# Cost-Analysis of Universal Newborn Hearing Screening in the Philippines

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**ABSTRACT**

Objective. The prevalence of congenital bilateral permanent profound hearing loss in the Philippines is 1.3 per 1000 live births. The prevalence increases to 22 per 1000 live births for unilateral mild to moderate hearing loss. This study was conducted to determine the cost of establishing a universal newborn hearing screening (UNHS) program. Local prevalence data and current costs of screening, diagnostic and intervention strategies for bilateral permanent hearing loss were utilized to estimate the costs of implementing the program.

Methods. Both short-term and long-term costs for hearing screening centers and for families caring for hearing-impaired children were determined using a societal perspective. Calculations included cost of hearing screening given local published prevalence of congenital hearing loss and the effectiveness of testing strategies. In this study the societal cost was considered although some of the costs pertained to costs borne by individual patients or their families since none of the screening, diagnostic and intervention strategies are paid for by insurance companies. An exception is the partial subsidy for cochlear implantation that is reimbursable with the Philippine Health Insurance Corporation.

Results. Using published data on the prevalence of hearing loss and experience from a pilot universal newborn hearing screening project at a national tertiary hospital (Philippine General Hospital), the long-term benefits and savings from UNHS on a national scale greatly outweigh the immediate costs of testing and intervention.

Conclusion. The cost benefit of UNHS program at a national level outweighs the financial burden of hearing impaired individuals and their families.

*Key Words: newborn, hearing screening, cost analysis*

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## Introduction

Congenital hearing impairment which is bilateral, profound or permanent congenital hearing loss (PCHL) occurs in 1.3 per 1000 live births. This rate is at par with rates of congenital hearing impairment worldwide. However, if babies with unilateral and milder forms of hearing impairment are included, the prevalence rate increases to 22 per 1000 live births. Some cases may be temporary, such as those due to otitis media in very young children as noted by reports worldwide. However, it has been shown that even for the milder and unilateral forms of hearing impairment, there is a significant delay in mental development during infancy, which encompasses development of locomotor, personal-social, hearing and speech skills, hand and eye coordination and performance tests.[1] Thus, it is important that babies with hearing impairment be identified by age six months, so that early intervention can be given. This is to allow these children to develop mentally as their normal hearing peers.[2]

### Rationale

There are at least three options for detection of hearing impairment in newborns: 1) no screening or passive detection; 2) early screening for high-risk babies only or targeted newborn hearing screening (TNHS); and 3) early screening for all babies or universal newborn hearing screening (UNHS).

The first option, passive detection, will obviously result in delay in detection, with age at diagnosis of hearing impairment usually by 2 years old. The intervention, whether by hearing aids or surgery, is then expected to also be delayed.

The second option tests only those who are high-risk based on existence of the factors[3] shown in Table 1. This second strategy of targeted or high-risk screening, although more selective and economical in terms of number of babies to test, may not be cost-effective due to the high number of false-positives (or wrongly labeled as hearing-impaired when the child is normal) based on risk factor history alone.[4] Also, it usually misses those children who may be hearing-impaired but do not exhibit any of the risk factors. Studies have shown that the proportion of such children may be higher than those who are high-risk and have hearing impairment, with as much as 78% of newborns who fail hearing screening as having no risk factors.[5] A study by

Olusanya highlighted the diverse operational constraints that limit its effectiveness as well as the fact that evidence of the validity of high risk factors especially in resource poor countries where such TNHS have been recommended is limited.[6]

**Table 1.** 2007 JCIH Criteria for High Risk of Congenital Hearing Loss

| |
|---|
| caregiver concern regarding hearing, speech, language or developmental delay; |
| family history of permanent childhood hearing loss; |
| neonatal intensive care of more than 5 days or any of the following regardless of length of stay: extracorporeal membrane oxygenation or ECMO [which is similar to a heart-lung machine], assisted ventilation, exposure to ototoxic medications [or drugs that are toxic to the ear such as] (gentamicin and tobramycin) or loop diuretics (furosemide/Lasix) and hyperbilirubinemia [jaundice] that requires exchange transfusion [replacement of blood or plasma]; |
| in utero [prenatal and maternal] infections, such as cytomegalovirus, herpes, rubella, syphilis, and toxoplasmosis; |
| craniofacial anomalies [deformities], including those that involve the pinna, ear canal, ear tags, ear pits, and temporal bone anomalies |
| physical findings such as white forelock, that are associated with a syndrome known to include a sensorineural or permanent conductive hearing loss; |
| syndromes associated with hearing loss or progressive or late-onset hearing loss, such as neurofibromatosis, osteopetrosis, and Usher syndrome; other frequently identified syndromes include Waardenburg, Alport, Pendred, and Jervell and Lange-Nielsen; |
| neurodegenerative disorders, such as Hunter syndrome, or sensory motor neuropathies, such as Friedrich ataxia and Charcot-Marie-Tooth syndrome; |
| culture-positive postnatal infections associated with sensorineural hearing loss, including confirmed bacterial and viral (especially herpes viruses and varicella) meningitis; |
| head trauma, especially basal skull/temporal bone fracture that requires hospitalization; |
| chemotherapy. |

