

# Agreement between Human Voice (“Baah”) Test and Otoacoustic Emissions in Screening of Infants for Binaural Hearing Loss

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## ABSTRACT

**Objective.** To determine the agreement between Otoacoustic Emission and “Baah” tests for detecting binaural hearing loss in infants referred for hearing evaluation in a local community setting.

**Method.** This is a retrospective review done in a Private Community-based Secondary Specialty Hospital. Bilateral hearing test results of 788 neonates and infants obtained between September 2011 and January 2013 using human voice “BAAH” test and OAE were reviewed from January 2014 to September 2015.

**Results.** There were 432 males and 356 females (male: female ratio 1.2:1) with a mean age of 11.17 days (range of 0-143 days). Of the 780 infants with bilateral “Pass” using OAE, all were screened as “with response” by “Baah” tests. Five infants with bilateral “refer” results using OAE yielded “no response” on “Baah” test. Sensitivity of ‘Baah’ test was 100%, specificity was 99.5%, with positive predictive value of 62.5%, and negative predictive value of 100%. There was good agreement noted between OAE and “Baah” ( $\kappa=0.77$ ,  $p<0.001$ ).

**Conclusion.** The “Baah” test is a possible alternative to OAE in initially detecting binaural hearing loss in areas where equipment and personnel are limited. Although “Baah” test could only detect 62% of infants with binaural hearing loss and could not detect unilateral hearing loss, infants detected with binaural hearing loss can be immediately referred to centers with more sophisticated equipment.

**Key Words.** bilateral hearing loss, binaural hearing loss, hearing tests, otoacoustic emissions

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## Introduction

Hearing loss is a common congenital condition. With a prevalence of bilateral profound hearing loss of 1 per 724 babies in the general population or 1.38 per 1000 live births,<sup>1</sup> it is expected that at least 8 babies are born deaf daily out of 2 million babies born in the Philippines annually.<sup>2,3</sup> To address this, the Philippines and various countries have newborn hearing screening programs.<sup>3-7</sup> But even with passage of a law on universal hearing screening (Republic Act 9709), the Philippines lacks personnel, infrastructure and equipment for newborn hearing centers in the different cities and municipalities nationwide to screen 2 million babies a year. In provinces and far-flung areas with limited equipment and personnel for hearing screening, the search for alternatives to diagnostic tests such as OAE and AABR continues. Two local studies have been published on one such alternative, the voice (“Baah”) test.<sup>8,9</sup>

Garcia et al. studied 101 infants less than 6 months old in a tertiary government hospital and showed that the sound “Baah” covers both high and low frequencies (150 to 5000 Hz) similar to the frequencies tested by OAE. The use of “Baah” was based on an earlier voice test study by Gloria-Cruz et al.<sup>8</sup> Compared to OAE as the gold standard, the Baah test was found to have a sensitivity of 71.4%, specificity of 95.7%, accuracy rate of 94% (95 out of 101 infants), positive predictive value of 55.6% and negative predictive value of 97.8%, showing potential as an accurate and cost-effective screening tool to identify infants that may be at higher risk for hearing impairment.

The objective of this study is to determine the level of agreement between OAE and the “Baah” test for detecting binaural hearing loss in infants referred for hearing evaluation in a local community.

## Materials and Methods

This is a retrospective review of the hearing screening results of neonates and infants who underwent routine newborn hearing screening (OAE) and the “Baah” test at the Malolos EENT Hospital from September 2011 to January 2013. The infants tested were referred from surrounding maternity hospitals in Malolos, namely: Mary Immaculate Maternity Hospital, Malolos Maternity Hospital, Ofelia Mendoza Maternity and General Hospital and Graman

Medical and Maternity Hospital. This study abided by the Helsinki Declaration.

The OAE and Baah test were both done in the ABR Room of the hospital. Two trained female testers (nurses) took turns in giving the tests every week. The OAE was done first. The infant was usually carried by the mother, who was instructed to keep silent and minimize movement during the examination. The OAE test was administered in each ear using Natus Bio-logic AuDX® Pro (Natus Medical Incorporated, USA). When a “refer” result appeared, the ear probe was removed, the baby’s ear was massaged to release ear canal retraction, and the test was repeated. If “refer” was obtained again, the test was repeated a third time. If the patient’s result was still “refer,” it was recorded as REFER. If the result was “pass,” it was recorded as PASS.

