Reliability of Auditory Steady-State Response (ASSR): Comparing Thresholds of Auditory Steady-State Response (ASSR) with Auditory Brainstem Response (ABR) in Children with Severe Hearing Loss

Tolga Kandogan · Abdullah Dalgic

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Abstract In this study, ABR and ASSR thresholds in children with severe hearing loss have been compared and the advantages and disadvantages of these methods discussed. Twenty children, nine female and 11 males, aged between 19 and 41 months were included to this study. All the children underwent otoscopy and ABR before the measurement of ASSR thresholds. ABR and ASSR threshold measurements were performed by different physicians. Each child was asleep with chloralhydrate (0.5 g/kg) during the test. The hearing thresholds in ABR correlated well with the threshold obtained with ASSR. In addition; in patients, where the thresholds for ABR were not measurable, it could be found in ASSR tests. If there is not any residual hearing for subjects, both tests resulted with no response. Based on these findings, both ABR and ASSR techniques may be used to provide an estimate of hearing sensitivity in children, but ASSR is a more valuable test than ABR, especially for cochlear implant candidates.

Keywords ABR · ASSR · Cochlear implantation

Introduction

Age guidelines have been reevaluated often since the introduction of cochlear implants into clinical practice in the 1970s. Patient age limits have been reduced to less than 12 months for devices undergoing clinical trials around the world. The trend of earlier device insertion may continue as the benefits of early implantation become increasingly

clear [1]. So, early diagnosis of hearing loss in children and providing hearing devices helps to develop speech, language, and listening skills needed for oral communication. Because of this reason, early detection of a possible hearing loss in children is crucial.

The reduction of minimum cochlear implantation (CI) age has increased the numbers of subjects requiring objective audiometry to determine cochlear implant candidacy.

There are several methods of hearing level measurement for children.

ABR is considered an objective electrophysiological measure and has been used to provide information about auditory sensitivity in patients who are either too young or who are functioning at a developmental level at which are reliable behavioral response measurements are not possible [2]. It allows assessment for those who are sleeping or sedated or for newborns.

Auditory steady-state response (ASSR) has been suggested as a tool for hearing assessment for children [3, 4]. Auditory steady-state responses are scalp-recorded potentials elicited in response to sinusoidal amplitude and/or frequency-modulated tones [5–9]. The response is periodic or continuous and phase-locked to the modulation envelope. As with ABR, ASSR can be recorded at low levels in sleeping and sedated subjects, including infants [3, 10].

There are several reported advantages to ASSR measurements. First, the response is elicited by a modulated pure tone. Thus, the stimulus is more narrowly defined in the frequency domain, compared with gated sinusoids or clicks. However, it is important to remember that once outer hair cell damage exists (which occurs in most cases of sensory hearing loss), the extent to which narrow cochlear regions can be excited is reduced. This is probably the case for gated tone bursts in quiet, tone bursts presented with a noise maske, and even for pure tones [2]. ASSR measurements also lend themselves to automatic response detection. Such a feature is

T. Kandogan · A. Dalgic (✉)
Izmir Teaching and Research Hospital, Department of
Otolaryngology, Inonu Caddesi 404/12, 35290 Izmir, Turkey
e-mail: dalgicabdullah@gmail.com

attractive in that it avoids problems associated with the experience and expertise the observer [2].

Finally, it has been suggested that ASSR measurements have a wider dynamic range than ABR measurements. That is, because of the stimulus' long duration, higher levels can be achieved with ASSR stimuli (in units of hearing level, HL), compared with the case for the brief duration/rapid onset stimuli that are used with ABR measurements [2].

In this study, ABR and ASSR thresholds in children with severe hearing loss have been compared and the advantages and disadvantages of these methods discussed.

Materials and Methods

Totally 20 children, nine female and 11 males, aged between 19 and 41 months were included to this study. Mean age was 26 months. All the children underwent otoscopy and ABR (Amplaid MK 12[®], Amplifon, Italy) before the measurement of ASSR (GSI Audera[®], USA) thresholds (Table 1). ABR and ASSR threshold measurements were performed by different physicians. They were performed in a quiet room, where sound level is less than 50 dB. Each child was asleep with chloralhydrate (0.5 g/kg) during the test. At the time of the ABR testing, monaural rarefaction click stimuli were delivered via insert earphones. The ASSRs were evoked by means of dichotic single-frequency technique stimulating both ears simultaneously with the same carrier frequency modulated at different rates. ASSR threshold levels were determined at 0.5, 1, 2, 4 kHz. Pearson's correlation test have been used to evaluate correlation of the hearing thresholds of ABR and ASSR.

Results

The ASSR thresholds for the study group were also shown in Table 1. The hearing thresholds in ABR correlated well with the threshold obtained with ASSR (Pearson's correlation coefficient (0.231) is significant at the 0.01 level). In addition; in patients, where the thresholds for ABR were not measurable, it could be found in ASSR tests. If there is not any residual hearing for subjects, both tests resulted with no response.

Discussion

As the age of identification of hearing loss is reduced, the need for accurate objective electrophysiologic methods for determining auditory thresholds is increased, and this need may be served by multiple objective methods.