The third strategy, UNHS, is more comprehensive since it tests all babies, and ideally should catch all newborns with hearing impairment, whether high-risk or not. However, in the real-world setting, follow-up rates for second testing may be low, with as much as 73% of patients who require second testing lost to follow-up (PGH, unpublished data). Also, the screening test has a false-positive rate of 13.6% and false-negative rate (labeled as normal when actually hearing-impaired) of 0.6%.[1] It should be noted that the false-positive rate may mean additional tests which are unnecessary since the child is not hearing-impaired, while a low false-negative rate implies that only a small proportion of babies who are truly hearing-impaired are mislabeled.

The purpose of this article is to determine the cost of establishing a nationwide program of UNHS in the Philippines. This determination will make use of local data on prevalence and effectiveness of testing strategies used.

**Cost-effectiveness of NHS in the United States and other Countries**

Previous studies in the United States have been done in order to assess the cost-effectiveness of UNHS vs. high-risk screening only. The estimated cost of detection per child who is hearing-impaired was US$4,609 for UNHS vs. US$8,239-9,920 for selective NHS.[7] In a later study, it was shown that, in the absence of hearing screening, the cost per deaf child for passive detection was US$69,000. In comparison, selective NHS resulted in incremental cost-effectiveness of US$16,400 per additional infant while UNHS yielded an incremental cost-effectiveness of US$44,300 per infant whose deafness was diagnosed by age six months.[8] This makes selective NHS a more dominant cost-effective alternative than UNHS or no screening. However, selective NHS in Germany was found to be less cost-effective than UNHS when the number of missed diagnosis and the consequent delay in language development and the other interventions are factored in. In Brazil where prevalence of sensorineural hearing loss was 0.96 per 1000 live births. At a cost of US$7.00 for hearing screening, the annual cost of a UNHS program was estimated at US$26,940.47.[9] The cost effectiveness of UNHS in similar developing countries have been described.[10]

**Methods**

Short and long-term costs in establishing and operating hearing screening centers as well as costs borne by families from caring for hearing impaired children were estimated using a societal perspective. Calculations included cost of hearing screening given local prevalence rates of congenital hearing loss and the effectiveness of testing strategies. It should be pointed out that most of the costs for hearing screening, diagnosis and intervention are borne by individual patients or their families as third party payers do not pay for such services except for cochlear implantation during hospital confinement that is covered by the Philippine Health Insurance Corporation. Cost of hearing aids nor cochlear implant devices as well as speech therapy and auditory training are not covered.

For screening centers, operating expenses would constitute salaries of technicians and disposable supplies. In Manila, the standard salary for one technician would be P8,000/month. Disposable supplies such as batteries, alcohol, cotton, and office supplies may total at least P1,000/month.

## Results

### Projected Costs for Screening Centers

Initial costs for screening centers are capital-intensive due to equipment acquisition. For most, an otoacoustic emissions (OAE) machine plus an auditory brainstem response (ABR) machine would constitute basic requirements for establishing a Newborn Hearing Screening center. The OAE test takes only a few minutes to test in a quietly resting baby, while the ABR requires sedation and may take hours to complete. The current protocol that is being applied in most Philippine hospitals uses OAE as an initial test. For those who fail the initial OAE screening, a second OAE test is recommended, preferably within one month of the first test. For those who fail both OAE tests, confirmation by ABR is recommended. OAE has good concordance with ABR among Filipino neonates.[11,12,13] Thus, its utility as a screening tool has been locally established. An OAE machine may cost P230,000, while an ABR can range P800,000–P1,800,000. These machines are also very durable and can last more than 10 years with minimal maintenance costs.

Automated ABR has been recommended abroad as more practical for initial screening due to its lower false-positive rate and better cost-effectiveness as compared to OAE.[14] An automated ABR machine costs higher than OAE but lower than the typical ABR machine at P600,000–P800,000. However, we have no current data as to its sensitivity and specificity as a screening tool among Filipinos.

Although initial capital layout for equipment seems large, the actual cost becomes cheaper as more babies are screened over years of use.

