Journal of Clinical Anesthesia 36 (2017) 80–83

Contents lists available at ScienceDirect

Journal of Clinical Anesthesia

Original contribution

Effect of total intravenous vs volatile anesthetics on intraoperatively acquired electrically evoked compound action potential in children undergoing cochlear implant surgery: A randomized prospective study

Ala"a Alhowary, MD, Assistant Professor [a,*], Khaled EL-Radaideh, FFA, Associate Professor [a], Anas AL-Rusan, MBBS, Resident [a], Diab Bani Hani, MD, Assistant Professor [a], Wail Khraise, MD, Assistant Professor [a], Ahmad AL Omari, FACS, Assistant Professor [b], Firas Alzoubi, FRRC, Professor [b]

[a] Department of Anesthesiology, Faculty of Medicine, Jordan University of Science and Technology, PO Box 953, Irbid 21110, Jordan
[b] Division of Otolaryngology, Department of Special Surgery, Faculty of Medicine, Jordan University of Science and Technology, PO Box 3030, Irbid 22110, Jordan

ARTICLE INFO

Article history:
Received 21 April 2016
Accepted 27 October 2016
Available online xxxx

Keywords:
Anesthesia
Cochlear
Evoked potentialsImplants
General
Implants
Intravenous

ABSTRACT

Objective: The purpose of the present study was to compare the effects of inhalational anesthesia to those of total intravenous anesthesia on intraoperative electrically evoked compound action potential (e-ECAP) thresholds in children undergoing cochlear implantation.
Study design: Randomized prospective study.
Setting: Tertiary referral teaching hospital.
Patients: Forty children aged 6 months to 17 years with bilateral severe-to-profound sensorineural hearing loss and undergoing cochlear implantation were enrolled in the study.
Intervention: Patients were randomly assigned (1:1 ratio) into 2 groups to receive inhalational or total intravenous anesthesia.
Measurements: The e-ECAP measurements were obtained with neural response telemetry software.
Main results: All electrodes showed lower e-ECAP thresholds under propofol, and results were statistically significant for the apical electrodes ($P < .05$). There was no statistical difference in the impedances between the 2 groups. Propofol minimally affected the e-ECAP. In contrast, the impedance was not affected by anesthesia.
Conclusion: Volatile anesthetics result in higher e-ECAP thresholds in children, suggesting that e-ECAP thresholds acquired during inhalational anesthesia overestimate auditory nerve stimulation levels, which may cause discomfort postoperatively and adversely affect the child's adaptation to the implant. We recommend the use of total intravenous anesthesia for the measurement of the e-ECAP thresholds during cochlear implant surgery.

1. Introduction

Successful cochlear implantation depends on appropriate postoperative programming of the speech processor, as the sound characteristics depend on this programming. Excitation of the auditory nerve with a progressive increase in energy intensity is essential to detect the hearing threshold (T level) as well as the maximum intensity allowed without discomfort (C level) through subjective psychophysical tasks [1,2]. This task is challenging, particularly in infants and young children, because of limited communication capabilities and lack of auditory experience. There is a pressing need for objective methods that require minimal cooperation of the patient in the programming of the cochlear implant's speech processor and that do not rely solely on behavioral loudness judgments to determine the hearing dynamic range in small children. A range of different electrophysiological measures can be used for this purpose, namely, intraoperative electrode impedance measurement, electrically evoked stapedial reflex, and electrically evoked compound action potential (e-ECAP) [3,4]. At our center, we commonly use e-ECAP thresholds and electrode impedance measurement for guiding implant setting [5,6].

The e-ECAP thresholds are a measure of the activity of synchronous cochlear nerve fibers, which is elicited by electrical stimulation of the cochlear implant, and are determined using neural response telemetry

* Corresponding author. Faculty of Medicine, Jordan University of Science and Technology, PO Box 953, Irbid 21110, Jordan. Tel.: +1 962 0 795770906; fax: +1 962 2 7200621.
E-mail addresses: aaalhowary@just.edu.jo (A." Alhowary), elradk61@yahoo.com (K. EL-Radaideh), anas19187@gmail.com (A. AL-Rusan), dabanihani@just.edu.jo (D.B. Hani), wnkhraise@just.edu.jo (W. Khraise), aialomari@just.edu.jo (A. AL Omari), firasz@just.edu.jo (F. Alzoubi).

http://dx.doi.org/10.1016/j.jclinane.2016.10.008
0952-8180/

(NRT) software that can be used to objectively fit the sound processing system [7]. Impedance measurement is intended to ascertain the technical status of the implant's stimulator and electrodes [6,8]. The e-ECAP recordings can be made intraoperatively or postoperatively. When done intraoperatively, the child is still under general anesthesia. This allows the clinician to apply high stimulation levels, which results in a high success rate of recording e-ECAP responses [9].

In this situation, knowledge of the effects of anesthetics on these objective measures is important to optimize the outcome of pediatric cochlear implantation. An ideal anesthetic technique for cochlear implant surgery is one that has no effect on the evoked auditory responses that were measured.

Several studies that have investigated the influence of anesthesia on electrically elicited stapedius reflex threshold measurements revealed that the total intravenous anesthesia (TIVA) gives more consistent responses than volatile anesthetics [4,7], but there are insufficient data in the literature concerning its effect on e-ECAP.

