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OTHER ARTICLE

Tele Otology in India: Last 10 Years—A Scopic Review

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Abstract Hearing loss is the commonest sensory deficit among humans, affecting 466 million people worldwide. Early detection is the key to hearing rehabilitation, as speech and language develops early in the childhood. Scarcity of human resources and infrastructure in developing countries like India leads to difficulty in implementation of hearing screening programmes. Tele otology is very fruitful methodology in providing health care facility from distant site to the doorsteps of needy individuals. The action initiated in the field of tele otology in India was reviewed at electronic databases: Pubmed, Google scholar, Medline, Cochrane library, science direct and author mapper using the keywords 'tele otology' and 'tele audiometry' in January 2021. Eligible studies were those related to tele otology and tele audiometry in India. A total of 16 articles were shortlisted for the present study. Tele hearing testing was satisfactory for the parents in regard to accessibility, testing process and counselling. Tele audiometry surveillance shows better overall follow-up compliance rate then in-person audiological surveillance. During covid 19 pandemic virtual approach to the patient through video calling and telephone calls proved handy approach, ensuring safety profile of both health care professionals and patients. Even Tele ABR conducted in tele van shows similar results as in face-to-face mode ABR. Tele otology should be considered by the service providers and policy makers while planning for hearing screening programmes for both new-born and school going children in view of its reliability, low-cost, non-invasive and portability. The village health workers (VHWs) should be well trained in assisting tele practice and internet connectivity should be well established. Tele otology looks very promising in providing health services through the ever-expanding reach of global connectivity.

Keywords Tele otology · Tele audiology · Tele ABR

Introduction

The commonest sensory deficit among humans is hearing loss. As per NSSO, 2001 there are 291 person per lakh affected with hearing loss (severe to profound) in India. Approximately 6.3% i.e., 63 million people having significant hearing impairment. [1] Hearing loss as a disability is affecting 466 million people worldwide (432 million adults and 34 million children), comprising 5% of the world's population. However, by 2050 this may reach upto 900 million (i.e., 1 in 10 people). This approximately is possessing US$ 750 billion as annual global cost for prevention, identification and treatment of hearing loss. [2].

As in case of blindness, hearing impairment is not noticeable to others, resulting in isolation of the hearing-impaired individual from the family, friends and the

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society. The consequences of this are quite severe due to inability in fruitful speech and language development, resulting in depression, limiting school, higher education and professional growth of the individual. [3].

Telemedicine is a part of modern medicine that facilitates patient-doctor encounter without obligation of their physical presence. [4] They undergo virtual meeting avoiding distant travelling and mobility i.e., especially useful during lockdown in covid pandemic. [5] Being an otorhinolaryngologist and dealing with airway it is suggested to avoid direct patient contacts, in view of the safety of both examiner and patient.[6] Telehealth is the provision of providing health care facility by the health care specialist from their distant site to the client/patient at another local site.

The use of tele health services by the audiologist are termed tele-audiology which is prevailing since 1990s. The use of OAE for telehealth purpose was firstly attempted by virtual corporation in 1990 which framed the basis for schmeidge thesis in 1997. Schmiedge in 1997 used otoacoustic emissions for telehealth purposes to access the reliability of DPOAEs (Distortion Product Oto-acoustic Emissions) with beneficiaries located remotely in Canada using telephone modem and found that it is a rapid, reliable and easy method of obtaining DPOAE. The advantages of tele audiology were: no biasing of subjects, its rapidity, it had significant diagnostic information, and its being helpful in new-born screening and diagnostic programme. Also, it avoids distant travelling's and follow up losses. [7].

O neal et al. [8] advised that a new paradigm should be made so that each infant is connected to needed services, and audiology services through tele health is one of them.

Krumm and Schmiedge [9] discussed about the methods of testing a patient over a modem in real time. They also mentioned that asynchronous application includes remote computing software, interactive video, OAE and ABR systems for remote computing application. Asynchronous (store and forward) procedures were also discussed. Data includes case history, video clips of testing, video otoscopy images and real ear results.

A hybrid model which utilizes both synchronous and asynchronous technology was developed for tele audiology services. (Krumm 2007; Swanepoel and Hall, 2010).

If an audiologist uses video conferencing and remote DPOAE testing (synchronous technology) and send the results through scanned files of prior OAE/ABR (asynchronous technology), in this way, the hybrid tele health system provides the most flexible way of practice. Krumm et al. [10] first published study on tele health technology for infant hearing screening using DPOAE and ABR. It included 30 new-born infants between 11 and 45 days age, screened using face-to-face method and tele-technology method (no significant difference was seen between the two methods). Ciccia et al. [11] conducted a similar study on preschool children (< 6 years), including otoscopy, PTA, DPOAE and tympanometry. 411 children were screened in 2 years. In 1st year audiologist was supervising the screening (supervising the trained assistant by interactive video) while in 2nd year audiologist himself was doing screening remotely (using webcam, video otoscope, computerized audiometer and tympanometry). Interestingly no significant difference existed between two telehealth protocols. Hence, it was reported that interactive video can be used to supervise trained assistant in hearing screening while as remote computing is a desirable & reasonable method for audiologist in telehealth.

