Contents

2.1 Hearing loss and its prevention
   2.1.1 Status of hearing disability
   2.1.2 Early identification and intervention for hearing loss and its challenges

2.2 Community based approaches for hearing screening
   2.2.1 Advantages of community based program
   2.2.2 Community based hearing screening programs
   2.2.3 Hearing screening by community health workers

2.3 Tele-medicine and tele-audiology
   2.3.1 Tele-medicine and its application
   2.3.2 Tele-audiology
   2.3.3 Satisfaction with tele-medicine

2.4 Cost analysis
   2.4.1 Cost analysis of hearing screening programs
   2.4.2 Cost analysis of telemedicine programs
2.1 Hearing loss and its prevention

2.1.3 Status of hearing disability

According to WHO estimates, 32 million children have disabling hearing loss with a hearing loss greater than 30dB in the better ear (WHO, 2015). In India, hearing disability is the highest (0.60%) when compared to other disabilities, among children between 0-4 years (0.28%) and 5 to 9 years, (0.32%) (Census of India, 2011). Prevalence of congenital hearing loss in India is estimated to be approximately 5 per 1000 (Vaid et al., 2009; Nagapoornima et al., 2007).

Congenital hearing loss impacts self, family and society. Other than speech and language deficits and psychosocial impacts, children with disability, including hearing impairment, have a much higher incidence of not attending or dropping out of school. And in older individuals higher unemployment rate is also reported, thereby affecting financial and social stability (World Bank Report, 2007).

It has been estimated in the US that untreated deaf infants can cost society approximately $1,126,300 over the course of their lifetime (Keren et al., 2002). In the South-East Asia Region, hearing loss accounts for 2.3 % of all DALYs. While there have been no studies with regard to cost of deafness in the countries of South-East Asia, if the same proportionate costs occur in other countries, then deafness would cost 2.5 - 3% of Gross National Product of individual countries. This is estimated to be US$ 13.5 billion to the countries of the SEA Region (WHO, 2009b).
Acoustic stimulation in the first 18 months is crucial for the neurological development of auditory pathways (Finitoz et al., 1998 as cited in Grill et al., 2006, page 1). Lack of such adequate acoustic stimulation leads to communication deficits, which, if not intervened before 2 years of age, is not easily recovered (Grill et al., 2006). If a child with hearing impairment has good language outcomes, then this would result in a 10% decrease in special education costs and a 75% decrease in vocational rehabilitation costs (Keren et al., 2002).

The key for successful speech and language outcomes is in early identification and intervention. Systematic studies have been conducted to compare language development in early versus late identified children (Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998;), and it has been reported that identification after 18 months is not early enough (Yoshinaga-Itano, & Apuzzo, 1998). Children with hearing loss, identified at birth are found to have better language outcomes at school age as they are referred, diagnosed and treated earlier than those identified passively (Nelson, Bougatsos, & Nygren, 2008). Wake et al. (2004) as cited in Porter et al., 2009 in page 4, examined outcomes in children with hearing impairment who did not have access to early identification, and found that their psychosocial health-related quality of life differed significantly from children with normal hearing.

2.1.4 Early identification and intervention for hearing loss and its challenges

In order to promote early detection and identification of hearing loss, until 1970, hearing screening of newborns and infants was conducted using high risk factor checklists and behavioural methods. In order to streamline infant hearing screening protocols, the American Speech and Hearing Association (ASHA), American Academy of Paediatrics,
and American Academy of Ophthalmology and Otorhinolaryngology met as a National Joint Committee on Infant Hearing screening (JCIH) in 1970. The statement issued by JCIH based on the consensus was that, early identification is important, however mass or universal screening was not recommended due to lack of appropriate screening tools. During this time, risk factor screening, and behavioural responses using crib-o-grams were used to screen infants for hearing loss. In 1972, JCIH streamlined the risk factor based screening by listing the most critical risk factors, which was called as the “High risk register” (HRR) that warranted detailed audiological testing. Subsequently, hearing screening in infancy using HRR and behavioural observation was fine-tuned through the Nova Scotia conference in 1974, and Saskatoon conference in 1978. Subjective methods such as HRR and BOA had its limitations in sensitivity and specificity, however the advent of AABR and TEOAE revolutionised infant hearing screening in 1980s (Gravel & Tocci, 1998). These instrumental measures, with their higher sensitivity and specificity allowed for the progression to Universal Newborn Hearing Screening (UNHS). Recommendation and benchmark for UNHS were evolved based on hospital based models of hearing screening, where every child born is screened for hearing loss before discharge from the maternity ward.

JCIH and National Institute of Health, USA, continued to streamline infant hearing screening protocols and models based on subsequent consensus meetings. JCIH 2007 is the latest statement with additions in 2012.
Newborn hearing screening programs

The forerunners in UNHS in the United States that served as a model for NHS are the Rhode Island Hearing Assessment Project (RHAP)(1990), Colorado Newborn hearing screening project (1992) and the New York State (NYS) Department of Health and Education’s project (1995) (Gravel et al., 1998). Subsequently, UNHS was implemented in a phased manner across the United States. However, NHS is mandated only in two other countries and is adapted as national policy in four countries around the world (WHO, 2009). In 2010, WHO reiterated the importance of UNHS in developed and developing countries having rehabilitation resources.

Performance of NHS programs was evaluated in 46 countries across North America, Europe, Asia, the Middle East, Oceania and Africa by Tann, Wilson, Bradley, & Wanless, 2009. Data was compared to the UNHS benchmarks set by the Joint Committee on Infant Hearing (JCIH) in 2007. In the 21 countries where data on national screening coverage were available, the average coverage was 46%, and in the 32 countries where data on regional or local screening coverage were available, the average coverage was 64% (JCIH recommends 95% or more). In the 27 countries where data on referral rates were available, the average rate was 7% (JCIH recommends 4% or less) and in the 16 countries where data on follow-up rate were available, the average rate was 63% (JCIH recommends 90% or more). These results highlight screening coverage and follow-up rate as the challenges of NHS.
Infant hearing screening programs in developing countries with emphasis on Indian programs

Despite two-thirds of all persons with disabling hearing loss residing in developing countries, infant hearing screening programs are not widely adopted in these countries due to resource limitation, absence of political will, and limited contextual research (Olusanya et al., 2007). Early identification and intervention of hearing loss has not received due attention as these countries are burdened with other life threatening diseases which takes priority.

Information regarding financing, parental and health professionals' attitudes and achievements and challenges of infant hearing screening programmes (if any) in developing countries was obtained by Olusanya et al., 2007. Results showed that while most countries did not have national programs, pilot projects using objective screening tests were on-going in many countries. Screening services were provided at hospitals and/or community health centres but was charged in most of the countries. Attitudes amongst parents and health care workers are typically positive towards such programmes. Coverage of these programs was generally above 90% but poor follow-up rates was a common challenge.

In India, the prevalence of visual impairment is 0.8 per 1000 among children under 15 years (National Program for Control of Blindness [NPCB], 2010), which is lower than the estimated prevalence of congenital hearing loss. While the National Program for Control of Blindness was initiated in 1976 and School Eye Screening (SES) program became an integral part of the NPCB in 1994, the National Programme for Prevention and Control of Deafness (NPPCD) was launched only in 2006. Under this programme, both institution
Based screening and community based screening were implemented in more than 200 districts. The institution-based screening was modelled after the hospital based programs, and the community-based screening, was targeted towards babies who are not born in hospitals. Community based screening was conducted using a brief questionnaire and behavioural testing by a trained health care worker during immunization. Any baby who did not pass the screening was to be followed up at the district hospital for Oto Acoustic Emission (OAE) and Auditory Brainstem Response (ABR) and if required, for rehabilitation. Some of the key issues in the implementation of the deafness programme was identified as burden of disease, lack of human resources, inadequate infrastructure and low priority for deafness prevention (Agarwal et al., 2013).

