

Hearing health care in remote or resource-constrained environments

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Abstract

Hearing loss is a leading contributor to the global burden of disease with more than 80% of affected persons residing in low- and middle-income countries, typically where hearing health services are unavailable. This article discusses the challenges to hearing care in remote and resource limited settings with recommended service delivery models considering personnel and equipment requirements. The novel roles of telemedicine approaches in these contexts are also considered to improve access to preventative care. Finally, two case studies illustrate the challenges and strategies for service provision in remote and underserved settings.

Keywords

Audiology

Telehealth

Audiometry

Hearing loss

Low and middle-income countries

Need for hearing health services in remote or resource limited settings

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 ¹. When considering only permanent bilateral hearing losses of a disabling degree, an estimated 360 million are affected globally, constituting more than 5% of the world population ². The highest prevalence rates for hearing loss in children and adults are in South Asia, Asia Pacific and Sub-Saharan Africa. Since almost 50% of hearing loss could be prevented and most of the remaining losses could be treated effectively ³ making hearing health services accessible is a global priority ⁴. This is especially important in low- and middle-income countries (LMICs) where more than 80% of persons with hearing loss reside ⁵.

Recent surveys on the availability of hearing health providers globally indicate that in LMICs, these providers are often non-existent. An international survey by the WHO shows that there is an inequitable distribution of hearing health providers globally with low and middle -income countries commonly reporting less than one ENT or audiologist per million persons ⁶. In sub-Saharan Africa, a recent survey of hearing health providers indicate that there are between 0.1 to 4.6 ENTs per million persons across the region ⁷. Apart from South Africa, there is less than one audiologist for every million persons in sub-Saharan African countries ⁷. Over a ten year period between 2005 and 2015, there was no real increase in these ratios^{7, 8}.

Challenges to hearing health services in remote or resource limited settings

While the inaccessibility of hearing health care 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 LMICs 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 ^{9,10}.

Against this backdrop, many challenges exist when seeking to provide objective audiometric assessments in under-resourced communities that can be found in upper-, middle-, and more prevalently in low-income countries. Often such challenges arise from either the absence of Audiologists/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 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 that can include: high illiteracy; high humidity and temperatures; densely populated area with frequent disease outbreaks; poor air quality; poor hygiene and/or sanitation; sleeping on the ground; limited or no access to hearing loss prevention information and products; etc. ¹¹.

Models of Care

When considering the various means of engaging with the patient, one is often limited by their 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 would include the foundational components of bioethics; engaging in the standardised evaluation and outcome processes. As such, assessment and outcome processes would be dependent upon and sensitive to the broad needs of the populations being served. Identifying the appropriate care model is also dependent upon recognising hearing loss cannot be cured

and should be acknowledged as a chronic condition requiring lifelong engagement between patient and professional service provider. Not only is there a need to consider patient lifespan, but 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. There are some components that would be found in the Chronic Condition Model of Care that include: inclusive patient/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 that enables access to services in communities and strengthens hearing care across all levels within the system, especially at the primary level ¹². The components of such a model and the associated considerations can guide such an implementation (Table I). Establishing an ongoing and sustainable service includes a multidimensional approach that has to be sensitive to the realities of the specific context. Since 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, health providers and community members ⁴. ¹². Subsequent steps include planning, training, development of infrastructure, programmes, and data management systems ¹².

TABLE I.

A community-based hearing health care service-delivery approach in underserved contexts (adapted from Chadha¹²)

