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COMPARATIVE EVALUATION OF DESFLURANE AND SEVOFLURANE ANESTHESIA DURING SURGICAL CORRECTION OF VERTEBRAL AND SPINAL CORD INJURY IN CHILDREN

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Introduction. Currently, inhaled third-generation anesthetic agents, such as sevoflurane and desflurane, are commonly used in pediatric practice. Their properties and efficiencies are studied in detail. Information about the effectiveness and safety of these drugs as emergency anesthesia in children is very limited; there are no comparative studies.

The aim of this study was to conduct a comparative evaluation of desflurane and sevoflurane to maintain anesthesia during the surgical correction of vertebral and spinal cord injury in children.

Material and methods. This study included seventy-four 12–18-year-old patients (mean age, 14 years) who underwent immediate surgical correction of unstable fractures of the thoracolumbar and lumbar spine at the Turner Scientific Research Institute for Children's Orthopedics between 2015 and 2017. The patients were categorized into two groups: group D, in which anesthesia was maintained with desflurane (35 patients), and group C, in which anesthesia was maintained with sevoflurane (39 patients).

The following parameters were studied: systolic, diastolic, and average blood pressure (BP); heart rate (HR); respiratory recovery time; time to extubation; time to instruction completion; and presence of complications intraoperatively and within 24 h after surgery, including pronounced intraoperative hypotension, bradypnea, and desaturation (SpO_2 < 95%) in the postextubation period, agitation, nausea, vomiting, and measured blood loss.

Results. A comparative evaluation of the investigated parameters revealed that the systolic, diastolic, and average BP and HR in both groups did not exceed the limits of acceptable values. The results of the intraoperative monitoring of capillary blood parameters in all patients were within the reference range and did not differ significantly between groups. An analysis of the indicators reflecting the rate of awakening revealed that all stages of the termination of anesthesia were performed more quickly in group D. There was a comparable number of postoperative nausea and vomiting episodes in both groups. Group C displayed a high incidence of postoperative agitation. There were no related adverse respiratory effects in group D, whereas three patients reported such effects in group C.

Conclusions. The use of desflurane and sevoflurane provides a favorable hemodynamic profile intraoperatively and is not accompanied with the development of clinically significant side effects. Desflurane reduces the probability of certain adverse effects in the immediate postoperative period, provides a faster awakening, and has the possibility of reliable assessment of neurological status after surgery.

Keywords: vertebral and spinal cord injury; children; anesthesia; sevoflurane; desflurane.

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СРАВНИТЕЛЬНАЯ ОЦЕНКА АНЕСТЕЗИИ ДЕСФЛУРАНОМ И СЕВОФЛУРАНОМ ПРИ ХИРУРГИЧЕСКОЙ КОРРЕКЦИИ ПОЗВОНОЧНО-СПИННОМОЗГОВОЙ ТРАВМЫ У ДЕТЕЙ

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Введение. В настоящее время в педиатрической практике общепринятым является использование для поддержания анестезии ингаляционных анестетиков 3-го поколения — севофлурана и десфлурана. Сведения об эффективности и безопасности применения этих препаратов в ургентной анестезиологии у детей весьма ограничены, отсутствуют сравнительные исследования.

Цель исследования — провести сравнительную оценку применения десфлурана и севофлурана для поддержания анестезии при хирургической коррекции позвоночно-спинномозговой травмы у детей.

Материал и методы. В исследование включено 74 пациента в возрасте от 12 до 18 лет, которым была выполнена срочная хирургическая коррекция нестабильных переломов грудопоясничного и поясничного отделов позвоночника в период с 2015 по 2017 г. Все пациенты были разделены на две группы: группу Д, в которой поддержание анестезии осуществляли десфлураном (35 человек), и группу С, в которой анестезию поддерживали севофлураном (39 человек).

Исследовали следующие параметры: систолическое, диастолическое и среднее артериальное давление (АД), частоту сердечных сокращений (ЧСС), время восстановления самостоятельного дыхания, время до экстубации, время до выполнения команд, наличие осложнений интраоперационно и в течение 24 часов после оперативного вмешательства (выраженная интраоперационная гипотония, брадипноэ и десатурация (SpO_2 < 95 %) в постэкстубационном периоде, ажитация, тошнота, рвота, величина кровопотери).

