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Original Research Article

A study on hearing screening using oto-acoustic emissions in newborns delivered by normal vaginal delivery and lower segment caesarean section

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ABSTRACT

Background: Hearing is one of the most complex systems of the human body and is a skill involved in the human social evolution. It has been estimated that around 900 million people by the end of 2050, will probably suffer from hearing loss. Our study aims to find out the correlation between the mode of delivery and the effect it has on newborn hearing screening.
Methods: The Prospective study on 136 Newborn babies who were delivered in JLN Hospital & Research Centre, Bhilai, Chhattisgarh during October 2020 to August 2021. After obtaining detailed history all newborns underwent TEOAE screening and the data were then compared with the available literature.
Results: We observed normal vaginal delivery newborns have passed the test by 97.91% and 89.58% when compared to LSCS delivered infants 97.15% and 86.36% in screening and diagnostic frequency respectively. COVID-19 infection was seen in 2.94% of pregnant mothers in the 3rd trimester. There were no babies who required BERA in our study
Conclusions: Normal vaginally delivered newborns have higher pass rate in TEOAE test when compared with LSCS delivered babies. Covid-19 infection in antenatal mother can influence the outcome in 1st TEOAE tests. The pass rate in TEOAE hearing test in the screening frequency is found to be greater when compared with diagnostic frequencies. In a developing country like India, Universal hearing screening programs needs to be reached out to the most remote parts of the country, in order to identify at risk infants for hearing loss.

Keywords: TEOAE, Newborns, Vaginal delivery, Lower segment caesarean section

INTRODUCTION

Hearing is one of the most complex and sensitive systems of the human body and is a skill involved in the human social evolution.[1] The WHO estimates that over 5% of the world's population or 466 million people have a disabling hearing loss. It has been estimated that around 900 million people by the end of 2050, will probably suffer from hearing loss.[2] In India, approximately 63 million people have significant hearing loss, [3] and out of every 1000 children born in India, there may be 5-6 such children who cannot hear properly. OAE history- George

Von Bekesy, Noble Prize Laurette described the Travelling Wave theory in 1940, he said that waves from the Basilar membrane produces Sound but his theory had some drawbacks when the separate cochlear component and its frequency could not be explained. In 1948 astronomer Thomas Gold suggested that there must be positive feedback from the cochlear. He proposed that the active bio-mechanical cochlear amplifier is responsible for high sensitivity and high frequency selectivity of the sound. Tremendous amount of time was spent in the 1960 trying to explain the discrepancy between the precision of tuning and threshold sensitivity of the ear and the predictions made from travelling wave theory. Later, in 1978 David Kemp was able to record this sound generated by the biological activity of the normal cochlear. Otoacoustic emissions (OAE) are narrow band tonal signals which occurs due to the stimulations of ear, the vibrations travel from the outer hair cells of the cochlear to the middle ear, causing displacement of ossicles and the acoustic signals are measured in the external ear canal.[4] They are most probably generated by active mechanical contraction of the outer hair cells, spontaneously or in response to sound.

There are four types of OAEs: Spontaneous OAEs (SOAE) which are present in 50% of the normal populations. Transient evoked OAEs (TOAE) -the stimulus is given in the form of the clicks (Broad band of frequencies) which activates basal to apical regions of the basilar membrane in the cochlear. Distortion product OAEs (DPOAE); are elicited when two simultaneous pure tones are presented in closely spaced frequency which activates the same region in the basilar membrane of the cochlear. Stimulus frequency OAEs (SFOAE); are evoked when a pure tone is given continuously at a low intensity level which causes slow changes across a region of frequencies. The microphone records all sounds in the ear canal, and these include, in addition to OAEs, the sound evoking the OAEs when TEOAEs or DPOAEs are recorded, as well as other patient-generated and ambient sounds.[5] It has been observed that transient evoked otoacoustic emissions (TEOAE) has a sensitivity as high as 95%-98% and a specificity of 80%-85%.[6] In recent years, many studies have shown that infants born by caesarean delivery have failed their first otoacoustic hearing screening when compared to infants born through normal vaginal delivery. This has resulted in increase in anxiety and stress among mothers.[7] It has also caused agitation among the family members, and a general fear persists that their child may be born deaf. The risk factors for hearing impairment includes consanguineous marriage, infectious diseases during the pregnancy, intake of ototoxic drugs, birth deficiencies, neonatal jaundice, birth weight, meconium aspiration, post-natal infections and ear infection.[8] Research indicates that screening programs are the most effective way for early detection of hearing impairment among infants, and can improve their development. [9]

