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Effects of desflurane and sevoflurane anesthesia on intraocular pressure in pediatric patients

Abstract

Aim: One of the undesirable consequences of ophthalmic surgery is increase in intraocular pressure. Intraocular pressure can be greatly affected by surgical and anesthesia procedures. This study aimed to analyze the differences in intraocular pressure according to the anesthetics (sevoflurane or desflurane) administered during general anesthesia for strabismus surgery in healthy children.

Materials and Methods: This prospective study included 48 patients aged 6–15 years who were scheduled for one-eye strabismus surgery. Based on the agent, they were randomly assigned to the desflurane (n = 26) and sevoflurane (n = 22) groups. Intraocular pressure was measured in the contralateral eye. The hemodynamic parameters and intraocular pressure of all patients were assessed four times: before induction of anesthesia (Control), before intubation (up to 3 min) (T1), immediately after intubation (up to 1 min) (T2), and under deep anesthesia during mechanical ventilation (T3).

Results: In both desflurane and sevoflurane groups, intraocular pressure values fell considerably following anesthesia induction (T1) compared to control measures ($p < 0.001$ and $p = 0.014$, respectively). This reduction was more pronounced in the desflurane group than in the sevoflurane group ($p = 0.008$). A significant decrease in mean arterial pressure was observed only at the T3 time point in both groups compared to the control data. The decrease in mean arterial pressure at T3 was more significant in the sevoflurane group compared to the desflurane group ($p = 0.015$).

Conclusion: In pediatric ophthalmic surgery, the administration of desflurane and sevoflurane significantly decreased intraocular pressure levels during the induction phase compared to the awake state. Both anesthetic drugs are securely applicable in pediatric ophthalmic surgery due to their dependable anesthetic characteristics and their ability to reduce intraocular pressure.

Keywords: Desflurane; pediatric anesthesia; intraocular pressure; sevoflurane

INTRODUCTION

Modern ocular surgery primarily involves the irrigation, manipulation, and instrumentation of the eye, leading to the generation of dynamic pressure fluctuations inside the ocular structure. In several ophthalmic procedures, a significant elevation is noted in retinal and optic disc perfusion pressures, together with intraocular pressure (IOP). Maintaining stable IOP is essential for preserving the structural integrity and perfusion of delicate ocular tissues. Ocular perfusion pressure (OPP), defined as the differential between arterial pressure and IOP, is crucial for maintaining adequate blood flow to the retina and optic nerve (1).

Normal IOP ranges between 10 and 22 mmHg, and values exceeding 24 mmHg are generally considered pathological (2). Elevated IOP can reduce ocular perfusion and, when markedly increased, may compromise retinal and optic nerve function, potentially leading to ischemia and visual impairment (3). Perioperative fluctuations in IOP may therefore influence surgical outcomes and are affected by anesthetic management. Most anesthetic agents alter IOP in a dose-dependent manner. Intravenous agents such as barbiturates, opioids, sedatives, etomidate, and propofol are known to reduce both normal and elevated IOP (3). Inhalational anesthetics also decrease IOP in

a dose-dependent fashion (4). However, potential interactions between sympathomimetic mydriatics and halogenated inhalation agents should be considered (5).

Accurate measurement of IOP is particularly important in pediatric patients, especially in the evaluation and management of conditions such as glaucoma. Because of limited cooperation and difficulty maintaining immobility, sedation or general anesthesia is often required for reliable IOP assessment in children. In ophthalmic surgery, anesthesia plays a dual role: minimizing undesirable IOP fluctuations and enabling accurate intraoperative measurements. The effects of inhalational agents on IOP may vary depending on patient characteristics and anesthetic depth. Desflurane and sevoflurane are commonly used inhalational anesthetics with low blood–gas partition coefficients (0.42 and 0.65, respectively) (4). Desflurane provides rapid induction and recovery, whereas sevoflurane is widely preferred in pediatric practice due to its favorable airway profile. Although sevoflurane has been shown to significantly reduce IOP during induction and maintenance of anesthesia, data regarding the effect of desflurane on IOP in pediatric patients remain limited.

Therefore, this prospective randomized study aimed to compare IOP changes associated with desflurane and sevoflurane during general anesthesia for strabismus surgery in otherwise healthy pediatric patients.