Результаты. По результатам сравнительной оценки исследуемых параметров было установлено, что показатели систолического, диастолического и среднего АД и ЧСС в обеих группах не выходили за пределы допустимых значений. Данные интраоперационного мониторинга показателей капиллярной крови у всех пациентов находились в пределах нормальных значений и не отличались достоверно в обеих группах. Анализ показателей, отражающих скорость пробуждения, позволил установить, что в группе Д все этапы окончания анестезии осуществлялись быстрее. Количество эпизодов послеоперационной тошноты и рвоты в обеих группах было сопоставимо. В группе С отмечалась большая частота послеоперационной ажитации. Сопутствующие нежелательные респираторные явления в группе Д отмечены не были, тогда как в группе С таковые зафиксированы у троих пациентов.

Выводы. Применение десфлурана и севофлурана обеспечивает благоприятный гемодинамический профиль интраоперационно и не сопровождается развитием клинически значимых побочных явлений. Десфлуран снижает вероятность некоторых нежелательных эффектов в ближайшем послеоперационном периоде, обеспечивает более быструю динамику пробуждения и возможность достоверной оценки неврологического статуса после оперативного вмешательства.

Ключевые слова: позвоночно-спинномозговая травма; дети; анестезия; севофлуран; десфлуран.

Introduction

The relevance of timely surgical treatment of spinal and cerebrospinal injury in children cannot be overestimated. Although the number of cases of spinal injuries in the structure of isolated and concomitant injuries of the musculoskeletal system is relatively small (0.5%–5.0%), most of them are characterized by mechanical and neurological instability [1, 2]. This determines the extremely high risk of serious, often irreversible neurological complications, which often lead to disability (11%–30%) and a significant deterioration in the quality of life [1]. In addition, the overlay of persistent neurological deficit inevitably entails the development of secondary chronic complications, many of which, for example, thromboembolism, are life-threatening.

The primary causes of spinal cord injury in children are autotrauma (39.0%), catatrauma

(34.6%), falling of a heavy object on the back (15.0%), and sports injury (11.4%) [1].

The majority of pediatric patients with spinal and cerebrospinal injuries (73.9%) require surgical treatment [3]. Early surgical correction reduces the duration of treatment in the intensive care unit and the total hospitalization duration [4]. Additionally, surgical treatment performed during the first 72 h after injury reduces the duration of respiratory support, if necessary, as well as reduces the number of infectious complications [5].

Considering the urgent nature of the necessary surgical care for patients with spinal and cerebrospinal injuries, the ability to collect anamnestic data and perform preoperative examination and preparation are often limited. In addition, several patients are admitted to the hospital for emergency surgical care in a serious condition and often accompanied by phenomena that can make significant changes to the anesthetic management plan of the surgical intervention.

Anesthetic management of emergency surgical interventions in the treatment of patients with spinal and cerebrospinal injury is usually planned in pediatric practice when considering the following criteria [1]:

1) Rapid sequential intravenous induction with a combination of hypnotic (propofol 3–5 mg/kg), narcotic analgesic (fentanyl 4–5 μg/kg), and non-depolarizing muscle relaxant
2) Maintenance of anesthesia, i.e., total intravenous anesthesia
3) The ability to use inhalation anesthetic as the primary means for maintaining anesthesia with a complete deficit of circulating blood volume (CBV) and stable hemodynamics
4) Technical readiness for emergency immediate correction of pronounced hemodynamic disorders during anesthesia
5) Continuous monitoring, correction of possible deviations of the gas and electrolyte composition of the blood, impaired hemostasis, and blood oxygen transport function
6) Maintaining normothermia
7) Ensuring, if possible, the fastest possible assessment of the neurological status at the end of surgical intervention

Currently, the third-generation inhalation anesthetics sevoflurane and desflurane are widely used in pediatric practice [6]. Their properties and efficacy have been studied in detail, which is reflected in the large number of studies on the use of these medications for anesthetic maintenance of elective surgical interventions in children [7–14].

However, the data on the efficacy and safety of the use of these third-generation inhalation anesthetics in urgent anesthesiology in children is very limited. There are no comparative studies of these drugs that warrant the need for the present study.

This study aims to perform a comparative assessment of the use of sevoflurane and desflurane in the maintenance of anesthesia during the surgical correction of spinal and cerebrospinal injuries in children.

Material and methods

The study included 74 patients aged from 12 to 18 (mean age, 14) years who underwent urgent surgical correction of unstable fractures of the thoracolumbar and lumbar spine from 2015 to 2017 at the Turner Scientific and Research Institute for Children's Orthopedics. The patients were categorized into two groups: group D and S, in which anesthesia was maintained by desflurane (n = 35) and sevoflurane (n = 39), respectively.

The characteristics of the pediatric patients are presented in Table 1. In terms of age, body weight, and gender, the groups did not significantly differ from each other.

