Chapter **50**

Loss of Vision and Hearing

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Although the loss of vision and hearing has multiple causes, and the burden of these diseases is complex, three major points emerge from the outset:

- Impairments of the essential senses of vision and hearing contribute to early demise and are important causes of morbidity for individuals who are blind or deaf.
- Cost-effective interventions are available to address several causes of these burdens now.
- The number of cost-effectiveness analyses of interventions to preserve hearing or vision in developing countries is quite limited.

Table 50.1 summarizes the conditions causing the sensory deficits, the proposed interventions and sites of delivery, and the cost and effectiveness of these interventions to the extent of current knowledge. Earlier work by Evans and others (1996) in Myanmar does not appear because the cost data are quite old and because the cost-effectiveness data were in dollars per case of blindness averted rather than dollars per disability-adjusted life year (DALY) averted, which the latest information provides.

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Table 50.2 provides definitions of visual impairment, blindness, and low vision according to the *International Classification of Diseases, Injuries, and Causes of Death* (WHO 1993). At this time, the World Health Organization (WHO) is considering changing the classification in order to take into account uncorrected refractive errors, but this change has not yet been approved.

The major causes of adult-onset blindness are cataract (47.8 percent), glaucoma (12.3 percent), macular degeneration (8.7 percent), diabetic retinopathy (4.8 percent), trachoma (3.6 percent), and onchocerciasis (0.8 percent). Uncorrected refractive errors are also a major cause of morbidity related to vision, but this type of disability is not included in the global burden of disease by definition. It has been estimated to be on the order of 15 percent of the total blind population and could add 50 percent to the low-vision population. However, there are no published data to do more than speculate.

The major causes of childhood vision loss have marked regional variations. They include vitamin A deficiency (xerophthalmia) and ophthalmia neonatorum in low-income countries, retinopathy of prematurity and hereditary conditions in middle-income countries, and congenital cataract and glaucoma everywhere. Table 50.3 shows the estimated number of blind persons worldwide in 2002.

Vision loss is chronic and, almost invariably, without remission. The extent of morbidity is related to the level of alteration of vision function. However, 80 percent of cases are avoidable, either through treatment (cataract and refractive errors) or through primary prevention (onchocerciasis, trachoma, glaucoma, and diabetic retinopathy). Strictly speaking, blindness attributable to glaucoma and diabetic retinopathy can be prevented. However, prevention depends on the availability of a simple, cheap, and efficacious diagnostic test and rigorous treatment. These are not readily amenable to public health programs even in the most technologically advanced countries, especially in the case of glaucoma.

Table 50.1 Cost and Effectiveness Data for Vision and Hearing Care Interventions

Condition	Intervention	Cost data (2004 US$)	Effectiveness data	Incremental cost-effectiveness data (2004 US$/DALY averted)
Trachoma	Trichiasis surgery	7.14 per village-based surgery[a]	77 percent cure rate over two years[b]	4–82[c]
	Tetracycline	—	51 percent cure rate in children at six months following treatment[d]	>9,600[d]
	Azithromycin	—	88 percent cure rate in children at six months following treatment[e]	>4,100[d]
Cataract	Extracapsular surgery	—	—	<200 (low- and middle-income countries); <2,400 (high-income countries)[b]
Onchocerciasis	Ivermectin	—	—	40[f]

Source: Authors.
— = not available.
a. Frick, Keuffel, and Bowman 2001.
b. Baltussen, Sylla, and Mariotti 2004.
c. Baltussen and others (2005). Cost-effectiveness calculations are based on data from Frick and others (2001) for mass treatment of children only, not greater efficacy reported by Bowman and others (2000) and Solomon and others (2004) for mass treatment of entire communities. The greater efficacy reported in mass treatment of entire communities may lead to better cost-effectiveness.
d. Bowman and others 2000.
e. Reacher and others 1992.
f. Waters, Rehwinkel, and Burnham 2004.

