

## Review Article

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# Hearing healthcare in remote or resource-constrained environments

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## Abstract

**Background.** Hearing loss is a leading contributor to the global burden of disease, with more than 80 per cent of affected persons residing in low- and middle-income countries, typically where hearing health services are unavailable.

**Objectives.** This article discusses the challenges to hearing care in remote and resource-limited settings, and describes recommended service delivery models, taking personnel and equipment requirements into consideration. The paper also considers the novel roles of telemedicine approaches in these contexts for improving access to preventative care. Finally, two case studies illustrate the challenges and strategies for service provision in remote and underserved settings.

## Introduction

Hearing loss is a major global contributor to the burden of disease. In 2015, an estimated 1.33 billion people worldwide were affected, ranking it as the fourth leading contributor to years lived with disability globally.<sup>1</sup> When considering only permanent bilateral hearing losses of a disabling degree, an estimated 360 million are affected globally, constituting more than 5 per cent of the world's population.<sup>2</sup> The highest prevalence rates for hearing loss in children and adults are in South Asia, Asia Pacific and sub-Saharan Africa. As almost 50 per cent of hearing loss could be prevented, and most of the remaining losses could be treated effectively,<sup>3</sup> making hearing health services accessible is a global priority.<sup>4</sup> This is especially important in low- and middle-income countries where more than 80 per cent of persons with hearing loss reside.<sup>5</sup>

Recent surveys on the availability of hearing healthcare providers globally indicate that in low- and middle-income countries, these providers are often non-existent. An international survey by the World Health Organization (WHO) showed that there is an inequitable distribution of hearing healthcare providers globally, with low- and middle-income countries commonly reporting less than one otorhinolaryngologist or audiologist per million persons.<sup>6</sup> In sub-Saharan Africa, a recent survey of hearing healthcare providers indicated that there are between 0.1 and 4.6 otorhinolaryngologists per million persons across the region.<sup>7</sup> Apart from South Africa, there is less than one audiologist for every million persons in sub-Saharan African countries.<sup>7</sup> Over a 10-year period, between 2005 and 2015, there was no real increase in these ratios.<sup>7,8</sup>

## Challenges to hearing health services

The inaccessibility of hearing healthcare providers in the majority of the world is a major hindrance to care. Other challenges include poor public and professional awareness, limited resources, geographical barriers such as distance and difficult or remote terrains, and natural barriers such as severe weather. These barriers are not limited to low- and middle-income countries, and can occur in high-income countries where pockets of underserved people reside; for example, remote rural regions (e.g. parts of Australia and Alaska) or inner-city communities.<sup>9,10</sup>

Against this backdrop, many challenges exist when seeking to provide objective audiometric assessments in under-resourced communities, which can be found in upper-, middle- and, more prevalently, low-income countries. Often such challenges arise from either the absence of audiologists or audiological physicians in or near the community needing basic services. Even more concerning is the challenge of the inability to meet the burgeoning volume of need while performing at capacity on a daily basis, and significant budgetary constraints in acquiring essential equipment to conduct the specific measures called for in the identification, diagnosis or remediation of hearing loss and disorders.

Unfortunately, an abundance of individuals who are more at risk for hearing loss due to chronic conditions of the ear reside in under-resourced communities. Some of the conditions may be exacerbated by the local environments and factors that include: high

illiteracy; high humidity and temperatures; a densely populated area with frequent disease outbreaks; poor air quality; poor hygiene and/or sanitation; sleeping on the ground; and limited or no access to hearing loss prevention information and products.<sup>9</sup>

### Models of care

When considering the various means of engaging with the patient, one is often limited by innovation and imagination for delivery of services. Ultimately, all delivery modes are predicated upon patient- and family-centred best practices throughout the lifespan. These practices include the foundational components of bioethics with regard to engaging in standardised evaluation and outcome processes. As such, assessment and outcome processes are dependent upon and sensitive to the broad needs of the populations being served.