Even before the national program was launched, initiatives were taken by institutions and hospitals to establish NHS programs in India. Tertiary care hospitals such as St. Johns hospital, Bangalore, Christian Medical College, Vellore to name a few, initiated such programs. Indian hospital based programs have routinely reported on follow-up rate, while some studies based on relatively larger cohorts have reported on incidence and prevalence.

One of the early large scale attempts of NHS was by Yathiraj et al. (2002) in rural and urban areas of Mysore district to determine the most effective method of screening for hearing loss. Thousand babies were screened using High Risk Register (HRR) and BOA using calibrated noise makers and paediatric screeners and OAE. Out of thousand only 50 babies followed up for OAE. Based on their preliminary cost analysis, HRR based screening conducted by anganwadi workers was found to be the most effective. However, the authors reported that the sensitivity of OAE/BOA could not been studied due to poor follow-up for diagnostic testing.
Several hospital-based programs reported on the incidence or occurrence of hearing loss among the cohort under study. In a tertiary level hospital in South India, the weighted incidence of hearing impairment in a standardized population of at risk and not at risk neonates was estimated in a prospective non-randomized cohort of 1769 neonates. All neonates were screened using transient evoked otoacoustic emissions (TEOAE). The incidence of hearing impairment was reported to be 3 per 279 infants at risk and 7 per 1490 infants who are not at risk (Nagapoornima et al., 2007).

The possible burden of hearing disability was evaluated in babies born at a tertiary care hospital in Northwest India. One thousand newborns were screened using TEOAE. Auditory Brainstem Response (ABR) was used to confirm and determine the extent and type of deafness in the neonates who were screened positive. Four out of the 1000 babies screened were found to have moderate to severe degree of hearing loss (Jewel et al., 2013).

A centralised screening facility including 20 major hospitals with maternity units was initiated by the Indian Academy of Pediatrics (IAP) Cochin Branch. Three screening personnel with basic computer knowledge conducted two stage screening using three OAE screeners in these 20 hospitals. Over the period of 7 years from January 2003 till December 2009, a total of 10,165 babies were screened and the incidence of hearing loss in at risk group was reported to be 10.3 per 1000 and 0.98 per 1000 in the well baby group (Paul, 2011).

Challenges with respect to follow-up for re-screening and diagnostics is reported in several NHS programs. For example, in a hospital-based NHS program in a semi-urban town in South India, 500 neonates were screened by trained screeners under the supervision of
audiologist using DPOAE. Follow-up for re-screen and diagnostic ABR was reported as a challenge due to parents’ lack of perception of child’s hearing problem (John et al., 2009). In another hospital based NHS program in a major town in West India, high drop-out rate was reported for 2nd screening and diagnostic testing due to the logistics of distances that these patients had to travel (Vaid et al., 2009). Poor follow-up for diagnostic testing was reported as a major challenge in the centralized NHS program in Cochin (Paul, 2011).

The possibility of using personnel other than audiologist in infant hearing screening was explored by Basavaraj and Nandurkar in 2007 (as cited in RCI, 2007, page 121). Automated TEOAE screening and behavioural screening was conducted by mothers/caregivers, nurses and audiologists on infants with bilateral severe to profound hearing loss. They reported no significant differences in the behavioural screening outcomes between the mother/caregivers, nurses and in TEOAE screening there was no significant difference between the nurse and the audiologist. The outcome suggests that even mothers/caregivers can be sensitized regarding behavioural screening, which may be helpful as a preliminary measure especially in places where there is a resource constraint.

While there has been considerable efforts to implement NHS in India, a recent survey conducted on newborn hearing screening programs from 185 institutions (165 medical colleges and 20 Speech and hearing centers) showed that only 38.09% of the medical colleges programs. However, 80% of Speech and Hearing centers were providing services pertaining to NHS (Kumar & Mohapatra, 2011).

These studies indicate that NHS programs are being considered vital by ear and hearing care professionals. Though in its nascent stage, existing programs have conducted quality
evaluations on benchmarks recommended by international bodies and have also identified local challenges.

*Hearing screening among pre-school (young) children*

While there are some initiatives for new born hearing screening in counties like India, due to a lack of a systematic infant hearing screening program in low and middle income countries, most children are not identified until they enter primary school or at a later stage (Davis et al., 2014; Olusanya et al. 2008; Rout et al., 2010, Patel et al., 2014). WHO recommends that national plans for infants, toddlers and children be prepared for the prevention and control of major causes of avoidable hearing loss within the framework of primary health care (WHO, 2009).

The American Pediatric Association recommends that children between 2 to 2 ½ years should undergo at least one audiology assessment and all children between 4 to 5 years of age should undergo objective screening (Harlor & Bower, 2009), as a means to identify late onset and unidentified hearing loss in pre-school stage.

There are very few reports of screening among older children, possibly, because much of the published work is from the Western countries where UNHS is established for the last 15 to 20 years. In one the early studies on hearing screening programs, a "selective" hearing screening program was initiated in an early education project, where 3 year old children "at risk" for mild-to-moderate hearing loss were screened. The risk was determined using JCIH criteria, such as recurrent ear infections, or if there was parent or staff concern about the child's hearing (Palfrey, Hanson, Pleszczynska, Norton, & Levine, 1980).
In one of the early community based hearing screening initiatives, infants and children up to 11 years of age were included at seven child health clinics. Even though the primary aim was to screen infants, older children were included due to referrals from clinic nurses. The majority of positive screening results were associated with middle ear disorders, and this may be explained by the inclusion of the older age group, where hearing loss due to middle ear infections are common (McPherson, Key, Smyth, Latham, & Loscher, 1998).

In India, expert committee in RCI, proposed school screening by teachers in schools, where they are trained to screen school children using checklist. In addition, Ling's 6 sound test using picture pointing or phoneme pointing was also recommended as these simple tests require minimal training and expertise (RCI, 2007). Yet, other than school screening conducted by institutions offering Audiology and Speech, Language pathology courses, there is no known report on application of such recommendations in schools.
2.2 Community based approaches for hearing screening

2.2.4 Advantages of community based program

The most commonly used model to date has been hospital based screening of neonates in maternity units, employing nurses in the maternity unit before discharge. While a hospital based model can work where there are large maternity units, a unique problem in developing countries is that a significant number of births, do not take place in hospitals but either at home or in small clinics (Swanepoel, Louw, & Hugo, 2007). For example, in Netherlands a hospital based model is expected to cover only 50% of neonates as at least 30 to 35 % of the babies are born at home and in the remaining 65-70 % of cases the mother and baby are discharged from the hospital within 12 to 18 hours (Zanten, 2002).

Strictly emphasising hospital based models for new born hearing screening, reserves the benefits of early identification of hearing loss to high income countries with resources for such programs. However, in low and middle income countries with limited healthcare resources the probability of infant hearing loss is higher (Mencher & DeVoe, 2001 as cited in Swanepoel et al., 2007, page 322).

Narrowing such disparities in healthcare is important from an ethical and human rights perspective (Braveman & Gruskin, 2003 as cited in Swanepoel et al., 2007, page 322). There seems to be a progress towards community based and indigenous models in a growing number of developing countries (Olusanya, 2010) to address such disparities and to develop contextually relevant programs.
Community based hearing screening efforts have been initiated in countries like Bangladesh, Nigeria, Taiwan, Netherlands, U.K and India. (Owen, Webb, & Evans, 2001; Lin, Huang, Lin, Lin & Wu, 2004; Neumann et al., 2006 as cited in WHO, 2009).

