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Review Article

Chronological events in neonatal auditory screening - review

Manish Munjal[1]*, Vineeta Munjal[2], Vasu Bansal[1], Shubham Munjal[3]

[1]Department of Otorhinolaryngology - Head and Neck Surgery, Dayanand Medical College, Ludhiana, Punjab, India
[2]Department of Gynaecology and Obstetrics, Guru Teg Bahadur Sahib Charitable Hospital, Ludhiana, Punjab, India
[3]Department of Anatomy, Dayanand Medical College, Ludhiana, Punjab, India

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***Correspondence:**
Dr. Manish Munjal,
E-mail: manishmunjal30@gmail.com

ABSTRACT

Neonatal screening for auditory impairment necessitates a meticulous and exhaustive work to detect at an early age this deficit and thereby plan an appropriate rehabilitative modality test, the speech maybe effected.

Keywords: Auro-palpebral reflexes, Narrowband, Neonate, Otoacoustic emission, Pure tone, Screening

INTRODUCTION

Efforts to evaluate auditory functions in human neonate span, a 50 years period and encompass a variety of approaches, ranging from kymographic records of responses to uncalibrated stimuli to clinical screening with carefully calibrated stimuli and electrocardiographic measurements.[1-4]

REVIEW OF LITERATURE

Many of the early reports are contradictory or ambiguous and little definitive information is found in the more recent literature.[5] All of these studies indicate that the human neonates respond to a large number of auditory stimuli. None of them demonstrates conclusively that such factors as signal variables or age exert differential effects upon the pattern of responses. Measurement of change in respiratory rate during tonal stimulation was utilized as a measure to assess ability to hear.[6,7] In 1953 on the initiative of Hildu Nygren, the Minister of Education, a preliminary examination for a government enquiry was made if the hearing of 150 new-borns aged 1-7 days at the ear clinic and laboratory of audiology of Karolinska Sjukhuset. The stimulus was a cow-bell, held at half meter from the infant's ear. This gave rise to a sound spectrum with a peak at about 750 c/s and with a peak level of 125 dB. 149 neonates reacted with auro-palpebral reflex, 1 did not react. Wedenberg determined thresholds for auro-palpebral reflex and the levels necessary for wakening in 20 normal neonates age 1 to 10 days.[8] Auro-palpebral reflexes (APR) were elicited at 105 to 115 dB for tones 500, 1000, 1500, 2000, and 4000 Hz.

In a follow up study, it was concluded that an infant may have normal hearing if he responds to a tone of 105 to 115 dB or is awakened by a tone of 70 to 75 dB or less.[2] A cochlear problem with recruitment may be suspected if the child gives an APR to 105 to 115 dB, but requires greater than 75 dB to be awakened. A conductive or retro cochlear disorder may be present if the child gives an APR to 205 to 115 dB, but required greater than 75 dB intensity to be awakened. A conductive or retro cochlear disorder may be present if the child gives no APR to 105 to 115 dB level but is awakened by sound intensity greater than 70-75 dB. Wedenberg suggested high frequency signals as these are most effective in identifying congenital hearing losses. Buzzers set over a crib were used to determine the age at which normal infants over 26 week of age can localize sounds.[9] Murphy found that before 22 weeks of age the infant shows pure horizontal rotation in the general direction of the sound source. At 22 weeks a vertical

component is added. ARC movement begins at 26 weeks and true diagonal movement after 32 weeks of age.

Bartoshuk elicited cardiac acceleration in response to intense auditory signal. Beadle and Crowell in 1962 reported changes in pulse rate in one normal neonate following auditory stimulation, but with no consistent correlation of acceleration or de-acceleration with either frequency or intensity change. Bartoshuk obtained larger increases in heart rate for stimuli of successfully greater intensity. Steinschneider, Lipton and Richmond reported increase of heart rate and decrease in latency of responses with intensity increase. These studies used relatively intense sounds and some used broad band signals.[10,11]

Screening of the new born in the hospital nursery was popularised using trained volunteers as examiners under the supervision of an audiologist.[12] Downs and Hemmenway at the University of Colorado Medical genre conducted neonatal screening of 17000.[13] The acoustic signal was a high frequency 3000 Hz warble tone or band of noise with available outputs of 70, 80, 90 and 100 dB when the instrument was held at a standard distance from the infant ear 4-10.[14] Responses sought were APR, other face or head movements, startle reflex and other body movements were found deaf. 2 other babies were later identified as deaf, who had not been screened because they had left the hospital too soon. Incidence of deaf babies was 1 to 1000.[15] False positive rate was 3%, that is these neonates failed the screening but had normal hearing which was verified subsequently. One false negative was who passed the screening were later found to have hearing loss. 8 of the infants were "high risk" for deafness. The mean signal intensity was 78 dB depending on environment noise. Field, Copsk, Derbyshire, Driessen, and Marcus screened 45 neonates for responses to auditory stimulation. Three groups of neonates were studied: premature born at less than 2500 gm weight; "well born" babies suffering from diagnosable diseases as blood dyscrasias, cardiac disorders, born of diabetic mothers; and normal new born having no illness.

