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ORIGINAL RESEARCH

The effects of second-hand and third-hand smoke on postoperative emergence agitation in pediatric patients: prospective cohort study

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Abstract

Background: The aim of the present study was to evaluate the effect of second-hand smoke (SHS) and third-hand smoke (THS) on the incidence of postoperative emergence agitation (EA) in children. **Methods**: Six hundred children between the ages of 2–12 were enrolled in this prospective cohort trial. The children were divided into three groups. Group I (Non-smoker; Children whose parents do not smoke and who are not regularly exposed to smoking environments), Group II (Second-hand smoker; Children whose parents smoke in their vicinity, causing them to inhale sidestream or mainstream smoke involuntarily), Group III (Third-hand smoker; Children exposed to pollutants from smoking parents via inhalation, ingestion or dermal contact, despite not directly inhaling sidestream or mainstream smoke). Emergence agitation, postoperative pain, shivering, nausea and vomiting were evaluated in the postanesthesia care unit. Watcha scale was used in the evaluation of emergence agitation. **Results**: In total, five hundred eighty-six patients completed the study, and the incidence of emergence agitation was higher in Group II (32.7%) and Group III (33.7%) compared to Group I (15.0%) ($p < 0.001$). The incidence of emergence agitation was dramatically increased in Group II and Group III compared to Group I (32.7% *vs*. 15.0%; odds ratio (95% confidence interval): 2.74 (1.68–4.48); $p = 0.0001$, and 33.7% *vs*. 15.0%; odds ratio (95% confidence interval): 2.87 (1.76–4.70); $p < 0.0001$, respectively). There was no difference between the groups in terms of postoperative pain, shivering, nausea and vomiting evaluated in the postanesthesia care unit. **Conclusions**: In conclusion, the results of the present study revealed that SHS and THS significantly increase the incidence of EA in children. **Clinical Trial Registration**: The trial was registered with the Australian New Zealand Clinical Trial Registry (ACTRN12619001359123).

Keywords

Emergence agitation; Second-hand smoke; Third-hand smoke; Pediatric patients; General anesthesia

1. Introduction

Tobacco smoke comprises over 5000 toxic and carcinogenic chemicals [1]. There are three variants of tobacco smoke. Firstly, there is first-hand smoke (FHS), which refers to smoking the cigarette itself. Secondly, second-hand smoke (SHS) is the result of environmental exposure to tobacco smoke and consists of two components [2]. The first component is sidestream smoke, emanating from the end of a burning cigarette. The second is mainstream smoke, which is the smoke inhaled and exhaled by the smoker. Recently, a new pathway of exposure has emerged, contributing to the cumulative burden of cigarette smoke exposure. This is known as third-hand smoke (THS), which arises from residual cigarette smoke gases and the ingestion of smoke particles that settle on surfaces and dust [3].

SHS is a global health problem not only for adults but also for children. In 2017, 5% of deaths attributed to SHS were children under the age of 10, highlighting the severity of this issue [4]. THS is closely related to SHS, as it consists of harmful chemicals that settle on surfaces over time, forming accumulated chemical residues. These residues can persist indoors on different floors and surfaces for minutes to months after smoking [5]. Exposure to THS occurs through multiple pathways, including dust ingestion, dermal absorption and inhalation [5]. Similar to SHS, THS has been reported to have harmful effects, with recent studies showing its genotoxicity in human cells [6]. THS, like SHS, poses a serious public health problem. Unfortunately, millions of children suffer from the harmful effects of both SHS and THS. Although

numerous studies have evaluated the relationship between SHS and THS and adverse events, there is currently no data on whether they affect the emergence agitation in children after general anesthesia.

Emergence agitation (EA) is a phenomenon observed in the early stages of recovery from general anesthesia, characterized by components such as crying, excitation, disorientation, irritability and inconsolability [7]. EA is particularly prevalent in preschool children following sevoflurane anesthesia, although its incidence varies widely across different studies [8]. Children experiencing EA may have delayed discharge from the post anesthesia care unit (PACU) and an increased risk of injury, leading to dissatisfaction and anxiety among their relatives [9]. While the exact cause of EA remains unclear, several risk factors have been implicated, including pain, preschool age, inhalational (sevoflurane) anesthesia, preoperative anxiety, and specific surgical procedures (such as otolaryngologic or ophthalmologic) [9].