Identifying the appropriate care model is also dependent upon recognising that hearing loss cannot be cured, and should be acknowledged as a chronic condition requiring a lifelong engagement between the patient and professional service provider. As well as patient lifespan, one also needs to consider manageability, to improve quality of life through early detection and ongoing remediation, despite the inability to cure the chronic condition of hearing loss. The specific model of care chosen for mode of delivery will be dependent upon whether the recipients are infants and children or adults, and their significant caregivers. Components that would be found in the chronic condition model of care include: inclusive patient- or family-centred care, team-based care, stepped care, and accessibility.

Ensuring sustainability of services in under-resourced settings is an important prerogative. This often requires a decentralised community-based approach to hearing care, which enables access to services in communities and strengthens hearing care across all levels within the system, especially at the primary level.<sup>11</sup> The components of such a model and the associated considerations can guide such an implementation (Table 1<sup>12</sup>).

Establishing an ongoing and sustainable service requires a multidimensional approach that is sensitive to the realities of the specific context. As hearing loss is a silent disability that does not receive the necessary public health attention, much initial work requires raising awareness and advocating amongst stakeholders, including policy makers, healthcare providers and community members.<sup>4,13</sup> Subsequent steps include planning, training, development of infrastructure, programmes and data management systems.<sup>11</sup>

### Adults

The incidence of hearing loss and balance problems continue to increase as populations age.<sup>3,13</sup> In fact, 30 per cent of adults aged 65–84 years, and more than half of adults aged 85 years and older, will acquire a significant hearing loss.<sup>5</sup> Consequently, there is an expectation that the demand for hearing health professionals will equally continue to grow at a disproportionate ratio of professionals to patients.<sup>14,15</sup> This must be addressed through modifying and creating different models of hearing healthcare.

An inclusive model of care for an ‘adult’ patient would take into consideration those individuals with limited cognitive function due to dementia or psychiatric conditions, as well as those who have full capacity and the ability to engage

**Table 1.** A community-based hearing healthcare service delivery approach in underserved contexts

Components	Considerations
Planning & provision of services	Existing resources (infrastructure, equipment, personnel, etc.)
	Opportunities within health system (e.g. overlapping mandates)
	Education, livelihood & social support to ensure holistic services
	Ethnic, cultural & political context
	Evidence-based approaches
	Involving stakeholders across the board
Raise awareness	Policymakers
	Health professionals
	Community level healthcare providers
	Parents
	Teachers
Sensitisation & training	Workers
	Training master trainers (otorhinolaryngologists & audiologists)
	Obstetricians & paediatricians
	General primary level physicians
	Primary level health workers
Primary ear & hearing care training	Teachers & parents
	Identify person to be trained
	Define roles in provision of ear & hearing care
	Develop a training protocol
	WHO training manuals
	Training
Infrastructure development	Quality control
	Monitoring, feedback & evaluations
	Identify health facilities for services
	Agree on services to be provided
Development of priority programmes	Identify requirements for service provision
	Acquire & install equipment
	Infant hearing screening
	School screening
Data management, monitoring & evaluation	Screening in elderly
	Hearing aid service, etc.
	Develop indicators & monitoring tools
	Who will collect, when & how
Research & development	Decide periodicity of evaluation
	Develop suitable tools for promoting hearing care
	Strengthen multi-sectoral engagement & effective partnerships
Research & development	Epidemiological research
	Operational research

Adapted from Wattamwar *et al.*<sup>13</sup> WHO = World Health Organization

completely as a team member. It is expected that an adult model of care would include identification, intervention and monitoring hearing status, while simultaneously engaging other health disciplines as needed (e.g. communicable disease

health professionals for patients diagnosed with human immunodeficiency virus (HIV) or acquired immunodeficiency syndrome (AIDS), or tuberculosis), empowering patients, and promoting advocacy. In addition to the considerations for the paediatric realm, there is a stronger emphasis for hearing loss prevention in adults. As older adults likely have more than one chronic condition to address, there is a need to co-ordinate care with the multiple healthcare provider teams who may be involved.<sup>16</sup>

Within the environment of limited resources, it should be anticipated that provision of care would include a stepped care approach. That is to say, simpler interventions should be considered first, followed by a progressively more advanced intervention if the patient and resources are tolerated. Of course, foundations of bioethics (i.e. autonomy, beneficence, benevolence and non-maleficence) must also factor into the decision matrix of which next step is appropriate for each patient. One example in a stepped care provision of services would be a trained community worker, responsible for explaining to an adult in the local community the dangers of untreated draining ears and describing how to wick the drainage from the ear canal. If the self-treatment is unsuccessful, the adult would go to the next step of interacting with a healthcare assistant and ultimately to a professional to resolve the condition.