Another study by Ramkumar et al., [12, 13] reported 2 publications in 2013 and 2014 projecting infants screening in rural India in a mobile van using remote technology via satellite connectivity. Inspite of technical issues related to slow satellite internet, 100 infants were screened remotely. [12] No significant difference regarding outcome was reported between face to face and tele ABR, inspite of connectivity barriers.[13] In Rajendran et al. in their study [14], trained VHWs to provide tele health services at local sites for screening of new-born infants. VHWs being local and trusted individuals of communities were important in establishing rapport with community members.

Hayes et al. [15] reported hearing screening of infants in Guam by the clinicians at USA via remote computing technology (DPOAE & ASSR, ABR, video otoscopy and tympanometry. It documented the need of testing equipments for ensuring quality services. Authors also reported that the initial cost for start-up for tele health services approximately $60,000 and it require substantial continued form of income. Most of these projects may end because of lack of funds.

Providing good health care facilities in developing nation like India with limited resources is a challenge as it requires expensive equipments and manpower. The various challenges faced during implementation of hearing screening programmes in India are insufficient infrastructure, equipment, audiologist scarcity and poor follow up rates due to distant tertiary care centres. [16] However in western world tele practice has gained more acceptance in screening, diagnosing and intervention due to better internet penetration.

As most of the Indian population is staying in remote areas where there are least availabilities of health care facilities/infrastructure, ISRO (Indian Space Research Organization) in 2001 had started a telemedicine project aiming to provide telemedicine facilities at rural level. The district health centres/ hospitals were connected through satellite to super speciality hospitals for expert consultations. The mobile tele-vans were used for providing basic eye testing. The earliest participation of tele audiology in

India as an expansion of telemedicine was done in 2011.[12].

Though the goal should be hearing screening at birth before discharge from the birthing hospital, but due to limited resources in developing nation like India this goal is not being achieved. So, a school level hearing screening (as well as ear diseases) can be done, as the hearing loss prevalence among school entry children (i.e., 3–5 years) is 315,485 and among 5 to 9 years age group is 406,281 (Census 2011). [17, 18].

School screening is recommended by the Rehabilitation Council of India [19] but it has its limitations due to personal and technology barriers. Also, the number of audiologists available is one per 950,000 population. [20] These problems could be solved with the use of technology based tele audiology services.

Tele audiology is a useful methodology in respect to Indian prospective. It involves DPOAE screening by trained VHWs at the child's doorstep. Real time testing is done by an audiologist sitting at a tertiary centre, using satellite connectivity. Child is prepared by the VHW by placing the electrodes, positioning and ensuring connectivity and technical set up [21].

Though in hospital-based programmes, trained personnel's like audiologists are conducting the hearing screening while in community-based programmes community health workers conduct the screenings at community level. Training of these community health workers along with hand held objective hearing screening tools (DPOAE, TEOAE, ABR) increases the acceptance of such task shifting. Use of tele otology reduces the need of long, costly and unreliable travel by the patients [22].

There is high impact of HL on the mental and economic independence of an individual and is a social burden on the society. If we become successful in identifying and treating hearing disability at an early age, most of its negative effects can be avoided.

However, many challenges are seen in hearing screening such as need for a sound proof surroundings, expensive hearing assessment equipments which needs regular calibration and the skilled audiologists/professionals for conducting tests [23].

WHO has recommended for community level hearing screening and rehabilitation programmes as births are taking place at homes or primary health clinics. Its advantages are increased sustainability and local community volunteers/leaders reinforces the programme,

Material and Method

Search Strategy and Selection Criteria

The English literature was reviewed to analyze the work done in the field of tele-otology in India in last 10 years (2010–2020) so as to compile the known knowledge and frame the recommendations at a single platform. The study will be helpful for planning the hearing screening program. We searched the electronic database Pubmed, Google scholar, Medline, Cochrane library, science direct and author mapper using the keywords 'tele otology' and 'tele audiometry' in January 2021. Eligible studies were those related to tele otology and tele audiometry in India. All studies including tele hearing screening, hearing assessment using tele otology, tele otology related to ABR, follow-up in post steroid tinnitus patients using tele medicine, screening of MEDs in cleft lip and palate children were included. Studies related to tele otology cost effectiveness and outcomes were also included.

Data Collection and Extraction

During our data search process 3564 articles were identified using the above-mentioned keywords. Authors then scrutinized these articles by reviewing their titles, considering the inclusion criteria's. Following this screening, 33 articles were scrutinized. The abstracts of identified articles were reviewed independently by the authors; however, the differences were resolved by discussion. This abstract review resulted in exclusion of 15 articles [18wereselected], 2 articles were later excluded due to duplication. (Fig. 1) So, a total of 16 articles were selected for the present study.

Results

The results of all the articles have been tabulated in Table 1.

Discussion

General Screening in Kumbh Mela

Pratik shah et al. [24] reported a study conducted at a primary health centre at Maharashtra using technology enabled non-invasive diagnostic screening (TES). 494 individuals between 18 and 90 age visiting kumbh mela 2015 were screened using TES with smartphone in conjugation with routine health screening. TM disorders,

