



Effect of General Anesthesia on Auditory Brainstem Response Testing

Genel Anestezinin İşitsel Beyinsapı Cevap Testine Etkisi

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ABSTRACT

Objective: The auditory brainstem response (ABR) test is usually applied during natural sleep, but it can also be conducted under anesthesia. This retrospective study aimed to compare the ABR findings of a general anesthesia group and a control group that underwent ABR test during natural sleep.

Methods: The anesthesia group consisted of 42 (mean age 44.5±20.3 months) children, and the control group included 58 children (36.1±16.1 months). The results of the click ABR test of the two groups were compared in terms of amplitude, latency, interpeak latencies, and hearing thresholds.

Results: The amplitudes of waves III and V were significantly decreased in the general anesthesia group compared with that in the control group. The ABR latencies of waves I and V and the interpeak latencies for I-V and III-V were prolonged in the anesthesia group compared with that in the control group. Moreover, the click threshold obtained in the anesthesia group was significantly higher than those of the control group.

Conclusions: Clinicians and audiologists should advise families to know the effects of general anesthesia on ABR and be cautious in interpreting the results obtained in ABR test performed under anesthesia.

Keywords: Auditory brainstem response, general anesthesia, hearing evaluation

ÖZ

Amaç: İşitsel beyinsapı cevap (ABR) testi genellikle doğal uyku sırasında uygulanırsa da anestezi altında da yapılabilir. Bu retrospektif çalışmanın amacı, genel anestezi grubu ile doğal uykuda ABR testi uygulanan kontrol grubunu ABR test bulguları açısından karşılaştırmaktır.

Yöntemler: Anestezi grubu 42 (yaş ortalaması 44,5±20,3 ay) ve kontrol grubu 58 (yaş ortalaması 36,1±16,1 ay) çocuktan oluşmaktaydı. İki grubun klik ABR test sonuçları amplitüd, latans, dalgalar arası latans ve işitme eşikleri açısından karşılaştırıldı.

Bulgular: Genel anestezi grubunda, III ve V. dalganın amplitüdü kontrol grubuna göre anlamlı olarak azaldı. Genel anestezi grubunda, I. ve V. dalgaların latansları, I-V ve III-V dalgalar arası latanslarında kontrol grubuna göre uzama gözlemlendi. Ayrıca genel anestezi grubunda elde edilen klik eşiği kontrol grubuna göre anlamlı olarak daha yüksek elde edildi.

Sonuçlar: Klinisyenler ve odyologlar, ailelere genel anestezinin ABR üzerindeki etkilerini bilmesini tavsiye etmeli ve anestezi ABR ile elde edilen sonuçları yorumlarken dikkatli olmalıdır.

Anahtar kelimeler: İşitsel beyinsapı cevapları, genel anestezi, işitme değerlendirme

INTRODUCTION

Pure-tone audiometry is the gold standard for describing hearing loss in patients who are responsive and cooperative¹. However, pure-tone audiometry may not always provide reliable results. Especially, in pediatric patients, reliability decreases because of the inability to cooperate for the test or the presence of mental problems. In these cases, it is more appropriate to use

the auditory brainstem response (ABR) test, which is one of the electrophysiological tests.

The ABR test evaluates hearing sensitivity and consists of waveforms such as I, II, III, IV, and V². These waves represent structures in the central auditory system; for example, wave V originates from the inferior colliculus³. Wave V has the highest amplitude among other waves and is the most critical wave in determining

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hearing thresholds. If the hearing status of a patient is normal, wave V does not disappear even at the minimum intensity level, and this minimum intensity is accepted as the hearing threshold.

In certain situations, the ABR test may be performed under sedation or general anesthesia in the operating room under the supervision of an anesthesiologist. An ABR test performed under general anesthesia is the preferred method in patients who have sleep problems and those who are uncooperative with behavioral test techniques. Many studies have examined the results of ABR tests performed under general anesthesia^{2,4-7}. In these studies, various anesthetic agents (sevoflurane, isoflurane, enflurane, ketamine, etc.) were used, and their effects on ABR results were examined.

Previous studies have generally evaluated the results of latency and interpeak latency (IPL). Some studies have found prolongation in latency or IPL, whereas others did not find any significant changes. Manninen et al.⁶ examined the influence of isoflurane and isoflurane-nitrous oxide anesthesia on brainstem auditory evoked potentials (BAEP) in 10 healthy volunteers and found that the latency values of waves III-V and V were prolonged. Norrix et al.² compared latency and IPLs using sevoflurane anesthesia and the mask induction technique in groups of 12 children with and without anesthesia. They found a prolongation of the ABR wave V, and interpeak intervals for waves I-III, III-V, and I-V were prolonged compared with that in the control group. Contrary to these studies, Duncan et al.⁸ reported no changes in BAEP in children who were anesthetized with halothane.