Ultimately, to obtain successes in hearing health services provision, it is important to have uniform ease of access to services. Unfortunately, as pointed out previously, many provinces and countries do not have any access to professional hearing healthcare services, and any support is untenable to many ministers of health. As a consequence, innovative methods of providing personnel, equipment and methodology have become urgently necessary.

## Infants and children

Infants and children are difficult-to-test populations that require special adaptations of conventional hearing assessment and intervention strategies. This makes it particularly challenging to provide services to these populations in underserved contexts, where equipment is often scarce and very few hearing healthcare providers are typically available. Within such contexts, where no services exist, it may be best to initiate services that are focused on a specific programme. For example, a school-entry hearing screening programme could be developed as a first step towards early detection programmes. As a service, the implementation should consider the entire care pathway, from detection and referral to diagnosis and treatment. Once services have been developed and demonstrated to be effective and efficient, this can be scaled more easily to other communities. Other programmes may include infant hearing screening. In this case, innovative approaches to combine services with existing platforms, such as immunisation<sup>17</sup> or maternal obstetric unit visits,<sup>18</sup> can reduce costs and align services.

## Personnel requirements

### *Licensed or credentialed professional*

Each country, and even provinces within the same country, may have specific regulations pertaining to the training and didactic experience necessary to provide professional hearing care services. For instance, in a low- or middle-income country, it

is not unusual for a professional to obtain credentialing after completion of 4 to 8 years of matriculation, 400 to 1800 hours of practical training, and successfully passing a national examination to earn a professional license.<sup>19</sup> As such regulatory expectations are not realistic in most low- and middle-income countries, it is not unusual to find educational training experiences ranging from a one-month certificate course to a four-year, formal, didactic university-based degree programme.<sup>20</sup>

Optimally, once trained, the professional will be prepared to diagnostically identify the degree of hearing loss, as well as the possible aetiology, and potential sites of pathology or condition. As such, their full scope of practice will include using a variety of equipment, with screening and diagnostic capability to enable interpretation of the diagnostic results. However, the types of equipment are dependent upon the professional's training and the resources within the region.

Without a doubt, a short-term certificate training course will not equip an individual to provide the full-breadth and scope of diagnostic hearing care adequately, nor ultimately serve the wide span of the population that ranges from newborn infants, through end-of-life patients and the elderly. Though completion of a certificate programme has many limitations, it improves the possibility of individuals having access to affordable basic hearing care in a region that previously had none.<sup>21</sup> Conversely, a professional who completed the maximum matriculation and training would be welcome in under-resourced communities. However, the local economies would likely force a higher prioritisation of hiring many personnel with less education holding a certificate, or a general health practitioner or physician, over one highly degreed specialised professional in hearing healthcare. As a consequence, a low-income country will likely only have 1 or 0 audiologist or otolaryngology service to every 20 000 inhabitants.<sup>8,19</sup>

### *Non-professional*

As mentioned earlier, advanced objective and behavioural hearing assessments require extensive and specialised training. However, in the absence of a specialised trained practitioner, some basic procedures can be conducted by concerned individuals (e.g. volunteers, parent or guardian, and teachers) or trained individuals (e.g. community or health workers).

When considering the need to confirm or deny suspicions about the hearing status of adults, it is wholly appropriate to train and engage non-licensed or non-professional personnel, which could include: community workers, healthcare assistants or family members. It is possible to recruit such community workers from the local communities by identifying and engaging with local elders or leaders (political, faith-based and social), who are willing to act as the community 'cultural broker' to target appropriate potential team members.

Some of the benefits of engaging and possibly training non-licensed individuals within the local community include: raising awareness about risk factors and the negative consequences of poor hearing health, and allowing the community to see first-hand the significant medical and psychological complications known to occur as a result of ignoring ear and hearing conditions without early identification. Other added benefits are community education regarding the available remediation that dispels myths about hearing loss, and the contributions that those with hearing problems can make to the community.