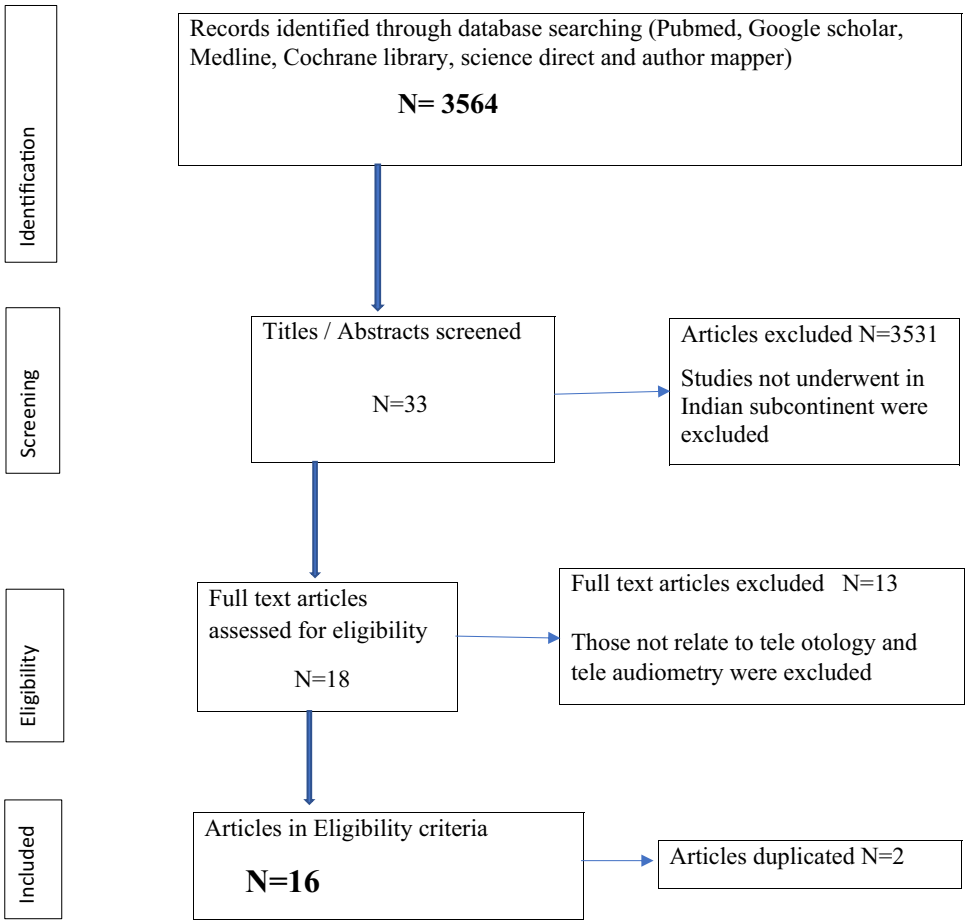

Fig. 1 Article inclusion flow chart

dental disorders, cardiac arrythmias (ECG), optic nerve disorders, neurological fitness and blood oxygen levels were evaluated using TES and conventional screening. The expert physician examines the TES data at a remote web-platform and compares it with routine screening method. Apart from the other disorders, TM disorders were detected in 13% of population and several had history of hearing difficulties. Many individuals who otherwise pretend to be normal in routine screening programs were found to be having significant abnormalities when tested through TES synergistically.

Pure Tone Audiometry & WBHA (Web Based Hearing Assessment)

In view of covid 19 pandemic where social distancing is of utmost importance, WBHA could be a helpful tool in screening individuals for hearing assessment. It consisted of earphones (connected with the laptop having internet connectivity), that generates same pure tones (for air conduction) across the 6 speech frequencies as in PTA. Although PTA measure symmetrical (resulting from presbycusis, ototoxic drugs chronic noise exposure etc.) and asymmetric (trauma, ear discharge etc.) patterns of HL, WBHA could access severity of deafness particularly in symmetrical HL only. WBHA takes more time and can be conducted by non-medical persons. It is a safe and reliable method of screening out the hearing-impaired individuals from the general population. In addition, any improvement in deafness can also be tested in regular home self-check-ups. Though WBHA is a good screening tool for hearing assessment but it's not a substitute to PTA as bone conduction and speech testing could not be done with WBHA. It is particularly applicable for rural population specially during covid pandemic. [25].

DPOAE

The goal in developed nations is to screen the neonate before discharge from the hospital (i.e. early detection of hearing status). Developing countries who don't have newborn screening programme, should have school screening programme as it covers large population between 3 and 5 years age group. A study by Saleth Monica et al. accessed feasibility of school hearing screening, operated by a specialist siting 400 km away using remote computing