Community based screening is generally conducted by health visitors or community health workers (Olusanya et al., 2008; Danhuer & Johnson, 2006; Owen et al., 2001). Community based screening program have been conducted at babies’ homes (Owen et al., 2001; Danhuer et al., 2006), community clinics and primary health centres (Owen et al., 2001; Olusanya et al., 2008).

Community based efforts have primarily focussed on feasibility of screening in the community and evaluation of programs to assess coverage, refer rate and follow-up rate. It is noteworthy that while these studies have reported on such quality indicators of a hearing screening program, the aim was not to meet the benchmarks of hearing screening programs which are based on western countries.

Community clinic based hearing screening programs emerged in some developed countries like UK, such services allow mothers in the community to avail services after they have fully recovered from the stress of child-birth (Bantock & Croxson, 1998). The positive predictive value of TEOAE screening conducted by nurses in a community health clinic for babies greater than 33 weeks was 18% and the refer rate for diagnostic ABR was 0.5% (Bantock et al., 1998).

In Australia, McPherson et al. (1998) studied the feasibility of conducting TEOAE screening on infants and children in a community clinic. While the primary purpose was to screen infants, this study has included older children up to 11 years of age based on
referral. Results based on 2305 infants and young children screened, indicated that TEOAE screening was feasible in the community setting.

In UK, Owen et al., (2001) assessed the feasibility of OAE screening delivered through health visitors in local health centres of urban areas and in babies’ homes in rural areas. Six hundred and eighty three babies were screened and their mothers were asked to fill a questionnaire regarding hearing screening. The study result showed that OAE testing through health visitors was feasible at homes and community health clinics and a high population coverage with less false positive rates could be achieved.

In addition to evaluating feasibility, community based programs have assessed service penetration, coverage rate and factors related to follow-up compliance. For example, in Nigeria, it was felt that parents hesitated to bring an apparently healthy child to a hospital visited by sick children, for hearing screening. Therefore, in an attempt to improve population coverage, infant hearing screening programs were attempted at primary health care immunization clinics (community based) (Olusanya et al., 2007). The community-based universal infant hearing screening programme was provided through health visitors using TEOAE and AABR. As an incentive for parents, all services provided under the programme and transportation to the diagnostic centres were free. The coverage was reported to be 88%, the mean age of screening was 17.7 days, with no parent declining screening. The overall referral rate for diagnostic evaluation was 4.1%, however only 61% of those referred returned for evaluation despite free transportation and testing at free of cost. Therefore, follow-up seems to be a hurdle even in community based programs (Olusanya et al., 2008).
Maternal and infant social demographic factors associated with follow up compliance in a community based hearing screening program was studied by Olusanya and Akinyemi (2009). In addition to the number of follow-ups required, and ineffective tracking system, place of delivery was reported to be the primary factor that influenced compliance.

Friderichs, Swanepoel, & Hall, 2012, evaluated the first systematic community-based infant hearing screening program in eight primary health care clinics in a developing South African community in the Western Cape metropolitan area. This is one of the few studies that reports of indigenous benchmarks of hearing screening programs that is specific to South Africa (Health Professions Council of South Africa 2007 Position Statement). Trained nurses conducted a two-stage DPOAE screening on 6227 infants over a 19-month period. Diagnostic audiological and medical evaluations were scheduled at referral hospitals. Overall first stage screen referral rate was 9.5% with 3% referred for diagnostic services at hospital level after a follow-up screen. Overall coverage rate across the eight clinics was 32.4%. The follow-up rate for 2nd screen was 85% (50-100% range), and for diagnostics was 91% (60-100% range). They reported that the nurses were heavily burdened with a variety of tasks and could not effectively combine screening with other regular duties (Friderichs et al., 2012).

In Brazil, the government enacted a law to perform NHS in all public hospital’s maternity ward. Community based mobilization using community health workers was initiated due to concerns regarding lack of penetration of such services due to family’s motivation (Araújo, Alvarenga, Urnau, Pagnossin, & Wen, 2013).
These programs have set the trend to attempt alternate models of service delivery for newborn and infant hearing screening. The quality evaluations of such programs may be helpful in setting benchmarks for community based programs, especially in developing countries.

2.2.6 Hearing screening by community health workers

In general, the personnel involved in hospital based programs have been nurses (U.S.A, Germany, Russia, China & Oman), audiologists (U.S.A, China, Korea, Russia, Brazil, India and Oman), and physicians (Germany, Russia, Korea & Oman) (Owen et al., 2001; Berg, Papari, Ferdous, Khan & Durkin, 2006, as cited in WHO, 2009). “Task-shifting” to the “lowest” category who can perform the task successfully, is an acceptable practice when demand cannot be matched to capacity in health care (Hansen & Tobler,2008). In this context, the personnel involved in screening in community based programs has been trained health visitors or community health workers.

WHO has provided simple guidelines in selecting community health worker, according to which , they should be from the community where they work, and should be supported by the health system but not necessarily a part of its organization, and they should have shorter but regular training which is competence and practice based than professional workers (Hansen et al., 2008). The strength in having a person from the community trained for such efforts lies in their familiarity with the people of the community, which is likely to positively influence the success of the program.

Community health workers, can promote hearing health, mobilise families for screening and follow-up and on guide the family through the rehabilitation process when necessary
(Melo, Alvarenga, Blasca, & Taga, 2010). However, it is important that they receive adequate training to be able to carry out their responsibility efficiently.

Outcomes of training community health workers for hearing screening

Only a few studies have reported on the specific content and outcome of training program conducted for health visitors or community health workers.

Owen et al., 2001, assessed the feasibility of health visitors (HVs) performing OAE screening in the community in UK. The training programme consisted of an introductory study day, followed by practical training by an audiologist at the targeted neonatal screening clinic of the hospital. Twelve HVs screened 683 babies in local health centres and babies’ homes in urban and rural settings in West Gloucestershire. The HVs screening was supervised and assessed for competence in the local health centre setting but not in home setting. However details on the evaluation conducted and its outcomes are not known. Based on the coverage achieved (99%), time taken for screening (median time 12.2 minutes) and parental feedback, the authors concluded that hearing screening was feasible with HVs.

In Sao Palo, Brazil, an eight hour training program was conducted for individuals who were high school graduates using WHO guidelines for training community health assistants in ear and hearing care. This was developed as a part of a government initiative, of infantile hearing health and the effectiveness of a training program regarding the hearing health of children for community health agents was evaluated.

Pre and post training evaluation was conducted using a questionnaire. While pre-training scores are not known, the results showed that the hearing conservation programs
showed better scores post training (40-100%), and 70% score was considered as satisfactory (Alvarenga et al., 2008).

An educational training program was designed for community health workers (CHWs), in a CD-ROM with video, text, images and audio information, with interactive modules in Brazil. Post training, CHWs were expected to mobilise parents for NHS in public hospitals. The effectiveness of this training program was evaluated using pre and post training test on two groups of CHWs, one group (43 CHWs) who had previously participated in at least one training activity involving hearing health, and another group (47 CHWs) who had received no prior training in hearing health.

The CD-ROM based program contained information on sound and the auditory system; audition, language, and hearing loss; the causes of hearing loss and attention to health; identification and diagnosis of hearing loss during the first year of life; and rehabilitation of hearing loss. The training module was four hours per session, conducted as two sessions for 2 days. Pre-post questionnaire with 20 questions was used to assess effectiveness of training. Pre-training the scores were 50-80 % and post training scores were 80-91% which was statistically significant in 2 out of 5 domains assessed. The CHWs performance was evaluated on a simulation activity (Araújo et al., 2013).