In order to achieve optimal capacity within a country or province, it is also possible for a minister of health to approve

multi-layers of hearing health workers, starting with a large number of community workers, fewer community health workers, even fewer audiology or hearing assistants, to very few audiologists and hearing health physicians. When working in the context of a community village, it is of particular importance to identify the cultural broker, who can negotiate approval from the local community or village chief or mayor. The influence that the chief or mayor wield over the community's acceptance and participation in any healthcare programme can be the difference between tremendous success or dismal failure, despite any financial investment made by a minister of health.

### Equipment and resource requirements

There are some readily available resources to accommodate screening and diagnostic measures, ranging from simple questionnaires and structured behavioural observations, to specialised equipment. In general, questionnaires and informal observations, potentially integral to stepped care, provide an entry level triage, which ultimately contributes a wealth of information to the results of objective audiometric measures that are eventually completed by the highly trained professional.

Many of the screening questionnaires (e.g. Early Listening Function questionnaire<sup>22</sup> and Hearing Handicap Inventory for Adults<sup>23</sup>) are printed in multiple languages, or can be easily translated, to assess the patient informally and determine family perceptions of hearing abilities together with handicapping conditions perceived as due to hearing loss. Many questionnaires are readily viewable through a simple search on the internet, and would require practice to imbue confidence on the part of the examiner. When reviewing the resources for community-based assessment, it is clear that one is limited by their creativity. With minimal instruction, a literate parent or community worker can easily utilise age-appropriate questionnaires in various languages that can provide informal assessments of listening abilities, from infants through to geriatric patients.

Behavioural observations and assessments specific to the patient's cognitive age can also be documented by community workers, a parent or guardian, or teacher. Though potentially considered grossly simplistic, some informal observations and assessments, like the finger rub test, whispered voice test or the distance test, conducted by a community worker or a trained hearing health assistant, can provide fundamental information about hearing status, which could result in a referral for complete diagnostic audiometric evaluation.<sup>24</sup>

Eventually, with the tiered personnel approach, more advanced assessments, conducted by better qualified professionals, can be engaged (depending upon the results of the first- and second-stage outcomes). As personal computing systems are more portable, accessible and affordable, there has been a proliferation of deployment into the audiology and hearing health industry. Cloud computing has 'virtually' reduced the distance between the patient and professional. Data capturing, sharing and management have become a reality thanks to the integrated connectivity between hardware and software systems throughout the world.<sup>25</sup> With the advent of digitisation of audiometric equipment, it is now possible to monitor calibration of the specialised equipment, as well as compliance of the test environment, while data are captured and seamlessly transmitted into cloud storage. In fact, every piece of audiometric equipment can be deployed for telepractice measures. This

makes screening and complete diagnostic evaluations possible in any part of the world.

A significant challenge in providing hearing assessment services revolves around the calibration of audiometric apparatus.<sup>25</sup> Low- and middle-income countries typically may not have any certified calibration laboratories, which may require expensive shipments of equipment for international calibration and results during downtime on site. While newer digital audiometric devices may offer novel ways to swap calibrated headphones to avoid downtime and reduce costs,<sup>25</sup> this remains a significant cost and opportunity challenge.

### Telehealth possibilities

Telehealth has been proposed as a service delivery model that can uniquely address some of the barriers to access in underserved or remote communities.<sup>10</sup> Telehealth is a way to which existing healthcare needs, like hearing care, may be served by using information and communication technology to link healthcare expertise with patients and with other health experts. The ultimate aim of telehealth is to provide improved access, efficiency, cost-effectiveness and even quality to health services like audiology.<sup>26</sup>

Telehealth services can be classified into two broad categories that relate to the timing of the information exchange and interaction between healthcare providers and patients, or between healthcare providers themselves. The first involves sharing pre-recorded clinical information from one location to another, and is referred to as 'store-and-forward' or asynchronous telehealth. Information may be sent from a remote site to a healthcare provider site, or between healthcare providers. The advantage of this mode is that healthcare providers do not need to interact with the information in real-time. A simple example may be transmitting a pure tone audiogram by e-mail to an expert colleague for a second opinion. In many cases, a facilitator at the patient's site is present to record clinical information, which is sent back to a healthcare provider.<sup>26</sup> The second category of telehealth, called 'real-time' or synchronous services, requires that the healthcare provider and patient, or the healthcare providers themselves, engage in information exchange at the same time, through information and communication technologies. A live consultation with a patient using video conferencing is a simple example. Clinical use cases may involve a hybrid of synchronous and asynchronous services.

