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Review articles

Auditory Brainstem Response with chirp stimuli in newborns: an integrative review

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ABSTRACT

Purpose: to review the literature available on electrophysiological findings on ABR with chirp stimuli in newborns.

Methods: articles were searched in PubMed, MEDLINE, Scopus, Web of Science, LILACS, and SciELO. Papers published in English and Portuguese between 2010 and 2020 were selected, including those that addressed ABR with air-conduction broadband chirp stimuli in newborns, that assessed ABR with a specific frequency, and that compared ABR results with chirp and click stimuli. Articles that assessed only bone-conduction results, duplicates, literature reviews, case reports, letters, and editorials were excluded.

Literature review: the search strategy resulted in nine selected articles. Four studies (44.4%) analyzed ABR wave amplitude and latency with chirp stimuli, three studies (33.3%) compared the time of ABR procedures between chirp and click stimuli, two studies (22.2%) analyzed only amplitude, and two (22.2%), verified the specificity of ABR with chirp stimuli in neonatal hearing screening.

Conclusion: chirp stimuli elicit responses with greater amplitudes, lower latencies, and shorter examination time than those with click stimuli in newborns.

Keywords: Infant, Newborn; Auditory Evoked Potentials; Brain Stem

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INTRODUCTION

The auditory brainstem response (ABR) is an examination routinely present in auditory diagnosis and screening services. Its purpose is to verify the integrity of the auditory pathway from the inner ear to the brainstem[1].

ABR is used in auditory diagnosis to verify possible retrocochlear changes, the maturation of the central auditory system in younger children, the type of hearing loss, and the electrophysiological hearing threshold[1]. This procedure consists of two sweeps (usually at 80 dBnHL), which verify the presence of three main waves (I, III, and V), tracing reproducibility, absolute latencies, interpeak intervals between waves, and the interaural difference between them[1].

Automated ABR (AABR), in its turn, is used in neonatal hearing screening (NHS), as it has a lower cost than ABR[2-4]. This procedure is widely used to screen newborns with risk indicators for hearing loss (RIHL)[5] because it can rule out retrocochlear changes and verify whether electrophysiological hearing thresholds are normal for this population. This procedure uses two sweeps at 35 or 40 dBnHL to verify whether the V wave is present.

The click stimuli are the most used in both ABR and AABR. However, due to click stimulation characteristics and cochlear tonotopy, the stimuli arrive in high-frequency regions before the low-frequency ones[6,7]. Neuronal fibers are stimulated at different moments, decreasing the neuronal synchrony necessary to evoke ABR[6]. Hence, the chirp stimuli were developed to obtain more synchronous responses, as they simultaneously stimulate all regions of the cochlea by delaying high-frequency stimulus presentation[6,7].

Considering that chirp stimuli ensure better auditory synchrony in ABR and were recently included in equipment for clinical practice, this study aimed at reviewing the literature available on ABR electrophysiological findings with chirp stimuli in newborns.

METHODS

Research strategy

This integrative review followed the recommendations of a national study[8] and was based on the following research question: “What are the ABR results with chirp stimuli concerning procedure parameters and in comparison with click stimuli in newborns?”.

The study was conducted between March and August 2022. The descriptors were chosen from the Medical Subject Headings (MeSH) and Health Science Descriptors (DeCS), which are used to index, catalog, and research biomedical and health information. The descriptors Infant, Newborn, Hearing Evoked Potential, Auditory, and Brainstem were used in combination with the Boolean operator AND to survey PubMed, MEDLINE, Scopus, Web of Science, LILACS, and SciELO.

Selection criteria

The article inclusion criteria were as follows: original articles published between 2010 and 2022, in English and Portuguese, in peer-reviewed scientific journals, addressing ABR use with air-conduction broadband chirp stimuli in newborns. After analyzing the selected articles, the ones that did not study ABR with chirp stimuli, that assessed ABR at specific frequencies, or that assessed only bone-conduction results were excluded.