Most of the developed countries have universal neonatal hearing screening programs. On the other hand, in India, such programs have not gained popularity due to social constraints and low financial support. Otoacoustic emissions are widely used as screening tool because of its low cost and easy availability. It measures perineural functions in the inner ear and can be accessed using non-invasive technique that does not require sedations. A two-stage screening protocol for newborns who failed the first two Oto acoustic emission (OAE) screening can be taken up for auditory brainstem response (ABR/BERA) to confirm and determine the extent and the type of deafness in the neonates. This overall practicability makes it relevant for our country, making it an ideal model screening program. This study aims to Comparative hearing screening using otoacoustic emissions in newborns delivered by normal vaginal delivery and lower segment caesarean section.

METHODS

Our study is a prospective observational study, the study was conducted in the Department of ENT of J.L.N Hospital and research Centre, Chhattisgarh and it included Newborn babies who were delivered only from our institute by department of obstetrics & gynaecology and later monitored by department of paediatrics during the period October 2020 to August 2021. The study population included 136 newborns that underwent 1st and 2nd TEOAE hearing test in our department. The newborn babies who will be selected as the subjects for the study will be divided into 2 groups, normal vaginal delivery group and LSCS delivery group. A predesigned proforma which includes detailed maternal and newborn history will be taken before enrolling the newborns into the study. In a preformed questionnaire maternal and neonatal history will be obtained prior to the test. Newborn babies will be subjected to thorough ENT examination and the ear will be examined with an Otoscope, before doing the neonatal Hearing Screening test using TEOAE within 7 days of life. The TEOAE probe (insert earphones, ER-100 probe) delivering stimulus in the form of clicks at 80 dB SPL, non-linear 1024 sweeps were presented at a rate of 19.30/sec using the intelligent Hearing System (U.S) Software 4717, 2.4 version.

The pass criteria for the TEOAE test were; A signal to noise ratio (SNR) of more than 3 dB at any two of the consecutive frequencies (1.0, 1.5, 2.0, 3.0 or 4.0 kHz) in screening test and in the other 3 frequencies for diagnostic test and Reproducibility of the test by 50%. All the Newborn who failed the 1st screening and diagnostic test in any ear will be examined for 2nd TEOAE in both ears after 3 months and in both the screening and diagnostic frequencies. Those who failed the 2nd TEOAE will be taken up for brainstem evoked auditory response (BERA). Analysis of the date and the inference on screening of newborn hearing using Transient Evoked Oto acoustic emission will be done.

Analysis of data

Categorical data will be presented as frequencies and percentage. Continuous data will be presented as mean (SD) and median (quartiles). Data will be checked for normality before statistical analysis. Normally distributed. Continuous variables will be compared using the unpaired t test, whereas the Mann-Whitney. U test will be used for those variables that will not be normally distributed. Categorical variables will be analysed using either the chi square test or Fisher's exact test. For all statistical tests, a p value less than 0.05 will be considered statistically significant and p<0.01 as highly significant. SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 20.

RESULTS

Sex wise distribution

In our study, out of the 57 (41.91%) Male babies, 22 were delivered by Normal vaginal delivery and 35 by LSCS. Among the 79 (58.09%) Female's babies 26 and53 newborns were delivered by Normal Vaginal and LSCS respectively (Table 1).

Mode of delivery

Among the 136 Newborns who were delivered in our hospital, majority of them were delivered by Elective LSCS 60 (44.12%), followed by 48 (35.29%) normal vaginal delivery and 28 (20.59%) by Emergency LSCS (Table 2).

Ears affected in first TEOAE screening test

The 1st TEOAE screening test, in two consecutive frequencies showed 60 Newborn babies who were delivered by Elective LSCS have 100 % passed the 1st TEOAE screening frequency test, while in the 28 Emergency delivered LSCS babies only 23(82.14%) have passed the test and the remaining 4(14.29%) babies in unilateral ear and 1(3.57%) in bilateral ear were found to be affected. Among the 48 babies who were delivered by normal vaginal delivery, 46 (95.83%) have passed and the remaining 2 (4.17%) babies had REFER result in unilateral ear and none in the bilateral ear. The p value (p=0.009) is found to be highly significant (Table 3).

Table 1: Sex wise distribution.

Sex	NVD	LSCS	Total, N (%)
Male	22	35	57 (41.91)
Female	26	53	79 (58.09)

Table 2: mode of delivery.

