce the burden of hearing loss (appendix p 23).

Of course, the benefits could go in both directions, such as with innovations developed in or for a partner country that are later applied in the university's country and elsewhere,⁹³⁻⁹⁶ so-called (and perhaps mistakenly and patronisingly called) reverse innovation. As Lord Nigel Crisp⁹⁵ put it, "We all, whether from richer or poorer countries, have things we can learn from each other and things we can teach".

A global initiative for a global problem

The present need for extra efforts and funding to reduce the currently unbridled burden of hearing loss was similarly recognised years ago for the prevention and treatment of losses in vision; that recognition led to the creation in 1999 of VISION 2020,^{97,98} which is a partnership between WHO and the International Agency for the Prevention of Blindness (IAPB). VISION 2020 has made a positive difference^{97,99-101} and its overarching goal is "reduction in the prevalence of avoidable vision loss by 25% by 2019" (starting from the prevalence recorded in 2010).⁹⁷ Possibly, a comprehensive global programme like VISION 2020 but for hearing instead of vision could be effective as well. An overarching goal for this suggested new initiative could be to halt the growth in the burden of hearing loss by 2025 (despite continuing growth in and ageing of the world's population) and then to reduce the burden from that 2025 peak by 20% by 2035. Other goals could of course be proposed, but this suggested goal would be achievable, pending adequate funding and the full support and partnership by the professionals and national and international organisations presently involved in hearing health care. Indeed, the collective and collaborative effort could be very much greater than the sum of the parts, just as in VISION 2020.

A single and easily identifiable lead organisation could greatly facilitate funding for the collective effort. Potential supporters need to know that their money would in fact help reduce the burden of hearing loss, and that the money would be applied in ways that would maximise cost-effectiveness. Additionally, a single target for funding would eliminate the present confusions about where to invest for improving global hearing health care.

We believe that a hearing counterpart to VISION 2020 would be highly appropriate. Indeed, hearing loss is an even more important global health problem than vision loss, as indicated by the total YLDs from GBD 2015 for mild-to-complete losses in hearing and vision (46.2 vs 24.5 million YLDs) and for moderate or worse losses in hearing and vision (34.6 vs 17.7 million YLDs).¹ More about the proposed programme for hearing, including possible structures and activities, is presented in the appendix pp 17-18.

The global initiative we have in mind most certainly would not supplant the wonderful and crucially important efforts already underway. Those efforts should be increased, not diminished. The initiative

would add value in the ways we have outlined here and in the appendix pp 17–18.

Conclusions

The burden of hearing loss is higher than ever and is growing largely unabated. However, the capacity to prevent and treat hearing loss is growing as well. Economies are improving, especially in some LMICs; costs for prevention can be stunningly low; an unprecedented potential exists for reducing the costs for treatments; and the internet connectivity that enables telemedicine is becoming available in places that do not already have it. Now is a highly propitious time to tackle the burden with full force. The opportunities have never been greater, and the need has never been greater.

The concluding sentences in *The Lancet* editorial⁵ are: “Global multidisciplinary and collaborative efforts are urgently needed to address the health needs of the child and adult with hearing loss” and “Hearing loss cannot and must not continue to be a silent epidemic”. We agree; such greater attention to hearing loss would be one of the least expensive and most effective ways to improve human health and happiness.

Contributors

BSW and GMO developed the starting concepts for this Review. The concepts were refined in discussions among GMO, DLT, BSW, and MHM, including extensive discussions during a 3 day visit to Duke University by GMO. GMO, DLT, and BSW did the literature searches, selected the initial sources, and prepared the first drafts of the manuscript. Early drafts were reviewed by internationally renowned authorities in the relevant fields, and their comments and suggestions, including suggestions for additional sources, were incorporated in later drafts, again by GMO, DLT, and BSW. MHM provided independent reviews of the latest three among those later drafts, and his comments and suggestions were incorporated by all four authors in the penultimate and final versions. Each author read and approved the final version before it was submitted for publication.

Declaration of interests

BSW is a consultant for MED-EL Medical Electronics GmbH in Innsbruck, Austria. All other authors declare no competing interests.

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