Data analysis

The articles were firstly selected based on predefined descriptors, and then their title and abstracts were read. Duplicate articles were removed. Afterward, the articles were read in full text, and the following data of the studies were tabulated: title, country of origin, year of publication, objectives, study design, sample, and results.

LITERATURE REVIEW

Initially, 471 studies were found with selected descriptors, of which 406 were excluded for addressing only click-stimulus ABR, and another three were excluded for addressing steady-state and tone-burst ABR. Of the remaining 62 studies, 49 were duplicates, leaving 13 – of which, only nine were included after reading their full texts, as shown in Figure 1.

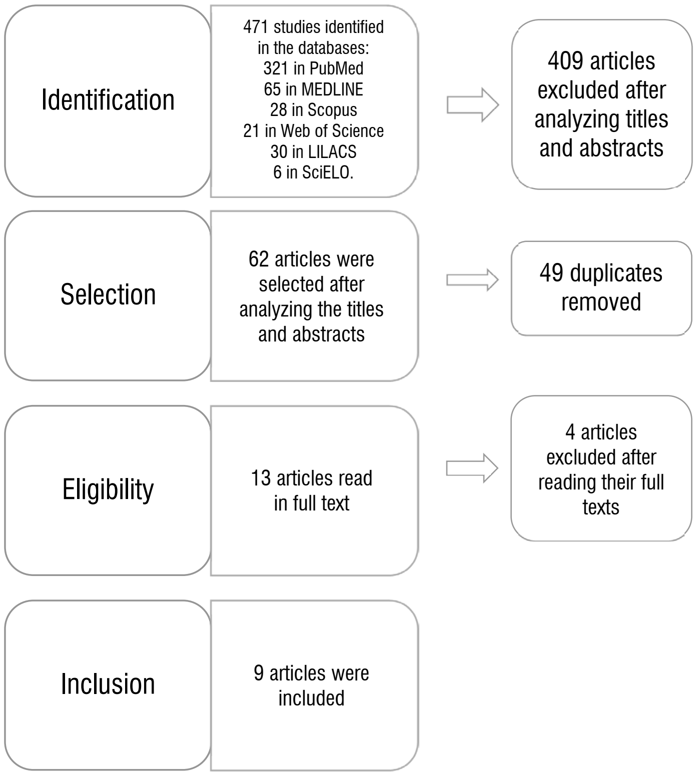

Figure 1. Article selection flowchart

Chart 1 summarizes the data obtained after reading the articles.

The nine selected studies were published in English and/or Portuguese – three were conducted in the United States[9-11] (33.3%), three in Germany[12-14](33.3%), and three in Brazil (33.3%)[15-17].

Regarding the study design, the nine papers are retrospective studies (100%)[9-17].

At the time of the studies, the participants' gestational ages ranged from 37 to 42 weeks[9], 35 to 41 weeks[13], 36 to 40 weeks[11], and 38 to 40 weeks[17]. Three studies (33.3%) did not consider the gestational age[14-16] but assessed newborns up to 48 hours old in the first stage of the study and, in the second stage, 6 to 8 weeks old[14], 18 to 27 days old[15], and 1 to 29 days old[16]. One article (11.1%) studied babies up to 48 months old[12], while another (11.1%) studied newborns 35 to 41 weeks old and adults 20 to 31 years old[10].

Six (66.7%) studies were conducted in newborns with no RIHL[9-11,13,15,16]; two (22.2%) studies addressed newborns without hearing loss but did not specify whether newborns with RIHL were included in the sample[12,14], and one (11.1%) study approached newborns with and without RIHL[17].

The most used ABR equipment in the studies was the GSI Audera (software v. 2.7)[9-11] (33.3%), followed by MB11 BERAPhone[13,14] (22.2%), Eclipse, manufactured by Interacoustics[12,17] (22.2%), Titan[15], also by interacoustics (11.1%), and Smart-EP, manufactured by Intelligent Hearing Systems[16] (11.1%).