The aim of the present study was to evaluate the effect of two environmental tobacco smokes (SHS and THS) on the incidence of postoperative EA in children undergoing surgery.

2. Materials and methods

2.1 Patient recruitment

Six hundred children between the ages of 2 and 12, with American Society of Anesthesiologists (ASA) physical status I or II, who underwent elective surgery under general anesthesia, were enrolled in this study. Patients with cerebrovascular disease, a history of drug use affecting the central nervous system, previous anesthesia experience, and those transferred to the ward without visiting the recovery room were excluded from the study. Additionally, patients whose parents refused participation were also excluded.

The children included in the study were divided into three groups as follows: Group I (Non-smoker): Children whose parents do not smoke and are not chronically exposed to smoking environments; Group II (Second-hand smoker): Children whose parents smoke in their environment, leading to direct exposure to sidestream or mainstream smoke, and involuntary inhalation of this smoke; Group III (Third-hand smoker): Children whose parents smoke, without direct exposure to sidestream and mainstream smoke, but experience involuntary inhalation, ingestion or dermal uptake of pollutants present in the air, dust and on surfaces. The division of children into these groups was conducted by a blind researcher who was not involved in other phases of the study.

2.2 Anesthetic procedure

All patients included in the study adhered to the fasting periods specified by the ASA, and none of them received premedication. Standard monitoring, including a pulse oximeter, non-invasive blood pressure cuff, and a 3-lead electrocardiogram (ECG), was applied in the operating room. Anesthesia induction was performed using 1–2 minimum alveolar concentration (MAC) of sevoflurane in oxygen, following the standard practice of our clinic. After face mask inhalation induction with 8% sevoflurane in oxygen in all groups, an intravenous (IV) catheter was placed, and fentanyl (2 μg/kg, IV) was administered. Following the establishment of IV access, a fluid infusion of 5% dextrose, 0.45% sodium chloride (NaCl), and 5–10 mL/kg/hour was initiated. Intravenous rocuronium 0.6 mg/kg was administered to facilitate tracheal intubation.

After anesthesia induction, volume-controlled mechanical ventilation (Tidal volume; 6–8 mL/kg, respiratory rates were adjusted to achieve an end-tidal carbon dioxide ($ETCO_2$) of 30–35 mmHg, and positive end-expiratory pressure was not applied, as in the standard practice of our clinic) was initiated. Sevoflurane in an oxygen-air (50%–50%, 4 L/min) mixture and remifentanil (0.25 μg/kg/min) was used for the maintenance of anesthesia. When there was a decrease of more than 20% in mean blood pressure (MBP) compared to basal values, the crystalloid infusion rate was increased up to 50%. If that wasn't enough, the concentration of sevoflurane was decreased and the maintenance of anesthesia was continued. Paracetamol (10 mg/kg) was preferred for postoperative analgesia. Anesthesia maintenance was gradually reduced and stopped as the surgery neared conclusion. Sugammadex (2 mg/kg) was used for neuromuscular recovery in all patients when anesthetic agents were turned off. Tracheal extubation was performed when adequate breathing depth was achieved (tidal volume >6 mL/kg, respiratory rate >16 per minute, and oxygen saturation (SpO_2) >98%). Following tracheal extubation, patients transferred to the PACU.

2.3 Measurements

In the post-anesthesia care unit (PACU), patients were evaluated for discharge based on the following criteria: Modified Aldrete Score >9, absence of pain, and no nausea or vomiting. Discharge from the PACU for all patients was conducted by an anesthesiologist who was blinded to the study, following the customary guidelines practiced in the institution.

Emergence agitation (EA) was assessed by anesthesiologists using the Watcha scale, which categorizes agitation levels as follows: 1 for asleep or calm, 2 for crying but can be consoled, 3 for crying and cannot be consoled, and 4 for agitated and thrashing around [10]. Children who scored 3 or 4 on the Watcha scale were considered to have EA. The treatment protocol for children who developed EA consisted of the standard treatment used in our clinic, which involved administering propofol at a dose of 0.5–1 mL/kg intravenously.

In the post-anesthesia care unit (PACU), postoperative pain was measured using the Face, Legs, Activity, Cry, Consolability (FLACC) scale [11], which is based on a 0–10 score. According to the FLACC scale score (0–10), patients' pain levels were categorized as follows: mild pain (0–3), moderate pain (4–7), and severe pain (>7). Postoperative nausea and vomiting (PONV) were evaluated using the Baxter Animated Retching Faces (BARF) scale.