Mode of delivery	Normal vaginal delivery	Elective LSCS	Emergency LSCS	Total
Number of new-born	48	60	28	136
%	35.29	44.12	20.59	100

Table 3: Ears affected in first TEOAE screening test.

Groups	First TEOAE screening, N (%)			Total, N (%)
	Bilateral Refer	Unilateral Refer	None	
Normal vaginal delivery	0 (0)	2 (4.17)	46 (95.83)	48 (100)
Elective LSCS	0 (0)	0 (0)	60 (100)	60 (100)
Emergency LSCS	1 (3.57)	4 (14.29)	23 (82.14)	28 (100)

$\chi 2=13.35$, p=0.009 HS

Table 4: Ears affected in first TEOAE diagnostic test.

Groups	First TEOAE diagnostic, N (%)			Total, N (%)
	Bilateral Refer	Unilateral Refer	None	
Normal vaginal delivery	2 (4.17)	5 (10.42)	41 (85.42)	48 (100)
Elective LSCS	4 (6.67)	5 (8.33)	51 (85)	60 (100)
Emergency LSCS	4 (14.29)	3 (10.71)	21 (75)	28 (100)

$\chi 2=2.98$, p=0.56 NS

Ears affected in first TEOAE diagnostic test

The 1st TEOAE test in the diagnostic three frequencies shows that among the 48 Normal vaginal delivered babies 41 (85.42%) have the highest pass rate while the remaining 5 (10.42%) infants in unilateral ear and 2 (4.17%) in bilateral ear were found to be affected during 1st TEOAE diagnostic test. Furthermore, out of the 60 Elective LSCS newborns 51(85%) have found to be pass the test while, 5 (8.33%) babies in unilateral and 4 (6.67%) in bilateral ears had REFER result. In the

emergency LSCS born babies 21 (75%) have cleared the test and the remaining 3 (10.71%) in unilateral and 4 (14.29%) in bilateral ear were found to be affected respectively (Table 4).

Ears affected in second TEOAE in screening and diagnostic frequency

All newborns that had REFER result either in the unilateral or bilateral ear during the 1st TEOAE screening and diagnostic test were subjected to the 2nd TEOAE hearing test in both ears after 3 months. In the 2nd TEOAE test in screening and diagnostic frequencies all of them have passed the test, among them 8 (32%) were normal delivered newborn, 9 (52.94%) in Elective LSCS and the other 8 (47.05%) in Emergency LSCS (Table 5).

Ear affected as per birth weight distribution in first TEOAE screening

In our study, all newborns whose birth weight was above 2500 grams have passed the 1st TEOAE screening test. 30 Babies who weight between 1500 – 2500 grams, 24(80%) have passed the test while 6(20%) babies in unilateral ear was found to be affected. The 1 baby in bilateral ear was found to be affected in weight less than 1000 grams. The p value ($p<0.0001$) is found to be highly significant (Table 6).

Table 5: Ears affected in second TEOAE in screening and diagnostic frequency.

Groups	Second TEOAE screening and diagnostic, N (%)			Total, N (%)
	Bilateral Refer	Unilateral Refer	None	
Normal vaginal delivery	0 (0)	0 (0)	8 (32)	8 (100)
Elective LSCS	0 (0)	0 (0)	9 (52.94)	9 (100)
Emergency LSCS	0 (0)	0 (0)	8 (47.05)	8 (100)

Table 6: Ears affected as per birth weight distribution in first TEOAE screening.

Birth weight (grams)	First TEOAE screening, N (%)			Total, N (%)
	Bilateral Refer	Unilateral Refer	None	
<1000	1 (100)	0 (0)	0 (0)	1 (100)
1500-2500	0 (0)	6 (20)	24 (80)	30 (100)
>2500	0 (0)	0 (0)	105 (100)	105 (100)

$\chi 2=158.14$, $p<0.0001$ HS

Comorbidities in pregnant mothers

we had 62 pregnant mothers who had either one or more comorbidities like GDM, Pre-Eclampsia, hypothyroidism during their antenatal period. 9 out of those 62 babies were born vaginally, while the reaming 53 babies were delivered by LSCS. In the 74 pregnant women had no significant comorbidities during their pregnancy, 39 babies were delivered vaginally and 35 by LSCS.