Table 1 Tele otology articles overview

S.no.	Author/year	Topic	Concept	Result/conclusion
1	Vidya Ramkumar [12]	Tele-ABR using a satellite connection in a mobile Van for new-born hearing testing	The feasibility of tele-ABR in mobile van with satellite connectivity was compared with ABR recordings made face to face in 24 new-born individuals aged 8–30 days during their 1st follow-up visit	No significant difference was seen in these two modes in the peak V latencies at three intensity levels. Real time tele ABR testing is a feasible component for new-born hearing screening with assistance of VHWs
2	Vidya Ramkumar [11]	Providing Tele ABR in Rural India	Community-based hearing screening was conducted in 100 infants and young children using two methods: one in a mobile van having satellite connection and other in a non-government organization having broadband connection	Various practical and logistic challenges faced in these two modes have been highlighted in the study related to their advantages/ disadvantages, difficulties in training technicians/ VHWs for tele practice and assistance
3	Mark Krumm, Vidya Ramkumar [6]	An Update: Use of OAEs in Telehealth (Tele audiology) Applications	Described the history of tele otology	OAE assessment has a long history with telehealth applications. Virtually, OAEs can be used effectively and reliably with telehealth technology in both synchronous and asynchronous methods with essentially the same outcomes
4	Vidya Ramkumar [20]	Parents' perceptions of tele-audiological testing in a rural hearing Screening program in South India	The quality of tele audiometric screening in rural community (tele testing using videoconferencing) and parents' attitude about it was assessed using questionnaire with 17 rater administered items by an audiologist	Parents were satisfied about the counselling, testing process & accessibility because of the logistic factor like reasonable travel time, accompanying local VHW, cost free testing and technical factors like good video quality
5	Saleth Monica [25]	School entry level tele-hearing screening in south India lessons Learnt	It assessed the feasibility of school hearing screening comparing tele health technology (video otoscopy, PTA and DPOAE) and in-patient screening in 31 students	The outcome revealed no significant difference between PTA and DPOAE performed in-person and tele-hearing screening methods
6	Pratik Shah [23]	Technology-enabled examinations jointly with Routine health screenings: An Observational study at the 2015 Kumbh Mela in India	494 participants visiting Kumbh mela were tested for ear, eye, dental, neural and blood disorders using smartphone/technology-enabled screening (TES) and compared with routine health screenings	Many individuals who otherwise pretend to be normal in routine screening programs were found to be having significant abnormalities when tested through TES synergistically
7	Vidya Ramkumar [29]	Identification and Management of MED in a Rural Cleft Care Program: A Telemedicine Approach	To devise a grass root level strategy to screen and manage MEDs in a community-based programme in CLP in rural communities of Tamilnadu using ENTraview device	The Tele-medicine approach using ENTraview successfully achieved better coverage and helped individuals having CLP with TM/ MEDs in receiving recommendations of the otolaryngologist
8	Vidya Ramkumar [15]	Cost and outcome of a community-based Paediatric hearing screening programme in rural India with application of tele-audiology for follow-up Diagnostic hearing assessment	Study analysed the cost outcome of the community-based hearing screening programme. Out of the 1335 children (< 5 years) screened, 22 referred in the 2nd DPOAE were sent for tele ABR testing in a tele van using satellite connection and broadband based screening. Five children (out of 19 who completed tele ABR testing) were found having HL	The cost outcomes were better with broadband based Tele-ABR in comparison to satellite based Tele-ABR

Table 1 continued

S.no.	Author/year	Topic	Concept	Result/conclusion
9	Vidya Ramkumar[21]	Validation of DPOAE screening conducted by VHWs in a rural community with Real-time click evoked tele-ABR	119 children < 5 year, were screened with 2 stage DPOAE by VHWs in rural community to access the validity of DPOAE. Real time tele ABR was then conducted by an audiologist at tertiary centre via satellite connectivity in a tele van	The specificity, sensitivity, negative predictive and positive predictive values of the DPOAE screening programme using VHWs proves its validity
10	Devendra Kumar Gupta [22]	Efficacy of Android Based Mobile Device as a Screening Tool for Hearing Loss in Quiet and Noisy Environments	The study determined the hearing levels using an android based device ENTraview in a sound proof as well as in open environment and compared it with the gold standard PTA	Android based ENTraview is a potential screening tool for early detection of hearing loss, which is accurate, reproducible and cheaper than PTA with the additional advantage of domiciliary testing
11	Vidya Ramkumar [26]	Implementation and evaluation of a rural Community-based pediatric hearing Screening program integrating in-person and tele-ABR	Pediatric hearing screening (< 5 years) conducted by VHWs with 2 step DPOAE testing, followed by in-person or Tele ABR testing for those with refer on 2nd DPOAE. coverage rate, rate of refer, 2nd screening follow-up rate and diagnostic testing were analysed	Lower refer rate, greater coverage rate and improved follow-up rate reflects the success of pediatric screening programme. Tele ABR group presented 11% improved follow-up rate Compairing to in-person group
12	Pranav Mishra [24]	Internet-Based Hearing Assessment During COVID era in Indian Population: Practical and Safe Option	Web Based Hearing Assessment (WBHA) was compared to PTA	Though WBHA is a safe and reliable method of hearing screening but it's not a substitute to PTA as bone conduction and speech testing could not be assessed with WBHA
13	Nishi Gupta [31]	Comprehensive Community Screening of Otological Patients by Trained Technicians Using a Telemedicine Device: An Efficient And Cost-Effective Way to Triage Patients with Ear Diseases	The retrospective study (2013–2019) conducted to emphasize the benefits of tele-otology shruti programme in screening and treating ear diseases patients in a community	The Potential for telemedicine to reduce inequalities in health care is immense but remains underutilized. Shruti has largely been able to bridge this gap as it is an innovative, fast, and effective programs that address the ear ailment in the community
14	Pavithra Ravi [28]	Tele-Audiological Surveillance of MED among Individuals with CLP in Rural South India	To compare in-person audiological and tele-audiological surveillance, for better screening and management of MEDs in patients of CLP in rural community	Tele audiology surveillance reported greater coverage, greater follow-up compliance (61%) and cost efficiency compared to in-person audiological surveillance
15	Vijayasundaram [30]	Proficiency of virtual follow-up amongst tinnitus patients who underwent Intratympanic steroid therapy amidst COVID 19 pandemic	To access feasibility and efficacy of virtual follow-up in tinnitus patient undergoing intratympanic steroid	80% patients showed improvement and were satisfied with virtual mode of follow-up. Virtual follow-up is a cost effective, efficacious, patient-friendly, safer and secure method of follow up specially in covid 19 pandemic
16	Medtronic shruti programme [32]	Impact Measurement Case Study	Studied the effect of shruti programme on low-income rural population with the use of technology	Shruti is a cost-effective equipment for community-based health care services