In a community-based infant hearing screening for early detection of permanent hearing loss in Lagos, Nigeria, community health workers were trained to conduct TEOAE and AABR screening. While no information is available regarding the content of training, the validity measures were reported as an indicator of their ability to conduct screening in the community clinics. The sensitivity, specificity and positive predictive value of the first
screening using TEOAE were 80.4%, 99.7% and 90.0%, respectively (Olusanya et al., 2008).
These studies suggests that grass root level personnel can be trained effectively to conduct such programs especially in the community.
2.3 Tele-medicine and tele-audiology

Community based approaches have been successful in addressing disparities in basic health care services, like hearing screening, which does not require the expertise of a professional. However, diagnostic services requires the expertise of an audiologist, whose services are available only at tertiary hospitals (Swanepoel et al., 2007). Just as community based programs have been initiated to improve coverage and reach of service, telemedicine is a relatively newer approach that has been explored to circumvent the problem of reaching expert services to remote areas.

2.3.1 Tele-medicine and its application

Telemedicine is defined as clinical practice for diagnosis, review, or management undertaken synchronously or asynchronously through the medium of information and telecommunications technologies (excluding telephone and fax) (Whitten et al., 2002).

Telemedicine has been applied in various disciplines of health care. World Health Organization’s global observatory for eHealth (GOe) conducted a survey in 114 countries, to examine four fields of telemedicine (teleradiology, teledermatogy, telepathology, and telepsychology) and four mechanisms (use of a national agency, national policy or strategy, scientific development, and evaluation) that facilitate the promotion and development of telemedicine solutions. High costs, underdeveloped infrastructure, and lack of technical expertise were found to be barriers to telemedicine in developing countries, while developed countries considered legal issues surrounding patient privacy and confidentiality, competing health system priorities, and a perceived lack of demand to be barriers to telemedicine implementation. Findings from the survey showed that teleradiology was most highly established globally (33%) and approximately 30% of countries
(both developed and developing) had a national agency for the promotion and development of telemedicine (WHO, 2010).

Successful implementation of telemedicine applications see telemedicine as a benefit and as a solution to political and medical issues, they are reported to have a clear understanding of local service delivery problems, there is collaboration between promoters and users, and issues regarding organizational and technological arrangements have been addressed (Obstfelder, Engeseth, & Wynn, 2007).

**Telemedicine in India**

Telemedicine has had a slow start in India primarily due to poor internet connectivity. At present, India has the least internet penetration at 19%, among major countries in the World. However, the latest research on ‘Internet in India 2014’, jointly conducted by IAMAI and IMRB International shows that Internet usage in India has increased by 32% from October 2013 to October 2014. And users have increased by 39% in rural India.(IAMAI, 2014).

Despite these challenges, tele-medicine activities were started in India in 1999. In the initial stages of telemedicine, satellite connectivity was primarily used due to stability and availability even in remote areas.

Indian Space Research Organization (ISRO) established tele-health facility in nearly 60 remote hospitals, which were connected with 20 super-specialty city hospitals (ISRO, 2004). Several telemedicine projects in India have been successfully interlinked, for example, the Andaman and Nicobar Islands telemedicine project links the G. B. Pant
Hospital at Port Blair with Sri Ramachandra Medical College and Research Institute, Chennai, while in Karnataka, Narayana Hrudayalaya is connected to District Hospital, Chamarajnagar and Vivekananda Memorial Hospital, Saragur (ISRO, 2005). Ministry of Health & Family Welfare Government of India has developed guidelines to establish low cost rural telemedicine infrastructure consisting of fixed, mobile and handheld platforms based on broadband and wide area network centering around the district hospital. The proposed four level system includes, level 1 as primary health centre (PHC), level 2 as the district hospital, level 3 as the state hospital and level M, which will be a mobile unit that will move about in the villages connected to the nearest PHC. The estimated total cost of fixed and recurrent expense is estimated to be Rs.85,67,60,000 (National Rural Telemedicine Network for India- MoHFW, 2007).

A Telemedicine Network Project was introduced in the state of Karnataka in 2001 as a pilot and was operational by 2008 in 25 district hospitals. Software, hardware, communication equipment, and satellite bandwidth was provided by ISRO and the hospitals provided human resource, infrastructure and were responsible for monitoring and evaluation of the system (Bhaskarnarayana, Satyamurthy, Remilla, 2009 as cited in Holla et al., 2013, page 279). This project was evaluated by Holla et al., 2013, using a 51-item survey questionnaire that captured data on infrastructure, technical aspects, and connectivity parameters. It was found that with respect to infrastructure, back-up power supply was present only in 40% of the centers, quality of satellite connectivity was mostly acceptable (72%), in the technical aspect all technicians reported that the training they received was inadequate. In the two years of implementation, the maximum number of cases per month was 13 and 16 and the maximum was 58 and 66. Only in 13 (52%) client centers, did doctors keep up with appointment regularly.
Other than these government initiatives, telemedicine has been initiated as pilot projects in various private hospitals and centres in India. Tele-technology has been used in areas such as ophthalmology (Verma et al., 2009; Bai et al., 2007), dermatology (Kaliyadan et al., 2009), pathology (Baruha, 2005), neurology (Ganapathy, 2005), cardiology (Sekar et al., 2007). While some of these studies used tele-technology in providing health care in general, others have used it for delivering health care primarily to rural areas.

2.3.2 Tele-audiology

Both the American Academy of Audiology (AAA) and the American-Speech-Language-Hearing Association (ASHA) have recognized the use of tele-health and tele-practice for audiology for clinical services, as well as education and supervision (AAA, 2008; ASHA, 2005). However, ASHA, 2005 specifies that telemedicine services should be equal in quality to those provided face to face, and should be primarily provided to individuals who have limited access to audiologists in their communities. It is also emphasised that diagnostic and rehabilitative audiology services provided via tele-mode should always be provided by, or supervised by, a qualified audiologist.

Real-time telemedicine applications have been investigated in tests where audiologist’s supervision was deemed necessary (example, pure tone audiometry, oto acoustic emission testing, auditory brainstem response recordings, hearing aid fitting). Store-and-forward applications have been explored to transmit case history information, hearing screening results, video-otoscopy and tympanometry. M-health applications such as mobile monitoring of hearing aid usage, mobile apps for hearing testing, auditory training, tinnitus management have been developed.
In the United States, teleaudiology services are integrated into the routine clinical practice and through the Veterans Administration hospitals and other organizations, such as the Alaska Federal Health Care Access Network (AFHCAN) (Jacobs & Saunders, 2007). Teleaudiology has been widely experimented in South Africa and Australia as well.

The initial studies have reported on the reliability and validity of tele-testing in comparison to face-to-face or standard testing, to ensure that the quality of service was maintained. Towers, Pisa, Froelich, & Krumm, 2005, reported on the reliability of auditory brainstem responses obtained from a distant site using tele-technology. Fifteen subjects were located with the examiners in Minot, North Dakota, while the data were acquired by an audiologist in Logan, Utah. Click-evoked and frequency-specific potentials at 500 and 3000 Hz were obtained at 75 and 55 dBnHL using alternating polarity a repetition rate of 21.1/sec. The absolute and interwave latency values when compared indicated that the trials conducted locally had a strong correlation with those collected from a distance in tele-mode. Marginal variability, which was not statistically significant, was reported to be due to earr-phone placement, electrode placement, and site preparation performed by facilitators in the distant site.

