OPEN ACCESS GUIDE TO AUDIOLOGY AND HEARING AIDS FOR OTOLARYNGOLOGISTS

SCHOOL-AGE HEARING SCREENING

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From the 1st year of life through to 6 years of age there is a significant increase in the prevalence of hearing impairment due to progressive and acquired hearing losses, especially in developing countries where environmental risks are more prevalent [1, 2]. Unidentified childhood hearing loss has historically been shown to dramatically deteriorate educational achievement and ultimately vocational outcomes [3]. Even minimal and unilateral permanent hearing loss may result in poor educational test performance, higher incidence of failed grades and greater dysfunction in aspects such as behaviour, energy, self-esteem and socio-emotional ability [4, 5, 6].

School-entry hearing screening is especially important in developing countries where limited legislation or healthcare mandates is available to conduct hearing screening on new-borns and infants. Such school-entry screening may actually be the first point of access to detect childhood hearing loss. This chapter provides guidance about the process of hearing screening on school-aged children taking into consideration the challenges faced in developing countries.

What is hearing screening?

Screening is the process of detecting among apparently healthy persons, individuals who with a greater probability of having a hearing impairment so they may be referred for further evaluation.

Audiometry for hearing screening typically determines whether a person responds to predetermined frequencies and intensity levels at which stimuli are presented. A specific pass/fail criterion is applied to all results and the possibility of a hearing impairment or the absence thereof is a "YES/NO" process. A "pass" result indicates no need for further testing, but a "fail" requires referral for further testing.

Screening is different to audiometric monitoring in which patients' hearing thresholds are determined (often with only air conduction stimuli) to determine if changes occur over time.

Key concepts related to screening

In order to determine the validity of a screening protocol the sensitivity and specificity of the screening tool must be determined. In order for a hearing screening protocol to be acceptable, it should correctly identify at least 90-95% of individuals with the existing condition (sensitivity) and fail no more than 5-10% of individuals who would be considered not to have the condition (specificity) [7]. The stricter the hearing screening criteria used in a protocol, the higher the sensitivity, but the lower the specificity. High sensitivity result in more false-positives, and consequently higher referral rates, increased cost for health care system and increased diagnostic follow-up and management. *Table 1* outlines the concepts related to validity of hearing screening.

Screening population

The target population for school hearing screening should at least include

- All school-entry learners (preparatory grade or grade 1)
- Learners at risk for academic failure or with parent/teacher concerns regarding hearing, speech, language, or learning ability
- Learners with previous or ongoing ear disease

Concept	Definition
Sensitivity	Accuracy of a tool to correctly predict individuals with the target condition being identified
Specificity	Accuracy of the tool to correctly identify individuals who do not have the target condition being screened for
False-Positives	Children without the target condition not accurately identified and classified as having abnormal hearing
False-Negatives	Children with the target condition not accurately identified and classified as having normal hearing
True- negatives	Infants without the target condition accurately identified
True- positives	Infants with target condition accurately identified
Positive predictive value (PPV) (NPV)	Ratio of the number of those scoring positive on the test, who truly have the target condition, to the number of all those who scored positive on the test
Negative predictive value (NPV)	Ratio of the number of those scoring negative, who truly do not have the target condition, to the number of all those scoring negative on the test

Table 1: Definition of concepts

However it is often not possible to screen every school-aged child in Grade 1 due to lack of time, equipment and staffing. Where resource constraints are evident, at-risk children should be prioritised to be screened. The following risk factors would suggest a need for screening [3]:

- Family history of late or delayed onset hereditary hearing loss
- Craniofacial anomalies, including those with morphological abnormalities of the pinna and ear canal
- Stigmata or other findings associated with a syndrome known to include sensorineural and/or conductive hearing loss
- Head trauma with loss of consciousness
- Reported exposure to potentially damaging noise levels or ototoxic drugs
- History of otitis media

Screening personnel

Screening personnel may include school-nurses or community health workers. They should receive adequate training in screening methods and referral pathways. This should be accompanied by regular monitoring and quality control and on-going training. An audiologist or other person with appropriate expertise may facilitate training and monitoring.

Screening technologies

A number of test procedures have been utilised for screening. The current recommendation for school screening is pure tone screening audiometry. This utilises a pass/fail criterion that determines the possibility of the presence or absence of a hearing impairment. Tympanometry can be used as a subsequent screening test to determine the status of the middle ear [3]. Speech audiometry, otoacoustic emissions (OAE´s), speech-in-noise testing and, questionnaires are other screening methods that have been utilised; these tests have not been suggested to be used as a substitute for pure tone audiometry school-based screening.