ABR, Auditory Brainstem Response; MED, Middle Ear Disorders; CLP, Cleft Lip and/or Palate; PTA: pure tone audiometry

software for audiometry, DPOAE. Each of the 31 students were screened using both in-person and tele health. In in-person method, the video otoscopy, PTA and DPOAE were conducted by an audiologist at school site personally while in tele technology the same is being conducted by an audiologist at hospital site remotely. The concurrence in finding of video otoscopy between in-person and tele-otoscopy was between 87.5% and 96.4%. The concurrence in finding in person PTA and tele PTA screening was 80.64%. In-person and tele-DPOAE screening showed 83.87%

concurrence between the two. Median testing time for in-person method and tele method were 10 min (6–25 min) and 11 min (7–37 min) respectively, indicating nearly equal timing in both. So, no significant difference was noted in PTA and DPOAE performed via in-person and tele-hearing methods. [26] (Table 2).

Tele ABR in Mobile Van

The feasibility of tele-ABR in mobile van with satellite connectivity was compared with ABR recordings made face to face in 24 new-born individuals. No significant difference was seen in these two modes in the peak V latencies at three intensity levels. Real time tele ABR testing is a feasible component for new-born hearing screening with assistance of VHWs.

In the mobile van, the video conferencing was done using satellite connectivity.

Participants were the babies from the post-natal ward being followed at their first follow up visit to the hospital in a mobile van located 1 km from the hospital.

Tele ABR and face to face ABR were obtained on random basis to avoid biasing. Tele ABR were conducted by the audiologist remotely at the tertiary centre while in face-to-face ABR were undertaken by an audiologist in van itself with the assistance of VHWs. Twenty-four new-borns of 8–30 days age were tested with ABR in face-to-face and tele modes. For comparison of ABR data recorded in these two modes, latency analysis was done for 33 ears at 30 dBnHL, 34 ears at 50 dBnHL and 38 ears at 70 dBnHL. Mean differences in latencies between these two modes at 30 dBnHL, 50 dBnHL and 70 dBnHL was 0.021 s, 0.057 s and 0.007 s respectively signifying a normal distribution in both the modes at all intensities. These suggest that the tele ABR whether done in mobile van or face- to-face mode produces same results/recordings with no significant difference between the two. [13].

Another publication by Ramkumar [12] discussed the challenges faced during real time tele-ABR diagnostic testing in rural community. Community-based hearing screening was conducted in 100 infants and young children using two methods: one in a mobile van having satellite connection and other in organization having broadband connection. The various practical and logistic challenges faced in these two modes have been highlighted in the study related to their advantages/ disadvantages, difficulties in training technicians/ VHWs for tele practice and assistance. [12].

ABR + DPOAE

Pediatric hearing screening conducted by VHWs who had undergone 5 days training programme in doing DPOAE (Distortion Product Oto Acoustic Emissions) and assisting in performing Tele-ABR. Firstly, DPOAE screening was undertaken by VHWs in 2 steps at the homes of children < 5 years. DPOAE screening were conducted for frequencies 2, 3 and 4 kHz at 55 dB SPL and 65 dB SPL intensities. In case a child is referred in first DPOAE, 2nd DPOAE was scheduled after 2 weeks period. Children with 'refer' in 2nd DPOAE as well, were then send to audiologist for diagnostic ABR testing under two groups.

Group A underwent ABR testing in-person by an audiologist at a tertiary centre. In Group B, real time tele-ABR

Table 2 Strengths and challenges in conducting tele-hearing screening

S. no.	Strengths and challenges in conducting tele-hearing screening in India
1	*Technical issues*
	1. Connectivity: Towns have limited internet penetration
	2. Bandwidths < 15 Kbps: tele-hearing screening not feasible
	Bandwidths 15–60 Kbps: video time lag results in difficulty in screening
2	*Child related issues*
	1. Children showed additional curiosity and excitement to interact with the hospital audiologist while videoconferencing
	2. Familiar environment (school) made children feel comfortable
	3. Screening is done in presence of school teacher whom they knew
3	*School related*
	1. Interest and enthusiasm of the school management is an influencing factor
	2. Concern of the management regarding educational, communication and attention difficulties among some children at school
	3. Dedicated space and a facilitator (teacher) to be assigned by the school
	4. Assistance of class teachers in preparing a schedule for each child
	5. Organizing a meeting with teachers to orient them about hearing screening

was undertaken in a mobile van by an audiologist sitting at a tertiary centre using remote access via satellite connectivity. The VHW prepares the child for test (ensures child don't sleep, places electrodes and ensures positioning).

Overall analysis was undertaken in reference to coverage rate, rate of refer, 2nd screening follow-up rate and diagnostic testing. In-person ABR testing and tele ABR testing outcomes comparison was also undertaken. In group A, 1335 children from 51 villages and in group B 1480 children from 43 villages were screened. Coverage rate was calculated on the basis of national birth rate (20/1000 population) and it was found to be 77% (65% group A vs 90% group B). Screening time was found to range between 10 to 60 min. Median follow-up rate for second screening was found to be 85%. Refer rate of 1st and 2nd screening were 4.4% and 0.8% respectively.

