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COMPARATIVE EVALUATION OF OPTIONS FOR POSTOPERATIVE ANALGESIA DURING SURGICAL CORRECTION OF CONGENITAL SPINE DEFORMITY IN CHILDREN

© *A.S. Kozyrev, A.V. Zaletina, K.A. Kartavenko, A.S. Strelnikova, M.S. Pavlova*

The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia

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Background. In the planning of anesthesia and postoperative therapy for surgical correction of congenital spinal deformity, the volume, the spine that is operated, and the patients' age are all factors to consider. In pediatric practice, the use of opioid analgesics for pain relief in the postoperative period after extensive and traumatic surgical interventions is generally accepted. There is very little information on the effectiveness and safety of prolonged epidural analgesia in young children in spinal surgery.

Aim. The aim of this study was to give a comparative assessment of the use of prolonged epidural blockade and constant drip of fentanyl as the main components of postoperative analgesia during surgical correction of congenital spine deformity caused by violation of the vertebra formation in children.

Materials and methods. The features of the postoperative period in 43 cases of correction of congenital spine curvature performed in the Turner Scientific Research Institute for Children's Orthopedics from 2016 to 2018 were retrospectively evaluated. Patient age ranged from 2 to 11 years. The patients were divided into two groups: group P included 22 patients whose main component of postoperative anesthesia was prolonged epidural analgesia, and group F included 21 patients whose main component of postoperative anesthesia was fentanyl. Anamnestic data analysis and clinical, laboratory, instrumental, and statistical analyses were used as methods of assessment.

Results. The data showed that the number of patients with undesirable respiratory disorders recorded in the first day in the form of bradypnea and desaturation was higher in group F than in group P. The number of patients who experienced nausea and vomiting and those who received antiemetics on the first day after surgery were comparable in both groups. However, the number of patients with fixed nausea, vomiting, and receiving antiemetics became significantly higher in group F in the next 2 days. In addition, at all stages of the assessment, there was an increase in the recorded episodes of peristalsis inhibition in patients from group F. The number of patients, who required additional anesthesia within 3 days of observation was comparable in both groups.

Conclusion. Prolonged epidural analgesia and constant drip of fentanyl are equally effective for providing pain relief in the postoperative period, but prolonged epidural analgesia provides a significant reduction in the frequency and severity of the gastrointestinal tract dysfunction.

Keywords: postoperative analgesia; congenital spine deformity; surgical treatment; children.

СРАВНИТЕЛЬНАЯ ОЦЕНКА ВАРИАНТОВ ПОСЛЕОПЕРАЦИОННОЙ АНАЛГЕЗИИ ПРИ ХИРУРГИЧЕСКОЙ КОРРЕКЦИИ ВРОЖДЕННОЙ ДЕФОРМАЦИИ ПОЗВОНОЧНИКА У ДЕТЕЙ

© *А.С. Козырев, А.В. Залетина, К.А. Картавенко, А.С. Стрельникова, М.С. Павлова*

ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург

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Обоснование. Планирование анестезиологического обеспечения и послеоперационной терапии при хирургической коррекции врожденной деформации позвоночного столба имеет определенные особенности, связанные с объемом оперативного вмешательства, отделом позвоночника, на котором осуществляются оперативные вмешательства, и возрастом пациентов. В детской практике широко применяют опиоидные анальгетики для обезболивания в послеоперационном периоде при обширных и травматичных хирургических вмешательствах.

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Данные об эффективности и безопасности применения продленной эпидуральной аналгезии у детей младшего возраста в спинальной хирургии практически отсутствуют.

Цель — провести сравнительную оценку применения продленной эпидуральной блокады и постоянного внутривенного введения фентанила в качестве основных компонентов послеоперационного обезболивания при хирургической коррекции врожденной деформации позвоночника, вызванной нарушением формирования позвонка, у детей.