Patients were continuously monitored for the occurrence of postoperative shivering (PS) during their initial 5 minutes in the PACU and subsequently every 10 minutes throughout their stay. Postoperative shivering was assessed using the scale described by Crossley and Mahajan [12]: Grade 0: No shivering; Grade 1: No visible muscle activity, but presence of piloerection, peripheral vasoconstriction, or peripheral cyanosis

(with other causes excluded); Grade 2: Muscular activity in only one muscle group; Grade 3: Moderate muscular activity in more than one muscle group but not generalized shaking; Grade 4: Violent muscular activity involving the entire body. All assessments were conducted by the same specially trained anesthesiologists (SA, SD and ESK) to minimize measurement errors. Patients were considered to have PS if they were evaluated as grade 3 or 4 in at least 2 PACU assessments.

Additionally, anesthesia duration and PACU stay were recorded. Anesthesia duration was defined as the time elapsed between the induction of anesthesia and the discontinuation of anesthetic agents.

2.4 The sample size

We based our sample size calculation on the 25% postoperative emergence agitation proportion reported in previously published systematic reviews and studies [8, 13]. To achieve 80% power and target a relative risk increment of 50%, with a maximal 5% risk of type I error, we initially calculated a sample size of 396 children. However, considering the significant variation in the rate of EA after surgery observed in previous studies and potential losses, we decided to include 600 patients (200 for each group) in the present study.

2.5 Statistical analysis

Statistical analyses were performed with SPSS Version 22.0 (Statistical Package for the Social Sciences Inc., Chicago, IL, USA). Data were tested for normality with Kolmogorov-Smirnov (with Lilliefors correction) and Shapiro-Wilk tests. Descriptive statistics were performed in both the patient groups; numerical data were expressed as median (the interquartile range (IQR)), while categorical data as numbers (percentages). A p-value less than 0.05 was considered statistically significant.

3. Results

A total of six hundred patients were included in this study, of which 586 completed the study, and 14 were excluded. Data analysis was conducted on the three groups.

The patients' demographics and clinical characteristics are summarized in Table 1. There were no significant differences between the three groups regarding age, gender, weight, ASA physical status, anesthesia duration, and type of surgery (p = 0.051, 0.057, 0.124, 0.087, 0.860, 0.264, 0.306, respectively).

The incidences of EA, PACU discharge time, incidences of PS, FLACC and BARF scale scores are summarized in Table 2. The incidence of EA was higher in Group II (32.7%) and Group III (33.7%) compared to Group I (15.0%) ($p < 0.001$). EA comparison between groups and risk ratios are summarized in Table 3. The incidence of EA was dramatically increased in Group II and Group III compared to Group I (32.7% *vs*. 15.0%; odds ratio (95% confidence interval): 2.74 (1.68–4.48); p = 0.0001, and 33.7% *vs*. 15.0%; odds ratio (95% confidence interval): 2.87 (1.76–4.70); $p < 0.0001$, respectively). The distribution of Watcha Scale Scores between groups is illustrated in Fig. 1. While the Watcha Scale Score was determined as 4 in only 7 (3.5%) children in Group I, it was determined as 4 in 42 (21.4%) children in Group II and 24 (12.6%) children in Group III.

There was no statistically significant difference in FLACC scale score, BARF scale score (≥6), and PS incidence (p = 0.312, 0.184, 0.628, respectively). The incidence of PS was the highest in Group II at 16.8%. Meanwhile, it was 14% in Group I and 13.7% in Group III. Similarly, the proportion of patients with a BARF scale score ≥6 was higher in Group II. PACU discharge time (median (IQR), min) was lower in Group

TABLE 1. Demographic and clinical characteristics of the patients.

