

# OPEN ACCESS GUIDE TO AUDIOLOGY AND HEARING AIDS FOR OTOLARYNGOLOGISTS



## SCHOOL-AGE HEARING SCREENING

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From the first year of life through to six years of age, there is a significant increase in the prevalence of hearing loss due to progressive and acquired hearing loss. This increase is more evident in developing countries where environmental risks are more prevalent<sup>1,2</sup>. Unidentified childhood hearing loss has historically been shown to dramatically hinder educational achievement and ultimately vocational outcomes<sup>3</sup>. 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<sup>5,6,7</sup>.

School-entry hearing screening is especially important in developing countries where limited legislation or healthcare mandates are available to conduct hearing screening on newborns and infants. Consequently, school-entry screening may be the first point of access to detect childhood hearing loss. It also provides an opportunity to educate children and teachers about healthy hearing and safe listening practices. This chapter provides guidance on the hearing screening process for school-aged children taking into consideration the challenges faced in developing countries.

### What is hearing screening?

Hearing screening involves presenting sounds at various predetermined frequencies and intensities to determine the child's ability to hear them. It is designed to detect potential hearing difficulties at an early age, allowing for timely intervention and management.

A specific pass/fail criterion is applied to all results and the possibility of a hearing loss, or the absence thereof is based on a

“YES/NO” paradigm. A “pass” result indicates no need for further testing, but a “refer” requires referral for further testing, usually conducted by an audiologist.

Screening is different to audiometric monitoring in which 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. For a hearing screening protocol to be acceptable, it should correctly identify at least 90-95% of individuals with the existing condition (sensitivity) and refer no more than 5-10% of individuals who would be considered not to have the condition (specificity)<sup>8</sup>. The more stringent the hearing screening criteria used in a protocol, the higher the sensitivity, but the lower the specificity. High sensitivity results in more false-positives, and consequently higher referral rates with increased cost to the healthcare 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/kindergarten 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 or hearing difficulties

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

*Table 1: Definition of concepts*

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

- Family history of late or delayed onset hereditary hearing loss
- Craniofacial anomalies, including morphological abnormalities of the pinna and ear canal
- Stigmata or findings associated with a syndrome known to include sensori-neural 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 Prerequisites

The World Health Organisation <sup>4</sup> recommends the following factors be considered when planning school-based screening programmes:

- Procedures must be in place for follow-up of referrals ensuring ear and hearing care services are available for referred children, or they should be developed concurrently.
- Noise levels at the screening site must be controlled.
- Screening must be calibrated regularly (preferably at least annually), using reliable equipment.
- Consent or assent must be given by the parent/caregiver and child (active or passive, in line with local policies).
- Normal asepsis measures must be established for infection control.
- Management and accountability of the programme must be ensured.

### Screening personnel

Screening personnel may include school-nurses, trained healthcare workers or lay 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 ongoing training. An audiologist or other person with appropriate expertise may facilitate training and monitoring.

The training should include the following <sup>4</sup>:

- Importance of hearing – especially for education
- Purpose and protocol of screening
- Basic anatomy of the ear

- Causes of hearing loss
- Basic operation of the screening programme and the process for reporting
- The role of the screener
- Screening and referral methods
- Screening room setup and calibration of equipment
- Use of equipment, including maintenance and troubleshooting if not working
- Background noise measurements
- Otoscopy and tympanometry (where available)

### Screening technologies

Several test procedures have been used for screening which includes pure tone screening (automated or non-automated), speech-in-noise testing, ear examination (otoscopic) and middle ear pressure assessment (tympanometry). This chapter will focus on pure tone screening audiometry which utilises a pass/fail criterion that determines the possibility of the presence or absence of a hearing loss.

Tympanometry, speech-in-noise testing, and otoscopic examinations can be used as a subsequent screening test only where trained staff and decision support for examination and diagnosis of ear disease is available either immediately or remotely<sup>4</sup>.

### Goal of a hearing screening program

The goal of a hearing-screening program is to identify children with a hearing loss to permit further diagnosis and intervention. It should be relatively *simple to perform, require minimal preparation, and be cost-effective*. To achieve this, clear goals need to be identified with specific criteria, which would not overwhelm under-resourced healthcare systems with excessive referrals.

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)*<sup>3,9</sup>. ESHL is any form of hearing loss that could potentially interfere with a child's academic performance. It 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 in some guidelines<sup>3,9</sup>, other programmes use intensity levels of 25 dB HL or even 30 dB HL<sup>3,9,12,13,14</sup>.

*Appendix A* illustrates how a hearing-screening program can be effectively implemented 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) <sup>10</sup>.

