Predictors of hearing loss in school entrants in a developing country

Olusanya BO, Okolo AA[1], Adeosun AA[2]

Institute of Child Health,LUTH, Lagos; [1]Department of Paediatrics,UBTH, Benin; [2]Department of ORL, UCH, Ibadan; Nigeria.

Correspondence:
Bola O. Olusanya, FRCPCH
E-mail:
b.olusanya@ich.ucl.ac.uk

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ABSTRACT

Background: Hearing loss is a prevalent and significant disability that impairs functional development and educational attainment of school children in developing countries. Lack of a simple and practical screening protocol often deters routine and systematic hearing screening at school entry.

Aim: To identify predictors of hearing loss for a practical screening model in school-aged children.

Settings and Design: Community-based, retrospective case-control study of school entrants in an inner city.

Methods: Results from the audiologic and non-audiologic examination of 50 hearing impaired children in randomly selected mainstream schools were compared with those of a control group of 150 normal hearing children, matched for age and sex from the same population. The non-audiologic evaluation consisted of medical history, general physical examination, anthropometry, motor skills, intelligence and visual acuity while the audiologic assessment consisted of otoscopy, audiometry and tympanometry.

Statistical Analysis: Multiple logistic regression analysis of significant variables derived from univariate analysis incorporating student t-test and chi-square.

Results: Besides parental literacy (OR:0.3; 95% CI:0.16-0.68), non-audiologic variables showed no association with hearing loss. In contrast, most audiologic indicators, enlarged nasal turbinate (OR:3.3; 95% CI:0.98-11.31), debris or foreign bodies in the ear canal (OR:5.4; 95% CI:1.0-36.03), impacted cerumen (OR:6.2; 95% CI:2.12-14.33), dull tympanic membrane (OR:2.2; 95% CI:1.10-4.46), perforated ear drum (OR:24.3; 95% CI:2.93-1100.17) and otitis media with effusion OME (OR:14.2; 95% CI:6.22-33.09), were associated with hearing loss. However, only parental literacy (OR:0.3; 95% CI:0.16-0.69), impacted cerumen (OR:4.0; 95% CI:1.66-9.43) and OME (OR:11.0; 95% CI:4.74-25.62) emerged as predictors.

Conclusion: Selective screening based on the identification of impacted cerumen and OME will facilitate the detection of a significant proportion of hearing impaired school entrants.

KEY WORDS: School screening, hearing loss, risk factors, impacted cerumen, otitis media

Hearing loss among school-going children in the developing world has been widely reported as a significant health problem.[1-6] Since mainstream schools are auditory-verbal environments, hearing impairment has adverse consequences on educational attainment. Hence, hearing screening at school entry has been proposed for the early detection and rehabilitation of hearing impaired school children in the developing world.[7,8]

Unfortunately, school-aged children are rarely screened for hearing loss during routine clinical examination and most school health authorities make no provision for audiometric assessment. This is usually attributable to low awareness among parents, school authorities and healthcare providers on the consequences of slight/mild hearing loss. The overwhelming burden of prevailing communicable and fatal diseases on the available/limited resources in most communities further diverts attention away from routine auditory screening.

Where it is possible to introduce school audiometry, it is likely that the detection of hearing impaired children will be based on the World Health Organisation (WHO) definition of "disabling hearing impairment" in children under the age of 15 years described as "a permanent unaided hearing threshold level in the better ear of 31 dB or greater".[9] This criterion however, has some inherent limitations. For example, it excludes children with conductive hearing loss, which is common in this age group as a result of recurrent, chronic or acute otitis media.[1-5] It also, does not recognize children with unilateral hearing loss of any degree or those with permanent (sensorineural or mixed) hearing loss less than 31 dB. Yet, these children experience communication difficulties under adverse listening conditions such as noisy classrooms. Such conditions might impair their educational performance.[10-12] Therefore, a significant number of school children with "disabling" hearing loss are unlikely to be detected by hearing screening based on the WHO criterion alone. While children with moderate-to-profound permanent and bilateral hearing loss (>40 dB) may be detected through initial parental suspicion, those with slight/mild hearing loss (16–40dB) are unlikely to be so detected, because the handicap is associated more with receptive rather than expressive linguistic skills.[13,14]

Consequently, we examined the audiologic and non-audiologic profile of hearing impaired school children to identify predictors of hearing loss as a basis for a practical screening protocol. The parameters were derived from conventional school health and child surveillance programmes.[15,16]

