

Evaluation of volatile and intravenous anesthetics, effects on the threshold of neuroresponse telemetry and the threshold of acoustically evoked stapedial reflex in children undergoing cochlear implant surgery

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Abstract

Background and Aims: Congenital hearing loss affects about 1 in every 1000 live births. Cochlear implant is an effective therapeutic method for aural rehabilitation in children suffering from severe-to-profound hearing loss. The aim of this study was to compare the effects of the intravenous and inhalational anesthesia techniques on neuroauditory threshold and stapedial reflex threshold responses.

Material and Methods: After approval of the university ethics committee and obtaining written informed parental consent, 110 children with severe or profound bilateral sensorineural hearing loss undergoing cochlear implant surgery were randomly divided in two groups. The effects of the total intravenous anesthesia (propofol and remifentanil) and inhalation anesthesia (sevoflurane) techniques were evaluated on the neuroauditory threshold and stapedial reflex threshold responses of patients. Variations in systolic and diastolic blood pressures and mean arterial blood pressure were measured in both groups.

Results: No significant difference was observed in the following parameters: age, weight, duration of anesthesia, and surgery. No side effects was observed in the two groups. No significant difference was found in the Telemetry Neuroal Response Test (TNRT) reflex between the two groups ($P = 0.294$); however, the difference between the two groups was significant ($P = 0.001$) for Electrical Stapedial Reflex Threshold (ESRT) reflex. In the sevoflurane group, in 39 patients in the electrode 3 and in 17 patients in the electrode 9 (compared with 20 and 6 patients in the Propofol-remifentanil group) complete suppression of stapedial reflex existed.

Conclusion: Our results suggest that, during the cochlear implant surgery, use of inhalation anesthetics should be avoided for achieving controlled hypotension because this may suppress or even fully eliminate stapedial reflex. Remifentanil and Propofol infusion has a slight effect on hearing thresholds and is recommended for determining hearing thresholds during cochlear implant surgeries.

Keywords: Anesthesia, cochlear implant, neuroresponse threshold, pediatric, Propofol, remifentanil, sevoflurane, stapedial reflex, surgery

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Introduction

Congenital hearing loss affects about every 1 in 1000 live births. Cochlear implant (CI) is an effective treatment for restoring hearing in patients with severe-to-profound hearing loss (hearing threshold of 70 db in audiometer with poorer tone).^[1] The prostheses implanted in the cochlea allow patients with profound sensorineural deafness to hear by stimulating the auditory nerves.^[1,2] To adjust the external implant system, the audiometrist needs to use the Electrical Evoked Compound Action Potential (ECAP) and Electrical Stapedial Reflex Threshold (ESRT) domains obtained during CI.^[3,4]

Electric stimulation of stapedial reflex during surgery is used to determine the most comfortable listening level (MCL) for humans. Producers of CI have developed the NRT software, which measures the ECAP resulting from CI.^[5]

Due to the neuroanatomical structure of the stapedial reflex, it could be affected by sedatives and central nervous system (CNS) inhibitors during cochlear implantation, and these anesthetic compounds can undermine the stapedial reflex.^[1,6]

However, in intravenous anesthetic compounds, the stapedial reflex response always exists, and the midazolam–ketamine compound is slightly and mutually effective. Because flunitrazepam has the least effect on the stapedial reflex threshold it is more suitable for sedation and midazolam–ketamine is more suitable for anesthesia.^[7] Various studies have reported that there is a strong correlation between the level of hypnosis and the mean stapedial reflex, and it is thus postulated to decrease the concentrations of inhalational agent with maintenance of normal CO₂ level. To prevent the adverse effects of improper adjustment of prosthetics during surgery we decided to study the effects of inhalation anesthesia with sevoflurane and total intravenous anesthesia (TIVA) with propofol on the suppression of the neural responses during CI surgery.

Material and Methods

After obtaining informed parental consent, 110 CI candidates with a physical status of ASA-I or II and aged between 6 months and 7 years were included in the study. Surgery employed was the same for all cases (mastoidectomy and cochleostomy).

Children who demonstrated side effects to drugs used in the study were omitted. Based on Crawford's study (2008),

in which stapedial reflex suppression levels with propofol and desflurane 1.5% were reported to be 90% and 52%, the sample size was calculated for each group considering $\alpha = 0.05$ and power = 80%.^[2] The total sample size calculated was 50 and a total of 55 patients were eventually recruited in each group.

