REVIEW OF LITERATURE

3.1 Prevalence of hearing impairment in developed countries

The prevalence of hearing impairment in infants varies from 1.96 to 10 / 1000. For babies in Neonatal Intensive Care Unit (NICU), it is 8 to 13 / 1000 and in well baby nursery, it is 0.9 to 2 / 1000 (Khairi, Din, Shahid, & Normastura, 2005; Prieve et al., 2000). The prevalence of significant hearing impairment in developing countries is 6/1000 (Swanepoel, 2009). If we include mild hearing impairment, it could be much higher. On extrapolation of these studies, the prevalence of hearing impairment is presumed to be approximately three to four times more in developing countries than other countries.

In United Kingdom

Various studies have been carried out in UK to ascertain the accurate prevalence rates of hearing impairment. However, there has been considerable disagreement on the prevalence rates. Enormous differences in sample population, hearing levels included in the study, fluctuating numbers of children, and the criteria of confirmation of hearing impairment have all contributed to such variation in prevalence rates. Due to these reasons, there was an unclear scenario about the exact prevalence till 1990s. This can be illustrated by the differences in the results of two studies in the same region. In Nottingham, prevalence of permanent hearing impairment (PHI) was estimated at 0.55/1,000 by Pabla, McCormick, and Gibbin (1991) while another study showed 1.2/1,000 (Davis & Wood, 1992) with almost double the prevalence.
An extensive study of epidemiology of PHI was carried out for the Trent Regional Health Authority by Fortnum and Davis (1997). The aim was to survey all children with a permanent hearing impairment with the definition of pure tone average of 40 dB HL or greater in their better ear. The study period was between January 1985 and December 1993 and the children were living within the boundary of Trent Regional Health Authority at the time of data collection. Sources of information included the Education Database, the Community Audiology and Child Health Database, the Neonatal Screening Database, audiology, medical records and hearing aid records. The data collected were divided into two main groups: congenital hearing impairment and acquired hearing impairment.

The congenital group consisted of those children presumed to have had a prenatal or perinatal cause of hearing impairment. The acquired group included those whose hearing impairment which started later in life due to disease, progressive hearing impairment or late-onset hearing impairment. In the second category, cases were selected only based on some evidence that the child may have been able to hear at an earlier stage. Prevalence rates of 1.3/1,000 for both acquired and congenital permanent hearing impairment were reported. For congenital hearing impairment alone, the prevalence rate was 1.1/1,000. With this prevalence rate, the authors have estimated approximately that there would be 1,000 children with a hearing impairment with at least moderate severity in UK per annual birth cohort, with 84% being a congenital hearing impairment. These numbers undoubtedly contributed to a decision by the government of UK to develop a newborn hearing screening programme.
In another attempt to measure the prevalence rate across the whole of United Kingdom, Fortnum, Summerfield, Marshall, Davis, and Bamford (2001) approached the health professionals and the educators of children with hearing impairment, requesting details on every child with PCHI under their care. A total of 486 professionals replied, with over 26,000 sets of details. Many of these data overlapped if the child was known to access both education and health services because the child’s details were provided by both the relevant professionals. The fact that there was no total overlap implies that there was some error in the assessment. The errors were adjusted with suitable statistical methods such as capture-recapture methods. The records for 17,160 children suggested that there were around 21,500 children aged 3 to 18 in UK with a permanent bilateral hearing impairment more than 40 dB. The inclusion of such a large number in the study allowed a more accurate breakdown into subgroups.

It was shown in the above study, that the observed prevalence increased with age until reaching a plateau at age 9, and that this was present at all three severities studied (41–70, 71–95, >95 dB HL). The adjusted prevalence at age 3 was around 1.1 per 1,000, rising to 2.1 per thousand at ages 9–16, a rise of 92%. This significant rise in prevalence during early childhood could be highly relevant for the planning of audiology and support services for secondary prevention of complications of hearing impairment. Caution has to be taken in the implication of these findings for current scenario since the data can change with time.
The focus then shifted towards the newborn hearing screening program for investigating prevalence of hearing impairment. By every means, this method was considered superior. In a study in East London (Bamford et al., 2007), the records of relevant cohorts born between 1992 and 2000 and numbering around 33,000 were analyzed. These children had UNHS, some had the infant distraction test, and they all had a school-entry ‘sweep’ screen. Newborn screening identified 1.58 per 1,000 children as having PHI. More babies with PHI were later detected due to parent suspicion or health visitors' suspicion before the children were 12 months old. They were found to be 0.24 cases per 1,000. A further 1.30 per 1,000 children were identified as having permanent hearing loss at age 5, detected mainly due to parental concern. Finally, 0.34 per 1,000 were identified by the school-entry screen. A final calculation of combined total prevalence of 3.47 per 1,000 children by primary school age identified as having PHI. Among them, 43% were of > moderate severity of bilateral hearing impairment, 35% mild bilateral and 22% unilateral (mild or above).

A very recent study in UK (Turton & Smith, 2013) estimated the prevalence of severe to profound hearing impairment as 6.7% in clinical population i.e people with hearing impairment and 0.7% in general population. This finding was extracted from the database of a University hospital in Coventry and Warwickshire and was based on retrospective observations of Glasgow Health Status Inventory (GHSI). This hospital covered a population of 310,000. The database contained the patient details from 2003 to 2008. This figure is way higher than the previous studies based on NHS because it covered all the age groups in the region.
In United States of America

The overall prevalence of hearing impairment in United States is 1-6 per 1000 (Harlor & Bower, 2009; Kemper & Downs, 2000). In USA, the drive of EHDI programs to improve the outcomes of children with hearing impairment was legally required in 41 states by 2007 (Centers for Disease Control and Prevention (CDC), 2010). The nationwide study of prevalence of hearing impairment was started in 1990’s. The Metropolitan Atlanta Developmental Disabilities Study (Drews, Yeargin-Allsopp, Murphy, & Decouflé, 1994) was the first US, population-based epidemiologic study of the prevalence of school-age children with special needs such as hearing impairment. The study made a statistical estimate on the prevalence of various disorders such as mental retardation, cerebral palsy, hearing loss, vision impairment and epilepsy in children aged 10 years living in five counties in metropolitan Atlanta. In Atlanta, children with developmental disabilities were identified and provided with rehabilitative services from various health, social service, and education systems. Hence, a multiple-source case identification method was used to extract the necessary details. A hearing loss was defined as a permanent impairment of 40 dB HL averaged across thresholds at 0.5, 1 and 2 kHz in the better ear. The results of this study yielded the prevalence of hearing impairment to be 2/1000. The same metropolitan study in its second round during 2006 yielded a prevalence of 1-3/1000 (CDC, 2007).

Boulet, Boyle, & Schieve (2009) estimated national data of health-related limitations, needs, and service use among US children. They included the data of
children with and without developmental disabilities. Retrospectively authors had analyzed the data from a sample of US households from the 1997-2005 National health interview surveys. Parents or other knowledgeable adults reported on their children’s’ developmental disability, health needs, and use of health and education services offered by the US government. The developmental disabilities included are attention-deficit/ hyperactivity disorder, autism, blindness, cerebral palsy, hearing loss, learning disability, mental retardation, seizures, stuttering/stammering, and other developmental delay. In that study, the prevalence of hearing impairment among all the children studied was 5/1000.

Another large population study to estimate the prevalence of childhood hearing impairment was the third National Health and Nutrition Examination Survey (NHANES III), which used a sample of 40,000 US population as a whole over 1988–1994 (Niskar et al. 1998). It was a report on children aged 6 to 19 who were asked about their hearing status and screened using pure-tone audiometry in a mobile examination center. The results of this self-reported ‘hearing difficulties’ was 34 per 1,000 children. They screened using frequencies representing speech (0.5, 1 and 2 kHz) and at higher frequencies (3, 4 and 6 kHz), and defined hearing loss as average thresholds for either frequency above 15 dB HL. A hearing loss in at least one ear was present in 149 per 1,000 children (14.9%), most of which was unilateral and slight in severity, and some of which was likely to have been temporary or fluctuating. With this finding, the authors estimated that there are 7 million US children at any one time that may need extra help in the classroom due to hearing impairment.
The report of the Individuals with Disabilities Education Act Program (IDEA, 2005) give break up of prevalence rates from 3 years to 12 yrs. The total number of children who were getting the funding for special education due to hearing impairment was 70,702 – ranging from 2,174 aged 3 to 6,269 aged 12. This was exclusive of children getting services under the deaf-blind and multiple disability categories.

A few recent studies are available from European countries. De Capua et al., (2007) in their experience with 19700 newborns in Italy, have found the prevalence of bilateral permanent hearing impairment to be 1.4 per thousand. The study was done in the UNHS set up between 1998 and 2006 which used the two stage strategy of TEOAE testing. The confirmation of hearing impairment was done by ABR testing.

A national study (Szyfter, Wróbel, Radziszewska-Konopka, Szyfter-Harris, & Karlik, 2008) of Poland in Universal Neonatal Hearing Screening Program (UNHSP) presented data on prevalence of hearing impairment. The study was done for four years between 2003 and 2006 in all neonatal clinics in Poland. Transient evoked oto-acoustic emission (TEOAE) was used to screen all new born children in their first 2–3 days of life and auditory brainstem response testing (ABR) was performed on children, who got referrals in TEOAE screening. Diagnosed infants were further referred for appropriate rehabilitation. A total number of 1,392,427 babies were screened for hearing impairment. This covered approximately 96.3% of all delivered babies, as per the national register in Poland. The following were the number of children identified due to
this massive effort: 85 children with all types of hearing loss, 312 with profound loss (0.02% of population) and 145 with severe sensorineural hearing loss (0.11% of population). The account for the prevalence of hearing impairment as per this study was 1.7 per 1000.