Материал и методы. Ретроспективно оценены особенности послеоперационного периода в 43 наблюдениях коррекции врожденного искривления позвоночника, выполненных в ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России в период с 2016 по 2018 г. Возраст пациентов составил от 2 до 11 лет. Пациенты были разделены на две группы: группу П (22 пациента, основной компонент послеоперационного обезболивания — продленная эпидуральная аналгезия) и группу Ф (21 пациент, основной компонент послеоперационного обезболивания — фентанил). Использовали следующие методы оценки: анализ анамнестических данных, клинический, лабораторный, инструментальный, статистический.

Результаты. Количество пациентов с зафиксированными в первые сутки нежелательными респираторными нарушениями в виде брадипноэ и десатурации в группе Ф было больше, чем в группе П. Количество пациентов с тошнотой, рвотой и получавших антиэметики в первые сутки после операции было сопоставимо в обеих группах. В последующие двое суток количество пациентов с зафиксированными тошнотой, рвотой и получавших антиэметики в группе Ф было достоверно больше. При этом увеличение эпизодов угнетения перистальтики у пациентов группы Ф отмечено на всех этапах оценки. Количество пациентов, которым потребовалось дополнительное обезболивание в течение трех суток наблюдения, было сопоставимо в обеих группах.

Заключение. Применение продленной эпидуральной аналгезии и постоянного внутривенного введения фентанила одинаково эффективно для обеспечения обезболивания в послеоперационном периоде, но продленная эпидуральная аналгезия обеспечивает достоверное снижение частоты и выраженности нарушений динамических функций желудочно-кишечного тракта.

Ключевые слова: послеоперационная аналгезия; врожденная деформация позвоночника; хирургическое лечение; дети.

Background

Progressive forms of congenital spinal deformities due to vertebral malformation, especially of the lateral and posterolateral hemivertebrae, in the absence of timely surgical correction, lead to the development of severe spinal curvature in preschool-aged children. Furthermore, severe variants of congenital scoliosis often result in the dysfunction of the cardiovascular, respiratory, and digestive systems [1–3].

Congenital spinal deformities involving lumbar localization, as characterized by vertebral malformation, are among the most severe pathologies of the axial skeleton and lead to the rapid and gross biomechanical abnormalities of the spino-pelvic alignment [4]. Such curvatures require early surgical intervention with a complete radical correction of the congenital deformity, which involves the anatomical restoration of the spinal canal and physiological spinal curvatures [5]. The timely radical correction of congenital spinal deformities ensures a correct balance of the trunk and physiological development of the spinal column and the prevention of the development of complications in other organs and systems [6].

When planning anesthetic support and postoperative therapy for the surgical correction of congenital spinal deformities, the following aspects should be considered.

1. Congenital spinal deformities amid vertebral malformation are often combined with the developmental defects of other organs and systems, most often the cardiovascular and urinary systems.
2. The early surgical correction of pediatric patients under 3 years of age is complicated due to the lack of body weight to various extents.
3. The extent, duration, and injury rate of surgical intervention and possible massive blood loss during the surgical correction of congenital spinal deformities increase the risk of general surgical and anesthetic complications [7]. This case is especially typical for the simultaneous extirpation of an abnormally developed vertebra via the lateral lumbotomy approach and fixation with surgical hardware via the dorsal approach. Intraoperative blood loss in such situations can reach 80% or more of the circulating blood volume [8].
4. The extent and injury rate of surgical interventions determine the need for intensive and adequate analgesia in the postoperative period.

5. After the surgical correction of congenital deformities of the lower thoracic and lumbar spine with a combined approach, adverse side effects that most often occur in the postoperative period include intestinal paresis, bloating, delayed discharge of gas and stool, and vomiting.
6. The development of the clinical presentation of dynamic intestinal obstruction in the postoperative period is caused by various factors, especially the extent and location of surgical intervention. The lumbotomy approach involves a long displacement of the parietal peritoneum and abdominal organs, the need for intense analgesia with the use of strong opioid drugs, and possible gross intestinal dysbiosis with the administration of perioperative antibacterial prophylaxis. The most pronounced clinical manifestations occur on postoperative days 2 and 3.
7. Failing to ensure the proper positioning of the patient during surgery; intensive infusion therapy, including the use of donor blood components; and analgesia with opioid analgesics in the postoperative period often contribute to external respiration dysfunction, which may require respiratory support.