	Group I (n = 200)	Group II (n = 196)	Group III (n = 190)	p
Age, yr	5.5 (3–9)	6.0 (4–9)	5.0 (3–8)	0.051
Gender				
Male	138 (69.0%)	111 (56.6%)	122 (64.2%)	0.057
Female	62 (31.0%)	85 (43.4%)	68 (35.8%)	
Weight, kg	20 (15–37)	20 (16–33)	20 (15–26)	0.087
ASA PS				
I	150 (75.0%)	149 (76.0%)	147 (77.4%)	0.860
II	50 (25.0%)	47 (24.0%)	43 (22.6%)	
Anesthesia duration, min	60 (40–90)	60 (45–90)	50 (40–78)	0.264
Type of surgery				
Neurosurgery	3 (1.5%)	2 (1.0%)	1 (0.5%)	0.306
Thoracic surgery	4 (2.0%)	1 (0.5%)	3 (1.6%)	
Abdominal surgery	26 (13.1%)	32 (16.3%)	28 (14.8%)	
Urinary surgery	32 (16.1%)	40 (20.4%)	36 (19.0%)	
Orthopedic surgery	55 (27.6%)	46 (23.5%)	33 (17.5%)	
Reconstructive surgery	62 (31.2%)	68 (34.7%)	74 (39.2%)	
Ophthalmologic surgery	17 (8.5%)	7 (3.6%)	14 (7.4%)	

ASA PS: American Society of Anesthesiologists Physical Status Classification System. Data are presented median (IQR) or n (%).

TABLE 2. Post-operative outcomes.

	Group I (n = 200)	Group II (n = 196)	Group III (n = 190)	*p*
PACU discharge time, min	30 (30–36)	35 (30–40)	35 (30–40)	0.010
Incidences of emergence agitation, n (%)	30 (15.0%)	64 (32.7%)	64 (33.7%)	<0.001
FLACC scale score	2 (0–5)	3 (0–6)	3 (0–5)	0.312
BARF scale score, ≥6	39 (19.5%)	53 (27.0%)	48 (25.3%)	0.184
Postoperative shivering, n (%)	28 (14.0%)	33 (16.8%)	26 (13.7%)	0.628

PACU: Postanesthesia care unit; FLACC: Face, Legs, Activity, Cry, Consolability; BARF: Baxter Animated Retching Faces. Data are presented median (IQR) or n (%).

TABLE 3. Emergence agitation comparison between groups and risk ratios.

	Incidences of emergence agitation, n (%)	Risk ratio (95% CI)	*p*
Group I (Non-smoker) (n = 200)	30 (15.0%)	2.74 (1.68–4.48)	0.0001
Group II (Second hand smoker) (n = 196)	64 (32.7%)		
Group I (Non-smoker) (n = 200)	30 (15.0%)	2.87 (1.76–4.70)	<0.0001
Group III (Third hand smoker) (n = 190)	64 (33.7%)		

CI: confidence interval.