Materials and Methods

Sampling

The study was conducted in Mushin, a high-density inner city area of Lagos in Nigeria with a population of 11,689 school entrants in 76 public primary schools. EPI Info (6.04) statistical package was used to compute the initial sample size of 256 based on the following formula:

Sample size (N) = k/1- (k/population)];
where, $k = z^2 p (1 - p)/d^2$,
z = Z- score corresponding to 95% CI (i.e. 1.96),
p = available local prevalence rate in the target population (which was 2.8% obtained from a comparable local study[17]),
d = margin of error allowed (2%)

By building in an attrition rate of 20% the sample size was increased to 306 as a baseline. The sample was drawn from 8 (10%) schools chosen by simple random sampling. The first child was randomly selected from the class register and every third child thereafter. This process yielded a total of 361 children. However, parental consent was obtained for 359 who were enlisted for the study. They comprised 190 (52.4%) girls and 169 (47.6%) boys, aged 4.5-10.9 years (mean: 6.7 years). The majority (97.2%) belonged to the least affluent social classes III-V based on mothers' education and fathers' occupation.[18] Ethical approvals were obtained from the appropriate university teaching hospital and local educational authority. The data were collected over a period of six months within the same school year.

Non-Audiologic Examination

Medical History

A structured questionnaire was administered to parents to ascertain the medical, social and family status of the children.

Anthropometry

Height, weight and head circumference (occipitofrontal circumference or OFC) were measured based on the guidelines recommended by the Child Growth Foundation (UK) from where all the measuring instruments were obtained. A 'Minimeter 183' with a range of 0-183cm and accuracy of 1mm was used for the height measurement. Weight was measured with a self-calibrating scale - Soehnle 7209 – with a range of 0-130kg and an accuracy of 200g. Each child was weighed wearing the school uniform, which was light. The measurement was recorded without shoes and socks, to the nearest 100g. OFC was measured with a 'Holtain 2m' plastic tape, which has a range of 0-2m and an accuracy of 1mm. The measurement was recorded to the nearest millimetre, taken from midway between the eyebrows and the hairline at the front of the head and from around the occipital prominence at the back of the head. All the anthropometric results were interpreted using normalized international growth reference curves.[19]

Visual Acuity

Ophthalmologic tests were conducted using Snellen's chart. Children with visual acuity of 6/12 and above, in one or both eyes underwent the Sonsken Silver Acuity test. Those with visual acuity greater than 3/4.5 in one or both eyes were deemed to have failed the eye test and were referred to the eye clinic in a nearby university teaching hospital for further evaluation and treatment.

Intelligence Test

A non-verbal test of intelligence - the Draw-A-Man test- was administered during which the children were given paper and pencils in groups of 10 to 20 and were instructed to draw a person (mummy or daddy) as best as they could without using erasers. The test was then scored using recommended local guidelines.[20]

Motor Skills

Gross motor skills were assessed by asking the children to hop on each foot and walk heel to toe on a straight line. This was complemented by locally validated Slosson's Co-ordination Drawing Test designed to identify individuals with various forms of perceptual disorders involving eye-hand co-ordination.[21]

Other Medical Examination

General medical examination was undertaken to document any other routine clinical information.

School Performance

School performance was assessed using the end-of-year school examination results and the various continuous assessment reports from each class. Scores below 25th percentile in the combined schools' data were considered as failure.

Audiological Examination

Otoscopy and Audiometry

The ear canals were examined with an otoscope. Foreign bodies, debris and impacted cerumen were removed before audiometric tests which were performed in the quietest section in each school using a duly calibrated pure-tone audiometer with TDH-39 earphones and audiocups for extra attenuation. Tests were carried out only when the noise level meter reading was <45dBA.

A modified two-stage audiometric examination was conducted following a daily biological check of the pure-tone audiometer. At the first stage of the audiometric test, a pass or fail criterion of 20 dB HL was applied to each ear at frequencies 0.5, 1.0, 2.0, and 4.0 kHz. A pass represented correct responses to signals at all frequencies in both ears. A fail was recorded if there was no response at one or more frequencies in either ear. The children who failed were referred to the teaching hospital for threshold testing and bone conduction. A pure-tone average >15 dB HL at frequencies 0.5-4.0 kHz was considered as failure. Pure-tone averages were classified into one of the following hearing loss categories: slight (16- 25 dB HL), mild (26- 40 dB HL), moderate (41- 70 dB HL), severe (71- 90 dB HL), and profound (>90 dB HL). Hearing loss was classified as sensorineural if the air-bone gap was ≤15 dB and conductive if it was >15 dB. Hearing loss was regarded as mixed if the air-bone gap was >15 dB and the bone conduction thresholds were also elevated (>15 dB).