In pediatric practice, opioid analgesics are widely used during extensive surgical interventions for pain relief in the postoperative period [9–13]. This approach provides a sufficient level of analgesia in most cases, although adverse effects, such as respiratory depression, negative effects on peristalsis, nausea and vomiting, mental disorders, and the development of tolerance and addiction, are often noted [9, 13].

Prolonged epidural analgesia (PEA) is widely used for the surgical correction of idiopathic scoliosis in adolescent patients. The efficacy of PEA is similar to that of opioids but is not accompanied by such adverse effects [10, 14–17]. In addition, the use of PEA in the postoperative period after the surgical correction of idiopathic scoliosis in adolescents provides faster recovery of peristalsis, as compared with the use of opioid analgesics [10].

However, data on the efficacy and safety of PEA for pain management in the postoperative period after spinal surgery in young pediatric patients is very limited.

Therefore, **the aim of the present study** is to comparatively assess the use of prolonged epidural block and continuous intravenous administration of fentanyl as the main components of postoperative analgesia for the surgical correction of congenital spinal deformities caused by vertebral malformation in pediatric patients.

Material and methods

The specific characteristics of 43 pediatric patients (32 girls and 11 boys; mean age, 4 years; age range, 2–11 years) who underwent correction of congenital spinal deformities at the Turner Scientific Research Institute for Children's Orthopedics from 2016 to 2018 were retrospectively evaluated. The criteria for inclusion in this study were congenital scoliosis caused by vertebral malformation with localization in the lower thoracic or lumbar spine, isolated malformation of the spine, surgical correction of a congenital spinal deformity via the combined approach, compliance with the anesthesia protocol described below, the use of PEA or continuous intravenous administration of fentanyl as the main component of postoperative analgesia, and lack of need for an extended respiratory support in the postoperative period. In all the cases, the extent of surgical intervention included a simultaneous extirpation of the malformed vertebra via the lateral lumbotomy or thoracophrenolumbotomy approach and a radical correction of a congenital deformity with surgical hardware via the dorsal approach in combination with bone grafting. In accordance with the postoperative analgesia protocol, the patients were divided into two groups: group P (22 patients, PEA as the main component of postoperative analgesia) and group F (21 patients, fentanyl as the main component of postoperative analgesia).

The risk of anesthetic management and surgical intervention in all patients was assessed while taking into account the initial state of the patient, presence or absence of concomitant pathology, aspects of surgical correction, and intraoperative blood loss volume. The initial mean physical status score, according to the American Society of Anesthesiologists physical status classification guidelines, for all patients was 3 points. The total anesthetic risk was estimated at 4 points.

In all cases, combined general anesthesia was used in accordance with the following protocol. Premedication was performed 30–40 min before the start of anesthesia with benzodiazepine drugs (midazolam and diazepam). For the minimization

of painful manipulations and injections in the perioperative period, the oral route of administration was preferable (in 40% glucose solution). After achieving moderate drug sedation, inhalation induction with sevoflurane was performed. Strengthening of anesthesia and myoplegia before tracheal intubation was achieved by intravenous bolus administration of fentanyl and rocuronium bromide. Artificial lung ventilation was performed in the "pressure control" mode with parameters providing normoventilation. Anesthesia was supported by intravenous microfluid administration of propofol at a dose of 4–7 mg/kg/h and fentanyl at a dose of 4–5 mg/kg/h. If necessary, a split dose of rocuronium bromide was administered.

All patients underwent an installation of a gastric tube and bladder catheterization. To avoid massive blood loss, the mandatory components of anesthetic management were catheterization of the main venous vessel (subclavian or jugular vein) and peripheral artery catheterization.

Standard monitoring during anesthesia included electrocardiography, heart rate, hemoglobin oxygen saturation, fraction of inspired O_2 (FiO_2), end tidal O_2, fraction of inspired CO_2, end tidal CO_2, MS, blood pressure (systolic, diastolic, and average), and body temperature. An hourly monitoring of urine output and analysis of arterial samples (pH, O_2 tension, concentration of total O_2, ratio of arterial O_2 partial pressure to fractional inspired O_2, CO_2 tension, concentration of HCO_3, BE, concentration of total hemoglobin, hematocrit, Na^+, K^+, Ca^{2+}, Cl^-, glucose, osmolality, and lactate) were performed with an ABL800 FLEX blood gas analyzer (Radiometer Medical ApS, Brønshøj, Denmark).