The “Baah” test followed after the OAE test. The stimulus was produced by the trained tester (a female nurse), who was not blinded to the results of the OAE. The tester, positioned 2 feet in front of the baby, shouted or vocalized the sound “Baah,” with intensity of around 85 to 95 dB SPL guided by a portable A-and-C weighted sound level meter (TES 1350A Digital Sound Meter Level, TES Electrical Electronic Corp., Taiwan) placed beside the baby’s head. The same tester observed for a response which included any of the following: 1) blinking, 2) more forceful closure of the infants’ already closed eyelids, and 3) startling and stirring reflexes demonstrated by sudden head and body movement right after the sound was produced. If there was no response at 2 feet, the tester repeated the test at the same position at 2 feet. If there was still no response, the tester produced the sound from 1 foot away. The observer recorded the response as “with response” if the infant demonstrated 1 or more of the responses above and “no response” if none of the above responses was observed (Figures 1 and 2).

The results of the OAE test were categorized as “refer” and “pass”; with OAE “refer” indicating bilateral “refer” results, while OAE “pass” indicated either bilateral “pass” or unilateral “refer” results. The results of the Baah test were categorized as “no response” indicating bilateral hearing loss, while Baah “with response” meant no or unilateral hearing loss.

The data were encoded in Microsoft Excel 2010 (version 14.0, Microsoft Corporation, USA). Data was tabulated in a two-by-two table comparing the results of the human test “Baah” and the standard (OAE) and reviewed from January 2014 to September 2015. Agreement was measured using Cohen’s Kappa statistic and level of significance was assessed by McNemar’s test of agreement. Stata 13 (StataCorp LP, USA) was used for statistical computations.

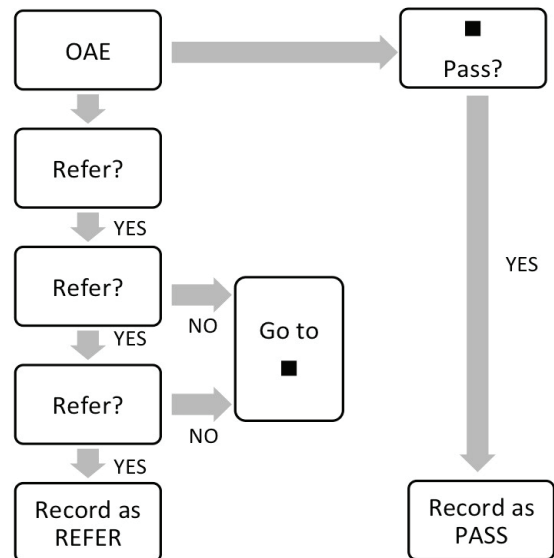
**Results and Discussion**

Retrieved records represented a total of 788 subjects who were tested with both OAE and “Baah.” There were 432

males and 356 females, with a M: F ratio of 1.2:1 and a mean age of 11 days (range, 0-143 days).

The majority (35%) of infants tested were aged 8 to 14 days. Almost all infants were tested within the ideal screening period of up to 3 months, except three infants tested at 103, 122 and 143 days of age (Figure 3).

**1. Right/Left Ear\***



\*REPEAT IN THE OPPOSITE EAR

Figure 1. Order of Testing of OAE.

**2. Baah Test**

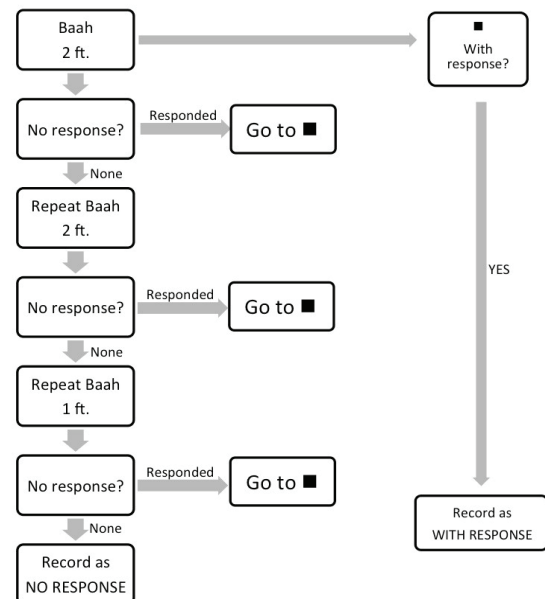


Figure 2. Order of Testing of BAAH.