Tele ABR group presented 11% improved follow-up rate Compairing to in-person group (86%vs 75%). These findings could be useful in planning hearing screening model. Success of this screening programme is reflected by its lower refer rate and improvement in follow-up rate. [27].

Ramkumar et al. [16] conducted a study for validation of DPOAE hearing screening by VHWs via community-based approach. In this a 2 stage DPOAE screening approach was followed, in which those who did not pass first screening were followed for 2nd DPOAE screening after 2 weeks. Real time click evoked tele ABR was then conducted to confirm threshold. In total 119 children under five years were screened by VHWs. An audiologist at the tertiary centre conducts the Tele-ABR in assistance by VHW via satellite connectivity in a mobile van. The screening specificity, sensitivity, negative predictive and positive predictive values for 2nd/rescreening stage conducted using DPOAE were analysed. Higher sensitivity is the desire as no child with HL should be missed because it can cause a greater economic burden on the community. [22].

A total of 119 children were screened and assessed with ABR. Upto 6 months age children no false response was recorded, false positive response increased with age. DPOAE screening identified 75% children with HL correctly (sensitivity). DPOAE correctly identified those who do not have HL in 91% (specificity). Positive and negative predictive values were 99% and 27% respectively. Thus, community based-screening programme using VHWs proves its validity to some extent. [22].

Similar study conducted by the same author, evaluated cost effectiveness and the outcomes of hearing screening programme.

This study analysed the cost outcome of the community-based hearing screening programme as economy plays a key role in the implementation of any health programme. Out of the 1335 children (< 5 years) screened, 22 referred in the 2nd DPOAE were sent for tele ABR testing. Five children (out of 19 who completed tele ABR testing) were found having HL.

Cost analysed for screening a single child was Rs 2276 and 2352 for broadband based and satellite-based screening respectively, representing a difference of Rs 76. Cost per child followed-up was Rs. 159,930 and 165,264 for broadband based and satellite based diagnostic tele ABR respectively, with a difference of Rs. 5334. The cost of identifying Hearing Loss per child was Rs. 607,734 and 628,005 for broadband based and satellite based diagnostic tele ABR, with a difference of Rs 20,271 per child. Author also conducted sensitivity analysis on broadband based diagnostic tele ABR at two ranges (i.e., least and most expensive for equipment and human resources). The least versus most expensive cost of screening per child was Rs. 1526 and 3041 respectively. Using least expensive resources, cost/child follow-up was Rs 102,065 (i.e., Rs 86,072 reduction/child). Lowest cost/child identified with HL was Rs. 388,237 (i.e., Rs 219,497 reduction/ child). The cost outcomes were better with broadband based Tele-ABR in comparison to satellite based Tele-ABR. Community based hearing programme can be benefited when constrained resources are used along with tele-ABR. [16] Estimated cost of untreated deafness in USA is $1,126,300.[28] No such data is available for South east Asian countries. 2.5%-3% gross national product is spent on deafness as per WHO 2009. Hence, the use of remote diagnostic tele-audiology in rural population has the potential of long-term cost saving in developing nations. [16].

Difficulties faced while implementation of hearing screening programme in India were audiologist's shortage, lack of infrastructure, difficulties in providing services to rural population and poor follow-up rates in distant tertiary centres. Technology plays a vital role in dealing these problems via tele otology and its application in screening, diagnosing and intervening health related problems in real time. (Table 3).

Parent Perception

Eighty seven of the 119 children parents, who were present during tele hearing testing participated in the interview. Seventeen interview questions (11 open ended and 6 close dichotomous questions) were asked to the participants. Questions were content validate by an audiologist, a social scientist and a specialist and questionnaires were modified as per their suggestions. The modified questionnaire was further verified weather appropriate or not, by retesting on 5 parents.

Table 3 Difficulties of screening programmes

Difficulties of screening programmes	
Shortage of audiologists Lack of infrastructure Difficulties in providing services to rural population Poor follow-up rates in distant tertiary centres Not all location in rural community had viable internet Bring the patient to the location of testing	Technology plays a vital role in dealing these problems via tele otology and its application in screening, diagnosing and intervening health related problems in real time

The interview was conducted by a different trained audiologist to avoid biasing. The interview took 45 min to 1 h at parent's home and following results were noted:

(i) *General information* All the parents were aware that children were tested to rule out HL by a professional. All were of the opinion that tele hearing is better test compared to screening by a VHW at home. (2) *Tele-testing perceptions and video-conferencing quality* Parents followed for tele testing due to their concerned regarding child hearing status, a few came as test were free of cost. The apprehensions about the test were due to use of wires in ABR, first time tests were done, child are quiet young, difficulty in having child asleep. However, parents were relieved to see the audiologist on screen, felt it to be comfortable technique as child was sedated. The experience was reported good and found it to be better than the in-person method. Poor video quality and inaccessibility of the audiologist were the reasons mentioned by those who were not satisfied. (3) *Access to tele-hearing testing* it has the potential of reducing rural travel time considerably, as the parents had mentioned less than 30 min travel time for seeking health services. (4) *Parent attitudes toward village tele-hearing testing* Parents preferred tele van mode of hearing testing because of easy accessibility through video conferencing with a bigger TV screen and stable satellite connectivity. The follow-up compliance to the testing sites was facilitated by the escorting VHWs, thus strengthening grass root level approach in hearing screening. Parents were satisfied about the counselling, testing process and accessibility because of the logistic factor like reasonable travel time, accompanying local VHW, cost free testing and technical factors like good video quality. [21].