A large hospital based study in Western Australia (Bailey, Bower, Krishnaswamy, & Coates, 2002) showed a lower rate of prevalence of bilateral permanent hearing impairment. The study was done in 2000 and 2001. Out of 13,214 eligible babies for NHS, 12,708 (96.2%) received screening. Of the screened babies, only 1% had fail response in one or both ears at either the initial or follow-up screen. Out of twenty-three babies referred for audiological assessment nine were diagnosed with bilateral permanent hearing loss. This study recorded the prevalence rate of PHI to be 0.68/1000 (95% CI, 0.31-1.28).
Developing Countries

In Zimbabwe, a cross-sectional study of the prevalence of hearing impairment in primary school children (Westerberg et al., 2005) was undertaken as part of ‘The Rotary Hearing Health Care Program’. The population of the study was primary schools in Manicaland, a province of Zimbabwe. All children in selected schools were tested. In total, 5528 students were screened for significant hearing impairment. The definition of hearing impairment used here was greater than 30 dB HL at 1, 2 and 4 kHz in a quiet classroom. Overall, 135 students (2.4%, 95% CI 2.0-2.8) could not meet this criteria in at least one ear and for at least one of the test frequencies. A transient hearing loss was found in 79 students (1.4% of the total), and a sensorineural hearing loss in 56 students (1.0% of the total). Significant hearing impairment was seen in 0.9% of children.

In Pakistan, a rare attempt of determining the prevalence of childhood hearing impairment was undertaken in the form of community screening program (Elahi et al., 1998). The Ministry of Population Welfare in Sialkot District, Punjab Province had supported this study. School-aged children in the age group of 5 and 15 years were tested for hearing impairment, according to World Health Organization (WHO) guidelines. A total of 607 children comprised the study population, which yielded a point prevalence of hearing impairment of 7.9%. Major portion of identified loss were of conductive in nature, which are treatable either through medical or surgical therapy. The authors also found that approximately 4% of the children had permanent sensorineural hearing impairment.
Minja and Machemba (1996) examined the prevalence of hearing impairment using pure tone audiometry among two primary school children in rural and urban place of Dar es Salaam, Tanzania. Eight hundred children were tested in total. Ear infection was seen in 222 (27.7%) children. Loss and 21 (2.6%) had chronic suppurative otitis media. 70 (8.7%) children were found with sensorineural hearing. Rural school students were having higher prevalence of cerumen impaction (20.45%) than the urban school children (14.8%), though it was not statistically significant. A significant difference (p < 0.001) was obtained in the prevalence difference of chronic suppurative otitis media between the rural school children (9.44%) and among the urban school children (1.3%). Another statistically significant difference (p < 0.05) was found in sensorineural hearing impairment which was found in 14.1% of the rural school children and in 7.7% of the urban children. This clearly portrays the rural-urban gap in the health status and the need to improve the ear care services in the rural areas.

In a similar attempt, Taha et al. (2010) examined the feasibility of identifying hearing loss in rural and urban schools, and investigated the prevalence of hearing impairment (HI) in Egyptian school students. The authors reported the results of evaluation of 555 children (6-12 years of age) from two schools each from a rural and an urban region in the Shebin El-Kom District of Egypt. Children were referred for diagnostic hearing evaluation at a regional medical facility after a 2-stage screening procedure in the school. The screening failure rate was 25.6%, and the prevalence of confirmed hearing impairment was 20.9%. Unlike the previous study, the rate of hearing impairment did not differ across the rural and urban school.
Recently, Fu, Chen, Dong, and Zhang, (2010) investigated the prevalence of hearing impairment in primary and middle school students in a province of China. In that study, a huge sample of 5 lakh students were tested using speech audiometry, 813 students were identified with HI. 232 were diagnosed with congenital HI and 560 cases had acquired HI, among which 276 cases had aminoglycoside-antibiotic-induced HI. The severity of HI could be further confirmed in 804 students, with 402 profound, 363 severe, 21 moderate and 18 mild HI. The age at HI onset of most students was under 3 years. The prevalence of congenital and acquired HI was 0.46 per 1000 and 1.11 per 1000 respectively.

Mencher (2000) conducted a four-phase study to determine the prevalence of sensorineural hearing impairment in Costa Rica. The four phases include 1) screening 12500 children in public schools 2) examined those who were enrolled for programs for hearing impairment 3) community search of children other than schools and special programs 4) extensive questionnaire administration to know the demographic data of the family. The prevalence of hearing impairment was determined to be 1.17 to 1.27 per 1000. This was the first study of prevalence in Latin American country and the authors concluded that the prevalence is same as the developed nations of Europe and North America.

About 62 million people aged less than 15 years were estimated by WHO to have hearing impairment in 2000 (Olusanya & Newton, 2007). The emergence of objective, accurate, and easy-to-use hearing screening technologies suitable for infants now
enable reliable epidemiological data for children in this age group. Attempts should be made to catch them as young as possible and create awareness among the community about acquired hearing loss in children. Evidence suggests that the rate of permanent childhood hearing impairment doubles by the age of 9 years compared to the age of below 5 years (Fortnum et al., 2001).

Christian Blind Mission (CBM, 2011) estimated that out of the 600 million individuals with HI worldwide 400 million resides in developing countries. Data presented by Tucci, Merson and Wilson (2010) indicated that more than 278 million people have moderate degree of hearing loss and above in both ears, and also that majority of them live in developing countries. Although 50% of these hearing losses could be prevented, the availability and cost of health care in these developing nations often makes treatment impractical. This fact has been well recognized by UNICEF, 2005. Its report said that the incidence of congenital hearing impairment in developing countries was probably substantially higher than the rates reported in developed countries because of poorer health and socioeconomic conditions in developing countries, even after accounting for the high infant mortality rate due to prevailing communicable diseases.

With the prevailing adverse perinatal disorders in these countries, the rate of permanent congenital and early-onset hearing impairment would not be less than 6 per 1000 live births. This figure implies that of nearly 120 million babies born yearly in the developing world, (UNICEF, 2005) about 718 000 will have permanent bilateral hearing impairment
as infants. Permanent congenital and early-onset hearing impairment originates at birth or in the first 28 days of life. It is an indicator of prelingual hearing impairment which coincides with the same adverse perinatal disorders that account for substantial infant mortality in the developing world.

There is a consensus on the prevalence of congenital hearing impairment being greater in underdeveloped countries, with Davidson et al. (1989) estimating that sensorineural loss in underdeveloped countries is twice as common in developed countries. Evidence also seems to point towards a higher rate of hearing impairment amongst disadvantaged communities in richer countries. A retrospective cohort study (Mytton & Mackenzie, 2005) of cases with dates of birth between 1st January 1986 and 31st May 2003 was undertaken to describe local epidemiology and establish the observed prevalence rate. Expected prevalence was determined by application of published national rates of UK to the susceptible Oldham population. The study identified 132 children in Oldham with significant HI. The prevalence of permanent childhood hearing impairment in the non-Asian community (1.34/1000 live births) was equal to published national rates (1.33/1000 live births), but that in the Asian community (4.64/1000 live births) indicated a relative risk of 3.5. Differences in prevalence between observed and expected rates were not by chance and were significant (p < 0.001). The authors confirmed the clinical suspicion of a raised local prevalence of permanent childhood hearing impairment in Oldham.
Bajaj et al. (2009) studied the prevalence of sensorineural hearing loss in Bangladeshi children living in East London. It was a cross sectional survey with the definition of hearing loss to be bilateral sensorineural hearing loss of 40 dB HL or more. In that study, 134 children in the age range of 9 months to 18 years of age were included. The prevalence of HI in Bangladeshi children in East London was approximately 3.86 per 1000 which is significantly greater than the average national prevalence of 2.1 per 1000 in UK (Fortnum et al., 2001).

The prevalence of hearing loss in these Bangladeshi children belonging to non-consanguineous families only was relatively less with 2.73 per 1000. The community related practice such as consanguinity seems to influence the prevalence of hearing impairment in UK.

Tucci, Merson, and Wilson (2010) in a massive literature review of hundreds of articles from 1980 till 2009, reported that across the globe, more than 278 million people have moderate-to-profound hearing loss in both ears, and most of them live in developing countries. The mean expenditure on health sector in developed countries is 2,716 US dollars, whereas the corresponding average cost expenditure in the “least developed” countries is 13 US dollars. In the United States, the government is spending for hearing impairment about 170 billion dollars per year, which is almost three percent of the gross national product. In their review the authors found that the rate of congenital bilateral sensorineural hearing loss (greater than 40 dB) was 2 to 4 per 1,000 live births in developed countries and more than 6 per 1000 live births in developing
countries. Therefore, the authors estimated that around seven lakh children are born per year with bilateral permanent hearing impairment. The funding allocated for hearing care services in Asia, Latin America, Caribbean and Middle East countries is significantly lesser than the developed countries. Incidentally, these countries have two-third of the world’s population.

It is also reported in the literature that socioeconomic status has a role in the prevalence of hearing impairment. Niskar et al. (1998) described the prevalence of hearing loss among US children by socioeconomic characteristics. It was a National population-based cross-sectional survey with an in-person interview and audiometric testing at 0.5 to 8 kHz. A total of 6166 children in the age range of 6 to 19 years completed hearing examination in a mobile Centre of the Third National Health and Nutrition Examination Survey conducted in span of six years from 1988. Children from families whose incomes at or below the US national poverty line were significantly more likely to have a hearing impairment when tested.

Before a decade, Rao et al. (2002) estimated the prevalence of hearing impairment among children of school entry age, in rural regions of coastal South India. The study adopted the World Health Organization (WHO) guidelines of the year 1999. An otoscopic and audiometric evaluation was done for a total of 855 children studying in the first year of school. Children with hearing impairment were examined twice to confirm the type of hearing impairment. The subjects’ details such as socio-economic status, family history of HI and history of consanguinity were collected by interviewing the mother. The examination revealed 102 children (11.9%) with hearing impairment
and impacted wax was found to be the most common cause of hearing impairment (86.3%). The prevalence of hearing impairment was 32 per 1000. The hearing loss was predominantly conductive (81.6%). One of the important factors affecting the prevalence of HI was socioeconomic status. The prevalence of hearing impairment was significantly lower among children belonging to high socio-economic status (P<0.005).