Components	Considerations
Planning and provision of services	<ul style="list-style-type: none"> ● Existing resources (infrastructure, equipment, personnel, etc.) ● Opportunities within health system (e.g. overlapping mandates) ● Education, livelihood and social support to ensure holistic services ● Ethnic, cultural and political context ● Evidence-based approaches ● Involving stakeholders across the board
Raise awareness	<ul style="list-style-type: none"> ● Policymakers ● Health professionals ● Community level health providers ● Parents ● Teachers ● Workers
Sensitization and training	<ul style="list-style-type: none"> ● Training master trainers (ENT's & audiologists) ● Obstetricians and paediatricians ● General primary level physicians ● Primary level health workers ● Teachers & parents
Primary ear and hearing care training	<ul style="list-style-type: none"> ● Identify person to be trained ● Define roles in provision of ear and hearing care ● Develop a training protocol ● WHO training manuals ● Training ● Quality control ● Monitoring, feedback and evaluations
Infrastructure development	<ul style="list-style-type: none"> ● Identify health facilities for services ● Agree on services to be provided ● Identify requirements for service provision ● Acquire and install equipment
Development of priority programmes	<ul style="list-style-type: none"> ● Infant hearing screening ● School screening ● Screening in elderly ● Hearing aid service, etc.
Data management, monitoring and evaluation	<ul style="list-style-type: none"> ● Develop indicators and monitoring tools ● Who will collect, when and how ● Decide periodicity of evaluation ● Develop suitable tools for promoting hearing care ● Strengthen multi sectoral engagement and effective partnerships
Research and development	<ul style="list-style-type: none"> ● Epidemiological research ● Operational research

Adults

The incidence of hearing loss and balance problems continue to increase as population's age¹³.³ In fact, 30% of adults age 65 – 84 and more than half of adults 85 years and older will acquire a significant hearing loss⁵. 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^{14, 15} and must be addressed through modifying and creating different models of hearing health care soon.

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 ability to engage as a team member completely. It is expected that an adult model of care would include identification, intervention, monitoring hearing status, while simultaneously engaging other health disciplines as needed (e.g. communicable disease health professionals for patients diagnosed with HIV/AIDS or Tuberculosis), empowering patients, and advocacy. In addition to the considerations for the pediatric realm, there is a stronger emphasis for hearing loss prevention in adults. Since older adults likely have more than one chronic condition to address, there is a need to coordinate care with the multiple health provider teams who may be involved¹⁶.

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 will be tolerated. Of course, foundations of bioethics (i.e. autonomy, beneficence, benevolence and nonmaleficence) must also factor into the decision matrix of which next step is appropriate for each patient. One example in 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 how to wick the drainage from the ear canal. If, after being unsuccessful in self-treatment, the adult would then go to the next steps of interacting with health care assistant and ultimately to a professional to resolve the condition.

Ultimately, to obtain successes in hearing health services provision, it is important to have ease of uniform access to services. Unfortunately, as pointed out previously, many provinces and countries do not have any access to professional hearing health care service provision, and any support is untenable to many ministers of health. As a consequence, innovative methods of provision of personnel, equipment and methodology has 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 health providers are typically available. Within such contexts where no services exist, it may be best to initiate services that are focussed 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, referral, 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 immunization¹⁷ or maternal obstetric unit visits¹⁸ can reduce costs and align services.

Personnel requirements

Licensed/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 LMIC, 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 exam to earn a professional license ¹⁹. Since such regulatory expectations are not realistic in most LMICs, it is not unusual to find educational training experiences ranging from 1-month certificate course to 4 years of a formal didactic university based degree program ²⁰. Optimally, once trained, the professional will be prepared to diagnostically identify the degree of hearing loss as well as 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 solely dependent not only upon the professional's training, but also 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 elderly. Though completion of a certificate program has many limitations, it improves the possibility of residents to access affordable basic hearing care in a region that previously had none ²¹. 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 general health practitioner/physician over one highly degreed specialised

professional in hearing health care. As a consequence, a low-income country will likely only have one or no audiologist or otolaryngology service to every 20,000 inhabitants^{8,19}.

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/guardian, and teachers) or trained individuals (e.g. community or health workers). When considering the need to confirm or deny suspicions about hearing status of adults, it is wholly appropriate to train and engage non-licensed/non-professional personnel that could include: community workers; healthcare assistants or family members. It is possible to recruit from the local communities for such community workers by identifying and engaging with local elders/leaders (political, faith based as well as 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 negative consequences of poor hearing health; community seeing first-hand the significant medical and psychological complications that are known to occur from ignored ear and hearing conditions without early identification. Another added benefit is community education about available remediation that dispels myths about hearing loss and contributions that those with hearing problems can make to the community.

