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PECULIARITIES OF THE STATE OF PERIPHERAL OXYGENATION OF TISSUES IN DIFFERENT KINDS OF COMBINED ANESTHESIA IN CHILDREN WITH CONGENITAL SURGICAL PATHOLOGY

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In the presented work, we have assessed the features of peripheral oxygenation in children with congenital malformations of the surgical profile under various types of combined anesthesia.
The aim of the study. *To assess the state of peripheral oxygenation in newborns and infants with congenital malformations with various types of anesthetic support.*
Materials and research methods. *A retrospective study included 150 newborns and infants with congenital malformations of the surgical profile, depending on the anesthesia (inhalation + regional anesthesia; inhalation + intravenous anesthesia and total intravenous). The parameters of pulse oximetry were analyzed: peripheral oxygenation, heart rate. Additionally, the concentration of oxygen in the respiratory mixture of children was taken into account.*
Research results. *Peripheral saturation did not critically decrease at all stages of observation, with the exception of a decrease in the indicator in children of group I compared with group III at the stage of induction into anesthesia (97.79±2.45 versus 98.79±1.63, at $p<0.05$, respectively) and at the most painful moment of the operation (96.29± ±3.47 versus 98.10±2.47, with $p<0.05$). At the painful moment of the operation, it was in children of group I that a drop in heart rate was noted compared to group III (127.98±13.77 and 136.10±15.37, respectively, with $p<0.05$) and group II (134.02±18.43, at $p>0.05$) against the background of a decrease in SpO_2. Newborns and group I infants required higher oxygen concentrations in the breathing mixture. A significant difference in the indicator is noted between groups I and III at the traumatic stage – 0.47±0.29 and 0.33±0.2, with $p<0.05$, respectively, and immediately after the operation – 0.34±0,19 and 0.26±0.13, with $p<0.05$, respectively.*
Conclusions. *The expediency and effectiveness of pulse oximetry for children with congenital malformations at all stages of anesthetic support during surgical treatment was confirmed. The risk group for the formation of oxygen deficiency in organs and tissues, the occurrence of pain during the operation were newborns and infants, for whom combined anesthesia was chosen in the form of an inhalation method and regional anesthesia. In the case of the appointment of this type of anesthetic support, it is necessary to more closely monitor the indicators and promptly correct the deterioration of the child's condition*
Keywords: *newborns, infants, congenital malformations, combined anesthesia, pulse oximetry*

1. Introduction

The priority in the field of pediatric surgery is neonatal surgery, as in the structure of surgical diseases a large proportion are children with congenital malformations, namely the gastrointestinal tract, diaphragm, kidneys [1]. No surgery is possible without anesthesia, and modern methods of anesthesia are effective and safe for the patient. The main task of anesthesia is the maximum control of the body's stress response to surgical aggression to improve treatment outcomes in the future [2].

The quality of surgical treatment and quality anesthesia during surgery is significantly complicated by the severity of the congenital anomaly in the child, as well as the presence of concomitant and background perinatal pathology [3]. Among the diseases that complicate anesthesia and are characteristic of newborns and infants with congenital malformations (CM) in the early neonatal period, the most common are perinatal infections, lesions of the central nervous system, cardiovascular and respiratory failure [4]. Monitoring of their condition in a child during surgery is usually performed by pulse oximetry.

Until the early 2000s, pulse oximetry was the only measure to assess the effectiveness of oxygen supply to tissues to meet the metabolic needs of a particular child. Numerical studies have shown a higher survival rate in infants <28 weeks of gestation who were randomized to a target SpO_2 level of 91–95 % compared to the target SpO_2 group of 85–89 % [5, 6]. Clinical trials have also demonstrated an increased risk of morbidity in preterm infants with higher peripheral oxygen saturation targets, including an increased risk of chronic lung disease and preterm retinopathy [5–7]. In addition, pulse oximetry is widely accepted as a screening test to detect critical congenital heart defects in newborns [8, 9].

Taking into account the modern international experience, the presented work evaluates the features of peripheral oximetry in children with congenital malformations of the surgical profile under different types of combined anesthesia.

The aim of the research. Assess the state of peripheral oxygenation in newborns and infants with congenital malformations with different types of anesthesia.

2. Materials and methods

The retrospective study included 150 newborns and infants with congenital malformations (CM) who received surgical treatment at the "Dnipropetrovsk Regional Children's Clinical Hospital" of the Dnipropetrovsk Regional Council" (Dnipro) in 2019. According to the nature of CM, children with the pathology presented in Table 1 took part in the study. The most common congenital anomalies were intestinal obstruction (24 %) and abdominal tumors (21.3 %). The Commission on Medical Ethics at the "Dnipropetrovsk Regional Children's Clinical Hospital" of the Dnipropetrovsk Regional Council" on January 5, 2021 (Minutes 1) noted the compliance of the retrospective study with the requirements of biological and medical ethics and allowed open publication of the considered materials.