Lasisi, Sulaiman, and Afolabi (2007) found out that about one fifth of the chronic ear infections result in sensorineural hearing impairment. This finding was from a study done in densely populated areas of semi-urban region in Nigeria. The authors also found a significant correlation of socio economic status and the hearing impairment (r=0.138, p=0.02). Olusanya and Newton (2007) points out that National health system in developing countries are weak due to poor technical and financial support. These countries are therefore unlikely to invest in early hearing detection and intervention services irrespective of the weight of evidence in support of such an initiative.

There also seems to be an increased prevalence of middle-ear disease in disadvantaged communities and this can be of any level of severity, becoming chronic suppurative otitis media (CSOM) with or without cholesteatoma (Davidson et al., 1989). The presence of recurrent or chronic middle-ear disease is highly correlated with a permanent hearing loss in that population because of the reduced access to effective treatment (Elahi et al., 1998; Smith et al., 1996).
Smith et al. (1996) did a randomized control study on school children with CSOM. The authors enrolled 524 children with CSOM, aged 5-15 years, from 145 primary schools in Kiambu district of Kenya. The schools were randomly assigned for three different treatments. They assigned it in clusters of five with the ratio of two to dry mopping alone (201 children), two to dry mopping with topical and systemic antibiotics and topical steroids (221 children), and one to no specific treatment (102 children). Schools were matched on factors thought to be related to their socioeconomic status.

The primary outcome measures of the above study were resolution of otorrhoea and healing of tympanic membranes on otoscopy by 8, 12, and 16 weeks after induction. Absence of perforation was confirmed by tympanometry, and hearing levels were assessed by audiometry. 29 children were withdrawn from the trial because they took non-trial antibiotics. The authors used a cost effective method in the treatment of CSOM and found significant improvement in hearing thresholds; though a remnant sensorineural loss was present. The authors conclude that the expenditure which is done on the ear care programs in developing countries will determine the extent of recovery of CSOM.

da Costa, Rosito, Dornelles (2009) reviewed the files of one hundred and fifty two patients with unilateral CSOM. Comparison of BC thresholds for frequencies of 500, 1,000, 2,000, 3,000 and 4,000 Hz, were done between the affected and normal ear. Thresholds were examined separately for each frequency. The bone-conduction threshold averages for the normal side were better than those for the ear with chronic
otitis media. The threshold shift was statistically significant for each frequency (P<0.0001, Students t test). There were differences between the groups when analyzed for age (500 and 1,000 Hz) or the presence of cholesteatoma (1,000 Hz). This study showed that chronic otitis media is associated with a decrease in cochlear function.

A similar study by Papp, Rezes, Jókay, and Sziklai (2003) was aimed to determine whether CSOM can result in sensorineural hearing loss. The files of 121 patients with unilateral chronic suppurative otitis media were reviewed in a retrospective study. Air conduction and bone conduction threshold averages were calculated over the speech frequencies (500 Hz, 1,000 Hz, and 2,000 Hz). Thresholds at 4 kHz were examined separately but in a similar way. Multiple linear regression models were used to clarify the relationships between sensorineural hearing loss and chronic otitis media. Chronic suppurative otitis media was seen to be associated with sensorineural hearing loss. When age and normal side were corrected for, pure-tone and bone conduction thresholds at either the speech frequencies or at 4 kHz increased gradually according to the duration of the chronic suppurative otitis media. The threshold shift was more accentuated as age increased. The sensorineural hearing loss at 4 kHz seemed to be higher than that at the speech frequencies. The authors concluded that inner ear is vulnerable to CSOM.

3.2. Risk factors and New born hearing screening

Hearing impairment is known to be linked with certain prenatal, perinatal and postnatal factors referred to as high risk factors of hearing impairment. Joint committee
of infant hearing has enlisted these factors periodically from 1994. This list is prepared based on studies available from all over the world. The following literature review will highlight the importance of the risk factors:

There are specific risk factors which have strong association with newborn / infant hearing screening results. Korres et al. (2005) reported that congenital anomalies/syndromes were the most important risk factors for failing screening in both the neonatal intensive care unit and the well-baby nursery, as they showed the highest association with failing hearing screening. The second most important risk factor in neonatal intensive care unit was low birth weight, and the third was prematurity.

Pereira, Martins, Vieira, and Azevedo (2007) reported a significant correlation between failure in the hearing screening test and the presence of risk factors such as family history and presence of a syndrome. The child who presented with a congenital syndrome had 37 times more chances of failing hearing screening test and seven times more chances of failing in the right ear when there was a family history for hearing loss. The lower the gestational age (< 30 weeks) and birth weight (< 1500 g), the higher the chances of failing the hearing screening test (3 times more). In another study, infants with pre and perinatal risk factors, showed high rates of fail in initial and second screening results using TEOAE, compared to the infants without those factors. They also had high false positive screening results which were later confirmed with ABR testing (De Capua, De Felice, Costantini, Bagnoli, & Passali, 2003).
Watkin, Baldwin, and McEnery (1991) related risk indicators, neonatal hearing screening tests and subsequent behavioral hearing test findings. They found that 3% of newborns out of 10,686 live births had a risk factor for hearing loss. The prevalence of hearing impairment among the group with risk factors was 3.7% (12/322) but that overall prevalence of bilateral hearing impairment of at least moderate degree was 1.1/1000. Congenital ear malformation or family history risk factors were present for 6 of 12 hearing-impaired infants, and the other 6 had “perinatal illness” that included the risk indicators of low birth weight, prematurity, low Apgar scores, neurologic compromise, hyperbilirubinemia, and aminoglycoside administration.

Fowler and Boppana (2006) argued that UNHS may miss some infants with hearing loss due to infections such as CMV. CMV infections occurs in about 2.2% of all newborns (Roizen, 1999). Infants with this infection will have progressive, fluctuating and late onset hearing loss. Grosse, Ross, and Dollard (2008) estimated that approximately, 14% of children with congenital CMV infection are likely to develop SNHL of some type, and 3-5% develop bilateral moderate to profound SNHL. They found that among all children with bilateral moderate to profound SNHL, 15-20% were attributable to congenital CMV infection which was confirmed by urine examination (compared with a base rate of 7%). (Barbi, Binda, Caroppo, & Primache, 2006) reported that of 130 children with PCHI, 24.7% had CMV in blood retained from a sample at birth (base rate not given). The authors claimed that frequency and severity of hearing loss due to congenital CMV support the idea of setting up neonatal screening campaigns. Since there is availability of an antiviral treatment for CMV, (Kimberlin et al., 2003;
there is a recommendation for screening newborn babies for CMV (Barbi et al., 2006; Grosse, Dollard, Ross, & Cannon, 2009) that can then become a primary prevention of HI.

Dollard, Schleiss, and Grosse (2010) observed that only about half of the hearing loss resulting from congenital CMV infection is currently detected by universal newborn hearing screening because of late-onset hearing loss. Thus, much of the hearing loss and the majority of other CMV-associated disabilities remain undetected for years after birth and are never connected to CMV infection. Significant obstacles to the implementation of screening for congenital CMV include the lack of a standardized, high-throughput screening test and a protocol for follow-up of CMV-infected children. The authors felt that in spite of this limitation, merits of CMV screening at birth far outweigh the limitation.

Weichbold, Nekahm-Heis, and Welzl-Mueller (2006) examined the histories of twenty three 9-year-old children who had developed bilateral PHI after a clear newborn hearing screen. Eleven children had risk factors (as defined by JCIH 2000): three had a family history of hearing loss; two had recovered from meningitis; two had a cranio-facial malformation; one had persistent pulmonary hypertension; one had a congenital CMV infection; one received extracorporeal membrane oxygenation; and one had recurrent otitis media with effusion. They also found that five children had received therapy with antibiotics which are ototoxic (not on the list of risk factors at the time) and
two had been born before the 33rd gestational week (one child had a combination of the last two). Six children (26%) showed no risk indicators for post-natal hearing loss.

Two important guidelines currently in practice are given by JCIH (2007) and NHSP Clinical group (2012). A frequently quoted list of risk factors is published by the Joint Committee on Infant Hearing (2007). The list highlights some factors as particularly relevant to progressive or delayed-onset cases, and recommends that any child who has these risk factors is to be seen by an audiologist before 30 months old if the newborn screen is passed. The Newborn Hearing screening program (NHSP Clinical Group, 2012) UK, in its guidelines on management / surveillance of high-risk individuals recommends that, neonates with meningitis are referred directly to audiology without a screen, and children who recover from meningitis be offered an audiology appointment within 4 weeks of discharge from hospital. Babies born with craniofacial abnormalities or Down’s syndrome should be screened again at eight months. Other babies who should be offered an assessment at eight months and at intervals throughout their childhood are those with: a family history of PCHI; assisted ventilation in NICU for >5 days; neonatal jaundice to a level needing exchange transfusion; congenital TORCH- S infection; and developmental delay associated with a neurological disorder. They recommend audiological testing for babies who have had high levels of ototoxic drugs and advice against the use of ototoxic drugs in children with family history of hearing loss.
3.3. Risk factors and hearing loss

A) Genetic causes

Genetic causes constitute almost half of the population with childhood hearing impairment (Morton & Nance, 2006; Norris et al., 2006). It is estimated that one of 300 – 500 genes (About 1% of total genes) was responsible to cause hearing loss (Finsterer & Fellinger, 2005).