Table 50.2 Definitions of Visual Impairment Levels

Degree of impairment	Definition	Visual impairment categories
Low vision	Visual acuity of less than 6/18 (Snellen 20/70) but equal to or better than 3/60 (20/400) in the better eye with best possible correction	1 and 2
Blindness	Visual acuity of less than 3/60 (20/400) or corresponding visual field loss of less than 10 degrees in the better eye with best possible correction	3, 4, and 5
Visual impairment	Blindness as well as low vision	1, 2, 3, 4, and 5

Source: Authors, based on current international definitions by WHO 1993.

Table 50.3 Number of Blind Worldwide in 2002 from Various Conditions

Condition	Number blind (millions)
Cataract	17.6
Glaucoma	4.5
Age-related macular degeneration	3.2
Corneal opacity	1.9
Diabetic retinopathy	1.8
Childhood blindness	1.4
Trachoma	1.3
Onchocerciasis	0.3
Other causes	4.8
Total	36.8

Sources: Pascolini and others 2004; Resnikoff and others 2004.

Burden of Loss for Vision and Risk Factors

The risk factors for loss of vision are age, gender, poverty, and poor access to health care. The overall prevalence of vision loss, which mainly affects the population above age 40, is a function of age. It is estimated that more than 82.2 percent of all blind individuals are 50 or older. Increasing life expectancy results in a growing number of cases of age-related blindness (for example, cataract, glaucoma, macular degeneration). Among the 50 and older age group, cigarette smoking is a clear risk factor for both cataract and macular degeneration. Childhood vision loss represents approximately 4 percent of the total number of visually impaired. However, it is the second largest cause of "blind-person years," following cataract. Retinopathy of prematurity (ROP) is an important cause in middle-income countries (Gilbert and Foster 2001). Unfortunately, screening for ROP in preterm infants, as well as the organization and provision of low-vision services, is a tertiary-level function (requiring a well-equipped clinic or hospital with the most modern facilities), and no data on cost-effectiveness of interventions are available. More disease-specific factors are poor hygiene, overcrowding, ultraviolet radiation, diabetes mellitus, drugs, micronutrient deficiency, heredity and ethnic background, and consanguinity.

Estimates of the global burden of visual impairment in 2002 were updated using the most recent available data on blindness and low vision (Pascolini and others 2004). The global number of people who are visually impaired is in excess of 161 million,

of whom 36.8 million are blind (Resnikoff and others 2004). Because the international definition refers to the best-corrected visual acuity (table 50.2), these figures actually underestimate the magnitude of the global burden of the visual impairment, especially in developing countries, where most of the refractive errors are not corrected (Dandona and Dandona 2003; Fotouhi and others 2004; Naidoo and others 2004). A WHO working group has recommended the use of the more accurate "presenting vision," recognizing that many people do not have their best-corrected vision. This recommendation is under review and, if approved, would substantially increase the estimates of the burden of disease attributable to impaired vision.

The number of women with visual impairment, as estimated from the available studies, is higher than that of men, even after adjustment for age. Female-to-male prevalence ratios indicate that women are more likely to have a visual impairment than men in every region of the world: the ratios from past studies range between 1.5 to 1 and 2.2 to 1. (Resnikoff and others 2004). The major reported reason is women's reduced access to eye care services. Higher exposure to risk factors also contributes in the case of trachoma. (Abou-Gareeb and others 2001; Nirmalan, Padmavathi, and Thulasiraj 2003).

Several population-based surveys reported higher risk of mortality among people with visual impairment. Relative risk of mortality among blind and low-vision people varied from 1.5 to 4.1 and from 1.1 to 1.6, respectively. In industrial countries, the relative risk of mortality varied from 1.6 to 2.0. The effect may vary by gender (Lee and others 2002; Taylor and others 1991). The link between visual impairment and mortality remains poorly understood and cannot be attributed to known associations with underlying disease.

The burden from visual impairment accounts for approximately 3 percent of the total global burden of disease and 9 percent of total years lived with disability in 2001. Table 50.4 shows the global burden by vision-related cause in DALYs. Globally, half of the burden from visual impairment is due to cataract.

The burden of visual impairment is not distributed uniformly throughout the world; the least developed regions carry the largest share, as shown by World Bank region in table 50.5. Local and in-country variations, as well as regional variations, are related to the following factors:

- Epidemiology of cause (for example, onchocerciasis, trachoma).