This study compared amplitude and hearing thresholds, as well as latency and IPL, in a larger number of children than in previous studies. This study is a retrospective analysis of the amplitude, latency, IPL, and hearing threshold measures of ABRs recorded to click stimuli from children while under general anesthesia. For comparison purposes, the ABRs of the control group were examined without general anesthesia.

MATERIALS and METHODS

Data were obtained between April 21, 2017, and March 19, 2021, at the outpatient clinic of Medipol Mega University Hospital. This study was approved by the University of Istanbul Medipol Ethical Committee (decision no: 1020, date: 14.10.2021), and consent to use the data of the participants was obtained from the parents. The demographic data of the patients are presented in Table 1. Eighty-three ears were evaluated under anesthesia. These children consisted of Thirty-

three male and nine female. The mean age was 44.5 ± 20.3 months, which ranged from 17 to 95 months. The control group consisted of 116 ears, with Forty-four male and fourteen female. The mean age was 36.1 ± 16.1 months, which ranged from 17 to 90 months.

The families of all participants presented to our clinic with the suspicion that their children have hearing loss. Anesthetized ABR was employed on patients who could not undergo an ABR test with natural sleep. Both groups consisted of patients with normal hearing according to the click ABR test results. The inclusion criterion for the anesthesia group was wave V with a stimulus level at a maximum of 20 dB normal hearing level (dBnHL) in at least one ear. Participants were included in the control group according to the wave V threshold, which was lower than 20 dBnHL in the click ABR test. Children diagnosed with neurological dysfunction were excluded from the study. All children underwent otoscopic examination by an otolaryngologist. Children with normal otoscopy were included in the study. Tympanometry test was applied to all participants. Participants with types B and C were excluded from the study.

Anesthesia Group

Forty-two children met the inclusion criteria for at least one ear. If only one ear of the participant met the inclusion criteria, the patient was selected for the analysis. The ABRs of these children were recorded in the operating room under general anesthesia by the same anesthesiologist following a standardized method. All participants in this dataset had normal mental and physical development.

Control Group

This group included 58 children. The age of the participants in the control group was comparable with those of the anesthesia group. ABR testing was applied to this group without anesthesia. All of those in this group had normal hearing. Participants were included in the control group according to the wave V threshold, which was lower than 20 dBnHL in the click ABR test.

Table 1. Demographic features of the participants.

| | Anesthesia group | Control group |
|---------------------------------|------------------|-----------------|
| Participants | 42 | 58 |
| Included ears | 83 | 116 |
| Average of months (M \pm SD) | 44.5 ± 20.3 | 36.1 ± 16.1 |
| Lower limit (months) | 17 | 17 |
| Upper limit (months) | 95 | 90 |
| SD: Standard deviation, M: Mean | | |

ABR Recording Procedure

The ABR test of the control group was conducted in a sound-treated booth in the audiology clinic of Medipol Mega University Hospital. The ABR tests under general anesthesia were performed in the operating room at Medipol Mega University Hospital. In all cases, the test was conducted to assess the child's hearing sensitivity.

All data were collected with a commercial ABR software module (Interacoustics, Assens, Denmark, Version 4.2.0.8) running on an Interacoustics Eclipse EP25 platform (Hardware version 3.4.4). The click stimuli at alternating polarity, calibrated in dBnHL, were presented at a rate of 33.1/s via insert phones. After cleaning the skin's surface with NuPrep gel, recording electrodes (Ag/AgCl) were placed on the forehead (vertex), cheek (ground), and mastoids (i.e., reference electrode). Before the start of the recording, the impedance values of the electrodes were controlled below 3-5 kOhms. The electroencephalogram activity was amplified by 80 dB, bandpass filtered from 100 Hz to 3000 Hz using filter slopes of 12 dB/octaves, and digitized with a 16-bit resolution. An artifact rejection level of $\pm 40 \mu\text{V}$ was applied. The maximum intensity level was determined as 80 dBnHL, and waves I, III, and V were observed. Two runs each, consisting of the averaged responses from 2,000 sweeps, were obtained at each presentation level, and thresholds were established using a 10 dB down and 5 dB up with steps, which considered the last visible wave V as the threshold.