Approximately 120 of these genes have been identified so far – around 80 causing syndromes that include hearing loss and over 40 responsible for ‘non-syndromic’ hearing loss. Most of these genes are located on the autosomal chromosomes, up to 20% on the X-chromosome and up to 20% in the maternally inherited mitochondrial DNA (Davis et al., 2009). A population based study in genetic childhood hearing impairment (Parker, Fortnum, Young, Davis, & Mueller, 2000) confirmed these findings. In that study, the families of 526 hearing-impaired children (aged 4–13) were sent questionnaires asking about any family history of hearing loss, the results pointing towards different genetic disorders with autosomal dominant, autosomal recessive and sporadic inheritance. The genetic hearing loss can be classified as syndromic and non-syndromic.

1) Syndromic hearing loss

If hearing loss is combined with several clinical findings, the disorder is described as syndromic hearing loss. Approximately 30% of genetic hearing impairment is syndromal (Morton & Nance, 2006). Over 400 syndromes featuring PCHI have been
described and many of the genetic abnormalities responsible have been identified. Syndromic hearing impairment can be sensorineural or conductive, due to structural anomalies of the auditory system.

McClay et al. (2002) reported that the presence of any congenital syndrome significantly increased the risk of an abnormality of the temporal bone involving the cochlear or vestibular system visible on a CT scan. This risk was found to be elevated regardless of the presence of PHI, but higher still if PHI was present.

Chromosomal syndromes may occur either during meiosis or mitosis, resulting in too much or too little genetic material, and many increase the risk of PCHI. Two of the most common syndromes caused by chromosomal abnormalities are Down’s and Turner syndromes. Maatta et al. (2006) studied 129 individuals (mainly children) with Down syndrome, and found that one-third of the sample had hearing impairment or recurrent ear infections. Overall, the risk of sensory impairment increased with increasing levels of intellectual disability.

Arnos, Pandya, & Burton (2006) and Meyer (2012) formulated eight syndromes as the most common syndromes with hearing impairment. They are listed in the table with inheritance pattern and clinical features (table 1).
<table>
<thead>
<tr>
<th>Syndromes</th>
<th>Inheritance</th>
<th>Features</th>
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<tbody>
<tr>
<td>Waardenburg</td>
<td>Autosomal dominant</td>
<td>White forelock, moderate to profound unilateral or bilateral sensorineural hearing loss, vitiligo, hypopigmentation, and/or differently colored eyes or bright blue eyes Type I includes the appearance of widely spaced eyes (dystopia canthorum).</td>
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<tr>
<td>Treacher Collins</td>
<td>Autosomal dominant</td>
<td>downward sloping eye openings, flattened cheek bones, malformed or absent outer ears, small chin, coloboma (notch) of the lower eyelid, and conductive hearing loss.</td>
</tr>
<tr>
<td>Branchio-oto-renal (BOR)</td>
<td>Autosomal dominant</td>
<td>Sensorineural, conductive or mixed hearing loss with ear pits, fistulas or cysts of the neck; altered ear shape, and/or structural or functional changes in the kidney.</td>
</tr>
<tr>
<td>Syndromes</td>
<td>Inheritance</td>
<td>Features</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Usher</td>
<td>Autosomal recessive</td>
<td>Sensorineural hearing loss with retinitis pigmentosa (a progressive disease of the rod cells in the retina resulting in visual impairment); vestibular dysfunction in some types.</td>
</tr>
<tr>
<td>Jervell and Lange-Nielson</td>
<td>Autosomal recessive</td>
<td>Congenital sensorineural hearing loss associated with a heart defect, specifically a prolonged QT interval on ECG placing these individuals at risk for sudden death.</td>
</tr>
<tr>
<td>Pendred</td>
<td>Autosomal recessive</td>
<td>Sensorineural hearing loss (may be progressive), goiter (usually euthyroid), enlarged vestibular aqueduct and/or Mondini dysplasia.</td>
</tr>
<tr>
<td>Alport</td>
<td>X-linked</td>
<td>Progressive sensorineural loss, Progressive renal failure, anterior lenticous and perimacular flecks.</td>
</tr>
<tr>
<td>Stickler</td>
<td>Autosomal dominant and recessive</td>
<td>Congenital high frequency sensorineural hearing loss, Pierre Robin syndrome (Micrognathia and cleft palate) and Myopia.</td>
</tr>
</tbody>
</table>
Approximately 1% of syndromic genetic hearing loss has X-linked inheritance and mitochondrial (DNA mutation) has less than 1% (Dent et al., 2004) in origin.

2) Non Syndromic hearing loss

Autosomal recessive non-syndromic hearing impairment is the most common form of genetic hearing loss, accounting for around 80% of all cases. It can be estimated to account for around 40% of all profound PCHI. Numerous non-syndromal recessive hearing impairment genes have been localized, with Petersen and Willems (2006) reporting 85 loci on 39 different nuclear genes. (Birkenhäger, Aschendorff, Schipper, & Laszig, 2007) have reported around 120 loci with 57 autosomal dominant and 67 autosomal recessive mode of inheritance. Mitochondrial is around 4 and X-linked is 2. Despite the heterogeneity, 50% of the recessive non-syndromic hearing loss is attributed to GJB2 gene in western countries. However, this gene is less commonly affected in Asian countries (Smith et al., 2005). This gene codes for a protein called Connexin 26, a gap junction protein regulating the passage of ions in and out of the cell, and was identified in 1997. As with the mutations responsible for Usher syndrome, it has become obvious that genotype–phenotype relationships are more complex than once thought (Gualandi, Martini, & Calzolari, 2003; Norris et al., 2006).

Autosomal dominant inheritance is thought to be accounted for approximately 15% of the cases. X-linked inheritance accounts for approximately 2–3% of the inherited hearing impairments (Davis et al., 2009). Green et al. (1999) studied the prevalence of mutations in the GJB2 gene in 52 people with congenital sensorineural hearing loss at a
clinic in Iowa. Twenty-two were found to have GJB2 mutations, 19 of whom had a mutation on both chromosomes. Of the 41 abnormal copies of GJB2, 29 had the same mutation – 35delG. The siblings of these 52 people were also screened, and it was found that all those who had two abnormal copies of the gene also had PCHI. A total of 560 unrelated children were also screened and there were 14 in whom one copy of the GJB2 gene had a mutation. This gives a carrier rate of 3.0% (probable range 2.5–3.6%). It is important to remember that this finding will be specific for this particular population in mid-western United States.

Pandya et al. (2003) searched the DNA of children from the Annual Survey of Deaf and Hard of Hearing Children and Youth, North America, conducted at the Research Institute of Gallaudet University. They found that GJB2 mutations accounted for 22.2% of profound hearing loss in the overall sample but differed significantly amongst Asians, African Americans and Hispanics.

Ethnic differences are particularly seen where there was a small founder population, such as in some Jewish communities. Ben-Yosef and Friedman (2003) in their review of genetic hearing loss among Jews has reported that both syndromic as well as non syndromic hearing loss is caused by small number of founder mutations. These founder mutations were recently identified in many Jewish communities. The findings encourage population specific genetic screening.
Consanguinity is a common risk factor in some countries and communities. Al Khabori and Patton (2009) did a retrospective analysis of 1400 questionnaires on the causes of hearing loss in Omani children, collected from 1986 to 2000. It was found that 70% of the deaf children were from parents of consanguineous marriages, and 30% from non-consanguineous unions. In those with consanguineous families 70.16% were first cousin marriages, 17.54% were second cousins, and 10.86% were from the same tribe. The proportion arising from first cousin marriages was higher than the background rate of first cousin marriages in Oman.

Amini and Kamali (2010) reported that the prevalence of consanguineous marriage was about 30 % in Iran and this can increase the probability of incidence of genetic impairments such as hearing impairment. Hearing impairment in comparison with other hereditary disorders is the most incident. In their questionnaire based study of 130 parents of school children with HI, they found that consanguinity was present in 61.4%. First cousin consanguineous marriage was found among the parents of 43.6 % of the students and second cousin consanguinity was present in 17.9 % of them.

Zakzouk (2002) observed that consanguineous marriage is a tradition which is commonly practiced among Asian, African, and Latin American communities whether they are living in their own countries or settled in Europe or the USA. These communities, in addition to their custom of interrelated marriage, have large families and are a rapidly growing population. The siblings of consanguineous marriages have a significantly higher rate of autosomal recessive diseases including hearing impairment.
They conducted two large epidemiological surveys with 10 years apart. Subjects were 6,421 subjects from Riyadh City and 9,540 from all other parts of the Kingdom of Saudi Arabia.

A random sample was examined otologically and a questionnaire was filled in that included age, sex, family relation, number of siblings, etc. ENT examination and audiological assessment were performed. Consanguinity was found among 22 per cent as first cousins and 23 per cent as second cousins in the first survey. In the second survey 19 per cent were first cousins and 28 per cent second cousins. The rate of consanguinity was 45 per cent in the first survey and 47 per cent in the second. The prevalence of hereditary sensorineural hearing loss (SNHL) was 66.07 per cent and 36.6 per cent in the first and second survey respectively. The authors recommended that consanguinity should be discouraged through health education of the public about the adverse effect of interrelated marriages. Genetic counseling, premarital and antenatal screenings are to be applied whenever possible, at least for those at risk of developing genetic diseases including hearing impairment.

B) NICU admission

Kile (1993) documented that from 1970's to 1990’s, infants treated in NICU have increased percentage of hearing impairment. In the 1960s and early 1970s, low birth weight and perinatal factors in NICU were accounted for perhaps 2% of the children with hearing loss; however, with the introduction of effective ventilation for respiratory distress syndrome in the early 1970s, more and more at-risk infants were surviving. In
the next decade, approximately 13% of children with hearing loss had been of low birth weight, whereas 4% had perinatal causes, thereby increasing the percentage of children with hearing loss who were NICU graduates to 17%. In the next decade (1983-1992), the percentage of children with hearing loss identified by NICU admission increased further, with 19% of children being of low birth weight and 8% having perinatal risk factors.