Table 50.4 Global Burden of Visual Impairment, by Major Cause, 2002

Condition	Blindness (thousands of DALYs)	Low vision (thousands of DALYs)	Visual impairment		
			Thousands of DALYs	Percentage of total YLDs	Percentage of total DALYs
Cataract	8,798	15,053	25,251	4.5	1.7
Glaucoma	1,202	2,442	3,866	0.7	0.3
Trachoma	1,403	772	2,329	0.4	0.2
Onchocerciasis	203	146	484	0.1	0.0
Other	4,657	8,814	14,191	2.5	1.0
Total	16,263	27,227	46,121	8.2	3.2

Source: Pascolini and others 2004; Resnikoff and others 2004.
YLDs = years of life lived with disability.

Table 50.5 Global Burden of Visual Impairment, by World Bank Region, 2002
(thousands of DALYs)

Condition	East Asia and the Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	South Asia	Sub-Saharan Africa	Worldwide
Cataract	6,141	239	956	934	10,259	5,369	23,898
Glaucoma	1,184	168	165	401	566	1,009	3,493
Trachoma	410	0	102	201	226	1,272	2,211
Onchocerciasis	0	0	1	23	0	458	482
Other	5,821	903	1,031	971	2,447	1,046	12,219
Total	13,556	1,310	2,255	2,530	13,458	9,154	42,303

Source: Pascolini and others 2004; calculated from Resnikoff and others 2004.

- Socioeconomic patterns (poverty and socioeconomic deprivation), an essential element in most causes.
- Access to adequate eye care. Uneven access to good-quality eye care (for example, for cataract, glaucoma, diabetic retinopathy) results from such factors as distance, affordability, and culture. Lack of resources is only part of the problem; existing facilities are sometimes underused.

Interventions

Not all causes of visual impairment can be addressed using public health types of interventions. Cataract, trachoma, childhood blindness, and onchocerciasis are discussed below.

Cataract. Surgery to remove the opacified lens is the only effective treatment for cataracts. Neither diet nor medications have been shown to stop cataract formation. There are several possible approaches for the surgical extraction of cataracts. Intracapsular cataract extraction using aphakic glasses is a technique by which the whole lens is removed from the eye. After surgery, special eyeglasses are provided to patients to restore sight. A disadvantage of this intervention is the noncompliance of people who need to wear glasses, which has been found to be between 18 and 73 percent. Although this behavior may be characterized as noncompliance, it must be said that some programs do not provide glasses or provide aphakic glasses of inferior quality. Also, replacing needed aphakic glasses is impossible for some patients. It is also true that aphakic glasses cause tremendous distortions in vision, thus impairing compliance.

In extracapsular cataract extraction with implantation of a posterior chamber intraocular lens, the lens and the front portion of the capsule are removed and then replaced with an artificial lens. Baltussen, Sylla, and Mariotti (2004) have evaluated work on the cost-effectiveness of cataract surgery. That work (done by WHO regions rather than by World Bank regions) showed that both intracapsular and extracapsular surgeries are cost-effective ways to reduce the impact of cataract blindness. However, extracapsular surgery is both less costly and more effective than intracapsular surgery and can therefore be considered the best choice for cataract control. Its cost-effectiveness ratios are below US$200 per DALY averted in low- and middle-income countries and below US$2,400 in high-income countries.

Trachoma. WHO recommends an integrative approach to trachoma control through its SAFE strategy (surgery, antibiotics to control the infection, facial cleanliness, and environmental improvements). The facial cleanliness and environmental improvements are preventive public health measures aimed at reducing the incidence of infection. Antibiotic treatment, especially when given on a mass or community basis, is both primary prevention (reducing transmission in the community) and secondary prevention (treating active infection to avoid morbidity). Surgery is in fact tertiary prevention—that is, repairing (and halting further) damage. The SAFE strategy has not been subjected to a comprehensive economic evaluation, but some cost-effectiveness information is available regarding the antibiotic and surgery components.