The stimulus was a narrow band noise centered at 3 kc/s and a broad band noise which produced maximum energy in the 2 kc/s octave band. Each child was given 5 stimuli of 1-2 sec duration 30 second apart. It was found that mean of 4 out of 2 responses to 5 stimulus presentations was the probable event in a responsive child on a particular testing day. Normal new-borns showed no difference in the number of responses to noise of 70 or 90 dB sound pressure level (SPL). Nor was there any difference from the number of responses given by premature and well babies to 90 dB SPL However the premature and well babies showed significantly less responses to 70 dB stimuli. Habituation appeared to be present, but not marked. Observer agreement as to whether a response was present or absent was shown to depend in part on the method of recording responses.[14]

Mendel studied the response of 30 well babies infants ranging in age from 4-11 months, the sound stimulus used were: white noise between 200 and 12000 Hz with an overall SPL of 64 dB; same band of noise interrupted twice/sec); crinkling of onion skin paper with energy between 200-9000 Hz with a mean value of 64 dB SPL; narrow band noise entered at 3000 Hz and presented at 665 dB SPL; and warbled noise centered at 3000 Hz at 69 dB SPL.[15] Each stimulus had duration of 5 seconds with an inter stimulus interval for 5 sec and placed at a distance of 1 meter from the infant. With loudness and duration of the stimuli held constant, more responses occurred to broad band spectrum then to those of a limited band width. Temporal configuration of the sound had no effect on the number of responses elicited. Result from this study tend to support neither white noise nor the crinkling of onion skin paper.

In an infant screening programme, Heron and Jacobs screened 150 healthy neonates with modern portable audiometer. Each ear was tested separately and originally pure tone frequencies tested were 500, 1000, 2000, 4000: these were given at 60 dB and 90 dB to each ear for approximately five seconds continuously. The ear phone was placed 2-3 inches from the ear being tested. Subsequently they found that more consistent responses were apparent when using two frequencies exhibited alternately and continuously for 5 sec that is - 250 and 500 Hz; 1000 and 2000 Hz; and 4000 and 8000 Hz. These being produced at 40, 60, and 90 dB. These were given only when quite respiration had been apparent for a reasonable length of time. They recorded either increased or decreased respiration bore no relationship to intensity or frequency of the stimulus and was associated with a huge change in pattern at the end of stimulus. In 80% (120) neonates recognizable changes were for all frequencies and intensities, in 10 (6.75%) cases some of the intensities even at 40 dB showed no responses. In 15 babies (10%) tracing was not obtained due to irritability of the child. The pattern of respiration was so irregular in 5 babies (3.25%) when deeply asleep and without stimulation, that it was difficult to assess these results; this appeared during the first 6 days. They thus concluded that the response was best even from 7 to 14 days.[16]

The commonest response so far was a type of gasp, occurring 1-3 respiration after cessation of stimuli. The response could be elicited repeatedly. Hoverstatin and Moncur studied the stimuli and intensity factor in infants. Subjects were 21 three month old and 22 eight month old infants. The five test stimuli were: interrupted broad band white noise; interrupted 500 Hz pure tones; interrupted 4000 Hz pure tones; voice and music. All stimuli were taped for presentation and all were of three sec in duration, speaker placed 4 inches from the infant. Behavioural changes of infants were recorded. The average threshold was 43 dB for the 3 month old infants and 34 dB hearing loss (HL) for the eight month old infants. Percentages of responses increased with increased hearing level. Voice generally resulted in the largest percentage of responses for both age group at each hearing level. The three month old often gave fewer responses than the 8 month old infant at a comparable hearing level.[17]

Redell and Calvert studied the factors in screening hearing of new-born. 3200 neonates were screened. The stimulus used were: the vicon "aprition", a case and separate speaker, recommended by the manufacturer to be placed 4 inches from the ear (broad band and 3 kc/s setting); H. C. electronics "infant audiometer" entered at 3 kc/s, set at 70, 80, 90, and 100 dB SPL, the speaker to be held 6" from the ear; zenith "neometer" a model providing a tones modulated between 2750-3200 c/s, set at 70, 80, 90, and100 dB SPL, to be placed 12" from the ear; and tracor "warblet" providing a tone of 3 kc/s to be placed 9-10" from the ear. They concluded that the most common response was body movement and next most common was cessation of activity, others were change in respiration, crying, and startle. Most responses occurred even when infants were sleeping lightly. Crying was the next best condition; third best were infants who were awake at the time of testing. Deep sleep was less satisfactory and the infants who were moving responded least of all. Broad band noise stimulant was more efficient in eliciting responses than high frequency (3 kc/s) warbled tone. Neonates may be observed "covered" as well as bare.[18]