Tele versus face-to-face testing between two Universities in Utah was conducted using DPOAE and pure tone audiometry on adults. Three pure tone and three DPOAE measurements were conducted in one ear with each subject. Pure tone thresholds were obtained at 250–8000Hz. DPOAE trials were recorded at 2000, 2500, 3000, 4000 and 5100Hz for each subject with L1/L2 ratio as 65/55dB and the f2/f1 ratio as 1.20, and a criteria of 3dB SNR was used. Results were found to be equivalent on both modes for both
these tests. Small intra-subject variability was obtained for both tests, however, this is not attributable to telemedicine (Krumm, et al., 2007).

In another investigation by Krumm et al. (2008), DPOAE and automated auditory brainstem response (AABR) screening were conducted in infants at a distant hospital using remote computing with broadband internet connection. Eighteen males and twelve females ranging in age from 11–45 days were tested. Identical hearing screening results were obtained for face-to-face and telemedicine trials with all infants.

Hearing screening using video-otoscopy, immittance and pure tone audiometry (PTA) was compared between face-to-face and tele-mode on 32 children in 3rd grade attending an elementary school in rural Utah. Tele-video otoscopy and immittance was conducted using store forward method. PTA was conducted real-time using remote computing. While results of otoscopy and immittance were identical for all 32 children, five children responded differently to pure-tone stimuli presented by the telehealth protocol than by the on-site protocol. However, this difference was not found to be statistically significant. The discrepancy in response was obtained only at one frequency out of the three frequencies (1 kHz, 2 kHz, and 4 kHz) in both ears, for telehealth and on-site protocols. The authors suggest that children may be distracted by tele-health technology (video-conferencing) or the examiner conducting the telehealth screening procedures may have missed important environmental visual or auditory cues that interfered with the results of students. (Lancaster et al., 2008).
Agreement between diagnosis and management plans made during an initial videoconference appointment and subsequent face-to-face consultations in paediatric ear, nose and throat (ENT) surgery was studied on 152 consultations with 97 patients. Decisions about ENT surgical interventions for children assessed during videoconference clinics were found to be in close agreement with decisions made by the same surgeon during face-to-face consultation (Smith, Dowthwaite, Agnew, & Wootton, 2008).

Australian Hearing conducted a pilot investigation to assess the feasibility of providing hearing services using tele-audiology to adult clients in remote areas. The services on trial included hearing assessment, hearing aid fitting, and hearing rehabilitation. They reported that while tele-audiology was feasible, a major limitation in delivering a comprehensive service from diagnosis to intervention for hearing loss was the need for taking ear impressions, which must be carried out in person (Pearce, Ching, & Dillon, 2009).

A unique step in tele-audiology was taken in developing a web services-based distributed system with browser-client architecture to promote tele-audiology assessment. This system allowed an audiologist to perform web-based pure tone audiometry testing from anywhere in the world, to a client who is in a location with computer based audiometer. A pilot study conducted by 3 independent audiologist, on 25 subjects demonstrated the feasibility of replacing conversational "face to face" tests with the remote hearing tests using the distributed system (Yao, Jianchu, Givens, & Wan, 2009).

Elliott et al., 2010, explored the feasibility of integrating a mobile telemedicine-enabled ear and eye-screening service with existing community-based services for Australian
indigenous children. Four hundred forty two indigenous children (0–16 years) were assessed at school by an aboriginal health worker for conditions impacting hearing and vision. Screening data and video-otoscopic images were uploaded to a database. Tele-otology and tele-optometry consultations were conducted for children who failed ear (41%) and eye (15%) screening respectively.

A 16-year retrospective analysis of ENT specialty clinic wait times on all new patient referrals made by the Norton Sound Health Corporation providers in rural Nome Alaska before (1992–2001) and after the initiation of telemedicine (2002–2007) was reported. It was found that the average wait time during the first 3 years using telemedicine was 2.9 months, which was a 31% drop compared with the average wait time of 4.2 months for the preceding years without telemedicine. The wait time then dropped to an average of 2.1 months during the next 3 years of telemedicine, which was a further drop of 28% compared with the first 3 years of telemedicine usage (Hofstetter, Kokesh, Ferguson, & Hood, 2010). Therefore as the program gained experience, the quality of service improved which is reflected in reduced wait time.

A novel approach was used by Swanepoel, Koekemoer, & Clark, 2010 to circumvent the problem of poor internet connectivity by using mobile data for remote audiometry testing. The validity of remote pure tone audiometric testing conducted from North America on subjects in South Africa was assessed on 30 adult subjects. Face-to-face and remote audiometry thresholds differed by 10 dB in only 4% of cases overall. The average test duration was 21% longer for remote testing (10.4 vs. 8.2 min). There were no clinically significant differences between the results obtained by remote intercontinental audiometric testing and conventional face-to-face audiometry.
The feasibility of low-cost videoconferencing (using Skype) in urban community health clinics for speech, language and hearing screening of children up to six years of age was studied. Speech and language screening services were provided via videoconferencing and hearing screening was using tympanometry was conducted in store and forward method and DPOAE screening was conducted using remote computing, at two community clinics. The reliability of pure tone hearing screening, DPOAE screening and speech-language screening was 100%. Tympanometry screenings were 84% reliable. Families reported a high level of satisfaction with both the technology and with the videoconferencing (Ciccia, Whitford, Krumm, & McNeal, 2011).

Efficacy of tele-consultation for hearing aid fitting was assessed on 50 individuals with hearing impairment in the age range of 39 to 88 years. In 25 individuals face-to-face procedure was conducted, and in the other 25 synchronous tele-consultation with interactive video and remote applicative control was conducted. The hearing aids were programmed and verified (with microphone probe), and the subjects were given instructions regarding use and care for the device. A greater time for programming and verification and a lesser time for orientation were observed for the tele-consultation group. The total consultation time did not differ between the groups. The real ear measures’ matching to their respective targets was similar for both groups. No difference was observed between groups for the HINT results (silence and noise), the daily amount of use of hearing aids in hours. Therefore the teleconsultation was found to be an efficient procedure for hearing aid programming, verification and fitting when face-to-face services were unavailable (Campos & Ferrari, 2012).
A pilot project was conducted in Guam, where infants who failed newborn hearing screening received diagnostic audiological evaluation by an audiologist in Colorado over the Internet in real-time. The audiologists were assisted in service delivery by onsite Guam audiometrists, who were trained by audiologist for infant otoscopy, tympanometry, electrode application and coupling, probe and earphone placement, infection control, and other services needed to assist the infant and family. In all 9 infants who had "refer" were tested with ASSR, ABR and OAE, three had normal hearing, two were found to have mild hearing loss due to middle ear dysfunction, two had unilateral conductive hearing loss, one had unilateral sensori-neural hearing loss and one had unilateral auditory neuropathy (Hayes, Eclavea, Dreith, & Habte, 2012).

Clinical and research-based cochlear implant (CI) measures using tele-health versus traditional methods was obtained by (Hughes et al., 2012). Twenty-nine adults and pediatric CI recipients participated. Electrode impedance, electrically evoked compound action potential thresholds, psychophysical thresholds, map thresholds, upper comfort levels, and speech perception measures were obtained in traditional and remote method. Except speech perception measure, there was no significant difference between traditional and remote testing method. Speech perception was significantly poorer in the remote condition, which was likely due to the lack of a sound booth.

A mobile ear-screening service including video-otoscopy, tympanometry and audiometry was conducted in store and forward method in an Aboriginal community in central Queensland. Those who failed screening received teleconsultation from ear nose and throat (ENT) specialists at the tertiary children’s hospital in Brisbane. The community-based screening service led by local indigenous health workers, and linked to a tertiary children’s
hospital by telemedicine, was found to be an effective method for routine screening of children at risk of hearing impairment. The median waiting time from referral to specialist assessment reduced from 73 days in 2009 to 29 days in 2011 (Smith, Armfield, Wu, Brown, & Perry, 2012).