The initial trachoma infection can be effectively treated with antibiotics, either through mass treatment of all children below 10 years of age or through targeted treatment of infected children and household members. A work by Baltussen and others (2005) for trachoma-endemic areas in the world—similar to studies of cataract control surgery—reveals that interventions using antibiotics cost between US$4,000 and US$220,000 per DALY averted for all regions studied. Targeted treatment with antibiotics (be it on the basis of azithromycin or tetracycline) is not cost-effective, and mass treatment of all children (not entire communities) is cost-effective only when azithromycin is donated. In Myanmar, tetracycline has been shown to be moderately cost-effective (Evans and others 1996). Cost-effectiveness studies are not available on mass treatment of entire communities, the approach now most commonly in use with donated azithromycin. Recent studies by Solomon and others (2004) report a 70 percent fall in prevalence in an area in Tanzania; moreover, the total community burden of ocular *Chlamydia trachomatis* infection (measured by polymerase chain reaction) fell to 8.7 percent of pretreatment levels at six months after treatment. Additionally, Chidambaram and others (2004) have demonstrated that, after mass azithromycin treatment of a population in Ethiopia, an indirect protective effect occurred among untreated children who resided in villages in which most individuals had been treated. As noted in table 50.1, greater efficacy of azithromycin than that used to calculate cost-effectiveness of mass treatment of children alone may lead to better cost-effectiveness than shown in the table. To date, if governments purchased the drug, mass distribution would be excessively expensive from a societal perspective. However, from the perspective of the governments of countries in which azithromycin (donated by Pfizer Inc. through the International Trachoma Initiative) is being distributed, mass distribution appears to be relatively cost-effective.

Trichiasis scarring is amenable to surgical repair. To date, the cost-effectiveness analyses that have been done suggest that surgery is not particularly expensive per case of blindness prevented, assuming that the eyelid correction prevents blindness and that the individuals with operated trichiasis are not more likely to be affected by other conditions (for example, dry eye) that might lead to corneal opacification. Baltussen and others (2005) suggest that trichiasis surgery—with cost-effectiveness ranging between approximately US$4 and US$82 per DALY averted across trachoma-endemic areas—would be even more cost-effective than cataract surgery.

From these cost-effectiveness evaluations, one could conclude that it is best simply to correct lid damage attributable to

trachoma. Surgery (tertiary prevention) would then remain a low but continuing cost. These evaluations do not, of course, take into account the possibility of eliminating this blinding disease. The implementation of the full SAFE strategy includes primary, secondary, and tertiary prevention, and although more costly at the outset, it could eliminate infection, pain, and blindness (and the need and cost of lid surgery) into the future. The WHO Alliance for the Global Elimination of Trachoma (GET 2020) was established in 1997 to support the work of a broad spectrum of collaborating international organizations, nongovernmental development organizations, and foundations in implementing the SAFE strategy. Kumaresan and Mecaskey (2003) report that 10 countries have initiated trachoma elimination programs using donated azithromycin, and many more programs are expected. They make the point that the promise of elimination provides the justification for investing in trachoma control.

Childhood Blindness. In 1993, WHO estimated that as many as 13.8 million children have some degree of eye damage because of vitamin A deficiency; however, the number of children with actual blindness is much lower—less than 500,000 in 1992. Recent WHO studies (Resnikoff and others 2004) include vitamin A deficiency among causes of childhood blindness. Cost-effectiveness studies of vitamin A supplementation, discussed in chapter 56, focus only on deaths averted unrelated to blindness, but this public health intervention appears to be cost-effective.

Onchocerciasis. Onchocerciasis, or "river blindness," is endemic in 28 countries in tropical Africa, where 99 percent of infected people live. Isolated foci of infection also occur in Latin America (six countries) and Yemen. Although it accounts for only 0.8 percent of world blindness (Resnikoff and others 2004), the distribution of ivermectin, given at no cost by Merck, has so far proved successful in drastically reducing this cause of blindness. Additionally, patients suffer severe skin lesions and pruritus, also remedied by the annual dosing with ivermectin. Studies have shown that the cost per DALY averted is as little as US$40 when adjusted for inflation (Waters, Rehwinkel, and Burnham 2004).