Ling and co-workers in 1970 studied behavioral responses of 144 healthy neonates, 71 male and 73 female, aged 1-6 days to actual and simulated presentations of three different high frequency sounds of 85 dB. Stimuli were a narrow band noise entered at 2000 Hz, 3150 Hz and a pure tone increasing and decreasing in frequency between 2000-4000 Hz. A masking noise which prevented knowledge of stimulus event was presented to one member of each observer pair. Testing was undertaken only if the child was in a state of irregular sleep, drowsiness or quite waking (alert in-actively). The duration of each stimulus presentation was approximately 3 sec. Inter stimulus interval varied from 30-60 sec. Results indicated that an observer's judgement of infant behaviour may be significantly influenced by knowledge of stimulus events. More responses were observed with narrow band noise entered at 200 Hz. The most frequently observed responses were strong whole body movements. A decrement in response strength tended to occur with repeated stimulation. Neither positive nor false positive responses were related to sex, gestation period, birth weight, age at test or body temperatures.[19]

Bench and Bosack 1970, Down 1972, and Feinmesser and Tell 1972, stated that the result of mass screening programme of neonates was inconsistent and misleading. All the severe losses were detected by the screening but some the mild and moderate losses were missed.[20,21]

Routine hearing screening of total population of neonates is cumbersome and requires a huge effort, therefore limiting the testing of the infant population at greater risk is more feasible A vast majority of hearing impaired children fall into five categories of high risk recommended by a national join committee on infant hearing screening composed of representatives of the American Academy of Pediatrics, The American Academy of Otolaryngology and American Speech; and Hearing Association suggested the categories; as those, neonates with a history of hereditary childhood hearing impairment due to rubella or other non-bacterial intrauterine fatal infection such as cytomegalovirus or herpes infection; birth weight less than 1500 gm; exposed to any free or indirect serum bilirubin concentration judged to be potentially neurotic. Additional categories are - neonatal meningitis, fetal diseases, difficult delivery, respiratory distress syndrome, ototoxic drugs, and a low Apgar score (6 or less in 5 minutes).

Feinmesser and Tall, 1972 reported on the screening of 17708 neonates.[21] 5 hearing impaired children were detected. On follow up 4 additional children with hearing deficit were found. The sound stimulus was a high frequency 3000 Hz warble tone or band of noise with available output of 70, 80, 90 and 100 dB SPL. Responses sought were auro-palpebral, and face or head movement. Thomson and Those, 1972 recorded the responses of 45 well baby infants and children. The stimuli used were: broad band noise speech, high pass filtered noise, high pass filtered speech and 3000 Hz. Each of the five test stimuli was presented twice at 15, 30, 45, and 60 dB. Inter stimulus interval was 10 sec and stimulus duration was 2 sec. The infants 7-12 months were tested with a behavioral observation test method. The young children (22-36 months) were tested by either conditioned orientation reflex audiometry or play audiometric test methods, young children responded more frequently than infants, but regardless of age, both groups responded more frequently as the hearing level increased. In the infant group, the speech and high pass filtered speech produced the most responses (80%) and 3 kHz the least responses (30%). In contrast, the stimulus effect was negligible in young children. Children in the play audiometry group gave a significantly greater number of response than those in conditioned orientation reflex group. The result suggested that in young children, pure tones were as effective as complex stimuli in determining hearing threshold. In infants tested by behavioral observation methods, complex stimuli were better than pure tones.[22]

Mencher in University of Nebraska screened 10000 neonates and did a follow up of 2 years. The stimuli used were tones, with noise, narrow band noise. Pre-stimulus state of baby was recorded (light or deep sleep, awake and quiet etc.).[22] The type and intensity of responses were recorded. 8 babies had confirmed auditory impairment, 3 were highly suspicious, awaiting confirmation or denial of hearing loss, 2 false negative were found. One had sensorineural loss of 50 dB with a family history highly suggestive of congenital origin. The other had normal end organ function but had central hearing deficit. The study concluded that neonates in light sleep were more likely to respond to auditory stimuli than those in any other state particularly when narrow band noise was the stimulus; use of broad band signals as it sensitizes to alert the child to a narrow band or warble tone following, did not work to increase either the number or intensity of responses. Five of the 9 children with confined impairments were had high risk factors. Children tested in sleep state and identified as totally deaf, not one had responded with an arousal

response. Apparently, children with a loss of 75 dB or less in speech range will respond to the arousal test. Those with a loss greater than 75 will not. The results concluded that high risk register, coupled with the use of arousal response in mass hearing screening will result in optional identification procedures, and recommended its implementation in that combination on a large-scale experimental basis.