Asynchronous tele-otoscopy was attempted using tele-health clinic facilitator with no formal health care training. A 2 day training program on positioning, visual inspection of external ear, appropriate hand position, manipulation of direction of speculum, focus adjustment, image capture, video-otoscope software use, and equipment sterilization was provided to the facilitators. The sensitivity of tele-otoscopy conducted by facilitators was reported to be 0.80 as compared to an ENT's 0.91, suggesting that this was acceptable, especially for underserved primary health care settings (Biagio, Swanepoel, Adeyemo, Hall, & Vinck, 2013).

Constantinescu et al., 2014, investigated the effectiveness of a tele-AVT programme (eAVT) in the spoken language development of a group of young children with hearing loss. The language outcomes of children with bilateral hearing loss receiving eAVT with a control group who received therapy in person using Preschool Language Scale two years post optimal amplification. The eAVT sessions were conducted via Skype. The language outcomes between the two groups were not found to differ significantly and children undergoing eAVT developed language within normal range. The results suggest that early intervention AVT via telepractice may be as effective as face-to-face AVT.
These studies suggest that tele-audiology is reliable across various tests, some of the benefits of using tele-technology has been in reducing wait time for patients, increasing access to services, and patients have, in general, been satisfied with tele-services.

2.3.3 Satisfaction with tele-medicine and tele-audiology

One of the most researched areas in telemedicine concerns the issue of satisfaction. However, there are concerns regarding the generalizability of satisfaction measures obtained from the results from a specific telemedicine project. Telemedicine services can be integrated to routine health service when supported by improved research into patients’ satisfaction with telemedicine (Williams et al., 2001).

Whitten & Mair, 2000, based on review of 32 studies in telemedicine, reported that there is a paucity of data examining patients’ perceptions or the effects of this mode of healthcare delivery on the interaction between providers and clients. The use of telemedicine technologies may require different communication skills, and approaches to counselling and information giving which may significantly alter the nature of the clinical experience and the relationship between the professional and the patient (Alkmim et al., 2012).

Studies have commonly evaluated convenience, acceptability and willingness to use telemedicine, to understand patients’ experience of using telemedicine (Mistry, 2012). Further investigation of factors such as “art of care,” technical quality of care, accessibility, financing, physical environment, availability, continuity, and efficacy are. One of the limitations has been that, patient satisfaction studies have primarily focussed on videoconferencing experience rather than the inclusion of all forms of telemedicine (Williams et al., 2001).
**Patient perception in tele-audiology**

Limited studies have been conducted on patient perception and satisfaction in using tele-audiological services. As in the case with other telemedicine programs, tele-audiology satisfaction was also based on videoconferencing experience, internet based counselling and hearing screening. In some studies, willingness to participate in a telemedicine program was obtained hypothetically. Most studies reported that patients were satisfied with tele-mode of service delivery, however, some studies have reported poor or missed satisfaction.

Willingness to participate in telemedicine for ear and hearing related appointments was studied on 116 patients in audiology clinic in Australia. The results were indecisive as nearly equal percentage of patients expressed their willingness (30%) and otherwise (32%) to participate in tele-audiology appointments. Greater willingness was reported if tele-audiology resulted in reduction of wait time or cost for appointment and less willingness was reported by individuals who preferred for face-to-face appointments (Eikelboom & Atlas, 2005).

A qualitative investigation of the utility of an internet-based audiological counselling programme was conducted in Canada, and it was found that participants did not consider daily e-mail exchanges about the hearing-aid adjustment process intrusive or interfering with their private life, but were satisfied with such a programme (La plante, Fuller, & Gragn, 2006).

Patient preference between telephone and internet, as a method by which hearing screenings should be conducted, was obtained by Koopman, Davey, Thomas, Wittkop, &
Verchure (2008) from 202 hard of hearing individuals in Germany, the Netherlands, and the UK. Majority indicated a preference for internet based screening (61%), whereas 49% of respondents indicated that they would probably or definitely complete a hearing screening test conducted over the telephone.

Satisfaction with telemedicine for teaching listening and spoken language to children with hearing loss was assessed in an AVT program conducted by Hear and Say Centre in Brisbane Australia. A questionnaire was used to evaluate the level of satisfaction among parents and therapist with respect to the audio and video quality during videoconferencing, equipment use, parent-therapist interaction and communication during videoconferencing, service delivery and convenience and overall satisfaction with the outreach AVT programme.

Majority of the responders (61%) rated the audio quality as excellent or good, 58% rated the video quality as excellent or good, and however 61% found that they often or always experienced technical difficulties that required troubleshooting during the sessions. All parents reported being comfortable or as comfortable as face-to-face when participating in the outreach AVT sessions and 91% also rated their child’s level as comfortable or as comfortable as face-to-face. Troubleshooting was necessary for the majority of families on a regular basis due to poor connectivity. Parents, under the guidance of the therapist, disconnected and reconnected the videoconference and paused for longer before replying to allow the therapist to finish talking (Constantinescu, 2012).
Patient satisfaction was obtained from 94 cochlear implant users who underwent telefitting by an audiologist. Impedance, ECAP and or ESR measures were obtained followed by psychophysical measures in tele-mode. In four out of five patients, quality of the audio-video connection was not rated as good, contact with the audiologist was rated poorer and the patient's feeling of security was not satisfactory. Only 2 out of those 5 did not agree that tele-fitting was a good alternative for face-to-face visits (Wasowskp et al., 2012).
2.4 Cost analysis

Providing quality health care and taking preventive measures against preventable diseases is often national prerogative. However, allocation of limited resources for health is prioritised based on returns to society. This partly depends on the cost-effectiveness of interventions for various diseases.

Health economics is a branch of economics that assesses the issues related to efficiency, effectiveness, and value of resources in health and healthcare. Economic analysis seeks to identify and to make explicit a set of criteria which may be useful in prioritising the use of scarce resources (Drummond, Stoddart and Torrance, 1987, as cited in Shamanna et al., 1998, page 170).

2.4.1 Cost analysis of hearing screening programs

Cost evaluations in hearing screening have focused on cost per child screened, program cost and cost-effectiveness studies have been primarily related to comparison of selective versus universal hearing screening strategies, and comparison of different screening protocols. A few community clinic based programs have also reported costs and effects.

Cost analysis in some of the studies conducted in UNHS programs in hospitals, have reported the cost per infant screened to be between 13 USD and 33.05 USD depending mainly on the salary of the persons involved in the programme (Maxon, White, Behrens, & Vohr, 1995; Kezrian, White, Stewart, Bentkover, Gabbard, Lemons, 2001; Vohr, Stewart, Bentkover, Gabbard, Lemons, 2001 as cited in Nguyen et al., 2007, page 4; Ngyuen et al., 2007). Some studies have used actual cost incurred, and have included fringe cost, salary of all personnel including the screeners, clerical staff, secretarial staff, coordinators, and
audiologist (Maxon et al., 1995). Some other studies used modelling and assumptions in costing, but included even time costs (Vohr et al., 2001 as cited in Nguyen et al., 2007, page 4; Nguyen et al., 2007). But overall UNHS program was found to be profitable even at the most expensive budget of 35 USD per child screened, as it would be less than the supplementary costs of rehabilitation of late identification (Nguyen et al., 2007).

On account of the thrust on early identification and intervention, UNHS was emphasised by organisations such as JCIH and American Academy of Pediatrics. However, it is important for service providers and policy makers to understand the cost-effectiveness of such a program versus the existing realities of no screening or selective screening. Some of the early studies, primarily from Western countries like USA and UK, have focussed on this issue.