Tympanometry

Similarly, tympanometric evaluation was conducted in two stages at an interval of 6 weeks to allow for the resolution of any transient middle ear conditions. In the first stage, children with non-type A tympanograms were referred for a repeat assessment. Those with persistent non-type A tympanograms at the end of the second stage were considered as having failed the tympanometric test. Those with type B tympanograms among this group were classified as having otitis media with effusion (OME).

Nose and Throat Conditions

Children were examined for an enlarged nasal turbinate and enlarged tonsils, and the findings were grouped under "audiologic" variables.

Selection of Subjects and Controls

Fifty children had pure tone average >15dBHL in frequencies 0.5 - 4.0 kHz at the end of the second stage audiometry and were enlisted as subjects. They comprised 22 boys and 28 girls, with age range of 4.1-10.9 years (mean: 6.6 years). From the remaining 309 children, 150 were selected as controls, matched for age and sex at a ratio of 3 to 1.

Analysis

Univariate analysis incorporating student's t-test and chi-square was done to identify potential risk factors with Epi Info (version 6.04). Audiologic and non-audiologic predictors were established through multivariate logistic regression analysis using SPSS (version 11.0). All confidence intervals (CI) are stated at 95%.

Results

The degree and pattern of hearing loss are presented in Table 1. Forty-seven children had hearing loss in the better ear while 50 children had hearing loss, based on the worse ear thresholds, implying that 3 children had unilateral hearing loss. From the 50 hearing impaired children, 37 (74%) had slight/ mild hearing loss while 13 (26%) suffered from moderate/ moderately severe hearing loss. Eighteen (36%) children had conductive hearing loss, 12 (24%) children sensorineural, and 20 (40%) children had mixed type of hearing loss.[2] In effect, hearing loss can be said to be transient in 18 (36%) and permanent in 32 (64%) children.

Besides microcephaly and pre-auricular sinus, no other craniofacial abnormalities were observed in both subjects and controls. Similarly, no child was found with umbilical hernia or undescended testes.

The univariate analysis of non-audiologic variables (Table 2) showed an association between hearing loss and parental literacy (OR 0.3, CI 0.16 to 0.68). Of the audiologic factors, debris/foreign bodies in the ear canals (OR 5.4, CI 1.0 to 36.03), impacted cerumen (OR 6.2, CI 2.12 to 14.33), dull tympanic membrane (OR 2.2, CI 1.10 to 4.46), perforated ear drum (OR 24.3, CI 2.93 to 1100.17), OME (OR 14.2, CI 6.22 to 33.09) and enlarged nasal turbinate (OR 3.3, CI 0.98 to 11.31) were more likely to be found in hearing impaired children than in normal hearing children (Table 3).

However, after multiple logistic regression analysis, only parental literacy (OR 0.3, 95% CI 0.16 to 0.69), impacted cerumen (OR 4.0, 95% CI 1.66 to 9.43) and OME (OR 11.0, 95% CI 4.74 to 25.62) emerged as predictors of hearing loss (Table 4). A screening model based on these three factors has a sensitivity of 94% (CI 83.4 – 98.7) and specificity of 9.3% (CI 5.2 – 15.2) compared to a sensitivity of 90% (CI 78.2 – 96.6) and specificity of 55.3% (CI 47.0 – 63.4) when parental literacy is excluded from the model. With impacted cerumen alone, the sensitivity is 80% (CI 66.3 – 90) and specificity is 60.7% (CI 52.4 – 68.5), while with OME, the sensitivity is 66% (CI 51.2 – 78.8) and specificity is 88% (CI 81.7 – 92.7).