Four studies (44.4%) analyzed the response amplitude and latency in ABR waves with chirp stimuli[9-11,14]; three studies (33.3%) compared ABR procedure time with click and chirp stimuli[11,14,15]; two studies (22.2%) analyzed only the amplitude[11,12]; and two studies (22.2%) verified the specificity of ABR with chirp stimuli in NHS[13,17].

Seven studies (77.8%) compared air-conduction click and chirp stimuli[9-12,15,17] at 30, 45, and 60 dBnHL[9,10]; 80 dBnHL and electrophysiological hearing threshold[12,17]; 35 dBnHL[11,15]; 60 and 40 dBnHL[14]; and 30 and 35 dBnHL[17]. One study (11.1%) compared chirp stimuli between the sexes[16].

The stimulation rates used in ABR procedures with chirp stimuli ranged considerably: 40/s[12]; 90/s[13]; 20.3/s[14]; 57.7/s[11]; 8.7/s, 27.7/s, 57.7/s and 77.7/s[9,10], 93/s[15], and 27.7/s[16].

Five articles (55.6%) did not report stimulus polarity in the research methods[11-15]. Two studies (22.2%) compared alternating, rarefaction, and condensation polarity at 60 dBnHL[9,10], while another two studies (22.2%) used alternating polarity[16,17].

Chart 1. Data obtained from the selected articles

Authors (Year)	Design	Sample	Main findings
Cebulla et al.[13] (2012)	Cross-sectional study	6,866 newborns without RIHL up to 48 hours after birth, in the first stage, and 6 to 8 weeks old in the second stage	6,607 (96.2%) screened newborns "passed" the hearing screening before hospital discharge, using MB11 BERAphone1. Of the 259 newborns referred for a retest, 188 did not "pass", and 47 had hearing loss confirmed with diagnosis. The specificity of the device used in the study was 97.9%.
Muhler et al.[12] (2013)	Cross-sectional study	46 children up to 48 months old	The mean V-wave amplitudes elicited with chirp stimuli were much greater than with click stimuli, almost reaching adult values among older participants. Using chirp stimuli is indicated to research electrophysiological thresholds because they are more reliable and can be measured on higher levels of residual EEG noise than the click stimuli.
Cebulla et al.[14] (2014)	Cross-sectional study	96 normal-hearing newborns less than 5 days old	Chirp ABR differ from click ABR in that they have significantly greater ABR responses. The chirp stimuli are expected to produce more reliable results and especially shorter measuring times, leading to greater quality of hearing screening and hearing threshold assessments.
Stuart et al.[11] (2014)	Cross-sectional study	23 healthy newborns with gestational ages between 36 and 40 weeks	Using chirp stimuli in neonatal hearing screening can significantly improve ABR response amplitude and decrease the examination time. The loss in examination sensitivity may be a disadvantage of using chirp stimuli in ABR neonatal screening. Further studies with chirp stimuli to assess newborns are needed.
Almeida et al.[17] (2014)	Cross-sectional study	40 newborns with and without RIHL	AABR with CE-chirp stimuli has greater specificity and fewer false-positive cases than with click stimuli at 30 dBnHL and 35 dBnHL and shorter response detection time.
Cobb et al.[9] (2016)	Cross-sectional study	168 newborns without RIHL	In general, ABR V-wave amplitudes with air-conduction CE-chirp stimuli were significantly greater ($p < 0.05$) than with click stimuli. There were statistically significant systematic differences ($p < 0.05$).
Cobb et al.[10] (2016)	Cross-sectional study	168 healthy newborns and 20 normal-hearing adults	There are significant differences in ABR latencies and amplitudes between newborns and young adults using CE-chirp stimuli. These differences are consistent with click-stimuli differences and reflect age-related maturational differences. These findings further emphasize the importance of interpreting ABR results with normative data according to age.
Lopes et al.[15] (2020)	Cross-sectional study	46 newborns without RIHL	The mean time of the AABR procedure with CE-chirp stimuli is three times shorter than with click stimuli.
Ferreira et al.[16] (2020)	Cross-sectional study	30 full-term newborns without RIHL	ABR V wave in newborns is not influenced by their sex when broadband Ichirp stimuli are used.