The category of NICU graduates easily identifies a group of children who are at risk for hearing loss for a variety of reasons. As one of the indicators repeatedly stated by the Joint Committee on Infant Hearing as associated with the category of sensorineural or conductive hearing loss, NICU comprises of four factors. These include (1) Extra corporeal membrane oxygenation (ECMO); (2) assisted ventilation 3) ototoxicity 4) hyperbilirubinemia at a serum level, requiring exchange transfusion; In addition, three more indicators are related to risks frequently found in NICU graduates: (1) low birth weight (2) prematurity and 3) bacterial meningitis.

In addition, children with in utero infections, such as CMV, rubella, herpes, syphilis, and toxoplasmosis; craniofacial anomalies, including those with morphologic abnormalities of the pinna and ear canal; or syndromes known to be associated with sensorineural or conductive hearing loss, such as children with Down syndrome, are frequently admitted to NICUs for associated health problems. Further, children with sensorineural hearing loss who are NICU graduates have complex neurologic and other health problems. The lower the birth weight, the more likely a child will have
neurological problems, hearing loss or visual impairment, asthma, and cognitive impairment (McCormick, 1992).

Most studies designed to determine the cause of hearing loss in NICU graduates have found that the main associated factors include hypoxia, hyperbilirubinemia, exposure to ototoxic medications, and illness (Eavey et al., 1995; Speleman et al., 2012). The significance of the various causes in the pathogenesis of sensorineural hearing loss is not fully understood, and controversy still remains regarding their respective roles. Studies that have tried to identify specific causes for hearing loss found with increased frequency in NICU graduates have been complicated by multiple factors. Frequently, studies have identified their subjects by starting with what is determined to be a high-risk group, such as children with a gestational age of less than 36 weeks. Many of the studies have been retrospective in design and of small numbers of children.

In one of the studies by Eavey et al. (1995) forty NICU graduates of the Massachusetts General Hospital were selected for a detailed retrospective chart review evaluating prenatal, perinatal, and NICU medical conditions and treatment. Twenty-three patients identified with hearing loss and 17 infants with normal hearing were compared clinically. Univariate and multivariate analysis were performed on a subpopulation of patients (20 with hearing loss and 16 with normal hearing). A history of ventilation was associated with hearing loss ($P = 0.0023$), but this factor was not absolute. No other clinical parameters were convincingly linked to hearing loss. The
conclusion was that reliance on risk factors is an inadequate clinical method to select a patient for a hearing test and that each NICU survivor deserves audiometric evaluation.

Speleman, Kneepkens, Vandendriessche, Debruyne, and Desloovere (2012) attempted to determine the prevalence and significance of traditional risk factors associated with sensorineural hearing loss (SNHL) in a population of 615 neonates who attended the neonatal intensive care unit (NICU) of the University Hospital in Leuven, Belgium between January 2005 and December 2007. Auditory brainstem response (ABR) audiometry using 40 dB stimuli was performed in all 615 neonates. A retrospective medical database analysis was performed to evaluate the influence of 14 predetermined risk factors. The evaluated risk factors were ototoxic medication, hyperbilirubinemia, in utero infections (including CMV, rubella, syphilis, herpes, and toxoplasmosis), craniofacial anomalies, syndromes associated with SNHL, low birth weight (< 1,500 g), low Apgar score, mechanical ventilation lasting for 5 days or longer, bacterial meningitis, family history of hereditary childhood SNHL, endocranial hemorrhage, hypoxic ischemic encephalopathy, convulsions, and sepsis. Uni- or bilateral hearing impairment was diagnosed in 25 out of 615 neonates (4.1%). In utero infections (especially CMV), craniofacial anomalies, and syndromes known to include SNHL were significant risk factors. For the remaining risk factors, no significant correlation with SNHL was found.

In the above study, only in utero infections (especially CMV), craniofacial anomalies, and syndromes known to include SNHL were significant risk factors associated with SNHL. Adequate management of hyperbilirubinemia and ototoxic drug
administration may eliminate some of the major historical risk factors associated with SNHL in NICU neonates.

1) Hypoxia

Most studies on the causes of hearing loss in NICU graduates have identified hypoxia to be a factor. Hypoxia has been defined in different ways such as apnea, difficult delivery, a lower Apgar score at 5 minutes or a P02 of less than 50mm/Hg (Roizen, 2003).

Salamy, Eldredge, and Tooley (1989) studied prospectively 12 infants with sensorineural hearing loss from a group of 224 very low birth weight (> 1500 g) infants requiring NICU care. The authors found that the infants with hearing loss had a P02, less than 50 mm Hg more frequently than the control infants (p < 0.01). They concluded that each NICU survivor deserved audiometric evaluation.

In a study of risk factors of sensorineural hearing loss, Borradori, Fawer, Buclin, and Calame (1997) compared eight children with sensorineural hearing loss with a control group retrospectively matched for similar birth weight and gestation to identify clinical risk factors. The study group was presented with severe respiratory distress syndrome, requiring prolonged mechanical ventilation (11-55 days), and all had none or several pneumothoraces. No significant differences were found between the two groups in the incidence of perinatal asphyxia, hyperbilirubinemia, hyaline membrane disease, or persistent fetal circulation. The children with hearing loss were more likely to have
pneumothoraces \( (p = 0.001) \), bronchopulmonary dysplasia \( (p = 0.002) \), and renal failure \( (p < 0.002) \). Borradori and colleagues continued the study with a second control group with similar major perinatal complications, including respiratory distress syndrome, need for ventilation, and pneumothorax. The analyses of arterial blood gases and blood pressure did not reveal any statistical differences; however, the duration of mechanical ventilation \( (p = 0.0001) \) and the length of NICU stay \( (p = 0.005) \) were higher in the study group.

Simmons (1980) found that the NICU graduates with hearing loss had a higher incidence of certain factors than controls, including a difficult delivery by a factor of 3.8 and an Apgar score of 6 or less at 5 minutes by a factor of 7.9. The findings are supported by an analysis of 290,737 births in Utah (Eichwald & Mahoney, 1993). The Apgar scores of 0-4 at 1 minute and 0-6 at 5 minutes have been investigated as risk criteria in the Utah High Risk Hearing Screening Program. They also compared the Apgar score of 0-3 at 5 minutes recommended by JCIH (1990). The results indicated that the more lenient Utah cut-off criteria was justified. It was concluded that both Utah Apgar scores, even when moderately depressed, are sensitive risk factors for SNHL in infants. The authors found that the cutoffs of an Apgar score of 0 to 4 at 1 minute and 0 to 6 at 5 minutes were better indicators of possible hearing loss than were the previous criteria of a 5- minute Apgar score of 0 to 3.

Suzuki and Suzumura (2004) correlated the ABR findings with three different Apgar scores at 1 minute after birth. A group with four points or less \( (n = 25) \), a group
with five to seven points (n = 16), and a group with eight points or more (n = 15). The mean threshold and bilateral mean I–V IPL did not differ significantly among the three Apgar score groups.

2) Hyperbilirubinemia

In the past, many studies of risk factors associated with hearing loss in NICU graduates have found an elevated bilirubin to be associated with hearing loss. de vries, Lary and Dubowitz (1985) found that a higher mean duration of hyperbilirubinemia (48 hrs vs. 24 hrs), and lower birth weight, were associated with an increased risk for sensorineural hearing loss. Other investigators have found similar associations (Bergman et al., 1985; Doyle et al., 1992; Simmons, 1980). However, in a study of 224 extremely low birth weight infants, Waugh et al. (1996) found no statistically significant associations of maximum serum bilirubin level, intra ventricular hemorrhage (grade 2), multiple birth, or necrotizing enterocolotis with PHI.

Coenraad et al. (2010) studied 3366 infants who were admitted to NICU. Fifty eight infants were diagnosed with sensorineural hearing loss. Each patient was matched with two normal hearing controls from the neonatal intensive care unit of the same gender and post-conceptional age. In their attempt to investigate the association of each risk factor, he could not find an independent relationship of hyperbilirubinemia requiring phototherapy and peak bilirubin level with sensorineural hearing loss.
In two long term studies, strong relationship of extreme forms of hyperbilirubinemia and sensorineural hearing loss has been demonstrated. In Mexico, Villa-Guillen, Evia-Viscarra, and de Sierra (2002) conducted a retrospective chart review of term newborn infants with the diagnosis of pathologic hyperbilirubinemia as defined by the American Academy of Pediatrics (AAP) Provisional Committee for Quality Improvement and Subcommittee on Hyperbilirubinemia. They identified 115 patients who met the AAP criteria, with 21 having hemolytic and the remaining 94 non-hemolytic hyperbilirubinemia. The median age of admission was four days, and 24 (21%) infants required exchange transfusion. At follow-up, 21 (18%) had hearing loss, four of whom were classified with profound hearing loss. By univariate analysis, gestational age of < 38 weeks, age of onset of jaundice of < 24 hours, peak bilirubin of >30 mg/dl, and need of exchange transfusion were significantly associated with hearing loss. However, multivariate analysis failed to confirm any significant association.

Shapiro et al. (2002) studied 16 children with moderate to severe kernicterus born in the United States between 1989 and 2001. Kernicterus was diagnosed at 7 + 4.3 months of age (range 0.33–16 months) and the evaluation for the study was done at 5.5 + 3.8 years of age (range 0.67–12 years). All the children exhibited disorders of muscle tone, movement, or coordination, 12/16 had gaze paresis, and 11/16 had dental enamel dysplasia. In this group, the birth weight was 3215 + 661 g (range 1705–4318), the gestational age was 36.9 + 2.5 weeks (range 30–40), and most were male (11/16). Jaundice was first noted at 27 + 13 hours of age (range 0–48 hours) with the peak total bilirubin being 34.1 + 8.3 mg/dl (range 24–54). The cause of the high bilirubin was ABO
incompatibility in 4/16, a rare antigen in 2/16, unknown in 10/16, and Rh incompatibility in none. In follow-up, 12 of 16 had hearing impairment and four were reported as having no hearing loss. Auditory neuropathy was diagnosed in 6/16, all of whom had hearing loss.