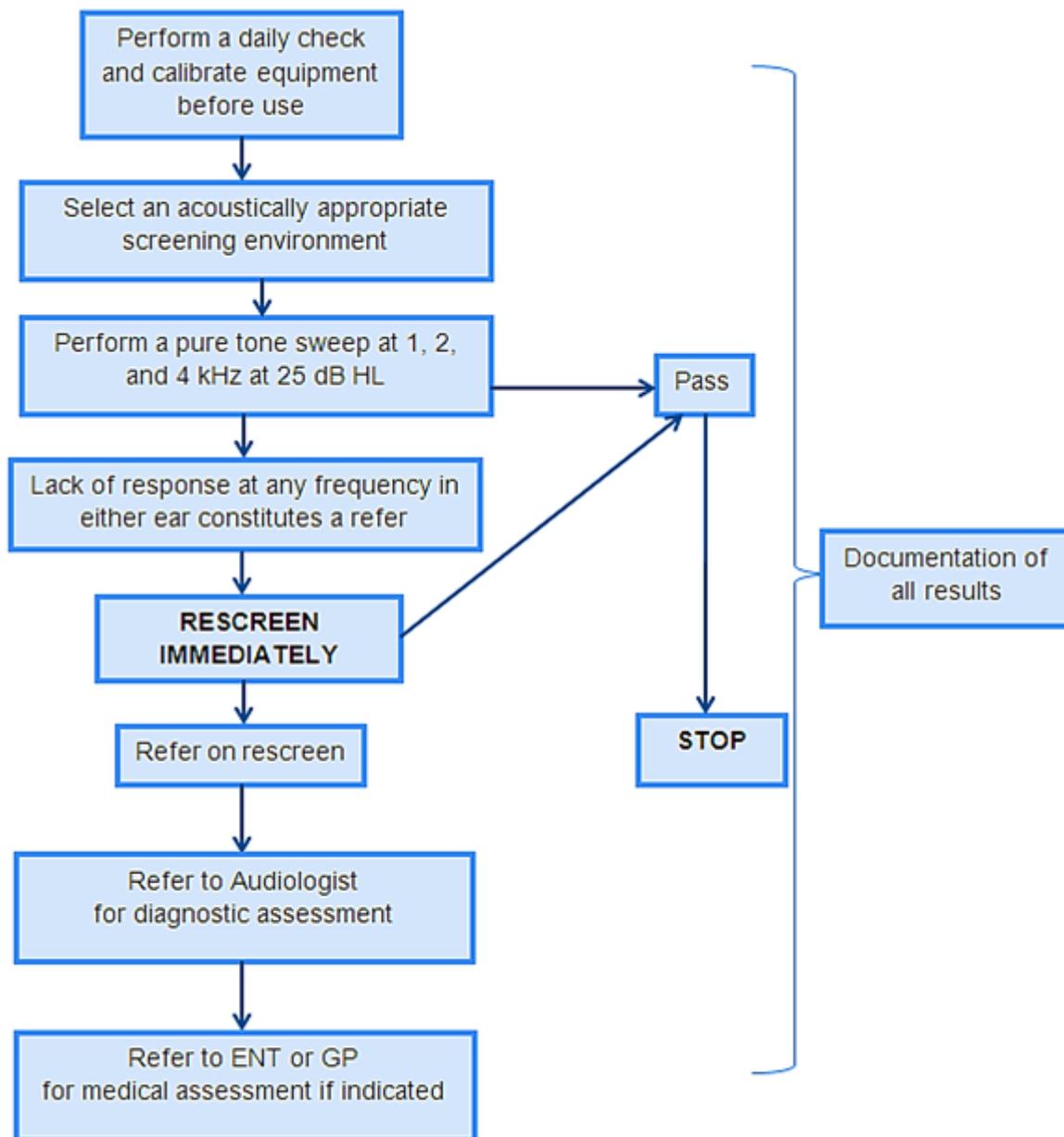


Figure 1: Flowchart depicting recommended procedure to follow in school-aged hearing screening using a 25 dB HL screening level

### Screening environment

Screening should be conducted in a quiet environment with minimal visual and auditory distractions. A quiet location should be identified within the school premises and noise levels should be checked beforehand. It is important to

ensure that noise levels do not exceed the maximum permissible levels (MPANLs) prescribed for the selected headphones and screening level. Maximum permissible ambient noise levels (MPANLs) according to ISO 389-1:1998<sup>9</sup> when using TDH39 are available in (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

Screening should be paused when there are transient increases in ambient noise. Ambient noise may occur as a result of ventilation, an adjacent hall or classroom, children moving about in the test room and screening personnel giving instructions. These factors contribute to difficulty with screening and may result in false-positive results.

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 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<sup>11</sup>.

### 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. Presentation can occur automatically or manually based on the screening device that is being utilised. 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 summarised in Table 3.



Figure 2: Seating position while conducting manual 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<sup>3, 8, 11, 12, 13</sup>.

**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<sup>14</sup>. 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<sup>3, 8</sup> 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 not respond to a single pure tone presentation when hearing screening is performed in the presence of varying levels of ambient noise. This occurs particularly in young children due to their 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<sup>3</sup>. 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 re-screen within the same screening procedure to which the child was previously referred. 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, noise levels, screening personnel and recommendations for rescreening, assessment, or referral should be documented (Appendix B is an example of a screening form) and kept confidential. Parents or caregivers should be informed of the results and recommendations. Information about follow-up, including personnel conducting follow-up, and the recommendations should be recorded.