An online random list generator software was used for randomization. Prior to induction, all patients received intravenous fentanyl 1 $\mu\text{g}/\text{kg}$ and midazolam 0.02 mg/kg as premedication. Patients were subjected to standard monitoring (pulse oximeter, blood pressure measurement, electrocardiography) (ECG). In all patients, anesthesia induction was carried out through injection of lidocaine 1 mg/kg, propofol 2–3 mg/kg, and atracurium 0.5 mg/kg, and then patients were intubated with proper size endotracheal tube.

In the first group (55 patients), anesthesia was maintained through remifentanyl 0.2–0.5 $\mu\text{g}/\text{kg}/\text{min}$ and propofol 100–150 $\mu\text{g}/\text{kg}/\text{min}$ infusion. In the second group, anesthesia was maintained with sevoflurane inhalation with a concentration of 2–2.5%. Both groups received a 50:50 mixture of N₂O–O₂ during maintenance of anesthesia. The patients were mechanically ventilated during operation.

Electric stimulations were obtained using electrodes located in the upper (electrode number 20), middle (electrode number 9), and lower (electrode number 3) positions. Current units were measured using the CI software. Five hundred milliseconds sequential electric pulses (number of pulses in each burst: 4500; width of each electric pulse: 25 μs ; intervals between stimulations: 7 μs) were created with a 10-unit exponential increasing trend for current, and the 5-unit impulses were induced to determine ESRT. The stapedial muscle movements were observed with a microscope. ESRT was the lowest electrical stimulation for induction on stapedial. ECAP was measured at electrode which were two electrodes higher than the stimulated electrode on the cochlear internal chain. Electric flows were created with a velocity of 80 Hz and 10-unit consecutive decreases to the point that electric responses were not observed by the audiologist. The minimum observable stimulation was determined as the threshold. The surgeon and audiologist were unaware of the anesthesia drug. After measuring ESRT and TNRT till the end of the surgery, fentanyl 1 $\mu\text{g}/\text{kg}$ was used for postoperative sedation.

This study is registered under IRCT201104026022N3 on the IRCT.ir website.

Statistical analysis

The collected data were analyzed using SPSS-17 statistical software. The collected data were expressed as percentage and mean \pm SD. Continuous (quantitative) variables were compared by independent samples and paired *t*-test. Categorical (qualitative) variables were compared by contingency tables and Chi-square test or Fisher's exact test. $P \leq 0.05$ was considered statistically significant.

Results

The demographic data are given in Table 1. There was no significant difference between TNRT results obtained with electrodes 9, 3, and 20 using the two anesthesia methods, and both methods similarly affected TNRT results with the electrodes ($P > 0.05$) [Table 2].

Table 3 indicates that there was no significant difference between ESRT results obtained with electrode 3 using the two anesthesia methods ($P = 0.760$). However, with electrodes 9 and 20, the mean ESRT results for group A were significantly higher than group B ($P > 0.05$).

Except for the periods 15, 30, and 45 min after induction, when the mean SBP of group A was significantly higher than group B ($P < 0.005$), there was no significant difference between the two groups at other times ($P < 0.005$). Only diastolic blood pressure (DBP) levels 30 and 165 min after induction were significantly higher in group A than group B. At 15, 30, and 45 min after induction the MAP of group A was significantly higher than group B ($P < 0.005$).

The heart rate of group B before induction was significantly higher ($P < 0.005$). The heart rate of group A 30, 45, and 60 min after induction were significantly higher ($P < 0.005$).

Analysis of responses and no responses in TNRT and ESRT tests with the study electrodes indicated that only in the case of ESRT with 3 and 9 electrodes the rate of no-response was significantly higher in group A [Tables 4].

Discussion

CI is a device that substitutes for cochlea and converts sound energy to electric signals. For CI programming in children, objective tests have to be employed due to the young age of patients and lack of cooperation. Hence, in many children's centers, patient's audio dynamic area is determined through ESRT measurements during surgery and ECAP.^[8]

Table 1: Demographic data

Variables	A	B	P
Sex (M/F)	27/28	35/20	0.124
Age (year) (mean standard deviation)	3.5 \pm 1.0	3.8 \pm 1.1	0.101

Table 2: TNRT of patients with electrodes 3, 9, and 20 between two groups

Variables	Group		P
	Sevoflurane	Remifentanil	
Electrode 3	200.9 \pm 37.7	197.5 \pm 33.0	0.649
Electrode 9	180.8 \pm 33.6	181.8 \pm 30.1	0.882
Electrode 20	177.4 \pm 30.1	170.5 \pm 39.4	0.321

Table 3: ESRT of patients with electrodes 3, 9, and 20 between two groups

Variables	Group		P
	Sevoflurane	Remifentanil	
Electrode 3	229.1 \pm 28.9	226.4 \pm 29.1	0.760
Electrode 9	223.8 \pm 19.8	207.4 \pm 21.5	<0.001
Electrode 20	217.2 \pm 18.9	203.4 \pm 18.5	0.001