Discussion

The hearing loss was predominantly slight/mild and bilateral in this study population. Of all the seven factors associated with hearing loss, six were audiologic, suggesting that the hearing impaired children would not have been detected during routine clinical examination without a systematic audiologic screening. Furthermore, of the three risk factors that emerged after multiple regression analysis two were audiologic. This may explain the reason behind the inclusion of routine and systematic hearing screening in well-established child health surveillance programmes in developed countries.[15,16]

Screening is justifiable only where the required treatment is available and affordable. It may be argued that the provision of hearing aids is an expensive treatment in poor communities. However, it should be borne in mind that the hearing impaired children in this population would have benefited significantly from basic intervention such as preferential seating in classroom even without using hearing devices. With proper education, they were also less likely to be misunderstood by people with whom they interacted in difficult listening situations. Moreover, selective screening based on risk factors has been advocated as a cost-effective alternative to universal screening in developing countries.[22]

Studies from the developing world have documented impacted cerumen as the commonest ear disease or aetiology of hearing impairment, with prevalence rates of 7.4% to 63%.[1-5,23] Our find-

Table 1: Degree and pattern of hearing loss in the better ear and worse ear

Degree of hearing loss	Better Ear (n = 47)				Worse Ear (n = 50)			
(Hearing thresholds)	CHL	SNHL	MHL	Total	CHL	SNHL	MHL	Total
Slight (16 - 25dB)	7	6	11	24	2	1	2	5
Mild (26 - 40dB)	8	5	8	21	8	9	15	32
Moderate (41 - 55dB)	1	1	-	2	6	2	2	10
Moderately Severe (56 - 70dB)	-	-	-	-	2	-	1	3
Total	16	12	19	47	18	12	20	50

CHL = Conductive Hearing Loss; SNHL = Sensorineural Hearing Loss; MHL = Mixed Hearing Loss.

Table 2: Non-audiologic profile of hearing impaired children compared with controls

Selected profile	% of Subjects (n = 50)	% of Controls (n =150)	Odds Ratio *P* Value (95% CI)
Family/Social History			
Belongs to polygamous family	30 (15)	31 (47)	0.86
Siblings >4	32 (16)	43 (64)	0.18
Belongs to social class 5	48 (24)	62 (93)	0.082
Both parents did not complete secondary education	52 (26)	77 (115)	<0.001 0.3 (0.16 – 0.68)
Medical History			
Maternal rash with fever	1 (0)	1 (1)	0.56
Non-hospital delivery	16 (8)	17 (25)	0.91
Premature delivery	10 (5)	9 (13)	0.78
Neonatal jaundice	4 (2)	1 (1)	0.09
Febrile seizures	2 (1)	7 (9)	0.09
Incomplete immunization	30 (15)	22 (33)	0.19
Measles	12 (6)	24 (36)	0.07
Nocturnal enuresis	28 (14)	37 (56)	0.23
Developmental			
Delayed social smile	14 (7)	17 (25)	0.66
Speech delay	2 (1)	1 (2)	0.74
Gross-motor delay	0 (0)	2 (3)	0.31
Poor eye-hand coordination	18 (9)	21 (31)	0.68
Low intelligence	12 (6)	13 (20)	0.81
Bilateral genuvarum deformity	2 (1)	1 (2)	0.74
Hemiparesis	2 (1)	0 (0)	0.83
Polio paralysis in lower limbs	0 (0)	3 (4)	0.24
Medical Examination			
Poor dental hygiene	16 (8)	23 (34)	0.19
Squint	0 (0)	1 (2)	0.41
Poor visual acuity	2 (1)	5 (7)	0.40
Stunted growth	24 (12)	21 (32)	0.69
Microcephaly	8 (4)	11 (16)	0.59
Inguinal hernia	0 (0)	0 (0)	-
Umbilical hernia	6 (3)	7 (11)	0.75
Cardiac murmur	0 (0)	0 (0)	0.56
Seborrheic dermatitis	4 (2)	3 (5)	0.82
Scabies	0 (0)	2 (3)	0.31
Fungal skin infections	2 (1)	2 (3)	1.0
Undescended testes	0 (0)	0 (0)	-
Educational			
History of learning difficulties	36 (18)	45 (68)	0.25
Poor school performance	20 (10)	23 (34)	0.69