Intraoperative blood loss was estimated by summing the amount of blood entered into the reinfusion apparatus and the indicators obtained after weighing the drapes used during the intervention. The main blood preservation methods used for all patients included appropriate patient positioning on the surgical table during surgery to ensure conditions for the maximum decompression of the abdominal cavity, moderate hemodilution, control of normothermia, hardware reinfusion of auto-erythrocyte concentrate, and hemostatic therapy (intravenous administration of fibrinolysis inhibitors and donation of coagulation factors with a blood loss of more than 30%–40%, namely, a prothrombin-converting complex concentrate or quarantine fresh-frozen plasma). The average volemic load during anesthesia was 20–40 ml/kg/h, depending on the rate and volume of blood loss.

To ensure analgesia for the group P patients, at the end of the dorsal fixation with surgical hardware, before suturing the wound, the epidural space was catheterized through the surgical wound using a standard set in accordance with the following procedure. Via the median approach, through the inter-arch space, one segment above the proximal level of instrumentalization, the puncture of the ligamentum flavum was performed under the control of "loss of resistance." A catheter was inserted in the cranial direction to the Th_8–Th_9 level. The distal end of the catheter was removed from the surgical wound through a separate skin puncture. A test dose of local anesthetic was administered after the patient was awakened, and the neurological status of the lower extremities was evaluated.

Tracheal extubation was performed at the end of the surgery and anesthesia, in the absence of indications for prolonged respiratory support, after the restoration of effective independent breathing and elementary consciousness. Further monitoring of all patients was conducted in the Anesthesiology, Life Support, and Intensive Care Unit ward for 3 days.

Postoperative intensive care included the following:

- Infusion therapy in the normal hydration mode, taking into account physiological needs, pathological losses, and necessary correction of electrolytes. For the prevention of intestinal paresis, K^+ was administered in accordance with the 1.5-phase flow regime.
- Analgesia: PEA with 0.2% ropivacaine solution at a dose of 0.3–0.4 mg/kg/h (group P) with the continuous intravenous administration of fentanyl at a dose of 1–2 μg/kg/h on day 1, 0.75–1.0 μg/kg/h on day 2, and 0.5 μg/kg/h on day 3 (group F). In both groups, paracetamol was administered intravenously at age-appropriate dosages for up to 3 days. If necessary, additional analgesia with ibuprofen or metamizol was performed. If indications exist, then intravenous midazolam was administered continuously in accordance with the recommended doses based on body weight for sedation, along with antibacterial prophylaxis with broad-spectrum drugs; symptomatic therapy; additional stimulation of motility of the gastrointestinal

tract, if necessary, via micro-enema; and laboratory control.

During the follow-up period in the Anesthesiology, Life Support, and Intensive Care Unit ward (3 days), the following parameters (presence or absence) were evaluated: bradypnea and desaturation (SpO_2 < 95%), agitation, episodes of nausea and vomiting, administration of antiemetic drugs, bloating, marked inhibition of peristaltic sounds, absence of stool over the first 3 days after surgery, the need for additional stimulation of peristalsis, the need for additional pain relief, and the need for sedation.

Parametric and nonparametric analyses were performed using the Statistica 13.3 software package (TIBCO Software Inc., Palo Alto, CA, USA). Values calculated with the Mann–Whitney *U* test were compared with the critical values at a significance level of $p < 0.05$. If the calculated value of *U* was equal to or less than the critical value, then the differences were considered statistically significant. The Fisher's exact test was also applied. The difference was considered significant if the value obtained with the Fisher's exact test was less than 0.05.

Results and discussion

Considering the age of the patient cohort in the comparison groups and the respective difficulties in determining the objectivity of complaints, the signs of each patient were evaluated by the presence or absence on the current day. The analytical results of the studied parameters are presented in Table 1, which provides the number of patients having a particular sign.