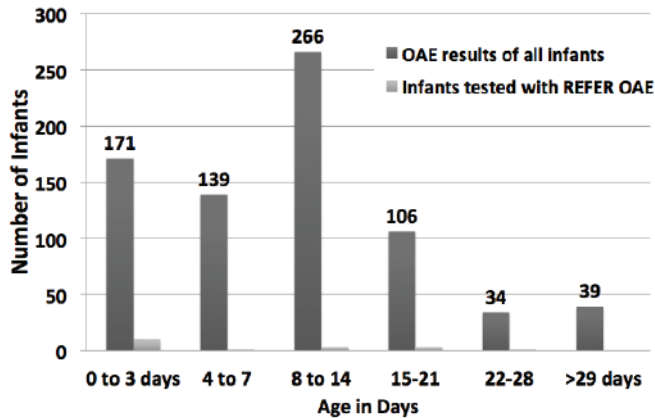


Figure 3. Age Distribution of Infants Tested with OAE\*.

Table 1. OAE vs Baah (N=788)

	OAE Refer (Bilateral)	OAE Pass (Bilateral & Unilateral)	Total
Baah NO RESPONSE	5	3	8
Baah WITH RESPONSE	0	780	780
Total	5	783	788

Number of observed agreements: 785 (99.62% of the observations)  
 Number of agreements expected by chance: 775.1 (98.36% of the observations)

Kappa= 0.77; p = <0.001

SE of kappa = 0.0346; 95%

confidence interval: From 0.512 to 1; McNemar p = 0.25

Sensitivity = 100%

Specificity = 99.6%

Positive predictive value= 62.5%

Negative predictive value= 100%

Table 2. Risk factors of the infants who failed Baah but passed their OAE

Infant	Age (in days)	Profile
1	12	Bleeding (first trimester), UTI, no medications taken
2	17	Pre-eclampsia, UTI, Medications: Cefazidime, Oxacillin, Amikacin
3	7	No noted risk factors

“Refer” was defined as bilateral “refer” results, while “pass” was defined as bilateral “pass” or unilateral “refer” results.

Of the 788 infants, 8 (1.01%) had no response to the “Baah” test. Plotting the OAE and “Baah” results on a 2x2 table revealed that of the 788 subjects, 5 had both “refer” OAE and “no response” Baah. (Table 1)

Three out of 788 infants had a false positive result with no response on the Baah test and a ‘pass’ response with OAE. These 3 infants had the following profiles (Table 2).

The results of this study show an acceptable level of agreement between OAE and “Baah” test in screening for bilateral hearing loss. The low positive predictive value of 62.5% indicates that given a positive result in the Baah test, there is only a 62.5% chance that one has bilateral ‘refer’ OAE result and probably possible bilateral profound

hearing loss. The difference in the predictive value of this present study compared to the previous study where the positive predictive value was 55.6% could be based on the fact that the previous study defined hearing loss as both unilateral or bilateral “refer” OAE results, while this present study took into account those with bilateral OAE Refer results only.<sup>8</sup>

The ‘Baah’ test may be used as an initial screen prior to formal OAE screening for bilateral profound hearing loss in provinces and in areas where OAE is not available in the meantime. Results may promote further testing with OAE for those with failed ‘Baah’ test. However, this positive predictive value suggests that 37.5% or almost 40% may falsely fail the ‘Baah’ test, and might unwarrantedly be referred for ABR testing.

It is important to note that the “Baah” test can only detect binaural hearing loss<sup>8</sup> and those with unilateral hearing loss and intact hearing in the contralateral ear can still have a response to the “Baah” test.

Further studies on the reproducibility and validity of “Baah” compared with auditory brainstem response should be pursued to evaluate its robustness as a screening tool. Recording the reaction using a video camera and blinding the testers to avoid bias can be done in succeeding studies. Another recommendation is to further investigate the reason for the 3 false positive “Baah” results. This could be attributed to a flaccid child, intra-observer variations, or even ambient noise levels, which according to Rhoades et al.<sup>10</sup> can influence the results in the testing environment as seen in their investigation of the effect of increased background noise on click-evoked OAEs. While a quiet environment was ensured in the area, future studies could limit the effect of ambient noise by making sure it does not exceed 50-55dB.

A previous study by Garcia et al. showed that “Baah” test compared to OAE had a specificity of 95.7%, hence a low false positive rate.<sup>8</sup> It would be prudent to follow-up the 3 infants who had a false positive result with either ABR or behavioral audiometry. Other suggestions for future research in this area would be comparison of “Baah” with ABR results, or follow-up of the babies for behavioral audiometry at an appropriate age.

In conclusion, the voice test “Baah” is a possible alternative to OAE in detecting binaural hearing loss in areas where equipment and personnel are limited. While it cannot detect unilateral hearing loss, time and effort are saved if the infants diagnosed with binaural hearing loss can be immediately referred to other centers with more sophisticated equipment.

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