Goal of a hearing screening program

The goal of a hearing-screening program is to identify children with a hearing loss in order to allow for further diagnosis and intervention. It should be relatively ***simple to perform, require minimal preparation,***

and be cost-effective. In order to achieve this, clear goals need to be identified with specific criteria, which would not overwhelm under-resourced health care systems with excessive referrals.

However, the degree and type of hearing loss to be identified is defined by establishing a target disorder. The target disorder for school-aged hearing screening is often referred to as an ***educationally significant hearing loss (ESHL)*** [3, 8]. ESHL is any form of hearing impairment that could potentially interfere with a learner's academic performance. ESHL may include permanent sensorineural, conductive or mixed hearing loss but may also include transient conductive losses. Whilst ESHL is specified as a threshold > 20 dB HL at 1, 2, or 4 kHz in either ear by some guidelines [3, 8] other programmes use intensity levels of 25 dB HL or even 30 dB HL [3, 8, 11,12,13].

Appendix A is an example of how a hearing-screening program can be effectively utilised in a developing country *e.g.* rural Kenya.

Hearing screening protocol

A hearing screening protocol includes the tests and procedures that are used in the hearing-screening program. Once the target disorder has been identified, a decision about equipment and procedures is made. *Figure 1* provides a schematic representation of the procedures and protocols that could be utilised in a hearing-screening program in order to determine an appropriate diagnosis and intervention.

Calibration of equipment & daily check

The purpose of routine checking is to ascertain that equipment is working properly, that its calibration has not noticeably altered and that its attachments, leads and accessories are not defective and may affect the test results. A daily listening check should be performed by the tester to rule out distortion, crosstalk and to determine that defects do not exist in major components. It is advisable that the equipment is calibrated at least once a year according to the international and national standards (*e.g.* ISO 389-1) [9].

Screening environment

Screening should be conducted in a quiet environment with minimal visual and auditory distractions. Ambient noise from ventilation, an adjacent hall or classroom, children moving about in the test room and screening personnel giving instructions all contribute to difficulty with screening and may result in false-positive results.

Maximum permissible ambient noise levels (MPANLs) according to ISO 389-1:1998 [9] when using TDH39 headphones must be adhered to during screening to ensure reliable results *(Table 2).*

Screen intensity	**1 kHz**	**2 kHz**	**4 kHz**
20 dB HL	31.0	37.0	49.7
25 dB HL	36.0	42	54.7

Table 2: Maximum permissible ambient noise levels (MPANLs) for TDH 39 headphones in dB SPL

Most school systems, especially in developing countries, do not have the equipment or expertise to take ambient noise measurements in areas used for screening. Although not ideal, an alternate approach is to use a biologic noise level check prior to the start of hearing screening. This is defined as the ability to establish hearing thresholds at least 10 dB below the screening level (*e.g.*15 dB HL for screening conducted at 25 dB HL) at all