MATERIALS AND METHODS

This study was approved by the Ordu University Faculty of Medicine Ethics Committee and was conducted in accordance with the Declaration of Helsinki (Approval no: 219, Date: 07/10/2021). Written informed consent was obtained from guardians of the patients. The study was conducted between January 2022 and December 2024.

This prospective study included 48 pediatric patients aged 6 – 15 years with American Society of Anaesthesiologists

(ASA) scores I and II, without any ocular disease other than refractive error, who were scheduled for strabismus surgery (horizontal rectus recession due to esotropia or exotropia) in one eye. Patients who were excluded from the study comprised patients with a documented allergy to any anesthetic drug, patients exhibiting spherical refractive error greater than $> 4D$ (hyperopic or myopic) or cylindrical refractive error exceeding $> 2.5D$, patients with a known ocular disease or suspicion of glaucoma (history of high IOP, deep or large optic disc cupping, and family history, among others), patients with a history of intraocular surgery, patients currently taking systemic or ocular medications that could potentially influence IOP, and those who could not undergo IOP assessment due to uncooperativeness before induction of anesthesia. Furthermore, patients for whom two or more attempts at endotracheal intubation were required, had a history of reactive airway disease, exhibited signs of upper respiratory tract infection, or required rapid sequence induction were excluded from the study. Demographic characteristics and medical history were recorded for all participants.

Patients were randomly allocated to either the desflurane group ($n = 26$) or the sevoflurane group ($n = 22$), based on the choice of anesthetic agent administered. Patients were randomized using a computer-generated randomization sequence. IOP measurements (Tono-Pen AVIA, Reichert, Inc., Depew, NY, USA) were performed on the eye opposite to the one undergoing surgery. The ophthalmologist responsible for IOP measurements was blinded to group allocation. Hemodynamic parameters (mean arterial pressure [MAP], heart rate) and IOP were measured at four predefined time points in all patients. When the patient arrived in the operating room, measurements were performed before induction of anesthesia (Control); after induction of anesthesia and before intubation (up to 3 minutes) (T1); immediately after intubation (up to 1 minute) (T2); and in deep anesthesia during mechanical ventilation (T3) (Figure 1).

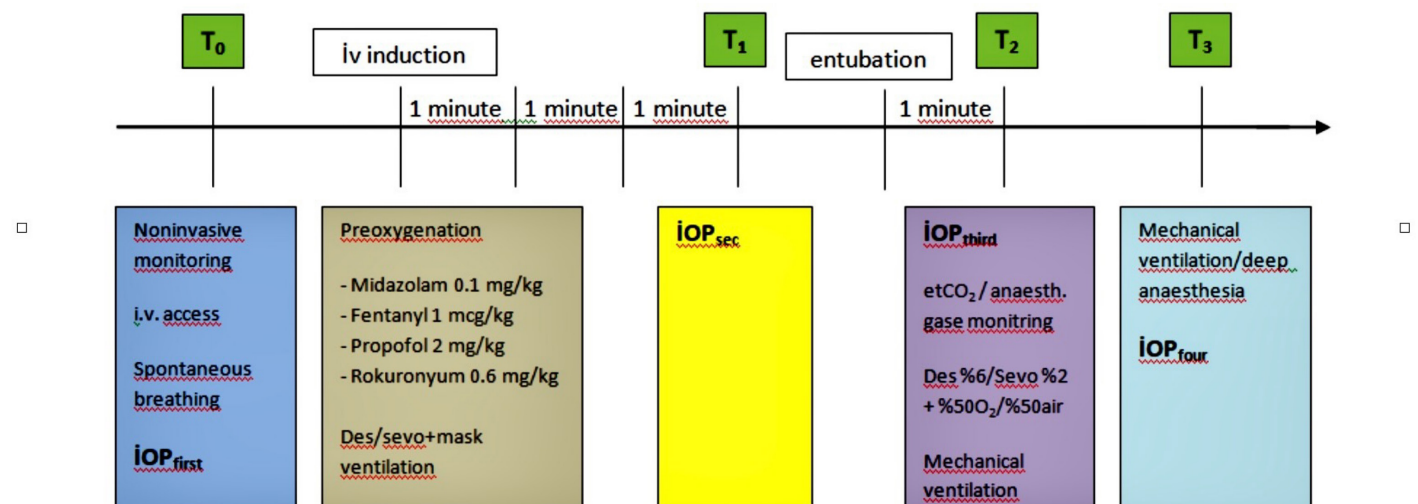


Figure 1. Anesthesia work flow chart.