Anesthesia was induced in both the groups by intravenous administration of 4 mg/kg propofol

Table 1

Characteristics of the study patients by age, body weight, and gender

Indicators	Group D (n = 35) $M \pm m$	Group S (n = 39) $M \pm m$	Significance level
Age	14.53 ± 0.28	14.21 ± 0.26	0.163
Weight	48.4 ± 1.42	50.78 ± 1.45	0.224
Gender, male/female	13/22	15/24	

and 2 μg/kg fentanyl. After myorelaxation with intravenous injection of rocuronium at a dose of 0.5 mg/kg, orotracheal intubation was performed.

Artificial ventilation of the lungs was performed in all patients with pressure control and the support of normal ventilation (Datex Aestiva or Datex Avance, GE Healthcare Technologies, USA).

Anesthesia was performed using inhalation anesthetic (desflurane and sevoflurane in group D and S, respectively) with maintenance of 0.8–1.0 MAC (minimal arterial concentration). In both the groups, intravenous micro-bolus administration of fentanyl was performed at the rate of 3–5 μg/kg/h. If necessary, at the stage of surgical access, rocuronium bromide was administered by bolus at the rate of 0.5 mg/kg.

Intraoperative infusion therapy was performed at the rate of 10–12 mL/kg/h. Intravenous drip infusion of crystalloid (Ringer's solution) and colloid (Gelofusine) solutions was performed at a ratio of 2:1.

During the entire period of anesthesia, normothermia was maintained via electric heating of the surgical table and injected infusion solutions.

During anesthesia, the systolic, diastolic, and mean arterial blood pressure (BP) were monitored by a non-invasive method, and the heart rate (HR), SpO_2 of capillary blood, concentration of O_2, CO_2, desflurane, and sevoflurane during inhalation and exhalation, and skin temperature were measured using Datex-ohmeda Cardiocap 5 Anesthesiology Monitor (GE Healthcare Technologies, USA). The following capillary blood parameters were monitored: pH, pO_2, pCO_2, sO_2, BE, $pHCO_2$, cGlu, cLac, cK^+, cNa^+, cCa^{2+}, cCl^-, ctHb, and Ht using the ABL 835 Gas Analyzer (Radiometer, Copenhagen).

Anesthetic support in both the groups was completed according to the following scheme: 15 min before the end of the surgical intervention (skin suture), the administration of fentanyl was stopped. At 5 min before the end of the intervention, the inhalation component was reduced to 0.6 MAC. Immediately after surgery, the inhalation anesthetic supply was completely stopped.

After the restoration of effective independent breathing and elementary consciousness, tracheal extubation was performed. Further monitoring of the patients was performed in the anesthesiology, reanimation, and intensive treatment departments. For 30–40 min after admission from the operating room, the patients were provided oxygen through an oxygen mask.

The volume of intraoperative blood loss was assessed by summing up the amount of blood in the surgical electric aspirator and the results of swab weighing used during the intervention.

The following parameters were investigated: systolic BP, diastolic BP and average with the non-invasive method, HR, recovery time of spontaneous breathing (min), time to eye response (min), time to extubation (min), time to execution of instructions (min), the presence of intraoperative complications, and within 24 h after surgery [severe intraoperative hypotension, bradypnoea, and desaturation (SpO_2 < 95%) in the post-extubation period, agitation, nausea, vomiting, and blood loss].

Statistical analysis of the obtained data was performed using the software package Statistica 6.0. The mean value (M), standard deviation (s), and the error of the mean value (m) were calculated. The Wilcoxon test ($M \pm m$) was used to compare the values within the group, and the Mann–Whitney test was used to compare the two groups. The statistical significance was considered at $p < 0.05$.

Results

The duration of surgical interventions and the volume of intraoperative blood loss in both the groups were comparable (Table 2).

The average duration of interventions was 175 ± 5.05 and 180 ± 5.22 min in group D and S,

Table 2

The duration of surgical interventions (min) and the amount of intraoperative blood loss (mL)

Parameters under study	Group D (n = 35) $M \pm m$	Group S (n = 39) $M \pm m$	Significance level
Duration of surgical intervention	175 ± 5.05	180 ± 5.22	0.25
Mean amount of intraoperative blood loss	640 ± 18.47	655 ± 18.90	0.4

Table 3

Dynamics of HR indicators (beats/min) and BP (mmHg)