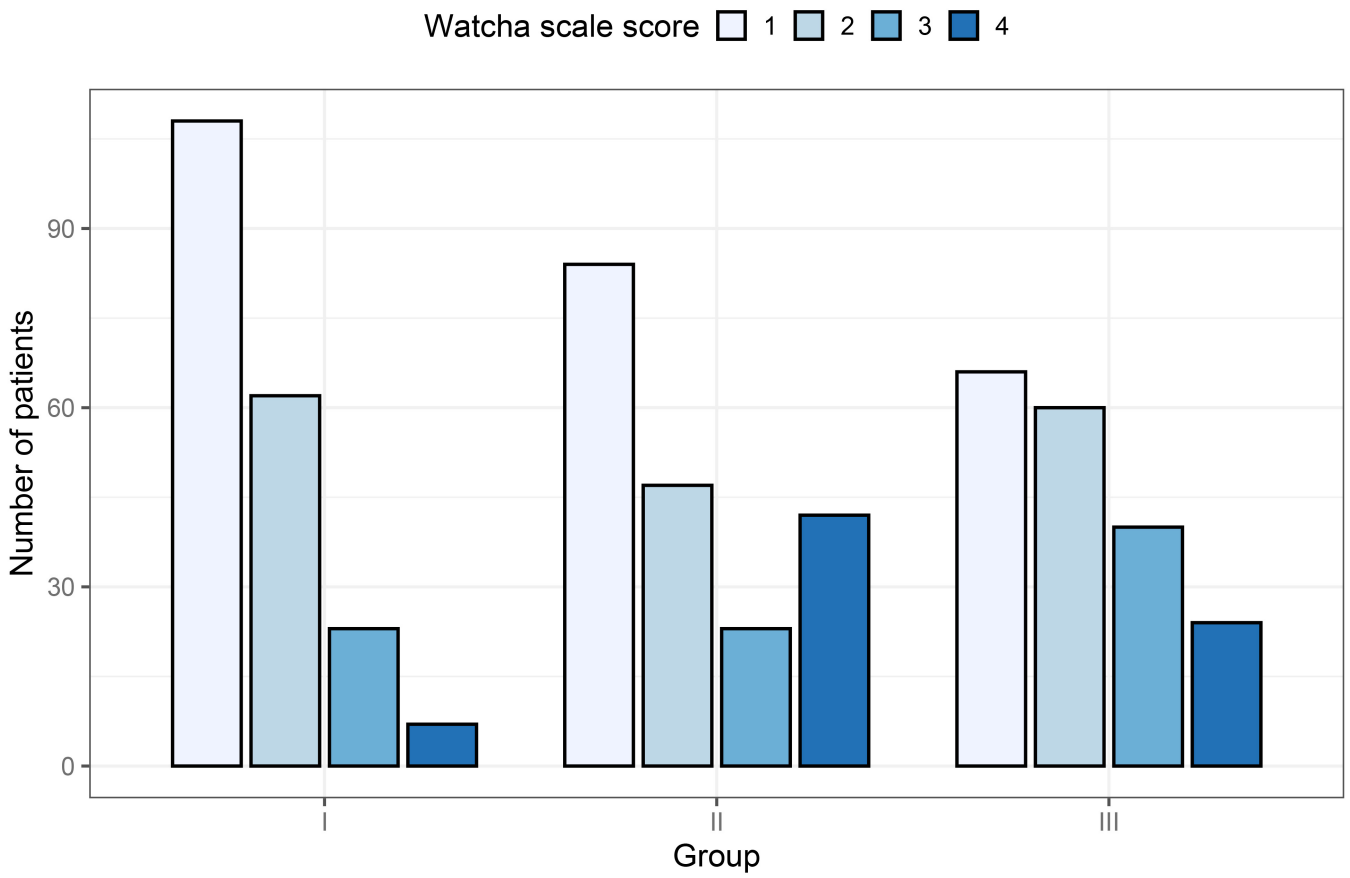

FIGURE 1. Watcha Scale Score distribution between groups.

I (30 (30–36)) compared to Group II (35 (30–40)) and Group III (35 (30–40)) ($p = 0.010$).

4. Discussion

The results of the present study indicate that both SHS and THS significantly increase the incidence of postoperative EA in children.

Indeed, the mechanisms underlying EA in children remain not fully understood, although various factors have been evaluated in numerous studies.

Inhalational anesthetics such as halothane, isoflurane, sevoflurane and desflurane can act as triggers of EA, but it has been revealed that EA development is higher in inhalation agents with low blood-gas partition coefficients such as desflurane and sevoflurane [14]. It is thought that very early and rapid awakening in sevoflurane and desflurane anesthesia increases the risk of EA [15]. It has been suggested that differences in clearance of inhalation agents from the central nervous system lead to varying recovery times in different regions of the brain [15]. It is hypothesized that delayed restoration of cognitive function compared to other brain functions as a result of different recovery times of brain regions causes EA. This hypothesis is supported by the rapid emergence of desflurane and sevoflurane anesthesia [9]. In the meta-analysis of Kuratani *et al.* [14] in which they compared halothane and desflurane anesthesia, it was shown that sevoflurane anesthesia is a risk factor for EA in children. In the present study, anesthesia induction of all our patients was performed with face mask inhalation, and anesthesia maintenance was continued with sevoflurane.

No relationship was found between the occurrence of EA in children and gender [16]. Conversely, studies in the adult population reported that the male gender was associated with EA [17]. In the present study, the gender distribution was similar between the groups.

It has been reported that preoperative anxiety and parental anxiety increase the risk of EA in children [9, 15]. Additionally, diseases such as attention-deficit/hyperactivity disorder have been shown to be risk factors for EA [18].

EA is more common in children than adults [19]. It has been reported in studies performed in pediatric patients that the incidence of EA is inversely proportional to age [20, 21]. In the present study, children between the ages of 2 and 12 were included.

Ophthalmological and ear-nose-throat surgeries are considered to be risk factors for EA [22]. Specifically, previous studies have shown that strabismus surgery and tonsillectomy are independent risk factors for EA in pediatric patients [16]. None of the children included in the present study had undergone ear-nose-throat surgery. However, among the children included in the study, there were those who had undergone ophthalmologic surgery. This situation was not specifically selected, and the surgical procedure distributions of the patients who were accepted to be included in the study and met the inclusion criteria during the study period developed spontaneously. Additionally, it was observed in the present study that the group with the highest rate of EA had the lowest rate of children who had undergone ophthalmologic surgery.