3) **Persistant pulmonary hypertension/ Extra corporeal membrane oxygenation**

Persistent pulmonary hypertension (PPHN) and extracorporeal membrane oxygenation (ECMO) are indicators in the Joint Committee on Infant Hearing guidelines (Joint Committee on Infant Hearing, 2007) for periodic audiologic monitoring until three years of age, as late-onset hearing loss has been reported (Hutchin, Gilmer, & Yarbrough, 2000; Kawashiro, Tsuchihashi, Koga, Kawano, & Itoh, 1996). In a study by Kawashiro et al. (1996) eight of 10 children with hearing loss associated with PPHN or ECMO had a late onset hearing loss.

Van Den Hondel et al. (2012) determined the prevalence of hearing loss in school-age children who had undergone neonatal extracorporeal membrane oxygenation treatment. The authors designed a prospective longitudinal follow-up study within the framework of a structured post-extracorporeal membrane oxygenation follow-up program. Hearing was normal in 75.7% of children. Five children (3.7%) had bilateral sensorineural or combined hearing loss. The prevalence of sensorineural hearing impairment exceeded the prevalence in normal population of United States.
Fligor, Neault, Mullen, Feldman, and Jones (2005) did a retrospective chart review with proportional-hazards regression analysis to identify specific risk factors for SNHL in an ECMO center of a tertiary care hospital. The list of patients was selected from the record of 1986 to 1994 who survived till discharge and underwent audiologic evaluations. Records of random sample of 30 ECMO graduates who did not undergo an audiologic evaluation were also selected. Twenty-nine (26%) of 111 ECMO graduates who underwent audiologic testing had SNHL at the last evaluation. Of these 29 subjects with SNHL, 21 (72%) had progressive SNHL, of whom 14 (48%) had delayed-onset SNHL. The age of identification of SNHL ranged from 4 months to 8 years 11 months. The proportional-hazards regression analyses revealed length of ECMO therapy to have highest hazards ratio (HR:718) for hearing impairment than congenital diaphragmatic hernia (HR: 2.60), length of aminoglycoside antibiotics treatment (HR: 5.56). The results revealed that all the children with ECMO treatment must be screened for hearing loss.

**C) Prematurity**

Recent studies have shown that prematurity is a significant risk factor for permanent hearing impairment in neonates and infants either in isolation or in combination with other risk factors (Bajaj et al., 2009; Korres et al., 2005; Olusanya, 2011; Paludetti et al., 2012).
Lin and Oghalai (2011) and Ancel (2004) attributed the increasing association of prematurity to increasing survival rates of infants due to improved perinatal facilities; though it is not clear how prematurity can directly lead to hearing impairment.

Tomasik (2008) did a prospective study from 1996 to 2002 to find the association of risk factors of hearing loss in premature infants. A total of 218 premature infants with birth weight 520-3000 g (Median-1300 g) and gestational age 22-36 weeks (Median-30) were tested by ABR and divided into 2 groups: with hearing impairment n = 18 and control n = 200. Significant risk factors of hearing impairment were gestation age (OR: 0.7; 95% CI: 0.6-0.97), hyperbilirubinemia qualified for exchange transfusion (OR: 13; 95% CI: 2.9-64), severe general condition and prolonged use of katecholamines > 8 days (OR: 18; 95% CI: 3.6-96), treatment with amikacin > 15 days (OR: 8; 95% CI: 1.6-43), hypoglycaemia 14 days was an additional risk factor associated with gestational age (OR: 8; 95% CI: 1.1-65).

Marlow, Hunt, and Marlow (2000) attempted to elucidate the clinical antecedents of hearing impairment in preterm infants. Fifteen children < 33 weeks' gestation with significant SNHL born between 1 January 1990 and 31 December 1994 were selected for study group. The infants were detected for sensorineural hearing loss within 9 months of birth. 30 matched infants were taken as controls. Perinatal variables in the two groups were compared using non-parametric tests and conditional logistic regression (EGRET). Children with SNHL had longer periods of intubation, ventilation, oxygen treatment, and acidosis, and more frequent treatment with dopamine or
frusemide. Neither peak nor trough aminoglycoside levels, nor duration of jaundice or level of bilirubin varied between groups. However, SNHL was more likely if peak bilirubin levels coexisted with netilmicin use (odds ratio (95% confidence interval) 14.2 (1.8 to 113.6)) or if acidosis occurred when bilirubin levels were over 200 µmol/l (OR 8.0 (0.9 to 71.6). Frusemide use in the face of high serum creatinine levels (OR 8.9 (1.1 to 74.5)) or netilmicin treatment (OR 5.0 (0.99 to 24.8)) was also associated with SNHL. At 12 months of age, seven of 15 children with SNHL had evidence of cerebral palsy compared with two of 30 controls (OR 12.3 (2.1 to 71)). In conclusion, preterm children with SNHL required more intensive care in the perinatal period and developed more neurological complications than controls. Among very preterm babies, the coexistence of risk factors for hearing loss may be more important than the individual factors themselves such as hyperbilirubinemia, low birth weight, low Apgar score and ototoxicity.

Serenius, Källén, and Blennow (2013) attempted to determine the neurodevelopmental outcomes of extremely preterm children at 2.5 years (corrected age). It was a population-based prospective cohort of consecutive extremely preterm infants born before 27 weeks of gestation in Sweden between 2004 and 2007. Of 707 live-born infants, 491 (69%) survived for 2.5 years. Survivors were assessed and compared with singleton control infants who were born at term and matched by sex, ethnicity, and municipality. Assessments were completed in February 2010 and comparison estimates were adjusted for demographic differences. The prevalence of hearing impairment was 0.9% vs 0% in study and control group. The prevalence was
statistically higher in the study group \((p = 0.02)\) compared to control group. These results are relevant for clinicians counseling families facing extremely preterm birth.

Steinmacher et al. (2008) followed up 70 of 91 infants admitted to the neonatal intensive care unit 67 of the 70 surviving infants were examined at a median corrected age of 5.6 years; the authors reported that only 1% of infants required a hearing aid. Improved survival was not associated with an increased risk of severe disability when compared with results of earlier publications.

Guillen et al. (2012) studied the effect of loss to follow-up rates and the prevalence of hearing impairment in extremely preterm infants at 18 -24 months. Based on the literature review of most credible studies, they found a strong relation between prevalence rate of hearing impairment and the follow-up rate. Hearing impairment varied from 0-9% in their study.

**D) Low birth weight**

An association between birth weight <2500 g and hearing loss has been long recognized. As universal hearing screening programs have become widely implemented in western countries and the survival rate of VLBW babies in modern intensive care units has increased, literature showed a substantially better understanding of the nature of this problem in the recent years.
Cristobal and Oghalai (2008) reviewed the association of low birth weight and hearing impairment. This review described recent data on hearing loss in the VLBW population and explained the current level of understanding about the physiological basis underlying the auditory deficits in these patients. The authors found VLBW to be commonly associated with multiple other risk factors that can alter hearing in a synergistic fashion. Therefore, the risk of hearing loss is substantially higher than in the general newborn population. They also found that children with VLBW were also at increased risk of experiencing progressive or delayed-onset hearing loss, and recommended that they should continue to have serial hearing evaluations after discharge from the neonatal intensive care unit.

Engdahl and Eskild (2007) aimed at estimating the impact of birth weight on the risk of sensorineural hearing loss in children. Their design was a case–control study. 327 children (cases) were identified through the Norwegian county registers of children with hearing loss, and 391,992 were matched controls born in the same counties, identified through the medical birth registry of Norway. The definition of a case was a child with mean hearing loss (MHL) of 35 decibel (dB) hearing level (HL) in the better-hearing ear. The MHL was averaged over the pure-tone hearing thresholds at 500, 1000 and 2000 Hz, which was diagnosed before the age of 5 years. Birth weight <1500 g, as compared with 3500–3999 g, gave an adjusted odds ratio to cause a sensorineural hearing loss of 6.3 [95% CI 2.4, 16.4]. The result was adjusted for the confounding variables such as gestational age, gender, parity, maternal age and concurrent birth defects. As the birth weight increased, the risk of hearing loss
decreased, with adjusted odds ratios of 4.4, 3.8, 1.7 and 1.4 for the birth weights 1500–1999, 2000–2499, 2500–2999 and 3000–3499 g respectively. The risk for various degree of hearing loss such as mild to moderate (MHL 35–70 dBHL) and severe/profound hearing losses (MHL >70 dBHL) were found to be associated with birth weight.

Studies have attempted to know the association of LBW with the co-occurring risk factors and its impact over time in the same geographical location. Kanji and Khoza-Shangase (2012) aimed at determining the type and frequency of high-risk factors for hearing loss in a group of very-low-birth-weight (VLBW) neonates in a tertiary hospital in South Africa with the objective of collating evidence that could be used in arguing for or against revisiting targeted hearing screening in developing countries. The study also attempted to investigate the relationship between the identified high-risk factors and hearing screening results. In a retrospective data review design, data were collated from files of the VLBW project in the hearing screening records, as well as records from participant medical and audiology files. Records of 86 neonates with birth weights ranging between 680 g and 1500 g were reviewed. Findings indicated that neonatal jaundice, exposure to human immunodeficiency virus (HIV), mechanical or assisted ventilation, and neonatal intensive care unit stay greater than 48 hours were the most frequently occurring high-risk factors for hearing loss. These factors are consistently seen in the high-risk register of the Health Professions Council of South Africa and JCIH.
Synnes, Anson, Baum, and Usher (2012) evaluated changes over time in the characteristics of permanent hearing impairment (HI) in extremely low-birth weight (≤800 g) children. Data from sequential visits up to 5 years of age assessing hearing and other neurodevelopmental outcomes were extracted from a cohort of ELBW subjects born between 1983 and 2006 at a Canadian hospital. Trends in HI incidence, severity and association with other impairments were analyzed in three 8-year epochs. Fifty of 586 ELBW children had a HI. HI rates increased from 5% in epoch 1 to 7% in epoch 2 and 13% in epoch 3 (p = 0.01). Mild HI decreased from 78% in epoch 1 to 35% in epoch 3 (p = 0.03). Median age at diagnosis decreased from 13 to 8 months. The authors also found significantly higher comorbidities in HI children than non-HI children: cerebral palsy (40% vs 14%, p < 0.0001), cognitive (38% vs 12%, p < 0.0001) and visual impairments (16% vs 6%, p = 0.009).