Anesthesia Procedure

All patients received a preoperative evaluation by an expert anesthesiologist. All children over 6 months were premedicated using midazolam (0.5 mg/kg) administered orally approximately 30 min before the induction. After oral premedication with midazolam 30 min before anesthesia, continuous electrocardiograph electrodes, an intravenous catheter, and a pneumatic blood pressure device for automatic oscillatory blood pressure measurement were placed. Anesthesia was induced with inhalation of sevoflurane in a 70% O₂+30% air mixture via mask technique. After accessing an intravenous line, propofol (2 mg/kg) and fentanyl (2 $\mu\text{g}/\text{kg}$) were administered intravenously, and then a laryngeal mask was inserted. During the ABR test, spontaneous breathing was maintained, and blood pressure, oxygen saturation, and heart rhythm were all continuously monitored by an anesthetist. The heart rate and blood pressure were recorded every 5 min, and the mean arterial pressure was maintained at higher than 55 mmHg. Anesthesia was maintained with 2% sevoflurane in the

oxygen-air mixture. When the ABR test was completed, the inhalation agent was discontinued, and patients were allowed to recover spontaneously from anesthesia. The laryngeal mask was removed, and patients were taken to the postoperative care unit.

Statistical Analysis

Statistical analysis was performed using the IBM SPSS Statistics for Windows, version 24.0 (IBM Corp, Armonk, NY, USA). Descriptive statistical methods [mean, standard deviation (SD), median, frequency, rate, minimum, and maximum] were employed to analyse the collected data. Continuous variables with a normal distribution were reported as mean with SD. Independent sample t-tests were performed to compare the two groups in terms of ABR wave latencies, wave amplitudes, IPLs, and hearing thresholds. In all analyses, $p < 0.05$ was taken to indicate significance.

RESULTS

To investigate group differences, ABR findings obtained from the anesthesia and control groups were compared in terms of amplitude, latency, IPL, and hearing threshold. Table 2 displays the amplitudes of waves I, III, and V recorded from the control group and anesthesia group. While wave I amplitudes were similar for patients in both groups, wave III and V amplitudes were significant ($p < 0.05$).

In Table 3, a prolongation of latency was observed in waves III and V in the anesthesia group compared with the control group. I-V and III-V IPLs were prolonged in the anesthesia group compared with that in the control group, as shown in Table 4.

Table 2. Mean wave amplitudes for the anesthesia and control groups.

| | I | III | V |
|--------------|-----------------------|-----------------------|-----------------------|
| Anesthesia | 0.381 (± 0.157) | 0.463 (± 0.208) | 0.318 (± 0.141) |
| Control | 0.393 (± 0.133) | 0.526 (± 0.167) | 0.432 (± 0.142) |
| p-value | 0.629 | 0.000* | 0.009* |
| * $p < 0.05$ | | | |

Table 3. Mean wave latencies for the anesthesia and control groups.

| | I | III | V |
|--------------|---------------------|---------------------|---------------------|
| Anesthesia | 1.41 (± 0.11) | 3.93 (± 0.26) | 6.02 (± 0.32) |
| Control | 1.42 (± 0.11) | 3.78 (± 0.18) | 5.72 (± 0.23) |
| p-value | 0.784 | 0.013* | 0.002* |
| * $p < 0.05$ | | | |

The mean value of the hearing threshold was 15.1 (±7.5) in the anesthesia group and 4.6 (±4.9) in the control group (p=0.000*, t=11.870). Figure 1 displays the hearing thresholds of the anesthesia and control groups, and the difference was significant (p<0.05).

DISCUSSION

General anesthesia is an effective method for patients who cannot sleep or cannot reliably complete behavioral audiometry tests. The ABR test is performed under anesthesia in the presence of special monitoring, an appropriate operating room environment, and an experienced anesthesiologist and audiologist. In this retrospective analysis, results of the ABR test in children with normal hearing were compared with and without general anesthesia.

The ABR test can be conducted using click, tonal, or chirp stimuli. In this study, the ABR test was performed using a click stimulus. The click stimulus was used because it evokes a large section of the basilar membrane, such as 0.5 kHz to 4 kHz^{9,10}, compared with other stimuli. The use of the ABR threshold response to predict auditory behavior threshold has become an important test for the diagnosis and management of hearing loss in children.

Results of the ABR test were compared under anesthesia and during natural sleep in terms of amplitude.

Table 4. Mean wave interpeak latencies for the anesthesia and control groups.

| | I-III | I-V | III-V |
|------------|--------------|--------------|--------------|
| Anesthesia | 2.44 (±0.35) | 2.08 (±0.19) | 4.59 (±0.30) |
| Control | 2.33 (±0.13) | 1.93 (±0.14) | 4.30 (±0.21) |
| p-value | 0.821 | 0.002* | 0.002* |

*p<0.05

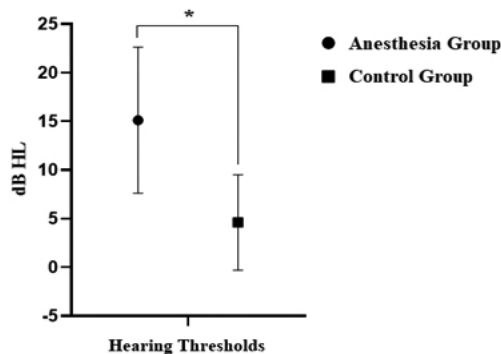


Figure 1. Average hearing threshold of the anesthesia and control groups.