The results of this study show that ASSR thresholds can be obtained reliably at various frequencies for children

with severe to profound hearing loss. Our study has also shown that ASSR testing is superior to ABR testing for the evaluation of hearing level in young children.

Obtaining threshold information at these elevated intensities is becoming increasingly relevant in light of the reduction in age of patients undergoing CI and the inability of other electrophysiologic procedures, such as the ABR to assess residual hearing at these high intensities [11].

If the hearing aids for a child with a profound hearing loss were not set at an optimal level according to actual threshold results, the child may not have had a "true" hearing aid trial [12]. From this point of view, determining thresholds for 0.5, 1, 2, 4 kHz is very important. Furthermore, absent ASSR thresholds indicate no usable hearing, whereas absent ABR thresholds are not. Because the ASSR allows for better hearing aid fittings, resulting in true hearing aid trials, and absent ASSR thresholds predict poor hearing aid benefit, the ASSR is uniquely suited, above the ABR, to assist in the assessment of young children for CI [13]. Several researchers have reported that ASSRs may be advantageous for the estimation of hearing thresholds for children who have no responses in ABR to click stimuli [11, 14]. Since the stimulus used to record an ASSR is a continuous signal, it is possible to deliver higher average sound pressure levels (SPL) compared with those delivered with short-duration click stimuli. This suggests that ASSRs may provide a measure of residual hearing in young cochlear implant candidates by providing estimated thresholds to frequency-specific stimuli presented at high stimulus levels if needed [15]. According to our results, both ABR and ASSR techniques may be used to provide an estimate of hearing sensitivity in children. It was also shown in Table 1, that if a child has a no-response ABR, some thresholds have been obtained with ASSR. A combination of ABR and ASSR thresholds complements the evaluation of auditory sensitivity.

For young children, ASSR thresholds may provide critical information for accurate hearing aid settings. Identifying children early with accurate hearing assessment leads to earlier fitting of sensory devices, including cochlear implants, which minimizes delays in auditory, speech, and language development [15]. Time to screen hearing thresholds for both ears is about 25–30 min in ABR, which is about 40 min in ASSR. It is worth to remember that ABR is limited to 90–100 dB Maximum hearing loss versus 120 dB in ASSR.

The ability to measure ASSR thresholds in patients with absent ABR is beneficial for cochlear implant evaluations. ASSR testing provides threshold information in the 90–120 dB range of hearing loss where amplification is not beneficial. On the other hand, ABR is a test of exclusion for these children to demonstrate that hearing is worse than 90–100 dB nHL without giving the exact level of hearing [1].

Table 1 Otoscopy results and hearing thresholds of the study group, tested with ABR and ASSR, each ear

Patient number	Ear	Otoscopy	ABR thresholds (dB)	ASSR thresholds (dB) 0.5–1–2–4 kHz
1	Right	Normal	NR	95–108–125–NR
	Left	Normal	NR	105–98–107–NR
2	Right	Normal	NR	NR–NR–NR–NR
	Left	Normal	NR	NR–NR–NR–NR
3	Right	Normal	85	118–120–113–NR
	Left	Normal	85	79–83–118–NR
4	Right	Normal	NR	105–118–118–NR
	Left	Normal	NR	105–108–125–115
5	Right	Normal	NR	112–112–108–108
	Left	Normal	NR	112–112–108–68
6	Right	Normal	NR	NR–112–NR–NR
	Left	Normal	NR	NR–115–NR–NR
7	Right	Normal	NR	NR–NR–126–NR
	Left	Normal	NR	117–NR–NR–NR
8	Right	Normal	NR	98–112–112–NR
	Left	Normal	NR	118–125–118–NR
9	Right	Normal	90	112–118–118–115
	Left	Normal	100	103–112–123–NR
10	Right	Normal	90	90–NR–NR–NR
	Left	Normal	90	118–NR–NR–NR
11	Right	Normal	NR	NR–112–123–NR
	Left	Normal	NR	NR–NR–125–NR
12	Right	Normal	80	99–108–102–88
	Left	Normal	90	105–95–90–88
13	Right	Normal	NR	NR–NR–NR–NR
	Left	Normal	NR	92–108–125–NR
14	Right	Normal	80	82–NR–NR–NR
	Left	Normal	NR	75–78–84–78
15	Right	Normal	NR	NR–NR–NR–NR
	Left	Normal	NR	NR–NR–NR–NR
16	Right	Normal	100	105–NR–NR–NR
	Left	Normal	100	100–125–108–NR
17	Right	Normal	NR	NR–NR–NR–NR
	Left	Normal	NR	NR–NR–NR–NR
18	Right	Normal	NR	NR–112–118–118
	Left	Normal	NR	NR–113–125–NR
19	Right	Normal	NR	98–88–96–87
	Left	Normal	NR	87–96–72–75
20	Right	Normal	90	118–112–118–NR
	Left	Normal	90	112–112–113–NR

NR no response

Conclusion

Based on these findings, both ABR and ASSR techniques may be used to provide an estimate of hearing sensitivity in children, but ASSR is a more valuable test than ABR.

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