Post natal monitoring

There were 48 normal vaginal delivered babies, 36 (26.47%) were well baby who were healthy and 12 (8.82%) required NICU care for neonatal jaundice, Low birth weight, or Respiratory distress. Among the 88 LSCS newborn, 56 (41.18%) were well baby and the 32 (23.53%) needed NICU admission.

COVID-19 infection in antenatal period

In our study, which was carried out during the COVID-19 pandemic era, we found out 4 antenatal mothers (2.94%) were found to be infected with COVID-19 virus during their 3rd trimester and all 4 babies were delivered by Emergency LSCS. The babies later tested negative for the virus. Also, 132 (97.06%) mothers were found to be negative for COVID-19 virus during their 3rd trimester (Table 7).

Table 7: COVID-19 infection in antenatal period.

COVID-19 infection	N	%
Positive	4	2.94
Negative	132	97.06

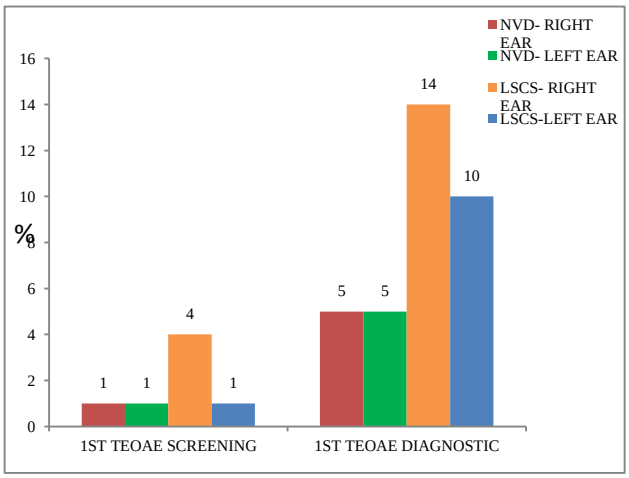

Figure 1: First TEOAE refer result and relation to type of delivery.

Comparison of first TEOAE and second TEOAE screening frequency

We can observe from the above table, the 1st TEOAE screening frequency result, which shows us that among the 136 newborns, 131 (96.32%) in right ear has passed while, 5 (3.67%) had REFER value. And in the left ear, 134 (98.52%) babies have passed and the remaining 2 (1.47%) did not. All of them later underwent 2nd TEOAE test after 3 months. In the 2nd TEOAE screening test all 25 (18.38%) infants who underwent the test has passed in both right ear and left ear respectively (Table 8).

Table 8: Comparison of first TEOAE and second TEOAE screening frequency.

Screening frequency		Pass		Refer	
		N	%	N	%
1st TEOAE (N=136)	Right ear	131	96.32	5	3.67
	Left ear	134	98.52	2	1.47
2nd TEOAE (N=25)	Right ear	25	18.38	0	0
	Left ear	25	18.38	0	0

Comparison of first TEOAE and second TEOAE diagnostic frequency

Out of the 136 newborn who underwent the 1st TEOAE diagnostic test 117 (86.02%) have passed in right ear and the other 19 (13.97%) had REFER result. In regards to left ear, 121 (88.97%) has passed the test and 15 (11.02%) babies did not. In the 2nd TEOAE diagnostic test all 25(18.38%) infants who underwent the test has passed in both right ear and left ear respectively (Table 9).

Table 9: Comparison of first TEOAE and second TEOAE diagnostic frequency.

Diagnostic frequency		Pass		Refer	
		N	%	N	%
1st TEOAE (N=136)	Right ear	117	86.02	19	13.97
	Left ear	121	88.97	15	11.02
2nd TEOAE (N=25)	Right ear	25	18.38	0	0
	Left ear	25	18.38	0	0

First TEOAE refer result and relation to type of delivery

In our study, we have found out, during the 1st TEOAE test, 7 newborns had REFER result in screening frequencies out of whom 2 babies were born by normal vaginal delivery and each had REFER result in right and left ear respectively, while the other 5 were LSCS delivered newborns, in whom 4 had REFER in right ear and 1 in left ear respectively. The 1st TEOAE diagnostic test shows 34 newborns that had REFER, 10 were born by normal vaginal delivery and among them, 5 babies each had REFER result in right and left ear. The remaining 24 LSCS babies, 14 had REFER in right ear and 10 in the left ear respectively. In our study, we have found out, that 25 Infants has not cleared the test and in their 1st TEOAE had Refer result in unilateral or in bilateral ear during either the screening or diagnostic frequency test. All infants were followed up for 3 months duration and they were subjected to 2nd TEOAE test in both the frequencies and in both ears irrespective of the 1st TEOAE result. Among the 25 babies who has underwent 2nd TEOAE, 17 (68%) were delivered by LSCS while 8(32%) by normal vaginal delivery. From the 2nd TEOAE test, we can observe that all 25 (18.38%) babies have passed in screening and in diagnostic frequencies in both right and left ear respectively. There were no babies who required BERA in our study (Figure 1).