During the past 25 years considerable progress has been made by the Onchocerciasis Control Program in West Africa, both through control of the black-fly vector (insecticide spraying) and through the distribution of ivermectin. This success, expressed in health, economic, and development terms, was the motivating rationale for the launching in December 1995 of a new program, the African Program for Onchocerciasis Control. The objective is to create, by 2007, sustainable community-directed distribution systems using ivermectin. In Latin America, the Onchocerciasis Elimination Program in the Americas is successfully using ivermectin distribution. A coordination group of nongovernmental organizations is working closely with all three onchocerciasis control programs and with national counterparts in virtually all endemic countries. If present efforts in endemic countries are successfully completed, the disease will be brought under control by 2010.

NATURE, CAUSES, AND EPIDEMIOLOGY OF HEARING LOSS

In this chapter, the term *hearing loss*, used by itself, denotes any or all levels of severity of hearing difficulty. These 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). The term *deafness* denotes profound hearing impairment (WHO 1991, 1997). Disabling hearing impairment in adults is defined as "a permanent unaided hearing threshold level for the better ear of 41 dB or greater; for this purpose, the hearing threshold level is to be taken as the better ear average hearing threshold level for the four frequencies 0.5, 1, 2, and 4 kHz." 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; for this purpose, the hearing threshold level is to be taken as the better ear average hearing threshold level for the four frequencies 0.5, 1, 2, and 4 kHz.

Mathers and others (2003) estimate that in 2002, 255 million people worldwide had disabling hearing loss (moderate or worse hearing loss in the better ear). Those 192 million people with adult-onset loss (age 20 years and above) and 63 million people with childhood-onset loss make up almost 4.1 percent of the world's population and just over 40 percent of all people globally with hearing loss of any severity. The prevalence rates of adult-onset hearing loss were estimated by subtracting the prevalence rate for childhood onset (estimated in terms of prevalence in ages around 15 to 19). Numbers with childhood-onset hearing loss by cause have so far not been estimated separately but are included among sequelae of other diseases (for example, infectious diseases such as meningitis, otitis media, congenital conditions). It has been estimated that at least 50 percent of the burden of hearing loss could be prevented by primary, secondary, and tertiary preventive measures (Brobby 1989; WHO 1991).

Causes and Characteristics

Hearing loss is grouped according to *International Classification of Diseases and Related Health Problems*, 10th revision, version for 2003 (ICD-10) into conductive and sensorineural loss and other hearing loss, ICD-10 codes 90–91 (WHO 2003). The main causes are shown in table 50.6 according to the proportion that these contribute to the total burden (WHO 1986).

Table 50.6 Main Causes of Hearing Loss, by Proportion of Total Burden

High proportion	Moderate proportion	Low proportion
Genetic causes	Excessive noise	Nutritionally related
Otitis media	Ototoxic drugs and chemicals	Trauma related
Presbycusis	Prenatal and perinatal problems	Menière's disease
	Infectious causes	Tumors
	Wax and foreign bodies	Cerebrovascular disease

Source: WHO 1986.

Chronic otitis media (COM, as in ICD-10 codes H65–H67) includes chronic suppurative otitis media and otitis media with effusion. These forms of otitis media, together with some other middle ear diseases, such as perforation of the tympanic membrane, cholesteatoma, and otosclerosis, are the major causes of conductive hearing loss. In most WHO estimates of the burden of otitis media, the data are not disaggregated into acute and chronic otitis media.

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, affects 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 causes difficulties with interpersonal communication and leads to significant individual social problems, especially isolation and stigmatization. All these difficulties are much magnified in developing countries, where there are generally limited services, few trained staff members, and little awareness about how to deal with these difficulties.

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 (2004 dollars; 2.5–3 percent of the gross national product of the United States in that year). Hearing loss accounted for about one-third of the prevalence of these communication disorders.