Role in Cleft-lip/Cleft Palate

As the patients with cleft lip and palate (CLP) are at increased risk of middle ear diseases (MEDs) due to lack of eustachian tube patency. Early identification of MED is necessary to prevent permanent hearing loss. Study undertaken by Pavithra Ravi et al. [29] aimed to compare in-person audiological and tele-audiological surveillance, for better screening and management of MEDs in patients of CLP in rural communities of Tamil Nadu.

In in-person audiological surveillance, investigations (PTA, tympanometry, video) were performed by audiologist in monthly camps. Individuals with suspected disease (like impacted wax and MEDs) were referred to specialist at local/district hospital.

In tele-audiological surveillance, video-otoscopies were done by trained community-based rehabilitation workers (CBRWs) while as PTA and Tympanometry were done by an audiologist sitting at tertiary centre via remotely assessed equipment using internet. Otolaryngologist then reports the diagnosis and treatment plan at its centre, which is then conveyed to the patient at the community level by the CBRWs.

Follow-up in tele audiological group was done at individuals' homes, and those in need of surgical interventions were referred to tertiary hospital while as follow-up of in-patient group was conducted at subsequent camps.

Tele audiology surveillance reported greater coverage (68% vs 38%), greater follow-up compliance (61% vs 19%) and cost efficiency (saving USD 47 per individual) as compared with in-person audiological surveillance. The per individual cost of testing in tele audiology was lower (USD 191) in comparison with in-person audiologic group (USD 238).

Author concluded that tele- audiology was beneficial for diagnosis and treatment of audiological problems in CLP patients of rural location and the same can be useful while programme planning's [29].

Another study was conducted by Vidya Ramkumar [30] aimed at devising a grass root level strategy to screen and manage MEDs in a community-based programme in CLP

in rural communities of Tamil Nadu. Home visits were conducted by the community workers who performs, stores and forwards video otoscopy using ENTraview device (Medtronic). Patient demographic data, and history were documented using customised mobile application 'shruti'. TM image was then captured using video otoscope and all data was uploaded on cloud using mobile data internet. Audiologist at the tertiary centre views the images using clickmedix platform. He then shares the data with otolaryngologist on same platform on appropriate management. Those in need of intervention were followed -up as per the otolaryngologist advice. Hearing assessment was also undertaken by the audiologist at tertiary centre in assistance with community worker using sentiero Path portable device (an integrated audiometer and tympanometer). PTA and tympanometry were conducted remotely using internet either at beneficiaries' home or at monthly camps. Individuals (160) with CLP between 3 and 35 years age group were screened by the trained community workers using ENTraview device. Those diagnosed with TM/MEDs were evaluated by diagnostic tele hearing evaluation using PTA and tympanometry. The programme achieved 80% coverage rate. 26% (82/320) were diagnosed with TM/MEDs after video otoscopy. Out of these 26% (82), 52 had otitis media, 20 had TM abnormality (scar, sclerosis, hemotympanum) and 10 had TM perforation. Out of these 82 individuals with TM/MEDs, 42 completed tele hearing evaluation and 52% (22/42) of them were diagnosed with some level of HL. The follow up rate with tele practice was noted to be 100% for individuals with TM/MEDs (without tele practice it was 3.5%), Regarding the follow-up compliance for recommended intervention, 78% (7/9) follow -up compliance was achieved for surgical interventions, and 31% (11/35) for medication intervention. This approach successfully achieved better coverage and helped individuals with TM/MEDs in receiving recommendations of the otolaryngologist.

Role in Follow-Up: Post Intratympanic Steroid in Tinnitus Patient

25 patients undergoing two cycles of intratympanic steroid injections for long-term tinnitus, were followed-up for 68 days by video calling and telephonic method. Evaluation was done using Tinnitus handicap inventory scoring (THI). Out of the twenty five, twenty patients (80%) had improvement in symptoms. However, most of the patients were satisfied with virtual mode of follow-up and were happy to follow the similar method in future. So, virtual follow-up is a cost effective, efficacious, patient-friendly, safer and secure method of follow up specially in covid 19 pandemic as it ensures social distancing. Patients with no mobile/telephone, profound hearing loss or with complication during the procedure were to be excluded from the study. Based on the patient THI score, further plan of action was decided. Patients who showed improvement in THI score were continued on cognitive and behaviour therapy while as those with no improvement were called to hospital for further audiometric and radiologic evaluation. [31].

Shruti Programme

Limited infrastructure effects screening and treatment of HL and creates its impact on whole societies' in developing nation like India. Most effective prevention of HL is its early identification and management through 'tele health'. The study determined the hearing levels using an android based device ENTraview in a sound proof as well as in open environment and compared it with the gold standard PTA. Hearing disability (HL $>$ 40Db) were assessed by three different methods: (a) trained audiologist conducting PTA in a sound treated room. (b) trained nursing staff using ENTraview device in a sound treated environment. (c) third accessor coordinated the ENTraview testing in a non-sound treated environment. The ENTraview device showed 96% sensitivity and 82% specificity in sound proof and 93% sensitivity and 64% specificity in open environment. Hence ENTraview is a best screening device in all respect for early detection of HL with additional benefit of being domiciliary but needs validity studies further. [23] (Table 4).