In addition to anesthetic agents, it was evaluated whether the depth of anesthesia had an effect on EA, and it was determined that deep and light anesthesia administered under bispectral index (BIS) guidance did not make any difference in terms of EA development [23]. In the present study, as in our routine practice, the depth of anesthesia was evaluated with clinical parameters, and BIS monitoring was not applied.

Although there are many factors thought to affect the development of EA in children, we could not find a study evaluating the effect of exposure to tobacco smoke on EA in the databases we applied for research (WoS All Databases collection, PubMed). Environmental exposure to tobacco smoke is divided into either direct tobacco smoke (SHS) or exposure to tobacco smoke-related residual particles (THS) [24]. There are more than 5000 chemicals in the composition of tobacco, of which at least 250 are known to be toxic [1]. There is exposure to these toxic substances as a result of both SHS and THS.

Tobacco smoke contains carbon monoxide (CO), which is produced by the incomplete oxidation of combustible carbon compounds [25]. Children may be exposed to CO through SHS [26]. Even through SHS, when CO is absorbed into the bloodstream after exposure, it binds to hemoglobin (Hb) with 200 times greater affinity than oxygen, forming carboxyhemoglobin (COHb) [26]. The formation of COHb causes tissue hypoxia by not only preventing the binding of oxygen to Hb but also impeding oxygen delivery to the tissue [27].

The relationship between preoperative COHb levels and exposure to tobacco smoke in children is not clear [28]. In a study evaluating exposure to tobacco smoke using pulse CO-oximetry, it was reported that values of SpCO (carboxyhemoglobin measured by pulse CO-oximetry) and serum COHb values did not show a correlation [29]. Therefore, it is suggested that pulse CO-oximetry is not a reliable screening tool for preoperatively detecting tobacco smoke exposure in children.

It has been shown that children with environmental CO exposure experience more postoperative complications, increased pain, and higher analgesic needs [30]. Exposure to tobacco smoke doubles a child's risk of perianesthetic adverse respiratory events [31]. The risk is particularly high for laryngospasm. In previous studies, it was stated that children exposed to tobacco smoke stayed longer in the PACU [32] and the incidence of unplanned night stays increased [33]. Although smoking provides some protection against postoperative nausea and vomiting in adults, it has been shown that children exposed to secondhand smoke have the same PONV rates as children who are not exposed [34]. In the present study, the length of stay in PACU does not differ between groups. In addition, criteria such as pain, nausea-vomiting scores, and postoperative shivering in PACU were also evaluated in the present study, and no difference was found between the groups, contrary to the literature. Furthermore, no other complications, including respiratory complications, were observed in the PACU in the present study.

Since THS is a newer and less well-known concept than SHS, the number of studies on THS is limited. Both THS and SHS have focused on respiratory complications, and there is insufficient or no literature data on many postoperative complications, including postoperative EA. In a study by Jung

et al. [35], SHS and THS were grouped separately, and it was demonstrated that THS also affects the lower respiratory system in children. The authors classified exposure to cigarette smoke similarly to the present study and noted a linear trend in symptom frequency among the three groups (non-smoker, SHS and THS groups). The results of this study indicated that symptoms, including cough and nasal symptoms, were most prevalent in the SHS group, followed by the THS and non-smoking groups, respectively. Although less than SHS, THS has been reported to have significant effects on the respiratory system of children. The results of the present study also revealed that the highest EA developed in the SHS group, followed by the THS group. However, it is noteworthy that there was a significant difference in EA between the THS group and the non-smoker group.

This study had several limitations. First, anesthesia induction was performed using face mask inhalation in all of our patients, primarily due to their age, and we could not rule out its potential effect on postoperative emergence agitation (EA). Second, exposure to SHS and THS was determined based on detailed family history, and patients' blood cotinine or COHb levels were not assessed. However, it should be noted that there are significant doubts in the literature regarding whether cotinine and COHb values serve as reliable preoperative markers for SHS and THS. Additionally, the lack of BIS monitoring could be considered another limitation. Nevertheless, we believe that maintaining uniform anesthesia procedures performed by the same team helps to mitigate this limitation.