Risk Factors

Occupations exposed to high levels of noise or ototoxic chemicals are also at risk, and noise exposure potentiates chemical ototoxicity in some cases (Fechter 1995; Morata 1998). Certain lifestyles (for example, use of personal stereos, noisy toys, firecrackers) and hobbies (for example, hunting) are also linked to levels of noise exposure that can cause hearing loss (Berglund and others 2000; Goelzer, Hansen, and Sehrndt 2001). Smoking may be a risk factor for high-frequency hearing loss, adding to the effect of noise (Mizoue, Miyamoto, and Shimizu 2003). Other risk factors include poverty, poor access to health care, poor hygiene, and overcrowding, all of which can lead to upper respiratory tract infections, otitis media, and other infections that may cause hearing loss, such as measles and meningitis. Detailed risk factors and indicators have been developed for neonates and infants (Joint Committee on Infant Hearing 2000); these include conditions that should require admission to a neonatal intensive care unit, stigmata of syndromes causing hearing loss, positive family history, craniofacial anomalies, certain in utero and post-natal infections (cytomegalovirus, herpes, rubella, syphilis, toxoplasmosis, meningitis), hyperbilirubinemia, conditions requiring prolonged mechanical ventilation or oxygenation, persistent otitis media with effusion, and others.

Ototoxic medications, low birth-weight, and low Apgar scores have also been cited as risk factors for neonates (Vohr and others 2000). Offspring of consanguineous marriages have a significantly higher incidence of autosomal recessive diseases, including hearing impairment. Such diseases are an important cause in communities where consanguinity is common (Shahin and others 2002; Zakzouk 2000). Certain ethnic groups (First Nations peoples such as Inuit and North American Indians, as well as Australian Aboriginal people) appear to be at higher risk of developing COM (WHO 1998).

Age, Geographic, and Gender Burdens

The prevalence of disabling hearing impairment that increases markedly with age is mainly related to the effect of presbycusis. The current shortage of data, particularly in developing countries, prevents accurate assessment of the global distribution of the burden and causes.

Male-to-female ratios of age-standardized adult-onset prevalence rates were found to be greater than 1 in most studies in all WHO regions (Mathers, Smith, and Concha 2005). This finding may be related to occupational noise-induced hearing loss, which differentially affects men.

Mortality

Barnett and Franks (1999) have found evidence that adults with postlingual onset of deafness have higher mortality than nondeaf adults. A 10-year longitudinal analysis of participants (age 55 to 74 years) in the U.S. National Health and Nutrition Examination Survey I found that, at baseline, hearing loss predicts mortality; relative risk = 1.17 (Mui and others 1998). Other studies have reported that the association disappears after controlling for age, and in any case, any relationship that may exist is too small to appear in published WHO estimates of deaths by cause (WHO 2004a, annex table 2) and by years of life lost, or YLLs (Mathers, Smith, and Concha 2005), in any region. A small number of deaths (4,000 globally in 2002) are recorded for otitis media (WHO 2004a), but these deaths are

mainly due to infective complications and, hence, are not directly caused by hearing loss.

Years Lived with Disability and DALYs

Data on years of life lived with disability (YLDs) and DALYs are available only for adult-onset hearing loss. The disease model used, the assumptions and methods used for calculation, and the disability weights are described elsewhere (Mathers, Smith, and Concha 2005). Total global YLDs for adult-onset hearing loss in 2001 are estimated to be 25.87 million, or 4.7 percent of total YLDs attributable to all causes, which makes hearing loss a leading cause of YLDs. Because YLLs are taken to be zero for all regions, the DALY figures are identical to the YLD figures. The most comprehensive data available are for all adult-onset hearing loss (WHO 2004b; Mathers, Smith, and Concha 2003). Fewer data on the burden are available at present for childhood hearing loss and specific causes.

Interventions

Effective interventions include screening programs, education, surgery, medications, and assistive devices.