Caption: RIHL: risk indicators for hearing loss

The objective of this article was to review the available literature on electrophysiological findings on ABR with chirp stimuli in newborns. Cross-sectional studies predominated in the researched literature[9-17], which indicates the relevance of such study design to investigate the topic addressed in this review.

Considering the studies that classified the sample in such terms, the gestational age ranged from 35 to 42 weeks[9-11,13,17]. Although some studies included premature newborns in their analyses[10,11,13], the results were not compared between premature and full-term newborns. Also, there were no analyses of response parameters related to research participants' corrected ages.

Most research was conducted in newborns without RIHL[9-16], whereas only one study included newborns in these conditions[17]. Even though it included such children, the results were not compared between newborns with and without RIHL.

The studies on ABR with chirp stimuli in newborns demonstrated the advantages of using these stimuli in comparison with the click stimuli[9-13,15], verifying greater wave amplitudes[9,11-13]. A study verified that the intensity can influence the difference between amplitudes – which is sharper at lower intensities since at 40 dBnHL the difference in amplitudes between click and chirp stimuli was greater than at 60 dBnHL[11]. ABR procedures with chirp stimuli were also faster than with click stimuli[11,14,15], even three times faster[15]. These parameters were better regardless of stimulus intensity and stimulation rate.

In the research conducted by Cobb (2016), which used various stimulation rates (8.7, 27.7, 57.7, and 77.7/s), the V-wave mean amplitude was significantly greater with chirp than click stimuli in all presentations[9].

The literature diverges regarding wave latency comparisons between click and chirp stimuli. A paper verified lower wave latencies using chirp stimuli in comparison with click stimuli at 60 and 40 dBnHL and 20.3/s rate[14]. Another study verified greater latencies[9] with chirp stimuli at 30, 45, and 60 dBnHL and 57.7/s rate with alternating polarity; this difference decreased at 60 dBnHL. Yet another study also found greater latency with chirp stimuli at 35 dBnHL[11].

Regarding amplitude and latency values with chirp stimuli, no statistically significant difference was found between male and female newborns[16]. This did not occur in newborns submitted to click ABR, as there were greater amplitudes at 20 dBnHL and lower latencies at 60 and 40 dBnHL in females than in males[16]. Also, no difference was found between the sexes in the response detection time with chirp stimuli[15].

Some studies did not verify statistically significant differences in the response detection time with chirp stimuli between the ears[15,16]. The response detection time in the first study was greater in the left ear, using either chirp or click stimuli[17]. The second study explains that the external/middle ear condition in the study population may have influenced such a difference[17].

It was found that, in NHS, chirp ABR requires fewer stimuli to elicit the "pass" response than with click stimuli[11]. Moreover, NHS specificity with chirp stimuli was 97%[13] – a higher index than with click stimuli[17]. Chirp ABR, as well as click ABR, is influenced by auditory maturation as well, with smaller latencies and greater amplitudes in older children[12] and adults[10].

Regarding the polarity used, one study[9] concluded that CE-chirp generates greater V-wave amplitudes, regardless of stimulus polarity.

CONCLUSION

Chirp stimuli elicit responses with greater amplitudes, lower latencies, and shorter examination times than click stimuli in this population. Nonetheless, the researched literature lacks findings about chirp ABR regarding various conditions of newborns, such as RIHL, prematurity, and V-wave response patterns per age on the date of the examination. Hence, further studies on the topic are needed.

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