Interest around telehealth has increased significantly as a way to improve the access, quality, efficiency and cost-effectiveness of hearing health services, particularly for populations who have traditionally been underserved.<sup>5</sup> Telehealth services have the potential to bridge the general barriers often created by distance, poor travel infrastructure, severe weather and unequal distribution of healthcare providers in urban and rural settings, or even across world regions.<sup>9</sup> The advantages that telehealth services offer are particularly appealing for hearing healthcare in places where there is a dearth of hearing healthcare providers.<sup>6,7</sup>

Advances in mobile phone technologies, and increased connectivity in low- and middle-income countries, are opening up affordable access to the detection and diagnosis of hearing loss and ear disorders.<sup>27-29</sup> Recent mobile phone technologies have been validated for hearing assessment, with calibrated headphones on low-cost smartphones, using automated testing, interpretation with an operator and environmental quality control features.<sup>25,27,30,31</sup> Employing a simple

user interface with the aforementioned features allows minimally trained persons to facilitate tests in communities, with remote monitoring of test quality from a cloud-based data management portal.<sup>27,31</sup> These types of technologies are making decentralised community-based services much easier to implement and monitor.

### Case study examples

Examples of service delivery in underserved populations are discussed in the following case studies of rural hearing screenings for children and adults.

#### Case one

After gaining genuine acceptance from the local chief and provincial minister of health to begin offering hearing screenings in the village, as part of an outreach programme in South Africa, a variety of training sessions were scheduled with the community workers and community health workers in the area.

All of the community workers met with the trainer (the audiologist) over three sessions. Using the WHO primary ear and hearing care training manual (2006),<sup>32</sup> these sessions covered: the importance of hearing, taking care of the ears and hearing, ear deformities, signs of hearing loss, personal hygiene and ear hygiene. The information would enable community workers to identify those with potential hearing problems within the community so that the community health worker could see them.

All of the community health workers met with the trainer (the audiologist) over six sessions. Again using the WHO primary ear and hearing care training manual,<sup>32</sup> these sessions covered: recognition of ear infections; hearing loss, due to meningitis, malaria and so on; understanding what a hearing screening is; learning the hearing screening protocols for children and adults; and understanding the pathway for those who fail the hearing screenings.

Some radio announcements were made about hearing screenings being scheduled in a rural area community centre. Simultaneously, the community workers were able to identify and encourage any local adults and school-aged students they encountered in the community to attend the scheduled hearing screenings. For the 5 scheduled days of hearing screenings, five community workers, five trained community health workers and two audiologists arrived with seven portable battery-operated screening audiometers, three screening tympanometers, patient perception questionnaires, otoscopes and two diagnostic audiometers.

At testing station 1, the patients, as they arrived each day, provided personal information (i.e. name, date of birth, mobile phone number, location of home, any known conditions such as HIV or AIDS, or tuberculosis). The information was entered by community workers onto a hearing health input form, to be carried through the subsequent stations by the patient. The community workers described, in the local dialect of the patients, what the testing stations are, and the tasks the patients are expected to complete for each stage (e.g. sit quietly and raise a hand when soft notes are heard through the ear-phones). A brief questionnaire about each patient's hearing status was completed by the community worker.

At testing station 2, community health workers viewed the ear canals through an otoscope, to identify any obstructions that would negatively affect the screening results. Those



Fig. 1. Otoscopy before cerumen management.

patients with obstructed ear canals proceeded to station 3. If there was no substantial ear canal obstruction, the hearing screening was completed. Those who passed the hearing screening were informed of this by the community workers, and were asked to contact the community workers or community health workers if their hearing changed. These patients did not continue further with the screening activities. If the patient did not pass the hearing screening, they were referred to testing station 4.

At testing station 3, ear canal clearance was completed by the audiologist, using irrigation or manual removal through loop curettes (Figure 1). When ear canal clearance was achieved, the patient returned to station 2 for hearing screening. In cases where ear canal clearance was not successful, the patient was sent home with instructions for using sweet oil for 2 days before returning for the community screening.