Population-Based Interventions. Neonatal or early infant hearing screening is important because early identification of hearing loss (before 6 months of age, with early intervention) is associated with significantly better language development and may lead to better school and occupational performance than that of children identified after 6 months with early intervention (Keren and others 2002; Yoshinaga-Itano and others 1998). Implementation of neonatal hearing screening raises from 20 to 80 percent the numbers of children with normal development of language, compared with children whose hearing loss is detected later (Yoshinaga-Itano and Gravel 2001). Early identification of hearing impairment can reduce the median age of identification of hearing impairment from between 12 and 18 months to 6 months or less. Universal neonatal hearing screening is highly sensitive, but depending on the test method used, it may result in many false positives (which may increase parental anxiety and lead to unnecessary follow-up tests and interventions). It has a low positive predictive value. Some screening protocols may decrease false-positive rates (Kennedy and others 2000). Universal neonatal hearing screening has been endorsed in developed countries (Joint Committee on Infant Hearing 2000), although some experts urge caution (Paradise 1999); however, it is expensive to implement and, for most developing countries, is not yet an option. Hearing screening targeted at high-risk neonates is generally used in developing countries that do any type of neonatal screening, but screening may fail to detect 50 percent or more of cases of impairment (Lutman and Grandori 1999). Neonatal screening programs will not detect the 10 to 20 percent of cases of permanent childhood hearing impairment that starts later in life and for which later surveillance is needed (Grote 2000). No publications were found that have addressed the DALY burden that might be avoided by implementing neonatal hearing screening.

A recent WHO meeting of experts on noise-induced hearing loss (WHO 1998) concluded that exposure to excessive noise is the major avoidable cause of permanent hearing impairment worldwide. They agreed that, in developing countries, occupational noise and urban environmental noise are increasing risk factors for hearing impairment. Experts attending the meeting recommended that all countries implement national programs for prevention of noise-induced hearing loss, including effective hearing conservation. However, there are no published reports yet on the effectiveness of such programs in developing countries. The United States has produced a guide to hearing conservation programs in the workplace (Franks, Stephenson, and Merry 1996). It advises how to appraise programs by assessing the completeness of their components and by evaluating both the individual audiometric data for threshold shift and the group data for variability compared with a nonexposed population. Even in developed countries, there have been few, if any, clinical trials and little convincing evidence of the efficacy of occupational hearing conservation programs (Dobie 1995).

Personal Services. Chronic suppurative otitis media is one of the most common causes of hearing impairment in developing countries. Opportunities for prevention arise at all levels of national health systems, particularly in the community and at the primary level through primary ear and hearing care (PEHC) (WHO 1998). Appropriate health promotion measures include breastfeeding, immunization, adequate nutrition, personal hygiene, improved housing, reduced overcrowding, and adequate access to clean water. Primary health care workers can be given appropriate training and basic equipment for early detection and management of chronic suppurative otitis media, but the effectiveness and cost-effectiveness of this intervention in developing countries has not yet been assessed.

Although WHO does not currently recommend treating what is commonly called *chronic middle ear infection* with antibiotics at the primary level (WHO 2000), evidence suggests that antibiotics, especially topical quinolones, are more effective and cost-effective than ear toilet alone (Acuin, Smith, and Mackenzie 2000). WHO is reviewing these recommendations (WHO 2004b). New methods of delivery of effective but expensive topical antibiotics may lower the cost in poor communities, but treatment failure may be due to a high reinfection rate attributable to poor hygienic conditions. To be effective as public health measures, interventions need to be implemented on a large scale, with good coverage of the targeted population (van Hasselt and van Kregten 2002). Ear surgery plays an essential part in the prevention of further hearing impairment and, sometimes, in the improvement of hearing.

Services at the secondary level of intervention include provision of hearing aids in developing countries, which should assign priority to children with moderate or severe hearing loss, followed by adults (Arslan and Genovese 1996; WHO 2004c). However, even though globally about 6 million hearing aids are dispensed annually (WHO 1999), there have been no published randomized, controlled trials of the effectiveness of hearing aids in reducing hearing disability in developing countries and few trials in developed countries.

A randomized trial of amplification in 194 U.S. veterans showed significant improvements in communication, cognition, and social and emotional function, plus significant alleviation of depression, with hearing aids compared with controls (Mulrow and others 1990). No significant differences were observed in clinical effectiveness and cost-effectiveness between newer hearing aids that use digital signal processing and those that do not—in particular, analog-based aids (Parving 2003; Taylor, Paisley, and Davis 2001). Digital signal processing aids are not affordable for most people in developing countries. Over-the-counter hearing aids that can be purchased and used without prior training are commonly available in some developing countries. Those aids were found not to meet the prescription gain requirements of the majority of elderly clients who usually purchased them (Cheng and McPherson 2000).