### **Diagnosis and intervention**

Prior to initiating hearing screening at schools, services should be in place or should be developed to accommodate referrals resulting from screening. The decision of who should receive referrals must be based on the local context, availability of ear and hearing clinicians and other trained health workers. A triaged referral approach can be followed e.g., medical concerns such as ear discharge, swelling etc., can be treated by a primary care physician or a trained nurse;

and hearing loss concerns should be referred directly to an ear and hearing care clinician<sup>4</sup>.

Children who obtain results requiring referral on hearing screening must be referred for further diagnostic testing to determine if hearing loss exists and if present, what type, degree, configuration and symmetry 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	<ul style="list-style-type: none"> <li>• Diagnostic evaluation of hearing</li> <li>• Fitting of hearing aids or FM systems</li> </ul>
ENT, GP or Nurse	<ul style="list-style-type: none"> <li>• Determine cause of conductive hearing loss</li> <li>• Management of conductive pathologies (e.g. wax, middle ear infection)</li> </ul>

*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 sourced, important environmental modifications can be made with immediate effect for children with hearing loss in school settings.

Such modifications can provide significant support in before audiological and/or medical interventions are commenced and may include the following:

- Seat a child in the front of the classroom
- Reduce background noise *e.g.* turn off music and choose a quiet place for activities 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 speaking. A gentle tap on the shoulder will usually get a child’s attention. Look at the child while speaking and *encourage* him/her to watch your lips

### Summary of school hearing screening process

- Calibrate equipment annually
- Calibrate and do a biological check of equipment prior to daily screening
- Only screen in an acoustically appropriate screening environment
- Obtain parental/caregiver consent
- Perform a pure tone sweep at 1000, 2000, and 4000 Hz at 25 dB HL (or alternative at 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 is an indication for referral
- Rescreen immediately
- Use tympanometry for a second-stage screening method to evaluate middle ear status
- Document the findings
- Make appropriate referrals and follow-ups

### Conclusions

Any loss of hearing sensitivity constitutes a major barrier to effective learning as all formal learning activities in school environments are mediated through hearing. Hearing screening programs should be initiated for preschool/kindergarten or school aged children to support equal educational opportunities for children who suffer from

communication disorders<sup>13</sup>. A systematic screening programme with correct equipment, trained personnel and adequate follow-up services will allow children with hearing loss to be accurately diagnosed and managed and 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”**

Joseph Kweya Ayieko, Manager at Swedish Rotary Hearing Aid Centre in Nyeri, Kenya

### ***Background facts***

Nyeri County is one of 47 administrative counties in Kenya and has an estimated population of 700.000. 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<sup>2</sup>. 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 large population of young scholars (3-15 years), those that have a permanent hearing impairment of >30 dB HL at 1000, 2000 and 4000 Hz in the better hearing ear. Priority is given to very young scholars of 3-7yrs, an age that is crucial to language development.
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 a classroom and about the need to have follow up hearing screening visits in schools.
5. To create a database with data collected from the activity, and to be used to inform government representatives and

other organisations about 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 is a permanent hearing impairment of >30 dB HL in the better hearing ear; thus a pass/fail criteria of 30 dB HL is used.***

### ***Equipment used (Figure 3)***



*Figure 3*

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

### ***Personnel***

Health clinic personnel trained in school screening procedure – e.g. staff members at a hearing aid centre (manager, audiometrist, 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 schools on certain dates before rolling out any term-based or annual program. School administrators are informed at

least 4 weeks before the screening visits to prepare the teachers, children and parents about the visits. Parents complete a questionnaire about each child's hearing and if there has been previous or recent ear disease. The teachers identify children with suspected hearing loss or with difficulties following the lessons or concentrating in class.

### **Summary of findings**

- About 1% of those screened have sensorineural hearing loss and have 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 diagnosed in < 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**

<b>Name of school:</b>	<b>Grade:</b>
<b>Name of learner:</b>	<b>DOB:</b>
<b>Age: _____ years _____ months</b>	<b>Gender:</b>

**Tympanograms**

	<b>Type</b>	<b>Volume</b>	<b>Pressure</b>	<b>Compliance</b>
<b>Right ear</b>				
<b>Left ear</b>				

**Pure tone screening**

	<b>1000 Hz</b>	<b>2000 Hz</b>	<b>4000 Hz</b>
<b>Right ear</b>	pass / refer	pass / refer	pass / refer
<b>Left ear</b>	pass / refer	pass / refer	pass / refer

**Overall results**

Pass/Refer      **Reason:** \_\_\_\_\_

**Refer to:** ENT / Audiologist / Other: \_\_\_\_\_

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**APPENDIX C; Informed consent from parent/caregiver**

Dear Parent

The Audiology Department renders hearing screening services to the school that your child is attending.

The screening usually takes between 5 and 10 minutes to complete.

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**