Before the procedure, the patients were instructed to fast for 6 and 2 hours for solid foods and clear liquids, respectively. None of the patients received premedication. Patients underwent standard monitoring including electrocardiography (ECG), noninvasive blood pressure measurement, and peripheral oxygen saturation (SpO₂). All patients were preoxygenated with tidal volume breathing for 3 minutes with 100% FiO₂ and oxygen at a flow rate of 10 L/min. In both groups, 0.1 mg/kg midazolam, 1 mcg/kg fentanyl, 1 mg/kg lidocaine, 2 mg/kg propofol, and 0.6 mg/kg rocuronium were used intravenously to induce anesthesia. After verbal response and eyelash reflex disappeared, orotracheal intubation was performed by an experienced anesthesiologist after controlled mask ventilation with inhalation anesthetics (desflurane 6% in Group 1 and sevoflurane 2% in Group 2). End-tidal carbon dioxide (etCO₂) monitoring was performed after the induction of anesthesia and intubation. Anesthesia was maintained with desflurane (6%) and O₂ (50%)/Air (50%) in Group 1 and sevoflurane (2%) and O₂ (50%)/Air (50%) in Group 2. Nitrous oxide was not used. No additional dose was used for muscle relaxation. Ventilation was monitored to ensure that the etCO₂ concentration remained within the range of 35 – 45 mm Hg. Bispectral index score (BIS) monitoring—to monitor the depth of anesthesia—could not be performed due to the intrusion of electrodes into the surgical field. The depth of anesthesia was maintained by closely monitoring the expiratory concentration of the anesthetic agent, in accordance with the hemodynamic parameters of the patients, while maintaining a minimum alveolar concentration value of 1 for inhalation anesthetics. All patients were administered 2 mg/kg sugammadex for neuromuscular blocking agent antagonism before extubation, and extubation was performed when adequate spontaneous respiration was established. Patients who demonstrated responsiveness by following commands such as hand squeezing, sticking out their tongue, and/or actively crying were transferred to the recovery

room after extubation. Patients were transferred to a regular ward when their Aldrete Score was ≥9.

Sample size estimation was performed based on previously published data reporting a mean IOP of approximately 15.9 ± 3.18 mmHg in pediatric patients under general anesthesia (4). Assuming a 20% difference between groups, with a power of 80% and a two-sided alpha level of 0.05, a minimum of 19 patients per group was required. Considering a potential dropout rate of 10%, at least 22 patients were planned for each group. All analyses were performed on SPSS v25 (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test was employed for the assessment of normalcy. Data are presented as mean ± standard deviation or median (minimum - maximum) for continuous variables based on distribution normality and as frequency for categorical data. Normally distributed variables were analyzed with the independent samples t test. Non-normally distributed variables were analyzed with the Mann Whitney U test. Categorical variables were analyzed with the chi-square tests. Repeated measurements were analyzed with the Friedman's analysis of variance by ranks. Pairwise comparisons were adjusted by Bonferroni correction. Spearman correlation coefficients were computed to assess correlations among continuous variables. The p-value was considered statistically significant at p < 0.05.

RESULTS

Our study included 48 patients (26 desflurane group and 22 sevoflurane group), with a median age of 7.5 years (6 – 15 years). Demographic and clinical characteristics of the participants in the desflurane and sevoflurane groups are presented in Table 1. No significant intergroup differences were observed in terms of age, sex, duration of anesthesia and surgery (time between induction of anesthesia and exit from the operating room), height, weight, body mass index, and surgical side (p > 0.05; Table 1).