5. Conclusions

In conclusion, the results of the present study indicate that both SHS and THS significantly increase the incidence of EA in children without affecting other postoperative adverse events such as pain, nausea-vomiting, length of stay in the PACU and shivering.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

MS, SD, SA—designed the research study. MS—wrote original draft. SD, SA, ESK—collected initial data and was in charge of data acquisition. MS, FC, MSU—analyzed and interpreted the data. MS, MSU—analyzed statistically; edited final manuscript. İK, JBC, FC—supervised and reviewed the study. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The trial was approved by the Ethics Committee of Selçuk University Faculty of Medicine (Konya, Turkey; reference no. 2019/32), and written consent from was obtained from the legal guardians of the children included in the present study. The trial was registered with the Australian New Zealand Clinical Trial Registry (ACTRN12619001359123). This prospective cohort trial was conducted from January 2020 to June 2022 at Selçuk University Faculty of Medicine Hospital. This study was conducted in accordance with the principles of the Declaration of Helsinki.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Talhout R, Schulz T, Florek E, van Benthem J, Wester P, Opperhuizen A. Hazardous compounds in tobacco smoke. International Journal of Environmental Research and Public Health. 2011; 8: 613–628.

[2] Acuff L, Fristoe K, Hamblen J, Smith M, Chen J. Third-hand smoke: old smoke, new concerns. Journal of Community Health. 2016; 41: 680–687.

[3] Ramírez N, Özel MZ, Lewis AC, Marcé RM, Borrull F, Hamilton JF. Exposure to nitrosamines in thirdhand tobacco smoke increases cancer risk in non-smokers. Environment International. 2014; 71: 139–147.

[4] GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2018; 392: 1923–1994.

[5] Matt GE, Quintana PJ, Destaillats H, Gundel LA, Sleiman M, Singer BC, *et al*. Thirdhand tobacco smoke: emerging evidence and arguments for a multidisciplinary research agenda. Environmental Health Perspectives. 2011; 119: 1218–1226.

[6] Hang B, Sarker AH, Havel C, Saha S, Hazra TK, Schick S, *et al*. Thirdhand smoke causes DNA damage in human cells. Mutagenesis. 2013; 28: 381–391.

[7] Mountain BW, Smithson L, Cramolini M, Wyatt TH, Newman M. Dexmedetomidine as a pediatric anesthetic premedication to reduce anxiety and to deter emergence delirium. The AANA Journal. 2011; 79: 219–224.

[8] Pickard A, Davies P, Birnie K, Beringer R. Systematic review and meta-analysis of the effect of intraoperative α2-adrenergic agonists on postoperative behaviour in children. British Journal of Anaesthesia. 2014; 112: 982–990.

[9] Kanaya A. Emergence agitation in children: risk factors, prevention, and treatment. Journal of Anesthesia. 2016; 30: 261–267.

[10] Watcha MF, Ramirez-Ruiz M, White PF, Jones MB, Lagueruela RG, Terkonda RP. Perioperative effects of oral ketorolac and acetaminophen in children undergoing bilateral myringotomy. Canadian Journal of Anaesthesia. 1992; 39: 649–654.

[11] Merkel SI, Voepel-Lewis T, Shayevitz JR, Malviya S. The FLACC: a behavioral scale for scoring postoperative pain in young children. Journal of Pediatric Nursing. 1997; 23: 293–297.

[12] Shorrab AA, El-Sawy ME, Othman MM, Hammouda GE. Prevention of hypothermia in children under combined epidural and general anesthesia: a comparison between upper- and lower-body warming. Pediatric Anesthesia. 2007; 17: 38–43.

[13] Ydemann M, Nielsen BN, Wetterslev J, Henneberg S, Lauritsen T,

Steen N, *et al*. Effect of clonidine to prevent agitation in children after sevoflurane anaesthesia: a randomised placebo controlled multicentre trial. Danish Medical Journal. 2016; 63: A5234.

[14] Kuratani N, Oi Y. Greater incidence of emergence agitation in children after sevoflurane anesthesia as compared with halothane. Anesthesiology. 2008; 109: 225–232.

[15] Voepel-Lewis T, Malviya S, Tait AR. A prospective cohort study of emergence agitation in the pediatric postanesthesia care unit. Anesthesia & Analgesia. 2003; 3: 1625–1630.

[16] Hino M, Mihara T, Miyazaki S, Hijikata T, Miwa T, Goto T, *et al*. Development and validation of a risk scale for emergence agitation after general anesthesia in children: a prospective observational study. Anesthesia & Analgesia. 2017; 125: 550–555.