As shown in Table 1, the number of patients with adverse respiratory disorders (i.e., bradypnea and desaturation) recorded on postoperative day 1 was greater in group F than group P. This result was not unexpected, as a large number of previous comparative studies on the use of regional anesthesia and systemic use of opioid analgesics in the postoperative period in pediatric patients reported similar results. In the present study, adverse respiratory events were relevant on postoperative day 1 and were stopped in all cases by additional oxygen donation through an ear-loop face mask. Mechanical respiratory support was not required. Through postoperative day 2, no patient showed signs of bradypnea or desaturation.

The number of patients with registered nausea, vomiting, and receiving antiemetic drugs on postoperative day 1 was comparable between groups. This result was probably due to the fact that, in this category of patients, the frequency of nausea and vomiting in the immediate postoperative period is largely caused by the duration and nature of the anesthesia, in addition to other factors unrelated to the nature of postanesthetic

Table 1

Number of patients with registered events under study

Sign	Day 1			Day 2			Day 3		
	Group P	Group F	*p*	Group P	Group F	*p*	Group P	Group F	*p*
Bradypnea and desaturation	1	5	<0.05	0	0	>0.05	0	0	>0.05
Agitation	6	2	<0.05	0	0	>0.05	0	0	>0.05
Nausea, vomiting	8	9	>0.05	3	8	<0.05	1	5	<0.05
Use of antiemetic drugs	6	5	>0.05	0	7	<0.05	1	6	<0.05
Bloating	0	3	<0.05	4	9	<0.05	3	10	<0.05
Inhibition of peristalsis	2	10	<0.05	2	7	<0.05	0	6	<0.05
Additional stimulation of peristalsis	0	0	>0.05	1	7	<0.05	0	6	<0.05
Additional pain relief	5	4	>0.05	7	6	>0.05	6	6	>0.05
Sedation	7	2	<0.05	3	7	<0.05	1	5	<0.05

Note. P — prolonged epidural analgesia; F — fentanyl.

analgesia. The anesthesia protocol was the same for all patients. At postoperative day 2, the number of patients with nausea and vomiting and those receiving antiemetic drugs was significantly greater in group F, demonstrating the greater emetogenic potential of opioids used as postoperative analgesia, as compared with regional anesthesia methods.

At the same time, an increase in episodes of peristalsis inhibition was noted at all stages of assessment in group F, which required significantly more frequent use of mechanical stimulation of the intestines on postoperative days 2 and 3.

Given the age-related characteristics of the patients, the FLACC behavioral scale and the Wong–Baker FACES Pain Rating Scale were used to assess the sufficiency of analgesia in the postoperative period. The criteria for determining the inadequacy of the level of analgesia and the prescription of additional analgesia were a total score of four or more points or three or more points on these scales, respectively. The number of patients who required additional analgesia during the 3 days of observation was comparable between groups, which confirms that the efficacy of the variants used for postoperative analgesia did not significantly differ in this category of patients.

The multidirectional change in the number of patients who underwent drug sedation is noteworthy. On postoperative day 1, the frequency of such cases was higher in group P, which correlates completely with the significantly larger number of patients in this group with agitation recorded on postoperative day 1. In group F, agitation episodes were noted in two patients on postoperative day 1, which indicates a more pronounced sedative effect of the prolonged administration of opioid analgesics in the postoperative period. No episodes of agitation were observed over the next 2 days in either group. However, sedation during this period was required significantly more often in group F, which was probably due to the expressed anxiety accompanying dyspeptic symptoms and bloating in young pediatric patients.

Stool retention of more than 3 days was noted in three patients in group P and nine in group F ($p < 0.05$).

Dysfunction of the gastrointestinal tract and respiratory problems most often cause a delay in the recovery phase and deteriorate the course of the postoperative period following the surgical correction of congenital spinal deformities. The development of adverse concomitant events in the digestive system and external respiration is also closely related to the method of postoperative analgesia [10]. The determination of an optimal protocol for multimodal anesthesia in the postoperative period for a specific variant of surgical treatment can significantly improve the quality and speed up the recovery phase, while minimizing possible associated adverse events.