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 less audiology/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/village chief or mayor. The influence the chief/mayor wield over the community's acceptance and participation in any health care 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 ranging from simple questionnaires, and structured behavioural observations to specialised equipment to accommodate screening and diagnostic measures. In general, questionnaires and informal observations, potentially integral to stepped care, provide an entry level triage that ultimately contributes a wealth of information to the results of objective audiometric measures eventually completed by the highly trained professional. Many of the screening questionnaires (e.g., Early Listening Behavior ²²; Hearing Handicap Inventory for Adults ²³) are printed in multiple languages or can be easily translated to assess patient informally and family perceptions of hearing abilities together with handicapping conditions perceived 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 geriatric patients.

Behavior observation/assessments specific to patient's cognitive age can also be documented by community workers, or parent/guardian or teacher. Though potentially considered grossly simplistic, some informal observation/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 ²⁴.

Eventually, with the tiered personnel approach, the more advanced assessments conducted by the more qualified professional can be engaged (dependent 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 ²⁵. 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 is captured and seamlessly transmitted into cloud storage. In fact, every piece of audiometric equipment can be deployed for Telepractice measures. Thus, making screening as well as complete diagnostic evaluations in any part of the world possible. A significant challenge in providing hearing assessment services revolves around calibration of audiometric apparatus ²⁵. LMICs typically may not have any certified calibration laboratories which may require expensive shipments of equipment for international calibration and results in downtime on site. While newer digital audiometric devices may offer novel ways to swap calibrated headphones to avoid downtime and reduce costs ²⁵, 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 ¹⁰. Telehealth is a way to which existing health care needs, like hearing care, may be served by using information and communication technology to link health care 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 ²⁶.

Telehealth services can be classified into two broad categories that relate to the timing of the information exchange and interaction between health providers and patients or between health 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. In this case, information may be sent from a remote site to a health provider site, or between health care providers. The advantage of this mode is that health providers do not need to interact with the information in real-time. A simple example may be transmitting a pure tone audiogram by email to an expert colleague for a second opinion. In many cases, a facilitator at the patient site is present to record clinical information that is sent back to a health care provider ²⁶. The second category of telehealth, called “real time” or synchronous services require that both individuals (e.g., the health care provider and patient) 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 include a hybrid of synchronous and asynchronous services.

Interest around telehealth has increased significantly as a way to improve access, quality, efficiency, and cost-effectiveness of hearing health services particularly for populations who

have traditionally been underserved ⁵. 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 ⁹. The advantages that telehealth services offer is particularly appealing for hearing health care globally where there is such a dearth of hearing health providers ^{6,7}.

Advances in mobile phone technologies and increased connectivity in LMICs are also opening up affordable access to detection and diagnosis for hearing loss and ear disorders ^{27, 28, 29}. Recent mobile phone technologies have been validated for hearing assessment with calibrated headphones on low-cost smartphones using automated testing and interpretation with operator and environmental quality control features^{25, 27, 30, 31}. Employing a simple user-interface with the aforementioned, allows minimally trained persons to facilitate tests in communities while remotely monitoring test quality from a cloud-based data management portal ^{27, 31}. 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.

Case 1 - Rural hearing screenings for children and adults

After gaining a genuine acceptance by the local chief and Provincial Minister of Health to begin offering hearing screenings in the village as part of an outreach program in S. 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) using the World Health Organization, Primary Ear and Hearing Care Training Manual: Basic Level (2006) ³² over three sessions that included: 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) also using the WHO, Primary Ear and Hearing Care Training Manual: Basic Level (2006) ³² over six sessions that included: Recognition of Ear Infections; Hearing Loss due to Meningitis or Malaria, etc; understanding what a hearing screening is; learning the hearing screening protocols for children and adults; 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 of those local adults and school aged students, that they encountered in the community, to attend the scheduled hearing screenings. For the five scheduled days of hearing screenings, 5 Community Workers, 5 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.