Keren et al., 2002 evaluated cost-effectiveness of no screening, selective screening and UNHS in terms of both short- and long-term benefits, harms, and financial costs from the societal perspective in the US. The evaluation was carried out using cost modelling on a hypothetical birth cohort of 80 000 infants. Probability and cost estimates for the decision model were obtained from published studies, expert opinion, and national and state sources. Findings suggested that selective screening identified 62 of the 128 infants with hearing loss, referred 0.18% of all infants for diagnostic evaluation, and had a positive predictive value (PPV) of 43%. UNHS identified 116 of the 128 infants with hearing loss, referred 1.6% of all infants, and had a PPV of 8.8%. In the absence of newborn hearing screening, approximately 30 infants with hearing loss were identified by 6 months of age by passive detection alone at a cost of $69 000. The ICER of selective screening versus no screening, was approximately $16 000 per additional infant whose deafness was diagnosed
by 6 months. The ICER of UNHS versus selective screening was approximately $44 000 per additional infant whose deafness was diagnosed by 6 months of age. Increasing the rate of follow-up to diagnostic evaluation from the base-case estimate of 77% to 100% decreased the incremental cost of UNHS to $38 000 per additional infant whose deafness was diagnosed by 6 months. Under the assumptions about lifetime savings that result from normal language with early intervention, UNHS resulted in normal language achievement for more deaf children and was estimated to be cost saving in the long term compared with both selective screening and no screening.

Cost-effectiveness of UNHS versus selective screening was calculated using cost-modelling in 8 provinces of China and ICER was compared between developed and developing provinces. Costing included implementation cost and DALYs, and included potential long-term costs saving from the use of the NHS program, including medical services, special education and rehabilitation.

They found that both UNHS and selective screening led to long-term costs saving which were greater than implementation costs. The long-term costs saving was more apparent, when the proportion of benefit population expanded. The factors that potentially influenced cost-effectiveness was reported as proportion of infants with one or more high risks, the prevalence of permanent congenital hearing loss in the general population and high-risk population, the validity, coverage, diagnosis rate, and intervention rate of the screening program (Huang et al., 2012).

In addition to studying cost-effectiveness of UNHS versus selective screening, some studies have focussed on understanding costs between the different protocols of screening
such as TEOAE versus TEOAE/AABR, one stage versus two stage screening. Economics analysis of screening infants at risk of hearing impairment was conducted for UK and India using cost modelling on a hypothetical cohort of 100,000 newborn infants. The cost-effectiveness associated with UNHS versus selective screening infants and one-stage versus a two-stage screening process was investigated.

In the UK, the universal strategy was more expensive than selective strategy by £2.3 million but detected 63 more children with hearing loss, with an ICER of £36,181 ($58,497) per case detected. In India, the economic burden was found to be substantially higher when adopting a universal strategy due to the higher baseline prevalence of hearing loss. For extra 376 children identified with hearing loss, the extra cost was INR 5,90,74,752 ($9,84,579) with an ICER of INR 1,57,084 ($9863). The one-stage screening strategy accumulated an additional 13,480 and 13,432 extra cases of false-positives, in the UK and India respectively when compared to a two-stage screening strategy. This represented increased costs by approximately £1.3 million and INR 34.6 million. When long-term societal lifetime costs were the incremental cost per case detected for UNHS was found to be cost-saving in UK and in the Indian setting. This result demonstrates that utilising a universal strategy, although incurring additional costs in the short-term, can have major cost-saving implications in the long-term (Burke, Shenton, & Taylor, 2012).

During the transition from HVs based Infant Distraction Test Screening (IDTS) at 8 months of age to Newborn Hearing Screening Programme (NHSP) using OAEs in UK, cost and outcome was compared between the two methods. The average cost per case detected across NHSP sites (£31,410/case) was found to be approximately half that of IDTS sites (£69,919/case). Including family costs, the average total cost per case of NHSP (£34,826/case) was estimated to be almost a quarter of IDTS (£117,942/case). An average
family cost (travel, child care and wage loss) for NHSP, when the screen had not been completed in the maternity unit, was £20.10 and average cost for NHSP follow-up was £36.11. For IDTS, the average family cost was £20.24. The ICER of NHSP versus IDTS was found to be £12500 per each additional case detected (Uus et al., 2006).

Countries like France which progressed towards UNHS, also studied costs and outcomes of their screening program. Cost of two stage TEOAE screening was compared with a two stage TEOAE/AABR screening protocol in a hospital based program in the Upper-Normandy region of France hospital. Analysis was conducted after completion of 1,00,000 neonatal screening. Costs included were material cost (purchase, maintenance and disposable accessories), and human resource cost (testers, secretaries, coordinating physician). The two stage TEOAE protocol was found to be marginally cost saving (0.3€) than the two stage TEOAE/AABR protocol (Marcolla- Bouchetembl et al., n.d).

With respect to community based hearing screening programs, cost evaluations have been very limited. Studies have primarily emerged only from UK, where attempts were taken to integrate community health clinic based screening into the national hearing screening program.

A cost evaluation of a community based universal hearing screening using TEOAE in a community health clinic was carried out in UK. Tester’s time, equipment costs, cost of second tier clinic referrals and ABR costs were accounted. The estimated cost of staffing was £46,000 a year for 85 weeks of screening and supervision using nurses, to screen 4900 babies born plus 10% who need re-screen, using 4 OAE screener and one ABR screener. The total cost with 5 life years was estimated to be £61400 (Bantock et al., 1998). In
another community based hearing screening with health visitors in UK, the cost of serving a population of 339,000 persons, in 52 health centres with 11 OAE screening equipment for a whole day in a week was estimated as £21,450 (Owen et al., 2001).

Cost-effectiveness was assessed for hospital and community-based newborn hearing screening in England to understand the extent to which a national screen could encompass the two different models of delivery, and to determine the criteria for selecting one or the other model. Cost modelling was done using available costs data and screen performance data. The total cost was £3,690,000 per 100,000 screened children in hospital by screeners or nurses and the total cost was £3,340,000 in community where health visitors screened in home visit at 10 days of age. Cost per child detected with hearing loss was £25 in hospital and £23 in the community. Therefore the cost of hospital based model was marginally higher than the community based model. No difference in effectiveness was assumed, based on use of similar test parameters. Sensitivity analysis showed that prevalence had the most important influence on costs, where a lower prevalence would result in substantial higher costs for each site and in higher incremental costs (Grill et al., 2006).

Only two studies on cost-evaluation of screening programs on older children was identified. Cost of school-based hearing screening and delivery of hearing aids was estimated in China by Baltussen et al. (2009). Screening was conducted for 2,16,000 school children aged between five to 14 years and 206 hearing aids were delivered across tertiary care, secondary care and primary care levels. Health care cost per child fitted with hearing aid ranged from US$760 at the primary care level, US$940 at the secondary care level, to US$1,120 at the tertiary care level. Household costs were only a small fraction of the overall costs. Cost per child fitted ranged between US$209–US$365, depending on
perspective of analysis and study site. The program was always least costly in the primary care setting.

Cost effectiveness of strategies to combat vision and hearing loss among school children was conducted using cost modelling for sub-Saharan Africa, including those African countries with very high adult and high child mortality, and South East Asia, including those countries in Asia with high adult and high child mortality. They found that with respect to hearing, screening of otitis media was the most cost-effective. Screening of school children annually for hearing loss in combination with the delivery of hearing aids, at 80% coverage level, costs around $Int1000 per DALY averted and was reported as highly cost effective (Baltussen & Smith, 2012).

While these costs analysis studies are some indicators of how financial allocation may be carried out for hearing screening, in areas where screening is just getting under way, or in places where universal newborn and infant hearing screening may not be feasible, is important that each newborn and infant hearing screening programme documents its procedures, outcomes and costs. Furthermore, the conditions and variables involved in evaluating the cost-effectiveness of various approaches will vary from country to country and even between locations within the same country (WHO 2010).