Given that the initial capital and operating expenses will be the standard price for at least five years, the total cost for a screening center may then be at least P2,140,000.

In October to December 2007, a single technician was able to screen 995 babies or 75% of all newborns at the Philippine General Hospital or PGH (unpublished data; Table 2). Of those screened, 10.6% had a "refer" result and thus required a second OAE test to confirm hearing impairment. However, of 104 babies, only 27% followed up. Of those who followed up, only one child was confirmed by OAE to have hearing impairment. This may mean that we could have missed another 2-3 hearing-impaired children who failed the first OAE test but did not come back for a second test. If these numbers are projected to a 5-year period, a single technician should be able to screen 23,886 babies, (at 90% screening rate) plus at least 2,507 children for a second OAE test (at 10.5% refer rate). Once the program is established, there is a tendency to improve coverage due to greater public awareness and improved testing mechanisms to a 95% screening rate and 4% refer rate with about 80% follow-up or "recall" rate.

**Table 2.** Pilot OAE Screening of babies at the Philippine General Hospital

| | |
|---|---|
| Total No. of Babies Born in one quarter+ | 1,327 |
| Number of Babies Screened in one quarter | 995 |
| Rate (Actual) Screening | 75 percent (995/1,327) |
| Total Rate of Screening in 5 years | 90 percent (1,194 babies) |
| Ideal Rate of Screening after 5 years | 95 percent (1,261 babies) |
| Initial Refer Rate obtained | 10.6 percent (104 babies) |
| Ideal Refer Rate | 4 percent (48 babies or 4 percent of 1,194) |
| Follow-up or Recall Rate obtained | 27 percent (104/995) |
| Ideal Follow up Rate | 80 percent (80 percent of 48 babies or 38) |

*Philippine General Hospital, October-December 2007*

If we were to use the data above as basis for capital (i.e., without costing for place of testing/rent/bills, etc.) and number of hearing-impaired children detected over five years, the cost of detecting a hearing-impaired child on second OAE screening is at least P62,822 (Table 3). If follow-up testing have improved rates, that is at 100%, the cost of early detection may go down to as much as P57,473 per hearing-impaired child.

**Table 3.** Cost Calculations based on Projections of Baseline Data from the Philippine General Hospital

| | |
|---|---|
| 90 percent (Ideal Rate) of 1327 | = 1,194 |
| Projected for 1 year | = 1,194 x 4 quarters /year = 4,777 |
| Projected for 5 years | = 23,886( 4777 x 5 years ) |
| With 4 percent Refer Rate | = 955 |
| 80 percent Follow Rate for Initial OAE Refer Patients | = 764 |
| Total Number of babies Tested for 5 years (80 percent Follow-up Rate) | = 24,650 (P87 per OAE test) |
| Total Number of Babies Tested for 5 years With 100 percent Follow-up | = 24,841 (P86 per OAE test) |
| Based on Prevalence of PCHL | = 34 babies with PCHL in 5 years (P62,882 cost per HI child) |

The usual cost for OAE in testing centers is currently P300, while the ABR test varies from P800 to P2,000. Based on the computations above, the actual cost (without inflation) for screening a large volume over five years, if packaged at two OAE tests plus one ABR test, may amount to only P86 per child as shown in Table 3.

While the Philippine General Hospital, which is a university hospital with a high volume of patients, was used as a model (Table 3), this was done under the assumption that the UNHS program will involve networking of centers to screen about 1,000–4,000 using a single OAE machine. Networking centers will increase case load to ensure the viability of screening centers and provide for operational efficiency.

**Projected Costs for Individuals**

The impact of the previous calculation becomes more obvious if we were to compare the costs at an individual level. The change in expected impact and cost happens at two levels: (1) early detection, i.e., by age 6 months; and (2) early intervention, i.e., by age 1 year.

If a child who is hearing-impaired is not screened by age 6 months, chances are high that the hearing impairment will be detected much later, usually at age 2-3 years, when the parent already sees the speech and language development to be much delayed compared with other children. The cost of such an event is hard to quantify. If no intervention is done, then the lost opportunity to go to mainstream schools or the requirement for special education has a high price tag, which easily reaches hundreds of thousands of pesos over a period of 10 years. This has a snowball effect, which results in difficulty in acquiring a job in adulthood, not just because of speech and language impairment but also poorer mental development compared with hearing individuals, and also less socialization capabilities and probably emotional problems from isolation and depression. We can arbitrarily assign a value of P30,000 per year for special education for 10 years, and lost income of P100,000 per year for 40 years, for a total of P4.3 million over a lifetime. Please note however that this is a very conservative estimate with no additional costing for inflation.