Simmons et al described an automated screening system cribogram that functions effectively and economically. The test depends on recording movements on presentation of acoustic stimuli. A movement sensitive transducer was involved in the crib under the babies shoulder so that it can pick up the infants body movements. The output of movement sensitive transducer was amplified by an amplifier and the amplified signals were recorded on a moving strip for appropriate length of time before and after presentation of the stimulus. The cribogram has several advantages over conventional screening tests; like deception of acoustic response is objective and not subjective, no highly trained personnel are required in any phase of the procedure and since retesting is automatic no one is required to work nights, weekends to holidays. Moreover the data analysis is rapid and accurate and can be done by anyone after a few practical sessions.[23]

Simmons published a study on hearing screening for 6000 neonates with follow through and 6 months pre-screen with automated cribogram. A 20% positive response rate was required to pass the hearing screening or if two definite startle or arousal responses were present within 2 sec after the test sound (strongly positive) or weakly positive (within 4 sec). The average response rate for who passed was 38% and average response rate for babies who failed testing was 12%. They detected 12 babies with hearing loss. This is an incidence of 1:624 in well baby nursery and 1:86 in intensive care units (ICUs). They found that the early morning hour were found to be best for hearing testing and test accuracy was best when a baby was in regular or light sleep status. The most effective sound was 2- 4 kHz band of noise and a tone which swept rapidly upwards from 2 to 4 kHz in about 50 milli sec. The noise band produced 44% and the sweep tone 28% positive responses. The narrow band noise was also superior to broad band (32% positive responses) and to speech (28%).[24]

Simmons et al published a study on hearing screening of 11182 neonates with follow through and 7 months pre-screen with automated cribogram. They detected 34 babies with hearing loss of 45 dB or more. This was an incidence of 1.62 from the ICU and 1:819 from well-baby nursery. The rate for all new-borns was 1:329. The false positive rate varied around 8% for well babies and 20% for ICU. The well-baby nursery the test stimulus was 92 dB narrow band noise (2000-40000 Hz) produced by ceiling mounted loud speaker and in intensive care by a loud speaker placed at the foot of the baby's crib. Real response decreased at 2.6 sec after the sound begins. A 10% positive response rate was required to pass the hearing screening.[25]

Bennet used auditory response cradle to record neonatal head turn and startle responses. 203 neonates were studies. The stimulus used were 250 Hz pure tone 90 dB SPL, 1000 Hz pure tone 90 dB SPL, and broad band noise 90 dB SPL. No sound control, the stimulus period used was 5 sec, clear head turn and startle responses were obtained after the use of the sound.[26] The frequency of occurrence was highest for the noise, no response attributable to stimulus off were detected. The response rate for head turn was found to be unaltered by the initial head position but babies lying to the right, generally turned to the right and vice versa irrespective of the side from which the sound was presented. The response latency varied with stimulus. The mean broad noise and 1000 Hz pure tone values were 1.7 and 1.9 sec respectively while the 250 Hz results were similar to the 2.4 sec of controls.[26]

In today's era hearing evaluation in neonates and infants is undertaken utilizing the objective tests, namely the Kemp's otoacoustic emission (OAE) test which detects reflected sounds by the stimulation of the cochlear cells and the automated auditory brainstem response (ABR) which detects the average response of a neuron in response to varied frequency repeated auditory signals. These two hearing assessments are either undertaken individually or sequentially, OAE followed by the ABR i.e. in a two-stage manner. However, the otoacoustic signals often are not affected in patients with auditory nerve dysfunction, even though the ABR signal show an abnormal response. Implying thereby that if OAE is undertaken only as a confirmatory second-stage test, changes in the ABR alone may not be picked up.

DISCUSSION

New-borns should be screened for their acuity of hearing test one might miss a severe-to-profound hearing loss. The renowned audiologist Marion Downs emphasized after her lifelong exhaustive studies. In 1964 she reported the incidence of type of auditory loss to be 1 in 1,000 in infants. A program of universal screening of new-born infants for hearing loss has been developed globally. New-born hearing screening programmes exist in many countries, including the United States, United Kingdom, New Zealand and the majority of countries making up the European Union.[27-30] The early development of cerebral communication pathways is fundamental to this improvement, whether by speech, sign language, or both. An early comprehensive ability and using of spoken or signed, and written, language, is vital to appropriate development of the language, auditory and speech areas of the brain.

Screening segregation is divided into two groups. A high index group with possibility of a permanent congenital hearing loss and the low index group and likely to have a reversible temporary hearing loss. The first group subjects are referred for diagnostic testing and rehabilitative procedures, hearing aids and cochlear implants as the case maybe.[31] The second group is amenable to medications for fluid in the middle ear being the commonest cause of

hearing impairment or for surgical intervention for reconstruction of the conduction pathway of hearing, namely the ear canal and the tympano ossicular system.

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