Station 1 - As patients arrived each day, they would provide personal information (i.e. name, date of birth, cell phone number, location of home, any known conditions such as HIV/Aids, TB, etc) entered by community workers on a hearing health input form to be carried through the subsequent stations by the patient. The community workers would describe, 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 earphones, etc.). A brief questionnaire about each patient's hearing status will be filled in by the community worker.

Station 2 - Community Health Workers view the ear canals through an otoscope for any obstructions that will negatively impact the screening results. Those who have obstructed ear canals will go to Station 3. If there are no substantial ear canal obstruction, the hearing screening will be completed. For those who pass the hearing screening, they will be advised by the community workers that the results were positive, and to contact the community workers or community health workers if the hearing changes. They will then be released from continuing further with the screening activities. If the patient does not pass the hearing screening, they are referred to Station 4.

Station 3 - Ear Canal Clearance completed by the audiologist by using irrigation or manual removal through loop curettes (Figure 1). If the ear canal clearance is completed, the patient will return to Station 2 for the hearing screening. In the case where ear canal clearance is not successful, the patient is sent home with instructions for using sweet oil for two days before returning to the community screening.

Station 4 - Tympanometry screening is completed by the Community Health Workers for those who did not pass the hearing screening at Station 2. Regardless of the findings, the patients then move to Station 5.

Station 5 - Diagnostic Audiometry completed by the audiologist is the culmination of findings and ultimately, making critical clinical decisions dependent upon the findings from Station 5. Either the findings will reveal referral to medical treatment for middle ear problems, or referral for hearing aid fitting if the patient questionnaire results suggest a handicapping condition due to hearing loss. Depending on the number of patients that are screened, the audiologist/program director will be able to determine the frequency of screenings in the community. A successful screening program is dependent upon the local support from the community chief/mayor, community workers, community health workers, and audiologists.



Fig 1.
Otoscopy before cerumen management

Case study 2 - Community-based hearing and vision services for preschoolers

Children in LMICs typically do not have access to hearing screening, and as a result, hearing loss is only identified when entering the school 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 (ECD) centres by trained community members. The project utilized novel smartphone-based hearing assessment technology (hearScreen App & calibrated headphones) linked to a cloud-based data management and referral service.

The following initial groundwork was undertaken to initiate this project:

Step 1 - In partnership with a local community NGO two community-members were identified. These persons were selected based on their availability, local knowledge of ECDs and the recommendation by the NGO.

Step 2 - These two individuals visited all ECD facilities in the community informing them of the services to be offered and providing informed consent letters for parents. The ECD facilities were also mapped using the hearScreen smartphone application's facility function to geolocate the specific ECD centre.

Step 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 have the capacity for the children that may be referred.

Step 4 - The two screeners received training on how to test young children for hearing loss using the hearScreen App. This technology has been developed for use by minimally trained persons and therefore utilises automated test sequences and interpretation of screening results.

Step 5 - Practice screening sessions under the supervision of the trainer was conducted at a local ECD facility.

Once the groundwork was completed the service-delivery process included the following:

Step 1 - Screening was conducted by screeners using the smartphones, hearScreen App and calibrated headphones within ECD facilities.

Step 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.

Step 3 - Based on an initial low-quality index, retraining was initiated after which the quality index improved significantly.

Step 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 the referral is made to the closest primary health care facility for follow-up services.

Step 5 - When children arrive at the clinic for a follow-up assessment the same hearScreen application is used to look up the child's details, review the previous outcome and conduct a rescreen (Figure 2). This way children returning for follow-up are identified on the cloud-based data management system.

Step 6 - If the child fails a second time, threshold pure tone audiometry is conducted using the hearTest application³⁰. If there is a hearing loss and it is not due to medically treatable reasons (conductive) then an appointment with a hearing care provider servicing the primary health care clinics on a rotation basis is made.



Fig 2.

Primary health care clinic-based follow-up appointment (www.youtube.com/watch?v=SDWltCfbPrY)

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 decentralized 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 require minimally trained persons to facilitate services are enabling community-based access and monitoring. As awareness around hearing loss as a global health concern increases, the development, implementation and sustainability of services in LMICs must drive research and resources.

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