Parameters under study	Group D (n = 35) $M \pm m$	Group S (n = 39) $M \pm m$	Significance level
HR 10 min after the inhalation component inclusion	96 ± 2.93	84 ± 2.56	< 0.05
HR 30 min after the inhalation component inclusion	75 ± 2.29	74 ± 2.26	0.4
HR at the end of the surgical hardware installation	73 ± 2.23	74 ± 2.20	0.56
Systolic BP 10 min after the inhalation component inclusion	113 ± 3.45	104 ± 3.18	< 0.05
Systolic BP 30 min after the inhalation component inclusion	93 ± 2.84	91 ± 2.78	0.43
Systolic BP at the end of the surgical hardware installation	92 ± 2.81	89 ± 2.72	0.67
Diastolic BP 10 min after the inhalation component inclusion	62 ± 1.90	53 ± 1.62	< 0.05
Diastolic BP 30 min after the inhalation component inclusion	55 ± 1.68	52 ± 1.59	0.27
Diastolic BP at the end of the surgical hardware installation	53 ± 1.60	50 ± 1.53	0.33
Mean BP 10 min after the inhalation component inclusion	84 ± 2.49	73 ± 2.15	< 0.05
Mean BP 30 min after the inhalation component inclusion	72 ± 2.20	70 ± 2.14	0.78
Mean BP at the end of the surgical hardware installation	69 ± 2.10	68 ± 2.07	0.66

respectively. Statistically significant differences were not found in the duration of the intervention.

The average volume of blood loss in both the groups was 650 (450–800) mL, which did not exceed 20% of the CBV. This amount of blood loss was not required in any of the cases of intraoperative correction with the components of donor blood. In the postoperative period, the volume of drainage blood loss and the results of clinical blood tests were recorded. With a decrease in the hemoglobin level to <70 g/L and the appearance of clinical signs of insufficiency of the oxygen transport function of the blood, a donor erythrocyte suspension was transfused. A total of 11 blood transfusions were performed, i.e., 4 and 7 in group D and S, respectively.

A comparative assessment of the studied parameters revealed that systolic BP, diastolic BP, mean BP, and HR in both the groups did not exceed the allowable values (considering the age, initial state, nature of anesthesia, and surgical intervention). In group D, at the initial stages of desflurane administration, most patients showed moderate "hyperdynamia," which is typical for this anesthetic agent and caused by the activation of the sympathoadrenal system. This was manifested by a tendency of an increase in the mean BP and HR values. Within 4–6 min after reaching 0.8 MAC, the central hemodynamic parameters in group D stabilized and did not significantly differ in both the groups at further stages of anesthesia. At the main stages of surgical intervention, the mean BP values in group D and S were 69–72 and 68–70 mm Hg, respectively, with an average HR of 73–75 beats/min. Thus, the hemodynamic profile of both the variants of anesthesia provided the most favorable conditions for reducing intraoperative blood loss and did not create prerequisites for a significant reduction in the perfusion pressure in the structures of the central nervous system (Table 3).

The results of intraoperative monitoring of capillary blood parameters in all patients were within the normal values and did not significantly differ in both the groups.

The analysis of indicators reflecting the rate of recovery revealed that all stages at the end of anesthesia occurred faster in group D. Notably, in absolute numbers, the difference was not significant. However, we noted a clearer and more adequate

Table 4

Recovery time

Parameters under study	Group D	Group S	Significance level
Mean time to recovery of spontaneous breathing (min)	4.0 ± 0.24	7.0 ± 0.41	< 0.05
Mean time to extubation (min)	6.0 ± 0.35	9.0 ± 0.53	< 0.05
Mean time to opening eyes (min)	8.0 ± 0.47	12.0 ± 0.71	< 0.05
Mean time to execution of instructions (min)	8.0 ± 0.50	13.0 ± 0.76	< 0.05

Table 5

Frequency of adverse events

Indices	Group D	Group S	Significance level
Bradypnea	0 (0%)	3 (7.69%)	< 0.05
Desaturation (SpO_2 < 95%)	0 (0%)	3 (7.69%)	< 0.05
Agitation	8 (22.8%)	12 (30.7%)	< 0.05
Nausea	9 (25.71%)	10 (25.64%)	0.31
Vomiting	8 (22.86%)	8 (20.51%)	0.63

understanding of the speech delivered and requests to perform certain actions in group D patients. In most cases, this event enabled quick evaluation and reliable sensory and motor functions in the lower limbs. In all group D patients, it was possible to determine the full postoperative neurological status immediately after recovery before being transported to the anesthesiology, reanimation, and intensive treatment departments. In group S patients, the accuracy of the assessment of neurological status was often questionable due to the unclear command execution and difficult speech contact, which required repeated examinations in the immediate postoperative period (Table 4).

The analysis of the frequency of associated adverse effects and complications revealed that the number of postoperative episodes of nausea and vomiting in both the groups was comparable (Table 5).