2.4.2 Cost analysis of tele-medicine programs

Telemedicine, being an alternative service delivery, should be proved superior to the approach in-practice in terms of costs and or effects, before its adoption into routine practice (Roine et al., 2001). Evidence on the effectiveness of tele-health is accumulating. Despite study limitations such as small sample sizes and poor designs, the strongest evidence for the efficacy of telemedicine in clinical outcomes comes from home-based
telemedicine in the areas of chronic disease management, hypertension, and AIDS. Telemedicine has been reported to be comparable to face-to-face care in emergency medicine, surgical and neonatal intensive care units as well as patient transfer in neurosurgery (Hailey, Roine, Ohinamaa, 2002). While evidence of effectiveness is increasing, only 9% of studies in telemedicine were reported to have any cost benefit data (Whitten et al., 2002).

Wade, Karnon, Elshaug, & Hiller (2010), based on a systematic review of 36 articles containing economic analysis in telemedicine, reported that, majority of the studies (61%) found tele-health to be less costly than the face-to-face alternative, 31% found greater costs and 9% showed equal costs or mixed results. When tele-health was provided to rural areas, the health service provider paid more, but due to savings in patient travel, the societal perspective demonstrated cost savings. Improved health outcomes in tele-health was reported in 31% studies, but majority (58%) found outcomes were not significantly different from face-to-face services, 6% found that tele-health was less effective.

Majority of literature on the cost-effectiveness of telemedicine is reported to be from North America and Europe, and most of these studies were based on telemedicine programs that existed for two years or less (Mistry, 2012).

*Tele-health service cheaper than face-to-face service*

While tele-radiology, tele-nerosurgery, tele-ECG were all found to be effective in outcomes, economic analysis showed that only tele-radiology was cost saving, especially in transmission of CT images (Roine et al., 2001).
Allied health assessments via videoconferencing was conducted as a pilot trial for high dependency residents at a facility for elderly people in rural Australia. The cost of tele-assessment was compared with face-to-face assessments, both of which was conducted by five therapists in dietetics, occupational therapy, physiotherapy, podiatry and speech pathology, on a total of 60 assessments. For an annual workload of 1000 assessments, per videoconference assessment cost was estimated to be $84.93, compared with $90.25 for face-to-face assessments. Therefore, the cost saving using tele-assessment was estimated to be 850 Australian dollar per annum. The cost saving was reported to be primarily due to travel cost averted in video-conferencing (Hassall, Wootton, & Guilfoyle, 2003).

The annual costs of tele-ENT service for paediatric outpatients in Brisbane, Australia was compared to the cost of providing the face-to-face outpatient service for patients travelling from the same locality. Tele-ENT consultations were conducted via videoconference for 70 patients (88 sessions) and face-to-face consultations were provided for 117 patients (177 sessions). The cost of tele-ENT consultation was A$108 per consultation, compared with A$155 per consultation for the face-to-face service. Telemedicine was cheaper when the workload exceeded 100 consultations per year, and a cost saving of $7,621 per annum was estimated (Xu, Smith, Scuffham, & Wootton, 2008).

**Tele-health service more expensive than face-to-face service**

The cost-effectiveness of a tele-consultation service for paediatric cardiology after five years of operation was analysed for 78 infants who had received tele-consultation over a four-year period in Canada. Patient journey averted was the outcome measure for effectiveness. Tele-consultation was found to be an effective and reliable method of enhancing access to tertiary care and the number of patient journeys was reduced by 42%. 
However, the cost analysis demonstrated that tele-consultation did not result in overall cost savings as the total cost of tele-cardiology was C$272,327 and the total cost of face-to-face service was C$157,212. Telemedicine therefore represented a supplementary cost of C$1500 per patient. The incremental cost-effectiveness ratio of tele-consultation was estimated to be C$3488 per patient journey avoided. (Sicotte, Lehoux, Van Doesburg, Cardinal, & Leblanc, 2004).

The Department of health in UK, conducted a pilot study to assess the QALY gained by patients using tele-health in addition to the face-to-face care, versus patients using only face-to-face care. The QALY gained by patients using tele-health users was similar to that of patients receiving face-to-face care alone, but the total cost of tele-health intervention was found to be higher. Therefore, they concluded that tele-health was not a cost effective addition to standard support and treatment (Sanford-Wood, 2012).

Henderson et al., 2013, examined the costs and cost effectiveness of tele-health in addition to standard support and treatment for long term conditions such as heart failure, chronic obstructive pulmonary disease, or diabetes. Three thousand two hundred thirty people with one of these long term condition were recruited into the trial, where 845 were randomly assigned to tele-health and 728 to usual care. The net benefit analyses of costs and outcomes for 965 patients (534 receiving tele-health; 431 usual care) was calculated. The mean difference in QALY gain between tele-health and usual care was 0.012, but the total health and social costs was greater for tele-health by £206.

A tele-obstetric service was established connecting the Department of Obstetrics and Gynaecology at the Nordland Hospital in Bodø to the remote delivery unit at the Nordland
Hospital in Lofoten. The telemedicine service included a videoconferencing link (3 Mbit/s) for transmission of ultrasound scans and a low-speed data link (telephone modem) for transmission of cardiotocograms (CTGs). One hundred and thirty pregnant women entered the antenatal clinic in Lofoten during the eight-month study period. A total of 140 CTGs were recorded. The tele-ultrasound service was used in five cases (4%). Analysis showed that telemedicine service was not cost saving at annual workloads below 208. We conclude that the installation has to be used by other medical specialities to make it cost-effective (Norum et al., 2007).

Only one Indian study could be identified on cost of using telemedicine, where the cost utility telemedicine to screen for diabetic retinopathy in rural southern India was evaluated. The incremental cost-effectiveness ratios of different screening intervals was assessed, using a hypothetical cohort of 1000 rural diabetic patients above 40 years and with a follow up for 25 years. The rural tele-ophthalmology program was found to be cost-effective ($1320 per QALY) compared with no screening from a health provider perspective (Rachapelle et al., 2013).

**Cost-effectiveness in tele-audiology**

Even though tele-audiology has been adopted widely, cost analysis in tele-audiology programs has been very limited. Telemedicine applications were introduced in 2002 in the Audiology Department at the Norton Sound Health Corporation in rural Nome Alaska, prior to which direct consultations were provided by audiologist by travelling by air to local camp sites. A 16-year retrospective cost comparison of ENT specialty clinic before
and after the initiation of telemedicine was conducted. Cost included airfare cost for audiologist, travel cost of patient and travel cost for escorts was included for all children under the age of 18 and elders who required assistance. Tele-audiology set up costs were minimal compared to the time cost of an audiologist spending patient contact hours traveling to remote clinical locations. The cost-saving due to avoidance of trips for direct consultation in this tele-audiology program was reported to be $250,000 (Hofstetter et al., 2010).

In Poland, 94 tele-fitting of cochlear implant was conducted by audiologist with impedance, ECAP and or ESR measures followed by psychophysical measures. A cost reduction assessment revealed that the mean cost saving in using tele-fitting was 12.5% of the mean average national salary (Wasowskp et al., 2012).

From the review of literature, it can be surmised that early identification and intervention of hearing loss is important but is not a reality in all parts of the world. While hospital based screening models are an option, community based models are emerging as possible alternates in resource limited regions of the world. It also high highlights the availability of tele-health as a solution to increase access to specialised services such as diagnostic hearing assessments. Outcomes on standard of care, patient satisfaction and economic evaluations have been used to assess tele-health services.