The prokinetic potential of PEA, which is widely used for the treatment of acute surgical pathologies of the abdominal cavity in pediatric patients, has long been known and confirmed. We recommend the use of PEA to ensure effective analgesia and avoid problems related to impaired motor function of the gastrointestinal tract following the surgical correction of spinal deformities in pediatric patients.

Conclusion

PEA and continuous intravenous administration of fentanyl are equally effective in providing pain relief in the postoperative period following the surgical correction of congenital spinal deformities with a combined approach. Fentanyl, as the main component of postanesthetic analgesia, causes a more pronounced sedation in the immediate postoperative period. However, its use is accompanied by an increase in the number of adverse respiratory disorders, such as bradypnea and decreased saturation. By contrast, the use of PEA in the postoperative period following the surgical correction of congenital spinal deformities with a combined approach provides a significant decrease in the frequency and severity of gastrointestinal disorders.

Additional information

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Conflict of interest. The authors declare no obvious or potential conflicts of interest related to the publication of this article.

Ethical review. The study protocol was approved by the Ethics Committee of the Turner Scientific Research Institute for Children's Orthopedics (protocol no. 2017/9, dated 22.12.2017) and performed in accordance with the ethical standards of the Helsinki Declaration of the World Medical Association as amended by the Ministry of Health of Russia.

The consent of patients and their legal representatives for the use and publication of personal information from medical documentation in anonymous form was obtained.

Contribution of the authors

A.S. Kozyrev examined and treated the patients, analyzed the results, and wrote the article.

A.V. Zaletina edited the article.

K.A. Kartavenko conducted consultation on special aspects of surgical interventions and participated in patient treatment.

A.S. Strelnikova and *M.S. Pavlova* examined and treated the patients and analyzed the results.

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Information about the authors

Alexander S. Kozyrev* — MD, PhD, Head Doctor, Anesthesiologist-Resuscitator of the Department of Anesthesiology, Resuscitation and Intensive Care. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0002-2828-4063. E-mail: alexkozirev@inbox.ru.

Anna V. Zaletina — MD, PhD, Head of the Scientific-Organizational Department, Orthopedic and Trauma Surgeon of the Department No. 11. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0002-9838-2777. E-mail: omoturner@mail.ru.

Kirill A. Kartavenko — MD, PhD, Orthopedic and Trauma Surgeon of the Department of Spinal Pathology and Neurosurgery. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0002-6112-3309. E-mail: med-kart@yandex.ru.

Angelina S. Strelnikova — MD, Anesthesiologist and Resuscitator of the Department of Anesthesiology, Resuscitation and Intensive Care. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0003-2013-1553. E-mail: angelina.str.93@gmail.com.

Maria S. Pavlova — MD, Anesthesiologist and Resuscitator of the Department of Anesthesiology, Resuscitation and Intensive Care. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. https://orcid.org/0000-0003-2337-6847. E-mail: bosja86@rambler.ru.

Александр Сергеевич Козырев* — канд. мед. наук, главный врач, врач анестезиолог-реаниматолог отделения анестезиологии, реанимации и интенсивной терапии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-2828-4063. E-mail: alexkozirev@inbox.ru.

Анна Владимировна Залетина — канд. мед. наук, руководитель научно-организационного отдела, врач травматолог-ортопед отделения № 11 ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-9838-2777. E-mail: omoturner@mail.ru.

Кирилл Александрович Картавенко — канд. мед. наук, травматолог-ортопед отделения патологии позвоночника и нейрохирургии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-6112-3309. E-mail: med-kart@yandex.ru.

Ангелина Сергеевна Стрельникова — врач анестезиолог-реаниматолог отделения анестезиологии, реанимации и интенсивной терапии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0003-2013-1553. E-mail: angelina.str.93@gmail.com.

Мария Сергеевна Павлова — врач анестезиолог-реаниматолог отделения анестезиологии, реанимации и интенсивной терапии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0003-2337-6847. E-mail: bosja86@rambler.ru.