Tele audiometry has the potential to become a game changer in hearing evaluation in primary health care and in places with potential occupational hazards. So, smart phone applications are a good option for early detection of HL as it is economical, easy to perform and can be done any time.

The retrospective study (2013–2019) conducted under shruti tele otology programme included screening, diagnosing, management (medical/surgical) and rehabilitation (with hearing aid) of patients with ear diseases. Role of tele otology in screening patients with ear disease in underserved and underprivileged communities across 12 Indian states was assessed.

The device used was ENTraview, an android enabled mobile phone integrated with camera and otoscope, screening audiometer and chargeable light source. Camera of phone captures the tympanic membrane image, and the noise isolating headset enables audiometric screening. ENTraview allows the health workers at community in screening patients and generating patient unique number using smartphone app. The case file includes demographic data, patient history, TM image. Patients with decreased hearing undergo hearing screening through tele audiology using ENTraview device. The data is further uploaded on

Table 4 Internet-based hearing tests

Benefits	Limitations
High sensitivity	Surrounding environment also effects the accuracy of hearing procedure
Potentially good screening tool	Audiometry apps focus on the air conduction threshold only
Easy to use	Can be used only as a screening tool rather than for diagnostic purpose
Minimal cost makes it viable to be used on a large volume of subjects	User can manipulate the results as they are self-administering the tests
Takes short time	Instructions are in English,
Minimal manpower and infrastructure are needed	Needs quiet room,
Obtains valid audiometric data	Android application uses pure tones which are less reliable than speech audiometry
Useful in far flung and remote areas	It could not differentiate between conductive and sensorineural HL
Avoids distant travelling's	It may give inaccurate results at low frequencies due to ambient noise. Calibration issues can also affect results as smart phones are not calibrated
Improves follow-up	Change of earphones may also change the calibrations
Saves clinicians as well as patients time, useful for planning hearing screening programmes	ABR are not feasible in absence of minimal infrastructure like power supply, computer, some are battery operated
Game changer in hearing evaluation in primary health care and in places with potential occupational hazards	

cloud platform where an ENT specialist reviews and responds as per his time (i.e., it's not a real time consultation). Those in need of further intervention were referred to nearest district hospital.

In total 810,746 people were screened, out of which 33% (27875) had ear problems. Among them 57% (51067) had impacted wax, 18% (46792) suffered CSOM (chronic suppurative otitis media), 10% (27875) decreased hearing, 5% (12729) ASOM (acute suppurative otitis media) and acute otitis media, and 10% (27152) had otomycosis, foreign body etc.

Out of the total 265,615 referred patients, 8% (20,986) patients reported and received treatment through shruti programme, 11% (29,218) took treatment at nearby hospitals and 6% (16,221) were later treated by wax removal and hearing aid trial at their doorsteps. Three percent only opted for surgical intervention (ear surgery) while as 9% opted nonsurgical interventions (medical management, hearing aid etc.).

Shruti has been a fast, innovative and cost-effective programme to address ear diseases in the community [32].

Medtronic has implemented a shruti programme to improve people lives using technology, improve screening and treatment protocols and to develop better partnership with health service providers. It is a portable hearing screening kit which detects impairment in hearing and can be used in densely populated, low-income communities and rural population.

Shruti programme was active in India since 2013, it has a strong technology and analytics team who use portable otology devices and mobile phones (android-based otoscope) to collect data from communities, hospitals and clinics. Shruti team collected operational and health data using ENTraview and interview forms. A general screening survey (door to door) and a post treatment survey (3 months post discharge) was conducted by the team. As per the survey, 50% of those screened reported hearing problems, 11% of them were not having any symptoms, 31% had ignored their ailment. Main hurdle preventing people from seeking treatment was lack of awareness and different attitude towards hearing problem, however 20% reported financial burden of treatment to be the hurdle, 28% patients didn't know to whom and where to go for treatment, 24% didn't think that treatment was urgent, 41% did not have enough time for ear check-up. However, post treatment 87% patients had improvement in ear conditions, 35% reported improved performance at work place and 58% reported better social interaction and communication. So, shruti programme which takes ear screening to the doorstep of community is clearly addressing the challenges of low-income communities and provides affordable health care services [33].

Conclusion

- Telehealth has the capacity to provide services to the beneficiaries even when the clinician is located far away.
- In order to minimise the hospital visits specially during the covid 19 pandemic, follow up of the patients via virtual approach through video calling applications and telephone calls proves to be handy approach ensuring

safety profile of both health care professionals and the patients

- Tele health is a non-invasive, low cost and portable screening approach, which can be adopted for both new-born and school going children hearing programmes.
- Tele hearing testing was satisfactory for the parents in regard to accessibility, testing process and counselling. So, tele otology should be considered by the service providers and policy makers while planning for hearing screening programmes in view of its reliability and low-cost outcomes.
- The tele ABR conducted in tele van is a feasible mode and produces similar results as obtained in face-to-face mode ABR.
- Tele practice do have few limitations and clinicians must know the boundaries when to see the beneficiary personally.
- Technical factors like good video quality, logistic factors like reasonable travel time, ease to access and local VHW from the community may influence the tele health services. The VHWs should be well trained in assisting tele practice and internet connectivity should be well established.
- Tele otology/audiology has a significant role in screening, diagnostic testing, intervention, hearing aid adjustments, follow-up of cases, cochlear implant programme, tinnitus management and rehabilitation in field of otology.

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Declarations

Conflict of interest The authors declared that they have no conflict of interest.

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