Table 1. Between groups analysis of the patients' characteristics

Parameter	Groups		p
	Desflurane (n = 26)	Sevoflurane (n = 22)	
Age (years)	8.50 (6 – 15)	7 (6 – 15)	0.372 ^a
Gender (male/female)	13/13	12/10	0.981 ^b
Anesthesia time (min)	50 (45 – 80)	50 (40 – 60)	0.288 ^a
Operation time (min)	32.50 (25 – 65)	35 (25 – 45)	0.686 ^a
Height (cm)	127.73 ± 24.32	130.82 ± 19.39	0.634 ^c
Weight (kg)	28.50 (15 – 60)	33 (18 – 80)	0.771 ^a
Body mass index (kg/m ²)	18.18 (13.20 – 31.75)	18.22 (11.83 – 31.25)	0.820 ^a
Side (eye)			
Right	13 (50.00%)	13 (59.09%)	0.735 ^b
Left	13 (50.00%)	9 (40.91%)	

Data are given as mean ± standard deviation or median (minimum–maximum) for continuous variables according to normality of distribution and as frequency (percentage) for categorical variables. ^aMann–Whitney U test; ^bChi-square test; ^cIndependent samples t test.

The IOP values and hemodynamic parameters measured for both groups are presented in Table 2. All measurement values (control, T1, T2, and T3) were evaluated independently for each group. The IOP values recorded at baseline (in the awake state) when patients arrived in the operating room (control) were similar in both groups. IOP values measured after the induction of anesthesia (T1) exhibited a significant reduction in both the desflurane and sevoflurane groups when compared with the control measurements ($p < 0.001$ and $p = 0.014$, respectively). However, IOP measurements at the T2 and T3 time points showed no significant changes in both groups ($p > 0.05$). At the T1 time point, the decrease in mean IOP values observed in both the desflurane and sevoflurane groups was significantly different between the two groups, with a more substantial decrease observed in the desflurane group compared to the sevoflurane group ($p = 0.008$, Figure 2).

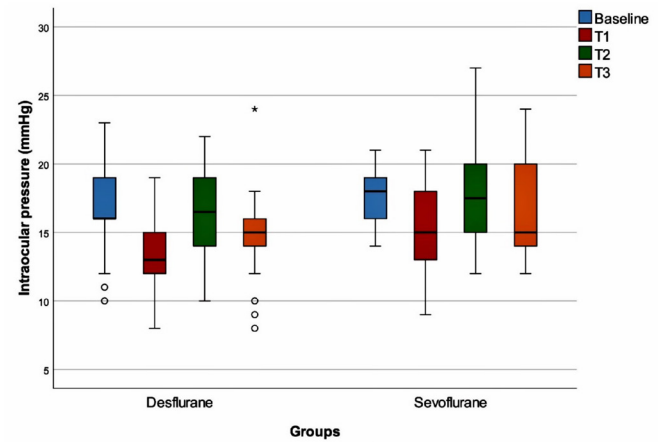


Figure 2. Intraocular pressure with regard to groups. The box represents 50% of the sample. The single line inside the box represents median. Small circles and asterisks represent the outliers at intraocular pressure.

Table 2. Analysis of the repeated measurements and pairwise comparison results for IOP and hemodynamic variables

Parameter	Groups		p (between groups)
	Desflurane (n = 26)	Sevoflurane (n = 22)	
IOP (mmHg)			
Baseline	16 (10 – 23)	18 (14 – 21)	0.444
T1	13 (8 – 19) ^a	15 (9 – 21) ^a	0.008
T2	16.5 (10 – 22)	17.5 (12 – 27)	0.119
T3	15 (8 – 24)	15 (12 – 24)	0.459
p (within groups)	< 0.001	0.001	
Heart rate (bpm)			
Baseline	100 (67 – 158)	102 (71 – 116)	0.425
T1	97 (67 – 141)	93.5 (64 – 115)	0.967
T2	110 (79 – 140)	103 (73 – 135)	0.156
T3	100 (66 – 152)	100.5 (66 – 137)	0.450
p (within groups)	0.190	0.213	
MAP (mmHg)			
Baseline	86 (75 – 109.33)	92.5 (79 – 108)	0.054
T1	74.5 (62 – 92)	77.5 (64 – 106)	0.070
T2	94 (72 – 107)	81 (64 – 110)	0.065
T3	73 (58 – 95) ^a	72.5 (62 – 88) ^a	0.250
p (within groups)	0.001	0.001	

Data are given as median (minimum – maximum) for continuous variables according to normality of distribution. Repeated measurements were analyzed with the Friedman's analysis of variance by ranks. Pairwise comparisons were adjusted by Bonferroni correction. ^aThere is a statistically significant difference compared to the baseline measurement. Abbreviations: Baseline, before operation, initial measurement; IOP, intraocular pressure; MAP, mean arterial pressure; T1, after anesthesia induction; T2, after intubation; T3, deep anesthesia.