Table 3: Audiologic profile of hearing impaired children compared with controls

Selected profile	% of Subjects (n = 50)	% of Controls (n =150)	Odds Ratio *P* Value (95% CI)
Medical History			
Hearing difficulty	4 (2)	1 (1)	0.09
Ear discharge	6 (3)	6 (9)	1.00
Medical Examination			
Enlarged nasal turbinate	14 (7)	5 (7)	0.025 3.3 (0.98 – 11.31)
Enlarged tonsils	4 (2)	1 (2)	0.24
Pre-auricular sinus	0 (0)	1 (2)	0.41
Debris or foreign bodies	10 (5)	2 (3)	0.012 5.4 (1.00 – 36.03)
Impacted cerumen	80 (40)	39 (59)	<0.001 6.2 (2.12 – 14.33)
Dull tympanic membrane	54 (27)	35 (52)	0.015 2.2 (1.10 – 4.46)
Perforated ear drum	14 (7)	1 (1)	<0.001 24.3 (2.93 – 1100.17)
Otitis media with effusion	66 (33)	12 (18)	<0.001 14.2 (6.22 – 33.09)

ing on impacted cerumen as a risk factor has been previously documented,[23] and corroborated in another research.[24] These studies have shown that impacted cerumen does not only cause hearing loss before its removal, but that a prior history of impacted cerumen constituted a significant risk factor for hearing loss and OME. Therefore, it is misleading to presume that hearing loss related to impacted cerumen is fully reversible after cerumen removal. The pathophysiology of this disease is still unclear from available literature.[25,26] However, children with cranio-facial anomalies are known to have a propensity for excessive/ impacted cerumen although such children were not found in our study population. It has been suggested that ex-

Table 4: Risk factors for hearing loss after multiple logistic regression analysis

Risk factors	*P* Value	Odds ratio	95% (CI)
Non-audiologic			
Parental literacy	0.003	0.33	0.16 – 0.69
Audiologic			
Impacted cerumen	0.002	3.96	1.66 – 9.43
OME	<0.001	11.01	4.74 – 25.62

cessive/ impacted cerumen is probably a product of complex interactions of several known and unknown factors, some of which have genetic linkage. This makes it rather difficult to outline effective prevention measures besides perhaps regular otoscopy and aural toileting.

Given the high prevalence of impacted cerumen in many developing countries, the prompt detection of children with this disorder should lead to the identification of a significant proportion of the hearing impaired children. Identifying children with impacted cerumen routinely for audiometric evaluation may not require a great deal of expertise beyond basic training in otoscopy. It is useful, at least to refer a child when no part of the tympanic membrane can be visualized due to occlusion of the external auditory meatus by cerumen during routine ear examination.

Otitis media is considered in some reports as the commonest cause of childhood hearing loss in developing countries.[27,28] Studies from Malaysia, India, Nigeria and Egypt reported prevalence rates of 13.8%-36.2% for OME among comparable school-aged populations.[2,4,29,30] The principal risk factors for OME are usually, poor hygiene, poor nutrition, poor housing conditions, viral/bacterial infection and upper respiratory allergy.[28]

A diagnostic marker for the precise identification of OME during routine clinical examination remains elusive. Pneumatic otoscopy is highly rated as the primary diagnostic method with tympanometry as gold standard.[31] Although, pneumatic otoscopy is cheaper, it is subjective, requires considerable skill and involves extensive training. Tympanometry is highly sensitive but quite expensive to use as a screening tool routinely. The accurate diagnosis of OME is still a challenge to many clinicians even in the developed world.[32,33] This, for instance, often results in over-diagnosis of acute otitis media (AOM) and its over-treatment with broad-spectrum antimicrobials.[34,35] AOM is a common but self-limiting childhood disease and only in few cases does it progress to OME. Hence, a more practical option for a developing country presently seems to be the prevention of OME as advocated by the WHO.[28]

The lack of correlation between hearing loss, history of hearing difficulties and ear discharge is corroborated by a study which found parents' prediction of hearing loss associated with OME unreliable.[36] However, it may be of interest to note that parents in the USA for instance, are being trained in rudimentary home otoscopy in an attempt to reduce reliance on physicians for uncomplicated middle ear infections.[37] The aim is to teach parents to recognize normal tympanic membranes and this allows parents to detect any occlusion in external auditory canal due to excessive/ impacted cerumen.