If a child is diagnosed to have hearing impairment by age 6 months but intervention is not given early enough, then we can assume that the cost is similar to the previous scenario, plus the additional cost of testing. There are also cases in which intervention is given at later than 1 year and some improvement in speech and language is seen; however, their development is still not at par with hearing children, and thus the cost may still be similar to the previous estimate, with additional costs from intervention.

If a child is diagnosed to have hearing impairment by age 6 months and intervention is given by age 1 year, then the chance of developing normal speech and language development is much higher. Currently one hearing aid may range between P10,000 to P100,000 depending on the model. If we take the average cost of P30,000 to P45,000 for one ear, then those requiring hearing aids for both ears would require about P60,000 to P90,000 for optimal development. If we assume that replacement of the unit is required every 5-10 years, then the cost for hearing aids over a 60-year period would amount to at least P240,000 to P720,000 (plus batteries). Compared to the scenario with no intervention, this translates to a lifetime savings at the individual level of about P3.3 to P4 million.

In some cases, instead of hearing aids, cochlear implantation is required. Cochlear implantation involves the surgical insertion of an electrode into the inner ear of a severe-to-profoundly deaf patient so that through electrical stimulation the neural cells can conduct impulses to the brain and the patient can hear again. The going rate for the entire treatment now runs at about P1.2 million. Since the technology is still new (only 17 years in the Philippines), it is hard to say how many times a cochlear implantee would need re-implantation, and most patients would probably prefer no additional surgery. If we assume that a re-implant is required, perhaps due to technological advances or wear-and-tear, but will be done only after 30 years, then the cost would double over a 60-year period, which would amount to savings of P1.9 million. If we also assume that no re-implantation is required, then the savings would be higher at P3.1 million.

Thus, at the individual level, a simple diagnostic exam with a basic cost of P87 can actually save an individual or family millions of pesos if done during the newborn period.

**Projected Costs for Nationwide Program**

If we try to imagine the costs and savings of the previous calculations on a nationwide scale, then we have to take into account the prevalence of congenital hearing impairment in the country and the sensitivity and specificity of OAE as a screening test. Studies have shown the cost effectiveness of a screening intervention to be largely dependent not only on the cost per patient but also the baseline prevalence (risk) of hearing impairment.[15] As previously reported,[1] the prevalence of bilateral profound hearing impairment among Filipino children less than 2 years of age is 1 in 724, or 0.14%. If we include those with unilateral and mild-to-moderate hearing loss, the prevalence is 16/724 or 2.2%. However those with unilateral or milder forms of hearing loss may not necessarily require intervention. Still they may be diagnosed using the OAE as a screening test, thus we use the higher prevalence estimate in our succeeding estimation. In the same report, the sensitivity or chance of detecting a truly hearing-impaired child using OAE (as compared to the gold standard, ABR) is 86.4%, while the specificity or chance of detecting a hearing child as normal is 99.4%.

Following the method of Gorga and Neely,[16] to estimate the cost-savings of a screening program, the posterior probabilities of each test result has to be computed, as follows:

$P_{00}$ = P(normal) x P(pass|normal) = 0.977901 x 0.994 = 0.972033

$P_{11}$ = P(impaired) x P(fail|impaired) = 0.022099 x 0.864 = 0.019094

$P_{01}$ = P(normal) x P(fail|normal) = 0.977901 x 0.006 = 0.005867

$P_{10}$ = P(impaired) x P(pass|impaired) = 0.022099 x 0.136 = 0.003006

The immediate cost for the first two outcomes that is *normal+pass* ($C_{00}$) and *impaired+pass* ($C_{10}$) is equal to the screening test, which we may assign as P300 which

represents the current charges for the screening test. This is because after the test, no other intervention is expected. For a *normal-fail* result, the cost ($C_{01}$) includes unnecessary testing with ABR, which when added to the screening OAE test, amounts to P2,000. The cost of *impaired+fail* result is negative because of savings from early detection of hearing impairment, since we prevent delayed language and speech. We can assign this value ($C_{11}$) as –P4.3 million. With these assumed probabilities and costs, we can compute the expected cost of the test per baby:

$$\begin{aligned}\text{Expected Cost} &= C_{00} \times P_{00} + C_{11} \times P_{11} + C_{01} \times P_{01} + C_{10} \times P_{10} \\ &= \text{P300} \times 0.972033 - \text{P4,300,000} \times 0.019094 \\ &\quad + \text{P2000} \times 0.005867 + \text{P300} \times 0.003006 \\ &= -\text{P81,799.62}\end{aligned}$$

Since the result has a negative value, this means that in the long-term the OAE screening test exceeds immediate costs when probabilities of each test outcome is applied. The value is the expected cost each time the screening test is administered. If about 1.8 million Filipinos are born yearly, then the benefit of performing a hearing screening test on every baby would be about P147.2 billion. This shows that the projected savings over 60 years or over the long term greatly exceeds the immediate cost of performing UNHS. Also if we compare the cost of testing each baby born in a year (i.e., P300 x 1,800,000 = P540,000,000) versus the total savings amortized on a yearly basis (i.e., P147,239,000,000 / 60 = P2,453,988,630), then it can be easily shown that the newborn screening program would be cost-effective even on the first year of national implementation.