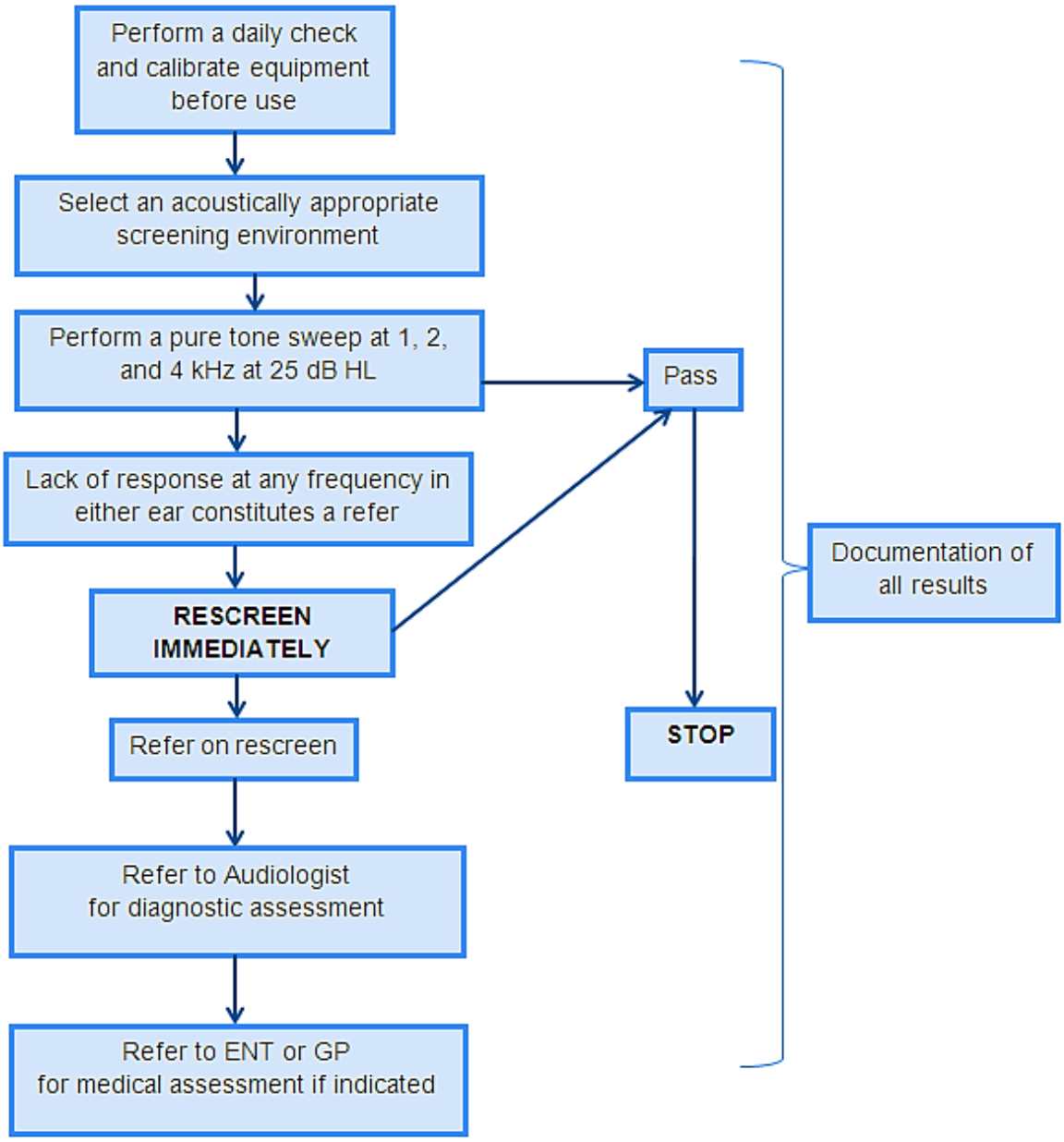

Figure 1: Flowchart depicting recommended procedure to follow in school-aged hearing screening using a 25 dB HL screening level

frequencies for a person with known normal hearing. If these thresholds cannot be established, the area must not be used for screening. Recent screening tools (automated smartphone audiometer) have also attempted to integrate monitoring of real-time noise to assist screeners [10].

Screening procedures

When utilising pure tone screening, pure tone signals are presented across different frequencies, first in the one ear and then in the other. Responses to the signals typically include a raising a hand or a conditioned response such as dropping a block in a bucket. The presence or absence of a child's response is recorded for each tone. The child should be seated facing a blank wall with his/her back turned towards the tester so that no visual cues can be detected *(Figure 2)*. The remaining

screening procedures are described below and summarized in *Table 3*.

Figure 2: Seating position while conducting pure tone audiometry screening

Considerations	Recommendations
Screening frequencies	1, 2 and 4 kHz
Screening intensity	20 dB HL (underserved, developing countries should consider 25 and 30 dB HL)
Number of presentations	Tone may be presented more than once, but no more than 4 times
Pass/refer criteria and rescreening	Fail at one frequency in either ear requires a rescreen, a rescreen fail at any frequency in either ear indicates a referral for further testing

Table 3: Summary of screening recommendations

Screening frequencies: Recommended test frequencies vary but general consensus of current guidelines is to use 1, 2 and 4 kHz as the test frequencies for screening [3, 8, 11, 12, 13].

Screening intensity: A pure tone screening level of 25 dB HL has been suggested to have the best combined sensitivity/specificity rates when screening for ESHL, but has poorer sensitivity when screening for minimal hearing losses [14]. The decision what level to use is based on the selected target disorder (*e.g.* ESHL), and how it is defined. Using the stricter criterion of 20 dB HL screen level as commonly recommended [3, 8] will identify milder losses but will also result in a significant increase in children referred for further testing which demands more health care resources. In developing countries where health resources are limited alternative screening levels may be necessary to ensure referral rates do not overwhelm already burdened health systems. A cut-off of 25 or 30 dB HL may provide a reasonable trade-off in terms of identifying hearing losses that will be educationally significant, at the risk of missing some milder losses, whilst ensuring acceptably low referral rates (e.g. < 4%).