Learning to use a hearing aid and developing "hearing tactics" are also important. Random assignment to a course for new hearing aid users significantly reduced the handicap compared with controls not assigned (Beynon, Thornton, and Poole 1997). Lack of compliance in use is a substantial problem everywhere among elderly and child users, including in developing countries (Furuta and Yoshino 1998; Sorri, Luotonen, and Laitakari 1984). Thus, measuring coverage without taking into account actual usage is not enough to assess alleviation of the burden.

Cochlear implants are provided to children and adults with severe and profound bilateral deafness on the basis that known short-term outcomes in auditory receptive skills (Richter and others 2002) will translate through various medium-term outcomes into greater social independence and quality of life (the social and quality outcomes have not yet been tested in a trial or observational study) (Summerfield and Marshall 1999). Cochlear implantation is beneficial in prelingually and postlingually deaf children (Makhdoum, Snik, and van den Broek 1997) and, when accompanied by aural (re)habilitation, leads to higher rates of mainstream placement in schools and lower dependence on special education support services (Francis and others 1999). Multichannel implants are superior to single-channel implants (Cohen, Waltzman, and Fisher 1993) and are more beneficial when implanted in young children (Richter and others 2002). There has been no economic analysis of cochlear implants in developing countries, and such interventions are currently not a priority in most parts of the developing world (Berruecos 2000; WHO 2004c; Zeng 1995).

Intervention Cost and Cost-Effectiveness. All the data on the costs and cost-effectiveness of interventions related to hearing loss (including school-age screening, treatment of COM, surgical interventions, hearing aids, and cochlear implants) come from developed countries. Although they can be summarized quite readily, it is not clear whether and how they relate to the costs that would be experienced in developing countries.

RESEARCH AND DEVELOPMENT AGENDA

The public health research and development agenda for controlling and reducing the burden of disease related to the loss of sight and hearing should include the following:

- further population-based studies on the magnitude, causes, and distribution of the burden
- economic analysis, especially on cost-effectiveness (for example, cost-effectiveness of each of the components of the SAFE strategy in trachoma control)
- research to develop eye and hearing care systems
- operational research on eye and hearing care delivery (particularly for cataract, diabetic retinopathy, and affordable hearing aids in underserved areas)
- clinical and field trials on interventions: pneumococcal and meningitis vaccines, treatment for chronic suppurative otitis media, primary care of ears and hearing, and prevention of noise damage.

Basic scientific research, particularly for age-related macular degeneration, must move forward, as it is doing in the industrial countries, where this disease constitutes a major burden and where highly developed research establishments exist.

CONCLUSIONS: PROMISES AND PITFALLS

With what we now know about some of the cost-effective interventions cited above, we could make significant reductions in the burden of disease related to loss of vision. Although waiting for someone to have a condition and then remedying the situation is not a particularly common "public health" recommendation, given the costs of and knowledge of prevention at this point, we can strongly recommend surgery both for cataract (the primary option) and for trachoma (apparently a better use of resources than mass treatment with antibiotics—even if not acceptable on a humanitarian basis). For example, clearing the backlog of cataract surgery globally could reduce the DALYs associated with vision loss by more than half.

Hearing loss interventions have only begun to demonstrate their potential effectiveness in developing countries, and no cost work has been done in these settings. Furthermore, although the means to reduce the burden of adult-onset hearing loss are not as straightforward nor as easily applied,

eliminating adult hearing loss would avoid slightly more YLDs than eliminating the cataract surgery backlog. The data suggest that these interventions (particularly cataract surgery) are relatively cost-effective, but a lack of political will, a failure to recognize that steps can be taken now, insufficient capacity within ministries of health to carry out the known beneficial interventions, and, finally, a lack of equipment or funding for the programs still remain barriers to alleviating disabilities related to vision and hearing loss.

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