DISCUSSION

Hearing is essential for the communication and development of a child. Neonates with undiagnosed or untreated hearing loss may adversely affect the cognitive, emotional, and social development of an individual, and these babies can behave differently from other normal children which can be misdiagnosed that the child suffers from the autistic or hyperactive disorder. The presence of risk factors like craniofacial anomalies, neuro-degenerative disorders, and in utero infections give a clue that these babies need a proper evaluation to rule out any congenital anomalies. The world health organization (WHO) recommends hearing screening tests for all newborns shortly after birth, as early diagnosis and rehabilitation of hearing deficits have better outcomes.[10] Transient Evoked Otoacoustic emissions are non-invasive, cost effective, easily performed, valid hearing test to access cochlear function. The OAE screening program has been implemented across India and the search to identify hearing-impaired children continues even through the COVID-19 pandemic crises. The main focus of the study was to compare hearing outcomes in vaginal-born and LSCS delivered babies by using the TEOAE hearing test.

Yucel et al showed that 50.8% female babies outnumbered 49.2% male babies which is seen in concurrence with our study, where we also had 58.09% female babies when compared to 41.91% males.[11] The studies conducted by Suleyman et al and Kulkarni et al had male babies of 51.5% and 54.24% when compared to female babies 48.5% and 45.58% respectively.[12,13] Erdogdu et al observed that the overall pass rate seen during 1st TEOAE test was more in vaginally born babies when compared with LSCS delivered newborns, this observation coincides with our present study.[12] While the pass rate of both studies was found similar, there was a different pattern of presentation in the REFER result when compared. Our study shows high REFER in the LSCS group when compared to NVD. Their study showed a contrast presentation where REFER was seen more in vaginally born babies when compared to LSCS delivered babies. From our study, we emphasize the point that, even though in the 1st TEOAE test, the pass rate among LSCS group was low, we have also observed that 100% of the Elective LSCS born babies have passed in

screening frequency. Kulkarni et al studied newborns by 1st TEOAE test and noticed failure rate as per ears observed 1% failed in both the ears, while 3% babies failed in the left ear and 2% infants failed in the right ear. When this inference was compared with our present study, it contradicts the findings, as more infants have failed in the right ear 3.67% when compared to 1.47 % in the left ear.[13]

A study by Oghan et al the study population comprises more Caesarean delivered 56.1% as compared to vaginal delivered 43.9% babies.[14] This pattern of presentation is also seen in our study where we had 64.71% of newborns who were delivered by LSCS and 35.29% babies by vaginal delivery. And his study points out in 10,767 infants where 1st TEOAE screening test highlights that bilateral passing rate is significantly higher in the normal delivery group of about 95.1% when compared with 92.9% in the LSCS group. This shows us that vaginally born babies have the high pass rate and least number of REFER when compared to LSCS born babies. A similar result is observed in our study also where 97.91% NVD babies pass while the number is seen slightly lower in LSCS groups 97.15%. In a study conducted by Olarte et al they observed 19 new-borns with birth weight <1500 grams, where 5 babies failed in the 1st TEOAE test and it was compared with our present study, where we had 1 baby with <1000 grams who failed the test in both frequencies, and later was re-examined after 3 months, and in the 2nd TEOAE test the infant passed.[15] The inference of our 2nd TEOAE study was in contrast to their findings where they noticed that 3 out of the 5 babies had failed in the 2nd TEOAE test when they were re-examined after 30 days. Kadhim et al examined newborns as per their birth weight and found 8 babies who weigh <2500 grams and all of them have passed the 1st DPOAE hearing test, this contradicts with our study where we examined newborns by 1st TEOAE and observed that among the 28 babies who weigh between 1500-2500 grams, 80% of them passed the test while 20% of infants had to REFER in screening frequency.[16]