**E) Infections**

Infections are considered to be the main cause of prenatally acquired hearing impairment. In the 1970s–1980s, congenital rubella syndrome (CRS) was the single most commonly reported cause of sensorineural hearing impairment in childhood, accounting for 16–22% of cases of hearing impairment in babies (Parving & Hauch, 1994).

CRS is a devastating syndrome which should be considered as a public health issue. Davis et al. (2009) documented that a rubella vaccine was first licensed in 1969.
By 1999, 105 (49%) of the 214 countries and territories reporting to WHO had introduced the rubella vaccine in their national immunization programme.

Tookey (2004) reported that in UK, the rubella vaccine was offered to schoolgirls in the United Kingdom from 1970, and post-partum susceptible women shortly after. Mass vaccination with MMR (measles–mumps–rubella vaccine) of babies was introduced in 1988. Schoolgirl vaccination was discontinued in 1996, although post-partum vaccination of susceptible women identified through antenatal testing continues. Reported cases of CRS declined from about 50 a year in 1971–1975 to just over 20 a year in 1986–1990 which is very significant.

Worldwide, an estimate of 1,10,000 babies are born every year with CRS, most of them in developing countries (WHO, 2012). Rittler, López-Camelo, and Castilla (2004) found 43 cases of CRS recorded from the records of 3,883,165 live births collected by the Latin-American Collaborative Study of Congenital Malformations, World Health Organization (WHO) Collaborating Centre for the Prevention of Birth Defects (ECLAMC), which suggests a prevalence of CRS in Latin America of around 1 : 100,000 live births.

Extrapolation based on worldwide data yields an estimated prevalence in India of 100-200 per 100,000 population (Panda & Panigrahi, 2009). Dewan and Gupta (2012) reported that around 21 studies have been done in India for the prevalence of Rubella in certain specific population. In this, only four studies assessed the confirmed CRS. There was only one large community based study (Vijayalakshmi et al., 2007).
which addressed prevalence of CRS in India. This was conducted in Tamil Nadu, over a period of 2 years (2002 to 2004), amongst 51,548 under-5 children. Probable CRS cases were recruited from hospital and outreach services of the Aravind Eye Care System. Clinical confirmation was based on the fulfillment of the World Health Organization (WHO) definition, and laboratory confirmation was based on a positive test for IgM antibody. 2.1% (n=1090) children had clinically suspected CRS (probable CRS) while 0.58% (n=299) were clinically confirmed CRS and 0.0009% (n=46) were laboratory confirmed CRS.

In a study from Vellore (Chandy et al., 2011), serum samples were collected from 92 infants presenting with features of intrauterine infections between 1996 and 1997. Rubella IgM antibodies were detected in 1 out of 13 children (7.6%) who had neurological abnormalities.

Another prenatal infection that causes congenital abnormalities is toxoplasmosis. Sever et al. (1988) studied 23,000 mothers and children from around 20 weeks gestation until 7 years old. Of these mothers, 38.7% had antibodies to toxoplasmosis during pregnancy, and children born to these mothers had double the risk of developing permanent childhood hearing impairment by the age of 7 years (0.4% vs. 0.2%, p = 0.01).

An Indian study (Sucilathangam, Palaniappan, Sreekumar, & Anna, 2012) was conducted to assess the seroprevalence of Toxoplasma gondii in and around Tirunelveli
by in-house IgG assay using ELISA (Enzyme-Linked Immune Sorbent Assay) test. Serum samples from 175 immunodeficient and 175 immunocompetent patients were collected at Tirunelveli district, Tamil Nadu from May 2006 to October 2007. They were subjected into in-house IgG assay using ELISA test in which tachyzoite soluble antigen derived from solubilised whole organisms was used. The overall seroprevalence of toxoplasmosis in and around Tirunelveli district of Tamil Nadu was 13.14% based on IgG ELISA.

Cytomegalovirus CMV is a common chronic asymptomatic infection in adults, which can cross over the placenta to affect the developing fetus and child. Roizen (1999) has observed that the rate of CMV infection is 2.2% of all newborns, making it the most common intrauterine infection. Lipitz et al. (2002) reported that from their sample of 18 babies with confirmed CMV infection, four (22%) had neurological problems at birth.

Fowler and Boppana (2006) summarized seven studies between 1982 and 2004, and found that the risk of permanent hearing impairment (PHI) was 22–65% in symptomatic babies and 6–23% in asymptomatic babies at birth. Amongst those affected by PCHI, there were progressive, fluctuating and delayed-onset cases. The authors couldn’t establish how much CMV infection contributes to the overall prevalence of PHI, as studies vary in their method of investigating infection.
In the meta-analysis by Morzaria, Westerberg, and Kozak (2004) the mean percentage of hearing impairment due to CMV in the studies from 1990 to 2002 was 0.92% (s.d. 1.07), and majority (41%) of the causes were unknown but Peckham, Stark, Dudgeon, and Hawkins (1987) reported that 14% of those diagnosed with PHI of unknown causes excreted CMV in their urine (compared with a base rate of 7%), and Barbi et al. (2006) reported that of 130 children with PHI, 24.7% had CMV in blood retained from a sample at birth (base rate not given).

An Indian study by Deorari et al. (2000) studied the incidence of intra uterine infections based on the analysis of 1302 cord blood samples. All these neonates were examined at birth and at discharge. The incidence of Rubella, CMV and Toxoplasmosis was 0.6%, 1.8% and 0% respectively and only one child with CMV went on to have sensorineural hearing loss. Others were normal.

Bacterial meningitis is a serious infectious disease in the neonatal period and throughout childhood. Bacterial meningitis may lead to a high frequency of neurological sequelae in 3 to 47% of cases, causing 160,000 yearly disabilities worldwide (Edmond et al., 2010; Ramakrishnan et al., 2009). Among the three main microorganisms causing acute bacterial meningitis, Streptococcus pneumoniae (Sp) is the most lethal and most disabling followed by Haemophilus influenzae (Hi) and Neisseria meningitidis (Nm) (Goetghebuer et al 2000). The former two organisms are commonly seen in children in developing countries including India. The probability of hearing loss in developed and developing countries is 10.5% vs 11.1% (Singhi, Bansal, Geeta, & Singhi, 2007).
Children who have lost their hearing due to meningitis are often considered to be the best candidates for cochlear implants due to their previous experience with language and their total loss of any auditory neural function. The rate of post-meningitic hearing impairment varies from 7 to 31%, depending on the type of meningitis and type of hearing impairment included. (Das, 1996; Fortnum & Davis, 1997; Kutz, Simon, Chennupati, Giannoni, & Manolidis, 2006).

Wellman, Sommer, and McKenna (2003) and Kutz et al. (2006) compared the complication rate between Hib and pneumococcus in bacterial meningitis, finding the latter significantly more likely to cause hearing impairment.

F) Ototoxicity

Children may be given a number of ototoxic medications, for example, aminoglycosides (such as gentamycin) for severe infections or those resistant to penicillin; platinum-containing chemotherapy such as carboplatin for retinoblastoma a childhood cancer of the eye, and radio-therapy for tumors in the glands of the neck (Davis et al., 2009). Many of these treatments are the best available (Yorgason, Fayad, & Kalinec, 2006) treatments but often the adverse effects of these drugs causes hearing impairment. The good news is that the effects can be minimized by action such as co-administering aspirin with gentamycin (Chen et al., 2007), careful dosing of carboplatin (Smits et al., 2006) and well-placed radio-opaque shields (Jereczek-Fossa, Zarowski, Milani, & Orecchia, 2003).
3.4. Risk factors of hearing impairment in different countries

**Data in developed countries**

Vohr et al. (2000) based on long term multi-centric study in United States assessed the relationship between risk factors and hearing test outcome. The study sample was 4478 high-risk infants in the NICU, 2348 infants from the well-baby nurseries (Non-NICU) with no risk factor, and 353 infants from the well-baby nurseries (Non-NICU) with risk factors. The authors had identified at least ten risk factors in NICU babies. The four most common were ototoxic treatment (44.4%), very low birth weight (17.8%), mechanical ventilation > 5 days (16.4%), and low Apgar scores at 1 or 5 min (13.9%). In contrast, only six risk factors were present in the non-NICU babies: family history (6.6%), craniofacial abnormalities (3.4%), low Apgar scores (2.8%), syndromes (0.5%), ototoxic medications (0.2%), and congenital infection (0.1%).

In a Malaysian prospective study based on NHS, Khairi et al. (2005) found that craniofacial malformations, very low birth weight, ototoxic medication, syndromes were associated with hearing loss and hyperbilirubinemia at the level of exchange transfusion as independent significant risk factors for hearing impairment.

In Netherlands, Coenraad et al. (2010) evaluated a series of risk factors and its association with hearing impairment in neonatal intensive care unit (NICU). Between 2004 and 2009, 3366 infants were admitted to the NICU, of which 3316 were screened with AABR. A total of 103 infants were referred for auditory brainstem response analysis after failure on neonatal hearing screening. Each patient was matched with two normal
hearing controls from the neonatal intensive care unit of the same gender and post-conceptional age. Fifty-eight infants were diagnosed with sensorineural hearing loss: 26 girls and 32 boys. The rate of dysmorphic features (P = 0.000), low Apgar score (1min) (P = 0.01), sepsis (P = 0.003), meningitis (P = 0.013), cerebral bleeding (P = 0.016) and cerebral infarction (P = 0.000) were significantly increased in infants with sensorineural hearing loss compared to normal hearing controls (n = 116).