At testing station 4, tympanometry screening in those who did not pass the hearing screening at station 2 was completed by the community health workers. Regardless of the findings, these patients then moved to station 5.

At testing station 5, diagnostic audiometry was completed by the audiologist. The audiologist collated the findings and, ultimately, made critical clinical decisions based upon the findings obtained at station 5. Either the findings led to referral for medical treatment for middle-ear problems, or referral for a hearing aid fitting if the patient questionnaire results suggested a handicapping condition due to hearing loss.

Depending on the number of patients that are screened, the audiologist or programme director is able to determine the frequency of screenings in the community. A successful screening programme is dependent upon the local support from the community chief or mayor, community workers, community health workers, and audiologists.

#### Case two

Children in low- and middle-income countries typically do not have access to hearing screening. As a result, hearing loss is only identified when the child enters the schooling system. A community-based project was therefore launched in an underserved community in South Africa to offer screening and referral services in early childhood development centres, carried out by trained community members. The project utilised novel smartphone-based hearing assessment technology (hearScreen® application and calibrated headphones, by the hearX group, Pretoria, South Africa) linked to a cloud-based data management and referral service.



**Fig. 2.** Primary healthcare clinic based follow-up appointment (accompanying video can be found online, at: [www.youtube.com/watch?v=SDWltCfbPrY](http://www.youtube.com/watch?v=SDWltCfbPrY)).

The following initial groundwork was undertaken to initiate this project. (1) In partnership with a local community non-governmental organisation, two community members were identified. These persons were selected based on their availability, local knowledge of early childhood developments and recommendation by the non-governmental organisation. (2) These two individuals visited all early childhood development facilities in the community, informing them of the services to be offered and providing informed consent letters for parents. The early childhood development facilities were also mapped using the hearScreen smartphone application's facility function to geolocate the specific early childhood development centre. (3) Referral clinics with ear and hearing services were also mapped onto the cloud-based data management system. These were consulted first to ensure they had the capacity for the children that may be referred. (4) The two screeners received training on how to test young children for hearing loss using the hearScreen application. This technology has been developed for use by minimally trained persons, and therefore utilises automated test sequences and interpretation of screening results. (5) Practice screening sessions, performed under the supervision of the trainer, were conducted at a local early childhood development facility.

Once the groundwork was completed, the service delivery process included the following. (1) Screening was conducted by screeners, using smartphones, the hearScreen application and calibrated headphones, within early childhood development facilities. (2) Test quality was monitored by tracking uploaded data on the cloud-based data management portal. The quality control indices include noise levels recorded by the smartphone, and a test operator quality index based on a random non-presentation of a stimulus which is flagged if

an operator indicates a response was present. (3) Based on an initial low-quality index, retraining was initiated, after which the quality index improved significantly. (4) If a child failed the screening test, an automated text message was generated from the cloud-based data management portal and sent to caregivers. Based on the geolocation, referral was made to the closest primary healthcare facility for follow-up services. (5) When children arrived at the clinic for a follow-up assessment, the same hearScreen application was used to search for the child's details, review the previous outcome and conduct a rescreen (Figure 2). Hence, children returning for follow up were identified on the cloud-based data management system. (6) If the child failed the screening a second time, threshold pure tone audiometry was conducted using the hearTest application.<sup>31</sup> If there was a hearing loss and it was not due to medically treatable conditions (conductive), an appointment with a hearing care provider (servicing the primary healthcare clinics on a rotation basis) was made.

## Conclusion

Access to hearing health services in remote or resource-limited settings is a pervasive global challenge. Innovative service delivery models are required to develop sustainable services in these settings. An emphasis on decentralised community-based approaches that strengthen hearing care, especially at the primary level, is necessary for sustainability and widespread access to services. New affordable technologies that leverage mobile phone technology and connectivity, and which allow minimally trained persons to facilitate services, are enabling community-based access and monitoring. As awareness of hearing loss as a global health concern increases, the development, implementation and sustainability of services in low- and middle-income countries must drive research and resources.

**Competing interests.** The first author has a relationship with the hearX Group that includes equity, consulting and potential royalties.

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