Number of presentations: It is not unusual for children to fail to respond to a single pure tone presentation when hearing screening is performed in the presence of varying levels of ambient noise. This occurs particularly when young children have limited attention spans, or when the intensity of the pure tone is close to the hearing threshold. Thus, a pure tone may need to be presented more than once at a specific intensity if a child fails to respond. Caution is however warranted to prevent that so many repetitions of the tone is provided that the eventual false positive responses will be considered a pass. Therefore, it is reasonable that more than one, but no more than 4 pure tone presentations are given if a child does not respond to the first presentation [3]. Other than for training purposes, it is important that the chosen decibel level screening criterion be adhered to throughout the hearing screening and that the level is never increased if the child fails to respond.

Pass/refer criteria and rescreening: A pass result for a child usually constitutes a pass at all frequencies (1, 2 and 4 kHz) at the recommended screening intensity (*e.g.* 20, 25 dB HL or 30 dB HL) in both ears. If a child does not respond at the screening intensity at one or more frequencies in either ear, the tester should instruct the child again, reposition the earphones, and rescreen within the same screening procedure in which the child failed. Children who do not pass the rescreen should be referred for further diagnostic hearing evaluation and if needed for a medical evaluation by a general practitioner or an Ear, Nose and Throat specialist.

Documentation of results

All identifying information, screening results, and recommendations for rescreening, assessment, or referral should be documented (Appendix B, example of a screening form). Furthermore, information pertaining follow-up, including personnel conducting follow-up, should be recorded. Prior to initiating screening, a process for notifying parents/guardians and teachers of the screening result should be arranged (Appendix C, example of a consent forms).

Diagnosis and intervention

Prior to initiating hearing screening at schools, services should be in place or should be developed to accommodate referrals resulting from the screening. *Table 4* indicates the professionals that may be needed to make an appropriate diagnosis and provide intervention:

Children who fail hearing screening must be referred for further diagnostic testing to determine if a hearing loss exists and if present, what the type, degree, configuration and symmetry of the loss is. As illustrated in *Table 3*, audiologists perform diagnostic assessments whilst medical personnel may be required to further examine children if a conductive hearing loss is identified. Interventions relating to the hearing loss should subsequently be provided by the audiologist or by medical personnel (ENT, GP or nurse) if there is a conductive hearing loss.

Professional	**Diagnosis & Intervention**
Audiologist	• Diagnostic evaluation of hearing • Fitting of hearing aids or • FM systems
ENT, GP or Nurse	• Determine cause of conductive hearing losses • Management of conductive pathologies (middle ear infection, wax)

Table 4: Personnel required for diagnosis and intervention

In some under-resourced settings, audiological or medical interventions may not be readily available. While services are sought out, important environmental modifications can be made with immediate effect for children with hearing loss in school settings. These modifications can provide significant support in the before audiological and/or medical intervention is commenced and may include the following:

- Sit the child in the front of the class
- Reduce background noise *e.g*, turn off music and choose a quiet place for activities in order to optimise listening and communication
- Use carpets, drapes, pillows and other soft materials to absorb disturbing "excess sound"
- Provide visual cues when talking to a child with a hearing disability, and make eye contact before you start to speak. A gentle tap on the shoulder will

usually get the child's attention. Look at the child while speaking and *encourage* him/her to watch your lips

Summary of school hearing screening process

- Have equipment calibrated once a year
- Obtain parental consent
- Perform biological check of equipment prior to daily screening
- Only screen in an acoustically appropriate screening environment
- Perform a pure tone sweep at 1000, 2000, and 4000 Hz at 25 dB HL (or alternative selected screening intensity and frequencies)
- Present a tone more than once but no more than 4 times if a child fails to respond
- Lack of response at any frequency in either ear constitutes a failure
- Rescreen immediately
- Use tympanometry in conjunction and as a second-stage screening method to evaluate middle ear status
- Document findings
- Make appropriate referrals and follow-ups

Conclusion

Any loss of hearing sensitivity constitutes a major barrier to effective learning as all formal learning activities in school environments are mediated through the sense of hearing. Hearing screening programs should be initiated for pre-school or school aged children to support equal educational opportunities for children who suffer from communication disorders [13]. A systematic screening programme with correct equipment, trained personnel and adequate follow-up services will allow children with ESHL to be accurately diagnosed and managed to provide them with equal learning opportunities.