A significant decrease in wave III and V amplitudes was found in the ABR test results performed under anesthesia (Table 2). Amplitude changes with anesthesia are more variable; changes in the amplitude have been examined, especially in studies with cats or mice. The interpretation of amplitude decrease concomitant with latency prolongation is somewhat complex. Decreases in peak amplitude can be expected from a decrease in the number of units responding or the level of synchronization in their activity. The suppression of the inhibitory neural activity by anesthesia could explain the observed amplitude changes⁷. Waves III and V have connections with the central auditory system. Therefore, it was thought that there was a decrease in wave III and V amplitudes as a result of the decrease in neuronal conduction with anesthesia. In several studies, although a change in latency was observed, no significant change was found in the amplitudes with anesthesia^{4,9}.

The ABR parameters are sensitive to the maturation of the auditory nerve and brainstem; thus, it is a suitable test for monitoring the maturation of the auditory brain¹⁰. Auditory structures develop with age. Auditory maturation continues until the age of two; afterward, waveforms and latencies in ABR tests begin to become similar to those of the adults. According to this consideration, the influence of anesthesia on the latency of the ABR waveform should be considered when reporting the test results¹¹. The ABR amplitudes depend on individual physiological parameters, such as the individual hearing level and maturational status of the infant, and stimulus parameters, such as stimulus type and repetition rate¹². All patients had normal hearing and the same stimulus parameters were used when recording. For this reason, maturation status may also affect the amplitude changes.

Wave III and wave V latencies were prolonged in the anesthesia group compared with that in the control group. Regarding the previous studies, these results are expected. Anesthesia can suppress neuronal activity in the brainstem¹³. Norrix et al.² examined 12 children to analyze the effects of anesthesia on click-evoked ABR test results. The general anesthesia group exhibited longer wave V latency and longer I-III, III-V, and I-V interpeak intervals than the control group². Similarly, several studies have shown that prolonged wave latencies were observed through ABR testing⁶⁻⁸. The prolongation of wave I-V latencies and IPLs reflects the depressant effect of volatile anesthetics on brainstem neuronal activity¹³. Egeli et al.¹⁴ performed ABR tests using nitrous oxide gas and found prolongation in wave I, III, and V latencies and IPL. These significant prolongations in all wave and IPLs during general anesthesia were thought to be due to the increase in intracranial pressure or to the positive

pressure created by the nitrous oxide gas used in the middle ear¹⁴.

The average hearing threshold in the ABR test performed in the anesthesia group was higher than that in the control group; however, it was within the normal hearing limits. ABR testing was conducted in the control group during natural sleep in a double-walled soundproof cabin, whereas ABR testing in the general anesthesia group was performed in an operating room. Non-surgical factors, such as the high background noise level in the operating room and electromagnetic interference from medical equipment, may degrade ABR responses, resulting in the overestimation of the hearing threshold.

Because the bispectral index is not routinely used in our operating rooms, we unfortunately could not measure and record the depth of anesthesia. However, the MAC values of the patients were recorded (1.0-1.5 MAC). Although the body temperatures of the patients were not measured during the ABR test in the operating room, we did not expect abnormal changes in the body temperatures of the patients because we used hot air blankets to warm the patients. Therefore, we do not think that body temperature can affect the test results. In addition, the length of the probe used in the ABR test and the volume of the ear canal, which may affect the ABR results, were not determined. However, before the test, the size of the probe was chosen according to the patient's ear.

CONCLUSIONS

The results of this study suggest that ABR testing can be performed under anesthesia. Clinicians and audiologists should be cautious in the interpretation of the ABR test results obtained under anesthesia. The patient should not be directed to an anesthetic ABR unless necessary. Performing ABR with natural sleep should be the first choice. Moreover, clinicians or audiologists should take a detailed history from families to have an idea of the correct hearing sensitivity of the patients, rather than relying solely on ABR test results obtained under anesthesia.

Ethics

Ethics Committee Approval: This study was approved by the University of Istanbul Medipol Ethical Committee (decision no: 1020, date: 14.10.2021).

Informed Consent: Consent to use the data of the participants was obtained from the parents.

Peer-review: Externally and internally peer-reviewed.

Author Contributions

Concept: P.K., M.B.S., Design: P.K., M.B.S., Data Collection and/or Processing: O.G., H.Y., Analysis and/or Interpretation: O.G., H.Y., P.K., M.B.S., Literature Search: O.G., H.Y., Writing: O.G., P.K., M.B.S.

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