It has been suggested that the depth of anesthesia can have a significant influence on the e-ECAP threshold and it is important to reduce the depth of anesthesia to achieve better results [6]. To the best of our knowledge, no studies have been performed to compare the effect of a volatile anesthetic with that of propofol anesthesia on intraoperative e-ECAP thresholds.

The aim of this study was to compare the effects of inhalational anesthesia with those of TIVA on intraoperative e-ECAP and impedance measurements in children undergoing cochlear implant surgery at our center.

2. Methods

After obtaining formal approval from our institutional ethics committee, we conducted a randomized, double-blind study involving 40 patients aged 6 months to 17 years with American Society of Anesthesiologists physical status I-II who were scheduled for elective cochlear implantation surgery under general anesthesia at a tertiary referral teaching hospital. All these patients had bilateral severe-to-profound sensorineural hearing loss. Children with compromised neural/cochlear anatomy were excluded. Implantations were performed consecutively between March 2013 and March 2014. For all patients, written informed consent for participation in the study was obtained from one of the parents or the legal guardian.

The patients were randomly assigned (1:1 ratio) into 2 groups based on computer-generated random numbers that were kept in a sealed envelope. Immediately before the administration of anesthesia, the sealed envelope was opened to reveal the anesthetic regimen that has to be used for this patient.

2.1. Anesthetic management

The patients were not premedicated. On arrival to the operating room, standard intraoperative monitors (pulse oximetry, noninvasive arterial blood pressure, and electrocardiogram) were applied and baseline values were recorded. General anesthesia was induced with 50% oxygen in nitrous oxide and 6% sevoflurane in the patients of the inhalational group (INHAL) or propofol (3 mg/kg) in the patients of the TIVA group. An intravenous line could be secured before the induction of anesthesia followed by fentanyl administration (2 μm/kg bodyweight).

Neuromuscular blockade was achieved with 0.3 mg/kg rocuronium to facilitate tracheal intubation. In group INHAL, anesthesia was maintained with 50% oxygen in nitrous oxide and 2%-3% sevoflurane administered via a pediatric circle breathing circuit, and fentanyl infusion (1 μm/kg per hour) titrated according to hemodynamic responses. Ventilation was controlled to maintain normocapnia. In group TIVA, anesthesia was maintained with 50% oxygen in nitrous oxide, propofol infusion (4-8 mg/kg per hour), and fentanyl infusion (0.3-0.6 μm/kg per hour) titrated according to hemodynamic responses.

2.2. Neural monitoring

Cochlear implants had 22 active electrodes, with electrode 22 inserted toward the apical end of the cochlea and electrode 1 at the basal end. Electrode impedance was measured using stimulation modes MP1 + 2 (the ball electrode [MP1] and plate electrode [MP2]).

2.3. Determination of the auditory thresholds

Auditory thresholds were determined after insertion of the intracochlear electrode array at least 90 minutes after induction of anesthesia. All electrodes (electrodes 1-22) were tested. Current level was measured in current units (CUs) as defined by the cochlear implant programming software. Each current level step is a 0.16-dB change in current. Electrical pulse trains of 500 milliseconds were delivered in a stepwise manner, first in increments of 10 CU and subsequently in decrements of 5 CU.

The NRT was measured at the electrode located 2 electrode positions apical to the stimulating electrode on the intracochlear array. An exception was made for electrodes 21 and 22 for which the recording electrodes were 19 and 20, respectively. All the measurements were made automatically by Custom Sound software (version 4, Cochlear Ltd, Sydney, Australia). The lowest level of stimulation at which a wave could be detected by the software was defined as the threshold. Both the surgeon and audiologist were blinded to the anesthetic drug.

The e-ECAP measurements were obtained with the NRT software and were judged by experts who assessed the success rate of the recordings and determined the threshold level for each patient to use the records as a reference for postoperative speech processor fitting.

2.4. Statistical analysis

SPSS version 18 (SPSS IBM, New York, NY) and SAS 8.1 (SAS Institute Inc, Cary, NC) were used to perform the statistical analysis.

Differences between intraoperatively measured values of impedance/e-ECAP under TIVA and under inhalational anesthesia of the 22 channels were analyzed using the unpaired *t* test. Data were presented as mean ± SD, percentage, or absolute number. Patient noncategorical characteristics were analyzed using analysis of variance. χ^2 Tests were used for comparisons of categorical demographic data. A generalized linear model for repeated measures was used to test for differences within and between groups.

Bonferroni correction was applied for all comparisons. *P* values less than .05 were considered statistically significant.

3. Results

All operations were performed by senior surgeon (FA). The patients were kept under general anesthesia, and the operation was performed using the minimally invasive lazy S–shaped incision and double-flap, transmastoid, posterior tympanotomy technique with round window insertion. All patients received Nucleus Freedom cochlear implant devices (Cochlear Ltd), which use NRT to elicit and record responses from the auditory system. All surgeries were completed uneventfully. Complete electrode insertion was ensured in all cases by impedance and NRT and confirmed on the next day by radiologic x-ray.

Our study population consisted of 40 patients. Twenty patients were enrolled in each group. The mean age of the INHAL group was 7 years and 3 months (SD = ±4.36) and that of the TIVA group was 7 years and 9 months (SD = ±4.37), which was not statistically significant ($P = .58$). The male-to-female ratio was 10:10 in the INHAL group and 8:12 in the TIVA group. There was no statistical difference in the impedances between the 2 groups (Fig. 1). All electrodes had lower