Table 3 illustrates the changes in IOP, heart rate, and MAP across various measurement time points for both the desflurane and sevoflurane groups. When evaluating the changes in IOP and

heart rate at the T1, T2, and T3 time points in comparison with baseline, no statistically significant intergroup differences were observed ($p > 0.05$; Table 3). Although absolute IOP values at T1

differed significantly between groups (Table 2), the magnitude of change from baseline did not demonstrate a statistically significant difference between the groups ($p = 0.064$). Evaluation of the changes in MAP measurements at the T1, T2, and T3 time points from baseline revealed a decrease only in the T3 time point compared with the control measurement in both groups. When desflurane and sevoflurane groups were compared in terms of a decrease in the MAP at the T3 time point, the decrease in the T3 time point from baseline was more significant in the sevoflurane group than in the desflurane group ($p = 0.015$). In intragroup

comparison of the measurements at all time points, no significant relationship was noted between IOP and heart rate and MAP ($p > 0.05$; Table 4).

In addition to other measurements, etCO_2 and SpO_2 values were continuously monitored for all patients in both groups throughout the operation. Inter- and intragroup comparison revealed that these values remained within normal limits at all time points both between and within the groups (etCO_2 , 35 – 45 mmHg; SpO_2 , 97% – 100%). No other intraoperative or postoperative complications were noted.

Table 3. Between groups analysis of the change in measurements

Parameter	Groups		p*
	Desflurane (n = 26)	Sevoflurane (n = 22)	
IOP			
Baseline vs T1	-3 (-13 – 2)	-1 (-8 – 1)	0.064
Baseline vs T2	0 (-11 – 4)	1 (-6 – 11)	0.559
Baseline vs T3	-1.5 (-10 – 8)	-2 (-8 – 6)	0.626
Heart rate			
Baseline vs T1	-12 (-33 – 30)	0.5 (-34 – 23)	0.147
Baseline vs T2	5.5 (-20 – 47)	7 (-21 – 34)	0.860
Baseline vs T3	0.5 (-38 – 71)	8 (-36 – 62)	0.717
MAP			
Baseline vs T1	-11 (-46 – 13)	-11.5 (-30 – 13)	0.860
Baseline vs T2	4.66 (-27 – 25)	-5 (-44 – 31)	0.065
Baseline vs T3	-12 (-26 – 8.66)	-20 (-44 – 1)	0.015

Data are given as median (minimum – maximum) for continuous variables according to normality of distribution; Negative values represent decrease in measurements and positive values represent increase in measurements; *Mann Whitney U test; Baseline: before operation, initial measurement, T1: after anesthesia induction, T2: after intubation, T3: deep anesthesia, IOP: intraocular pressure, MAP: mean arterial pressure

Table 4. Correlations between IOP and other measurements

Parameter		Baseline	T1	T2	T3
Heart rate (Desflurane)	r	-0.086	0.388	0.335	0.106
	p*	0.675	0.051	0.094	0.605
MAP (Desflurane)	r	0.366	0.087	0.345	0.185
	p*	0.065	0.671	0.084	0.365
Heart rate (Sevoflurane)	r	-0.099	-0.142	-0.405	0.001
	p*	0.662	0.530	0.062	0.996
MAP (Sevoflurane)	r	0.371	-0.406	0.182	-0.027
	p*	0.089	0.061	0.416	0.906

*Spearman correlation coefficient; Baseline: before operation, initial measurement, T1: after anesthesia induction, T2: after intubation, T3: deep anesthesia, IOP: intraocular pressure, MAP: mean arterial pressure

DISCUSSION

Perioperative regulation of IOP is an essential aspect of anesthesia management in ophthalmic surgery, especially in pediatric patients, where precise measurement and prevention of abrupt IOP variations are crucial. In this prospective study, we assessed the impact of desflurane and sevoflurane anesthesia on IOP at various perioperative intervals in children undergoing strabismus surgery. Our findings demonstrated that both anesthetic agents were associated with a significant reduction in IOP following anesthesia induction. A greater reduction in IOP was observed in the desflurane group during the post-induction, pre-intubation period (T1).