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APPENDIX A

A screening program for rural Kenya to identify hearing impaired school children aged 3-15 years: "How it could be done"

By Joseph Kweya Ayieko, Manager at the Swedish Rotary Hearing Aid Centre in Nyeri, Kenya, *(Degree: Diploma in Hearing Aid Acoustics at the Dept. of Speech-Language Pathology & Audiology, University of Pretoria, Pretoria, South Africa).*

Background facts

Nyeri County is one of 47 administrative counties in Kenya and it has an estimated population of 700.000 inhabitants. It is located in the Central Province at an altitude of 1900m above sea level at the foot of Mt. Kenya and covers an area of about 3500 km^2. The Government Mission hospitals and privately owned health institutions provide health services. The Swedish Rotary Hearing Aid Centre in Nyeri opened in 2003 and provides audiological services within Nyeri County and accepts referrals from the whole of Kenya.

Objectives of the program

1. To identify from a larger population of young scholars (3-15 years) those that have a permanent hearing impairment of >30dB HL at 1000, 2000 and 4000 Hz in the better ear. Priority should be given to very young scholars of 3-7yrs, an age that is crucial to language development in a person´s life
2. To increase community awareness about hearing loss and hearing health
3. To advocate for those identified with permanent disabling hearing impairment to seek hearing health assistance
4. To sensitise teachers about the need to have scholars screened for hearing impairment before placement in class and about the need to have follow up hearing screening visits in schools
5. To form a database with the figures collected from the activity to be used as facts to focus representatives from government and other organizations on the magnitude of the problem of hearing loss in scholars and to give it priority in a developing country

It should be noted that the target disorder was a permanent hearing impairment of >30dB HL in the better ear; thus a pass/fail criteria of 30 dB HL was used.

Equipment used *(Figure 3)*

- Two Heine "mini 2000" otoscopes and one 512Hz tuning fork
- Two screening battery-operated audiometers (Madsen "Micro mate 304")
- One Quick check tympanometer (Madsen)
- OAE otoport (optional)
- Laptop computer for data capturing

Figure 3: Equipment

Personnel

Health clinic personnel trained in the school screening procedure – e.g. staff members at a hearing aid centre (manager, audiometrician, nurse or nurse assistant).

Annual program

Between 25 and 32 schools (>6000 pupils) are visited each year. Some schools for the deaf are included to identify those who could benefit from hearing aids.

Figure 4: Screening at a Kenyan school

Protocols

The head of the screening team liaises with the local education department for permission to visit the schools on the dates provided before rolling out any term based or annual program. The school administrators are informed of the screening visits at least 4 weeks before they occur to prepare the teachers, children and parents about the visits. The parents fill out a questionnaire about each child´s hearing and if there has been any previous or recent ear disease. The teachers locate and indicate children with suspected hearing loss or with difficulties following the teaching and/or concentrating in class.

Summary of findings

- About 1% of those screened have sensorineural hearing loss and 1% conductive hearing loss
- Obstructing wax occurs in about 6% of ears and foreign bodies in the external ear canal in about 2% of ears
- Draining tympanic membrane perforations and dry perforations are seen in 1.3% of ears.
- Acute otitis media and otitis media with effusion are encountered in less than 1% of ears
- About 10% of pupils are referred to hospital for further ENT examination (8.5%) or conventional hearing tests (1.5%)

APPENDIX B

Hearing screening form

Background information:

Name of school:	**Grade:**
Name of learner:	**DOB:**
Age: _____years _____months	**Gender:**

Tympanograms:

	Type	**Volume**	**Pressure**	**Compliance**
Right ear				
Left ear				

Pure tone screening:

	1000 Hz	**2000 Hz**	**4000 Hz**
Right ear	pass / refer	pass / refer	pass / refer
Left ear	pass / refer	pass / refer	pass / refer

Overall results:

Pass/Refer **Reason**: _____

Refer to: ENT/Audiologist/ Other: _____

APPENDIX C

Informed consent to parent/caregiver

Dear parent

The Audiology Department renders hearing screening services to the school at which your child is attending. The screening usually takes between 5 and 10 minutes to complete and if your child fails a screening test they will be referred accordingly.
Should you wish to make use of these services, kindly complete the form below.

Kind regards

_____ _____

Consent:

Herewith I _____ (name) grant permission that hearing screening may be conducted on my child, _____(name).

_____ _____

Signature of parent / guardian: **Date**