Group S showed a high incidence of post-operative agitation. In group D, concomitant adverse respiratory phenomena were not observed, whereas in group S, they were recorded in three patients.

Discussion

The study included patients with baseline stable indicators of HR, BP, compensated CBV, and the extent of the upcoming surgery, which did not involve massive blood loss.

Thus, it was found that the use of third-generation inhalation anesthetics to maintain anesthesia during the surgical correction of unstable fractures of the thoracolumbar and lumbar spine in children was not accompanied by clinically significant adverse effects. The above mentioned options for anesthesia in combination with the standard infusion therapy provided a generally favorable hemodynamic profile. In turn, adequate analgesic and hypnotic components of anesthesia, stable parameters of hemodynamic, normothermia, laboratory monitoring, and careful surgical hemostasis form the integral components of intraoperative blood preservation.

The average blood loss in both the groups was comparable and did not exceed 20% of the CBV. In the group of patients with the main supporting agent, desflurane, a more favorable recovery dynamics was found in relation to the nature of the surgical intervention and the need to quickly and accurately assess the neurological status in the lower limbs immediately after awakening. Particularly, rapid and reliable detection of sensory and motor impairments are critical factors after the surgical correction of traumatic injuries of the spinal structures.

In patients with initially unstable hemodynamics, severe CBV deficit, or a high risk of massive intraoperative blood loss, the probability of inotropic and vasopressor support, both intraoperatively and in the postoperative period, is extremely high.

Inevitably, the combination of inhalation anesthetic and catecholamines can have a potentially arrhythmogenic effect. The inhalation anesthetics as the main components to maintain anesthesia along with administration of catecholamines, according to the recommendations of the manufacturers of desflurane and sevoflurane, should be carefully applied. In the above mentioned clinical situation, it is advisable to use total intravenous anesthesia.

The results of the comparative studies on the use of desflurane and sevoflurane in an elective pediatric anesthesiology agree with the results of the present study. For example, Gupta et al. performed a comparative assessment of the use of desflurane and sevoflurane for the elective surgical correction of spina bifida in children of average 5.8 years. Their data indicated faster dynamics of recovery, restoration of independent breathing, and consciousness after using desflurane. The authors also noted stability of the studied hemodynamic parameters (i.e., BP and HR) in the postoperative period in both the groups [15].

Lim et al. also came to similar conclusions. The authors performed a meta-analysis of 14 comparative studies on the use of desflurane and sevoflurane in elective pediatric anesthesiology. In their study, 1196 patients were included. Of these, in 588 patients anesthesia was maintained by desflurane and in 608 by sevoflurane. The results of their analysis revealed a shorter recovery time of consciousness and extubation in the group with desflurane. Notably, the authors did not reveal any significant difference between the groups in the number of episodes of postanesthetic agitation [12]. Driscoll et al. performed a comparative study on the use of desflurane and sevoflurane in elective otorhinolaryngology and found no significant differences in the frequency of postanesthetic agitation [12 (0–18) and 12 (0–20) in the desflurane and sevoflurane group, respectively; $p = 0.79$] [16]. In the present study, this indicator was 8 (0–35) and 12 (0–39) in the desflurane and sevoflurane group, respectively; $p < 0.05$.

In summary, it should be noted that the research data on the problems of postanesthesia agitation in elective anesthesiology in children and the methods of its prevention suggest that psychomotor agitation episodes in the postoperative period are quite frequent concomitant phenomena in patients who undergo anesthesia with the use of one or another inhalation component. A reliable relationship between the frequency of agitation and a specific inhalation anesthetic cannot often be identified. However, other factors, including pharmacological ones, that affect the frequency and severity of this complication have been established. For example, in the anesthesia protocol, the inclusion of a single bolus injection of drugs, such as propofol or dexmedetomidine, reduces the incidence of postanesthetic agitation [17]. The use of fentanyl as an analgesic component of anesthesia also reduces the frequency and severity of episodes of postanesthetic agitation [18].

Conclusion

1. The use of desflurane and sevoflurane as the primary components of anesthesia in the surgical correction of traumatic injuries of the spine and spinal cord in children with initially stable hemodynamic parameters provides a favorable hemodynamic profile and is not accompanied by the development of clinically significant side effects.
2. Desflurane reduces the likelihood of adverse effects, such as bradypnoea, desaturation after tracheal extubation, and agitation in the immediate postoperative period.
3. The use of desflurane to maintain anesthesia in the surgical correction of traumatic injuries of the spine and spinal cord in children provides faster recovery dynamics and the possibility of a reliable assessment of the neurological status after surgery.

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Ethical review. The consent of patients and their legal representatives for participating in the study and processing and publication of personal data was obtained.

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