A National NHS based study of Poland (Bielecki, Horbulewicz, & Wolan, 2011) conducted from 2003-2009, investigated the frequency of high risk factors of hearing impairment. A total of 5282 infants were examined. Subjects were categorized into two groups: the first group consisted of 2986 (56.53%) neonates with risk factors of hearing loss, while the second group included 2296 (43.47%) neonates without any known risk factors, but who twice tested positive on the TEOAE screening. The largest percentage of SNHL (15.52%) appeared in children with identified or suspected syndromes associated with hearing loss. The next highest frequency of SNHL was present in children subjected to mechanical ventilation for a period in excess of 5 days (11.45%). Only a small percentage (2.86%) of SNHL appeared to be due to the use of ototoxic medications, despite the fact that this factor is the most prevalent (33.13%) of all analyzed risk factors of hearing impairment. The percentage of other risk factors were as follows; premature birth (16.21%); low birth weight (12.04%); intensive care in excess of 7 days (10.64%). The study obtained the evidence for increase in the probability of SNHL with number of risk factors. The prevalence of hearing impairment in infants with five or more risk factors were double that of infants with one to four co
existing risk factors. This finding is also supported by Núñez-Batalla, Trinidad-Ramos, Sequí-Canet, Alzina De Aguilar, and Jáudenes-Casaubón (2012).

In Australia, Cone, Wake, Tobin, Poulakis, Rickards (2010) had found NICU admission as leading predictor for slight- mild sensorineural hearing loss. In a rare study to identify the causes of post natal hearing loss, Weichbold et al. (2006) in Austria found the JCIH risk factors such as family history of hearing loss, meningitis, craniofacial malformation, persistent pulmonary hypertension, congenital CMV infection, extracorporeal membrane oxygenation (ECMO), recurrent otitis media with effusion to be significant. In addition to it, ototoxic therapy and birth before 33rd gestational week were also present.

Data in developing countries

Taha et al. (2010) studied the risk factors in hearing impaired children of a primary school in Egypt. They found parental concern/ suspicion, middle ear disorders, household smoking, low socioeconomic status and post natal jaundice as the most important risk factors. Saunders et al. (2007) studied the etiology of hearing loss in rural Nicaraguan children. They found family history of hearing loss (33%) to be the most important factor. The other factors were maternal infection during pregnancy, neonatal distress, low birth weight or prematurity, and gentamycin exposure.

In Qatar, Bener, Eihakeem, Abdulhadi (2005) screened 2277 infants and found that family history of hearing loss did not have any association with hearing impairment.
The study revealed strong correlation between hearing loss, consanguinity ($r = 0.217$, $p < 0.01$), father’s illiteracy ($r = 0.293$, $p < 0.01$), mothers illiteracy ($r = 0.228$, $p < 0.01$), mother blood group positive ($r = 0.476$, $p < 0.01$), and father’s hypertension ($r = 0.570$, $p < 0.01$).

In a Chinese NHS based risk factor study (Nie et al., 2007), univariate analysis revealed that high-risk factors related to hearing loss were age of father, education backgrounds of parents, parity, birth weight, gestational weeks, craniofacial deformity, history of receiving treatment in neonatal intensive care unit (NICU), neonatal disease, family history of ear disease and congenital hearing loss. Multivariate Logistic regression analysis showed that 4 independent risk factors were related to bilateral hearing loss. They were parity (OR=16.285, 95% CI 3.379-78.481), neonatal disease (infections) (OR=34.968, 95% CI 2.720-449.534), family history of congenital hearing loss (OR=69.488, 95% CI 4.417-1093.300) and birth weight (OR=0.241, 95% CI 0.090-0.648).

In Turkey, Eras et al. (2013) had reported a series of post natal risk factors among premature infants. Multivariate analysis revealed that proven sepsis ($p = 0.019$), mechanical ventilation ≥5 days ($p = 0.024$), loop diuretics ($p = 0.001$), Patent Ductus Arteriosus (PDA) ligation ($p = 0.018$) and operation for retinopathy of prematurity (ROP) ($p = 0.034$) were significantly associated with hearing loss. They found the rate of hearing impairment among premature infants to be 1.8%.
Olusanya, Wirz, and Luxon (2008) studied the risk factors of congenital and early onset hearing loss in Nigeria. In a matched case control study, they sampled babies from four primary health centers of Lagos, Nigeria. Conditional logistic regression analysis revealed that first birth (OR 1.9, 95% CI 1.1-3.6), absence of skilled attendants at birth (OR 2.4, 95% CI 1.3-4.5) and a history of neonatal jaundice requiring exchange blood transfusion (NNJ/EBT) (OR 9.6, 95% CI 2.4-38.2) to be significantly associated with hearing impairment. After controlling for other variables, the absence of skilled attendants at birth (OR 4.2, 95% CI 2.0-8.6) and NNJ/EBT (OR 19.1, 95% CI 4.3-85.5) emerged as predicting factors of PHI, while small for gestational age (SGA) (OR 0.1, 95% CI 0.0-0.2) obtained inverse relationship with PHI. About 23% of children with PHI did not exhibit any risk factors.

**Indian scenario**

In India, studies done on identification and risk factors of childhood hearing loss are sparse. Census of India (2011) reports that around 2.7 crore people were having disability and hearing disability amounts to 19% of them. 0.3% of the hearing disability belonged to children below 4 years. In the past, it has been documented that the incidence of hearing impairment in India is between 0.05% (Nagapoornima et al., 2007) to 6.8% (ICMR, 1983).

Congenital hearing impairment in India is often identified late. A recent study in rural India (Rout & Singh, 2010) has reported the average age of mother's suspicion to be 1.5 years. Owing to reasons such as misguidance of physicians, ignorance and non-
availability of audiological services, the age of identification of hearing impairment by an audiologist is around 9 years. Habilitation has been started even before the parents met audiologist by around 6 yrs of age. Parents of children with mild – moderate loss and unilateral hearing loss did not show any interest in identification.

Unlike in Western countries, the NHS program is yet to become a national level program in India. Kumar (2011) has documented that only 38.05% of medical colleges have the facility of newborn hearing screening. In that, only 43% have audiologists employed and thus deprived of opportunity to confirm the hearing impairment. Habilitation initiatives towards the child are taken up by the parents, and often the initiation of it crosses the critical age of the child. Around 34% of children with HI are detected after five years of age (Bansal, Berry, & Deka, 2003).

Gupta, Anand, and Raj (1991) studied the correlation of various risk factors with hearing impairment in neonates. They reported that 19.2% of ‘at risk’ neonates in an intensive care nursery with one or more adverse perinatal clinical factors were diagnosed to have hearing impairment. On multiple logistic regression analysis, however, only 2 factors viz; hyperbilirubinemia at levels exceeding indication for exchange transfusion and birth weight less than 1500 gram, were found to be significantly correlated with the hearing impairment. Prematurity, birth asphyxia, neonatal seizures, infections and aminoglycoside administration had no significant correlation with hearing impairment in their study.
Chadha and Bais (1997) compared the auditory brainstem responses of 50 high risk neonates from NICU with those of 25 normal neonates. Infants with the risk factors of low birth weight, hyperbilirubinemia, asphyxia, septicemia and meningitis were included in the study group. Incidence of significant auditory impairment was 18%. On the basis of this study, the authors suggested that all high-risk neonates should undergo screening for hearing impairment.

3.5. Need for the study

1) Although several risk factors have been implicated with permanent hearing impairment there is lack of clarity in the individual and combined strength of association of risk factors. The clinical relevance of it is significant, as they can provide important information for both the family and health care providers regarding etiology, other associated health problems and risk of recurrence in subsequent pregnancy (Vohr et al., 2000).

2) In addition, the risk factor information could be used to determine the infants who are at risk for late onset hearing impairment and warrant audiologic monitoring and follow-up, despite a normal screen in the neonatal period.

3) Although sufficient data is available about the risk factors of hearing loss in western literature and other developing countries, there has been a dearth of systematic studies in India.

It is consistently reported in the literature that the importance of risk factors vary with different geographic locations. There is less information on risk factor trends which
makes it difficult to assess how they have affected the infants in this part of the world. It is hence imperative that attempts be made to estimate the magnitude of an association of risk factors with hearing impairment in a country like India. The knowledge of importance of risk factors in Indian condition will help in the following ways:

a) To facilitate early identification and follow-up of infants with hearing impairment.

b) To serve as baseline to document the effect of any ‘risk factor control program’ implemented.

c) To sensitize Pediatricians and ENT consultants who are the first point of contact with patients.

d) To develop public awareness materials reflecting current scenario of the country for the use of Educators and other professionals.

Hence, this study was undertaken.

3.6. Limitations of previous studies

In the past, majority of studies have attempted to study the risk factors based on hospital records only. Very few studies have been done in a systematic method to give a serious documentation of risk factors. Risk factors such as family history is very difficult to ascertain as it may not be found in the hospital records and requires a specific interview with the parents (Vohr et al., 2000). This limitation was overcome in the present study. Further, the association of consanguinity with permanent hearing impairment is not documented in the western literature due to its poor relevance in that community. Though some efforts have been made in Gulf countries, it is yet to be
studied systematically in Southern India where there is high prevalence of consanguinity (Bittles, 2012; Zlotogora & Barges, 2003). Olusanya (2011) points out the following limitation in literature of risk factors for developing countries in the last ten years; which is relevant to the current study.

1) Scarcity of literature in South-east Asia and sub-Saharan Africa

2) Only one study was available in the age group of neonates and infants (Nagapoornima et al., 2005).

3) Available literature has only looked at the established risk factors by JCIH and not region specific factors.

4) No study has been done based on UNHS in which all the neonates/infants were screened.

Further, JCIH guidelines being almost entirely based on US and UK studies, there is a great need to have studies from developing countries like India as well. The present study has tried to address most of the limitations listed by Olusanya (2011).