Table 4: Evaluation of Response and non-response status of patients between two groups

Variables	Groups		P
	Sevoflurane	Remifentanil	
TNRT			
Electrode 3			
Response	45	46	0.801
Non-Response	10	9	
Electrode 9			
Response	51	49	0.507
Non-Response	4	6	
Electrode 20			
Response	51	51	0.642
Non-Response	4	4	
ESRT			
Electrode 3			
Response	16	35	<0.001
Non-Response	39	20	
Electrode 9			
Response	38	49	0.010
Non-Response	17	6	
Electrode 3			
Response	41	48	0.089
Non-Response	14	7	

Anesthetics can affect ESRT and increase the threshold or fully suppress reflex.^[6]

The mean TNRT reflex values of the sevoflurane and remifentanil anesthesia groups did not differ significantly. Hence, the type of pharmaceutical group could not be

considered a factor influencing TNRT reflex. There was a relatively large difference between mean ESRT reflex values of the sevoflurane and propofol + remifentanil anesthetic groups.

Mark *et al.* (2008) studied 44 deaf children, who received CI, to study the effects of inhalation anesthesia (sevoflurane, isoflurane, and desflurane) and intravenous propofol anesthesia on stapedial reflex. They observed that, with an increase in concentration of inhalation anesthetics, the stapedial reflex threshold increased. In some patients, stapedial reflex was fully eliminated. Propofol had a smaller effect on ESRT, while the potential of evoked combined action was not affected by the type of anesthetic.^[2] They stated that, because inhalation anesthetics suppress stapedial reflex, measurement of ESRT during inhalational anesthesia leads to overestimation of MCL and postoperative inconvenience for patients. Moreover, this measurement has an adverse effect on adaptation to the implanted prosthesis.^[2]

Makhdoum *et al.* stated that with an increase in concentration of halothane and isoflurane the stapedial reflex threshold escalates.^[11]

Bissinger's study of 45 patients who were candidates for elective nasal and sinus, tonsil, pharynx, and soft neck tissue surgery indicated that N₂O, thiopental, and inhalational anesthetic drugs increase the reflex threshold to different degree. The reflex may even be eliminated completely. With intravenous anesthetics stapedial reflex is always recognizable, and the stapedial reflex threshold is not affected clinically with the midazolam–ketamine.^[16] Results of our research complied with the results of the above three studies. It also confirmed the findings of previous studies with a larger sample.

The study by Mark *et al.* revealed that none of the inhalational anesthetic drugs (sevoflurane, isoflurane, and desflurane) and intravenous propofol affects ECAP(2).

In the study by Mark *et al.*, 3 patients (7.5%), in whom the concentration of the MAC inhalation anesthetic was 0.75 and 18 patients (52%), in whom the MAC concentration was 1.5, stapedial reflex was fully eliminated. The concentrations had little effect on ESRT. Unlike our study, in their study no patient demonstrated complete stapedial reflex suppression with propofol.^[2]

Clinically, suppression of stapedial reflex by inhalation drugs leads to overestimation of MCL, which can have adverse effects on adaptation to the implanted prosthetic in children. This maladaptation may finally lead to postoperative discomfort. The background mechanism of reflex suppression based on dosage of anesthetics calls for contemplation.

Neural organization of stapedial reflex arc is polysynaptic and includes the auditory nerve (as the afferent nerves), ventral cochlear nucleus, body trapezoid, medial upper olivary nucleus, and efferent motor nerves, which travel along with nerve 7 and end to the stapes muscle. Inhalation anesthetics depress synaptic conduction more than axonal conduction. These drugs affect neuromuscular junction. They connect to the protein portion of acetylcholine nicotinic receptor and block the channel ion flow. ECAP is not affected by anesthetics because ECAP is an axonal response and it is improbable that it is affected by anesthetics in auditory nerve ESRT.^[2]

Further studies with larger samples are recommended to study the effects of different dosages of intravenous and inhalation anesthetics on stapedial reflex and neural response threshold during cochlear implant surgery, as well as to compare the results with subsequent effects of auditory-spoken learning on patients.

Conclusion

Our results suggest that, during the CI surgery, use of inhalation anesthetics should be avoided for achieving controlled hypotension because dosages of inhalation drugs, which lead to hypotension, can suppress or even fully eliminate stapedial reflex. Remifentanil and propofol infusion has slight effect on hearing thresholds and is recommended for determining hearing thresholds during cochlear implant surgeries.

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Conflicts of interest

There are no conflicts of interest.

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