Sensitivity analysis would show that these calculations are robust given the consistency with which OAE testing is able to detect the presence of hearing loss and the relative stability of the prices of services. From the time the study was initiated in 2008 to the present time the cost of testing and the machines have remained almost the same.

## Discussion

The study shows that the projected costs for screening based on individuals, the cost of running a newborn screening center and the societal perspectives were presented. The benefits at each level from the individual or patient as well as on a national societal perspective could be shown using local prevalence data and sensitivity and specificity of the OAE test used in the local setting (PGH). Republic Act 9709 was enacted in 2009 based on clear evidence of the benefits of a universal newborn hearing screening program as shown in this study which was initiated in 2008. The main problem, however, is the lack of awareness among Filipinos, even among physicians, of the need to refer newborns for hearing screening (CoNHScA, 2007). Also most of the hospitals that are equipped to test newborns are within Metro Manila, with 5 of 22 non-specialist government hospitals, and 18 of 24 private hospitals offering NHS. Of the 23 hospitals with NHS, only 6 provide UNHS (Lacanilao KR, 2007, unpublished). On the other hand, based on reports from otorhinolaryngologists during the 2007 Collaboration on Newborn Hearing Screening Advocacy (CoNHScA), at least four private clinics within Luzon but outside Metro Manila offer OAE services to newborns, while there are at least two private clinics each in Visayas and Mindanao with OAE. No OAE/ABR services for newborns were reported to exist within government institutions outside Metro Manila. This means that most Filipino newborns outside the National Capital Region have minimal or no chance at all of early detection and intervention for hearing impairment.

To test the rigor of our calculations discussed here it is hereby recommended that three main screening centers, one each in Luzon, Visayas and Mindanao, must be established to pilot the project in the first year. However, on the second or third year, it is hoped that at least one center per region or a minimum 14 additional testing sites, with both OAE and ABR, can be added. If a regional hospital can be tapped as the main area of testing, then funding for soundproofing must be earmarked, plus funds for equipment, disposables and personnel. If at least P2 million is earmarked for each center over 3 to 5 years, then this would require P6 million over the first year and additional P28 million on the second to fifth year. If we use the PGH model, 17 test sites with a single OAE technician who could screen an average of 4,800 babies a year would only screen 81,600 babies or only 4.5% of total babies born annually.

Additional funding for setting up the national registry for universal newborn hearing screening in order to monitor the coverage of newborn screening nationwide will be needed. A central depot of information, which can also serve as training center for health personnel who will provide support services, must be created. As stipulated in RA 9709, a Newborn Hearing Screening Reference Center must be in place and equipped with a database system and dedicated staff for several functions, including but not limited to: (1) administrative support for coordination of fund allocation, project initiation and implementation; (2) information systems support; (3) epidemiologic analysis; (4) training of technicians for OAE and ABR testing; (5) training of audiologists for hearing aid fitting and cochlear implant mapping, particularly in children; (6) training of otolaryngologists for cochlear implantation, especially for those who would practice outside Metro Manila; (7) accreditation of newborn screening centers, both public and private; and (8) promotion of UNHS to the general Filipino public. This has just recently been established within the National Institutes of Health in the University of the Philippines Manila.

## Conclusion

Universal newborn hearing screening is a cost-effective strategy that should merit support from government as a program for promotion of hearing health among Filipinos. Our estimates clearly show the huge financial benefits at the individual, hospital and nationwide levels that could be reaped from such a program if the required support services are provided, both at the early detection and early intervention stages. Indeed, the cost of UNHS needs further examination with respect to implications on funding of existing programs and as implemented in other developing countries could be incorporated in the existing program for maternal and child health and newborn care as well as immunization program. The current projections in cost have been made possible through the availability of local data on prevalence and effectiveness of testing strategies. Better cost-effectiveness will be assured if good follow-up can be maintained for those who fail the initial OAE screen and if low false-positive rates can be achieved by technicians, which underscores the importance of administrative support and training of health personnel.

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