[17] Rim JC, Kim JA, Hong JI, Park SY, Lee JH, Chung CJ. Risk factors of emergence agitation after general anesthesia in adult patients. Anesthesia and Pain Medicine. 2016; 11: 410–416.

[18] Lee S, Sung T. Emergence agitation: current knowledge and unresolved questions. Korean Journal of Anesthesiology. 2020; 73: 471–485.

[19] Demir CY, Yuzkat N. Prevention of emergence agitation with ketamine in rhinoplasty. Aesthetic Plastic Surgery. 2018; 42: 847–853.

[20] Choi HR, Cho JK, Lee S, Yoo BH, Yon JH, Kim KM. The effect of remifentanil versus N_2O on postoperative pain and emergence agitation after pediatric tonsillectomy/adenoidectomy. Korean Journal of Anesthesiology. 2011; 61: 148–153.

[21] Kain ZN, Mayes LC, Weisman SJ, Hofstadter MB. Social adaptability, cognitive abilities, and other predictors for children's reactions to surgery. Journal of Clinical Anesthesia. 2000; 12: 549–554.

[22] Dahmani S, Stany I, Brasher C, Lejeune C, Bruneau B, Wood C, *et al*. Pharmacological prevention of sevoflurane- and desflurane-related emergence agitation in children: a meta-analysis of published studies. British Journal of Anaesthesia. 2010; 104: 216–223.

[23] Frederick HJ, Wofford K, de Lisle Dear G, Schulman SR. A randomized controlled trial to determine the effect of depth of anesthesia on emergence agitation in children. Anesthesia & Analgesia. 2016; 122: 1141–1146.

[24] Torres S, Merino C, Paton B, Correig X, Ramírez N. Biomarkers of exposure to secondhand and thirdhand tobacco smoke: recent advances and future perspectives. International Journal of Environmental Research and Public Health. 2018; 15: 2693.

[25] Hampson NB, Scott KL. Use of a noninvasive pulse CO-oximeter to measure blood carboxyhemoglobin levels in bingo players. Respiratory Care. 2006; 51: 758–760.

[26] Prockop LD, Chichkova RI. Carbon monoxide intoxication: an updated review. Journal of the Neurological Sciences. 2007; 262: 122–130.

[27] Piantadosi CA. Carbon monoxide poisoning. New England Journal of Medicine. 2002; 347: 1054–1055.

[28] Yee BE, Ahmed MI, Brugge D, Farrell M, Lozada G, Idupaganthi R, *et al*. Second-hand smoking and carboxyhemoglobin levels in children: a prospective observational study. Paediatric Anaesthesia. 2010; 20: 82–89.

[29] Wilson KM, Wesgate SC, Pier J, Weis E, Love T, Evans K, *et al*. Secondhand smoke exposure and serum cytokine levels in healthy children. Cytokine. 2012; 60: 34–37.

[30] Koyuncu O, Turhanoglu S, Tuzcu K, Karcıoglu M, Davarcı I, Akbay E, *et al*. Effect of carboxyhemoglobin on postoperative complications and pain in pediatric tonsillectomy patients. Paediatric Anaesthesia. 2015; 25: 247–252.

[31] Chiswell C, Akram Y. Impact of environmental tobacco smoke exposure on anaesthetic and surgical outcomes in children: a systematic review and meta-analysis. Archives of Disease in Childhood. 2017; 102: 123–130.

[32] Niedermeier K, Selleck CS. Parental smoking and children undergoing anesthesia: is there a role for pediatric hospitals in smoking cessation? Journal for Specialists in Pediatric Nursing. 2016; 21: 170–177.

[33] Setzer N. The effect of tobacco smoke on children undergoing general anesthesia and surgery. Pediatrics. 1997; 100: 731.

[34] Chau DF, Reddy A, Breheny P, Young AR, Ashford E, Song M, *et al*. Revisiting the applicability of adult early post-operative nausea and vomiting risk factors for the paediatric patient: a prospective study using cotinine levels in children undergoing adenotonsillectomies. Indian Journal of Anaesthesia. 2017; 61: 964–971.

[35] Jung JW, Ju YS, Kang HR. Association between parental smoking behavior and children's respiratory morbidity: 5-year study in an urban city of South Korea. Pediatric Pulmonology. 2012; 47: 338–345.

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