The view that childhood hearing impairment is commonest in low socio-economic classes has become conventional wisdom because of the impact of poor hygienic conditions, low immunization rate and misuse of ototoxic medications. Our study, however, contradicts this inverse relationship and suggests that parents of hearing impaired children are likely to be more literate than those of normal hearing children. In addition, there was no association between childhood hearing loss and other indices of socio-economic status such as family size and social class. This observation reinforces the controversy on the association between socio-economic status, otitis media and hearing loss. For instance, in a cross-sectional study among 5-6-year-old pre-school children in Malaysia, it was found that the higher the working status and income of the parents, the higher the risk of having a child with OME.[30] The authors postulated that early enrolment of children into daycare centres by these working parents increased the risk of cross-infection. In contrast, some other studies reported a higher prevalence of otitis media in the lower socio-economic classes, while others found no association between otitis media and socio-economic status.[38-41] Given this variability, parental literacy by itself is unlikely to be a universal predictor of hearing loss in school-aged children. Furthermore, a screening model that only consists of impacted cerumen and OME, is perhaps more expedient for a developing country because of its significantly better specificity. When the detection of OME is impracticable, however, screening for excessive/impacted cerumen alone should be considered.

Although our study showed that normal hearing children were more likely to have a history of learning difficulties (45% vs. 36%) and poor school performance (23% vs. 20%), the difference was not statistically significant. The lack of standardized school tests across the selected schools may explain why our results differed from reports that documented adverse impact of slight/mild hearing loss on academic performance.[11,12]

This study demonstrates that hearing loss in school-going children cannot be readily detected during routine clinical examination without a systematic audiologic screening. Impacted cerumen and OME are important predictors of hearing loss in this population. When universal audiometric screening cannot be implemented, selective screening or referral based on these risk factors would facilitate the detection of a significant proportion of hearing impaired children for appropriate and timely intervention.

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Expert's Comments

Screening for auditory impairment in resource-poor countries

Loss of hearing, very early in life, can affect the development of speech and language, social and emotional development, and influence behaviour and academic achievement.[1] The critical or sensitive period for the acquisition of language extends from 1 to 5 years of age. However, impairment of hearing commencing after 5 years of age can also have serious consequences. Ninety-five per cent of school children suffer from middle-ear disease, sometime in the first 10 years of their life.[2] Otorrhoea and multiple ear infections are the risk factors associated with loss of hearing in this age group.[3] In the auditory-verbal environment of mainstream schools, such hearing-loss can endanger education.

Hearing-loss is much more common in developing countries. It is estimated that two out of three of the world's hearing-impaired are in developing countries.[4] The reasons include: absence of regular screening programmes for ear disease, poverty, malnutrition, ignorance and paucity of accessible healthcare.[4] A study in a rural primary school in South India has shown that the overall prevalence of otological abnormalities (excluding wax) was 21.5%.[4] A study in Tanzania found ear disease in 27.7% of primary school children.[5]

Loss of hearing should be identified as early in life as possible, if its long-term consequences are to be prevented. The technology used for screening of hearing, should be age-appropriate and the child also should be comfortable with the testing situation. Young children need special preparation. Screening should be conducted in a quiet area where visual and auditory distractions are minimal. Unfortunately, the instruments required for testing hearing abilities in the young children are not widely available in developing countries.

In developed countries, children are screened for hearing-loss routinely at periodic intervals. Implementation of such screening procedures is not feasible in the developing countries at the present moment. Screening at school entry is perhaps the most practical way of ensuring that children are evaluated for hearing capabilities, at least once. It would help if there were identified predictors of hearing impairment, so that children at greatest risk can undergo further evaluation. Researchers working in rural Nigeria have tried to do just this by attempting to determine the correlates of hearing impairment.[6] They used audiometery testing and tympanometery to identify 50 children with pure tone-deafness (greater than 15dBHL in the frequency 0.5 to 4 kHz). They studied these children against 150 controls with normal hearing. They found that the presence of impacted cerumen had a sensitivity of 80%, specificity of 61% and otitis media with effusion (OEM) had a sensitivity of 66%, specificity of 88%, for identifying hearing impairment. The researchers state that, not only does cerumen cause hearing loss before its removal; a history of impacted cerumen is more common in children with hearing impairment from other causes. This is interesting, given that it is known that children with cranio-facial deformities have a propensity for excessive and impacted cerumen.

Screening is justifiable only if a remedy for the screened disorder is available. In the case of school children with moderate auditory impairment in developing countries, the feasible solution may not be provision of hearing aids, but preferential seating in the class. They are placed closer to the teacher, such that they can hear the teacher and also see her face, to facilitate lip reading. The paper also emphasizes and brings out the importance of preventing and treating suppurative otitis media.

Rai S, Puliyel JM
St. Stephens Hospital, Tis Hazari, Delhi - 110 054, India.
E-mail: puliyel@vsnl.com

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