Inhalational anesthetics are known to reduce IOP through several mechanisms, including decreased aqueous humor production, increased aqueous outflow, and relaxation of extraocular muscles (6,7). Prior research has shown a decrease in IOP after the administration of sevoflurane anesthesia in pediatric patients (8-10). Our results align with these studies, as we observed a significant reduction in IOP at T1 in the sevoflurane group relative to baseline values. Nonetheless, data regarding the effects of desflurane on IOP in pediatric patients remain limited.

A key strength of this study is the direct comparison of desflurane and sevoflurane at predefined perioperative time points. At the T1 time point, the reduction in IOP was greater in the desflurane group compared to the sevoflurane group. This difference may be related to the pharmacokinetic properties of desflurane, which has a lower blood-gas partition coefficient than sevoflurane, allowing more rapid equilibration and onset of action (11). The T1 period represents a clinically relevant time point for IOP assessment, particularly in pediatric patients requiring anesthesia for reliable measurement.

Although the intergroup difference in absolute IOP values at T1 reached statistical significance, the magnitude of this difference was modest. Therefore, its clinical relevance should be interpreted with caution. Even small variations in IOP during this phase may be relevant in selected high-risk populations, such as patients with glaucoma or compromised optic nerve perfusion. Further studies are needed to determine whether the observed differences translate into clinically meaningful outcomes.

Endotracheal intubation is typically associated with sympathetic stimulation and transient increases in IOP (12). In contrast to this expectation, our study did not demonstrate a significant increase in IOP immediately after intubation (T2) in either group. This observation may be explained by adequate anesthetic depth during induction, the standardized use of intravenous agents, and effective neuromuscular blockade with rocuronium. In addition, reversal of neuromuscular blockade with sugammadex before extubation might have played

a role, given that sugammadex has been reported to exert minimal effects on IOP compared with anticholinesterase-anticholinergic combinations (13).

Hemodynamic changes during anesthesia may influence ocular perfusion. In our study, mean arterial pressure decreased during deep anesthesia, particularly in the sevoflurane group; however, no correlation was found between MAP and IOP changes. This supports previous evidence that IOP remains relatively stable within physiological MAP ranges (14).

Surgical positions, such as the upright Trendelenburg position or prolonged prone positioning, as well as surgeries that necessitate hypotensive anesthesia—particularly laparoscopic, spinal, and cardiac procedures may lead to changes in IOP and ocular perfusion (1). Numerous studies have pointed to surgical positions, particularly the prone and Trendelenburg positions, as risk factors for IOP changes (15-19). Because all IOP measurements in our study were performed with patients in the supine position, positional effects were minimized and were unlikely to have significantly influenced the observed differences.

Our study is among the limited number of investigations evaluating the effects of inhalational anesthetics on IOP in pediatric ophthalmic surgery. One important limitation is the absence of objective monitoring of anesthetic depth using bispectral index (BIS). In our study, anesthetic depth was evaluated based on hemodynamic parameters and end-tidal anesthetic concentrations, which may not fully reflect the precise level of hypnosis. This limitation may have affected the interpretation of IOP changes. BIS monitoring was not feasible because the electrode placement in the forehead and temporal regions could interfere with the surgical field. Future studies incorporating standardized depth monitoring may better clarify the relationship between anesthetic depth and IOP.

CONCLUSION

In pediatric ophthalmic surgery, both desflurane and sevoflurane were associated with a significant reduction in IOP at induction compared with the awake state; however, no significant changes were observed following tracheal intubation or during deep anesthesia. Additionally, absolute IOP values at the T1 time point were lower in the desflurane group than in the sevoflurane group. This time point may be clinically relevant for IOP assessment in pediatric patients requiring anesthesia. These findings are generally consistent with previous reports highlighting the impact of anesthetic agents on IOP during the induction phase. Within the limitations of this study, both anesthetic agents appear to provide acceptable IOP control during pediatric ophthalmic surgery. Further studies with larger sample sizes and different ophthalmic procedures are warranted to better clarify the perioperative effects of these anesthetic agents on IOP.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that there is no financial support.

Ethical Approval

This study was approved by the Ordu University Faculty of Medicine Ethics Committee and was conducted in accordance with the Declaration of Helsinki (Approval no: 219, Date: 07/10/2021).

Informed Consent

Written informed consent was obtained from guardians of the patients.

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