Yücel et al performed TEOAE test in Syrian refugee babies, they found out that 7 out of 16 infants with very low birth weight and 19 babies out of 96 with low birth weight, had referred results unilaterally or in the bilateral ear and there was a significant relationship between the presence of hearing loss and the presence and absence of low birth weight.[17] This is also similar to our study, where we observed REFER results in babies who weigh 1500-2500 grams in unilateral ear by 20% and 100% in bilateral ear in extremely low birth weight baby 1st TEOAE screening test. Our study result matched the finding of Korres et al research where the hearing status of very low birth weight infants was assessed just before their discharge from hospital which shows 20.8% of VLBW newborns have failed in the OAE test while 79.2% of them passed.[18] Ohl et al study highlights that birth weight <1500 grams in newborns are not a risk factor for hearing impairment, this contradicts our present study where we had 1 baby who failed in the 1st TEOAE and later passed the hearing test in the 2nd stage.[19] Zhou et al have examined 69 newborns born with Gestational diabetes mellitus their OAE hearing test shows 4.35% of infants had failed the test.[20] This goes with our study, where out of the 62 babies born to comorbid mothers, 1.61% baby in the bilateral ear and 3.23% in unilateral ear had REFER result in 1st TEOAE screening test. Wahyu et al study included 17 babies out of 40 who needed NICU monitoring for more than 48 hours, where all the babies were in the birth weight below 2500 grams, while in our study we had 12 babies in NVD and 32 in LSCS born who needed NICU care for more than 7 days.[21] In our study, during the COVID-19 pandemic wave, we had observed that 4 antenatal mothers were positive during their third trimester of pregnancy and among them, 2 out of the 4 babies have passed the 1st TEOAE test while the other 2 babies were referred for 2nd stage TEOAE test and passed the screening test after 3 months. John et al have screened newborns by 1st DPOAE test which showed 93.6% pass while 6.4% had REFER, while our study, screened newborns by 1st TEOAE method that showed 96.32% in the right ear and 98.52% in the left ear have passed the test.[22] This points out that the TEOAE test has a high pass rate when compared with the DPOAE test.

Bhatt et al screened high-risk newborns on 1st day of birth, where 45% of infants had REFER in both the ears and all babies when re-examined after 3 months showed the REFER rate to be lowered to 8%.[23] This implies that delayed hearing screening test has high specificity. A similar observation is also seen with our study, where 25 babies who failed in the 1st hearing test have passed the 2nd TEOAE test after 3 months. Tatiana Smolkin et al[24] pointed out that failure on the 1st OAE screening test was low when the babies were examined after 48 hours of life, while our study also highlights that delayed hearing screening reduces false-positive and false-negative results. Chaudhari et al examined 19 infants in 2nd stage DPOAE after 15 days of the first test, which showed 17 were passed and 2 new-borns had REFER. Further observation by BERA was done in those 2 newborns which showed 1 baby had bilateral hearing loss.[24,25] Singh et al observed the hearing outcome in high-risk babies and pointed out that 122 infants failed in 1st TEOAE and when these babies were examined in the 2nd stage 13 babies among them had REFER and were further followed up by BERA, while our study shows that all Newborns have passed in TEOAE tests.[26]

In our study, we examined newborns by TEOAE screening and diagnostic frequencies and any baby found to have REFER in either ear at any of the above frequencies were subjected to the 2nd TEOAE test. This method has helped us to identify false-positive patterns during the 1st stage of screening. Our concern with the early identification of hearing disorders in newborns by the OAE method is that it gives a clear picture of the middle ear and outer hair cell function in the cochlear and

it does not help in identifying the central auditory processing disorder. A child with OAE result pass but has not developed simple auditory skills, needs to be evaluated further by BERA, ASSR, OR MLR to rule out any pathology in the auditory pathway. Hence, all the above studies as well as our study highlights that mode of delivery influences the OAE screening. Furthermore, the birth weight of newborns also has a significant effect on the outcome of the hearing test. We highlight that the universal screening test in newborns should be performed in 3 months between the tests to avoid false-negative cases.

CONCLUSION

Following co relations were drawn from our study, Normal vaginally delivered newborns have higher pass rate in TEOAE test when compared with LSCS delivered babies. Birth weight of newborns had significant relation to the outcome of TEOAE Hearing test. Low birth weight babies had more REFER rate when compared to normal weight infants. COVID-19 infection in antenatal mother can influence the outcome in 1st TEOAE tests. The pass rate in TEOAE hearing test in the screening frequency is found to be greater when compared with diagnostic frequencies. All 25 infants who were subjected to 2nd TEOAE test have passed after 3 months.

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