Table 1

Types of congenital malformations in children, absolute numbers (%)

Congenital malformations	Esophageal defects	Intestinal obstruction	Embryonic hernia	Gastroschisis	Abdominal tumors	Intestinal defects	Anorectal defects	Lung defects	Total
Number of children	14 (9.3)	36 (24)	7 (4.7)	9 (6)	32 (21.3)	14 (9.3)	17 (11.3)	21 (14)	150 (100)

There were formed 3 groups depending on the type of combined anesthesia for surgical correction of anomalies: I (50 children with CM) – inhalation (sevoflurane) + regional anesthesia; II (50 children with CM) – inhalation (sevoflurane) + intravenous anesthesia (fentanyl); III (50 children with CM) – total intravenous anesthesia with 2 drugs: analgesic (fentanyl) and drug sleep on the background of intravenous injection of hypnotics (20 % sodium oxybutyrate). Operations were performed: thoracic, urological, abdominal.

Retrospective evaluation in the study was conducted in the following stages:

1) before surgical treatment and anesthesia (stage I),

2) putting the child under anesthesia (stage II),

3) traumatic stage of the operation: the middle of the operation or the most painful stage of surgery (stage III),

4) postoperative period (within 1 hour after transporting the child to the intensive care unit) (stage IV),

5) 24 hours after surgery (stage V).

The key study during all stages was the measurement of peripheral saturation (SpO_2), heart rate (HR) by pulse oximetry in all children with a Nihon Kohden monitor (Japan). Additionally, the need for oxygen concentration in the mixture inhaled by the child (FiO_2) was assessed.

Pulse oximetry is an optical method for determining the percentage saturation of hemoglobin with oxygen. It is based on the differences in the degree of light absorption by hemoglobin in the blood: oxyhemoglobin absorbs mainly infrared light, and deoxyhemoglobin – red. Because arterial blood analysis is required to assess lung function, the device is configured to detect hemoglobin saturation only in pulsating (arterial) vessels.

The obtained value is denoted by SpO_2 (the letter "p" emphasizes that the study was conducted by pulse oximetry). The thickness and color of the skin do not affect the measurement results. Pulse oximeters do not require pre-calibration, work stably, and the measurement error usually does not exceed 2–3 %. The period of time for indication of certain indicators on the pulse oximeter monitor can vary from 23 s to 1.5 min depending on the correct installation of the sensor, monitor model (ability to record the signal and duration of data update on the screen) and blood circulation in the patient [9].

Pulse oximeter determines the following indicators: SpO_2; heart rate (per minute); amplitude and shape of the pulse wave [9].

The relationship between PaO_2 and SpO_2 is determined by the oxyhemoglobin dissociation curve, the shape and displacement of which depends on pH, temperature, pCO_2, the amount of 2,3-diphosphoglycerate in erythrocytes and the ratio of fetal and adult hemoglobin. In a full-term newborn, the range of PaO_2 from 60 to 90 mm Hg roughly corresponds to the level of SpO_2 94–97 %. For premature infants with gestational age <28 weeks, who have predominantly HbF, SpO_2 of 86–92 % and, accordingly, PaO_2 of 45 to 90 mm Hg may be acceptable. Because the oxyhemoglobin association curve reaches the plateau at the top, an increase in SpO_2 of more than 97 % may indicate a dangerous level of hyperoxemia [9].

The accuracy of SpO_2 measurement is affected by:

1) the correct installation of the sensor;

2) the state of peripheral perfusion;

3) physical movements of the child;

4) additional lighting of the area where the sensor is located;

5) the presence of abnormal hemoglobin in the blood;

6) abnormal pulsation of venous vessels.

New generation pulse oximeters are able to identify most of these artifacts, which provides a high sensitivity of the method for the diagnosis of hypoxemia [9].

Data processing was performed using the program "Statistic" and the method of variation statistics. Because the Newman-Keuls test gives a more accurate estimate of the probability of alpha for more comparisons, two-sided significance tests were used and alpha was set for $p<0.05$. Bonferroni's corrections were used to resolve multiple comparisons.

4. Results of the research

Congenital diseases in children who required surgical treatment were distributed as follows: abdominal surgery – 98 (67 %), thoracic – 26 (18 %), urological – 23 (15 %).

Study newborns with CM by body weight and age in groups at the time of hospitalization for surgical correction were distributed as follows, the data are presented

in Table 2. No significant differences between groups were found. In all groups of children the body weight more than 3000 g prevailed, and the postnatal age at receipt in a children's surgical hospital reached 2 weeks.

Table 2

Body weight and age of children at the time of hospitalization for surgical treatment, M±m

Indicator	Groups		
	I (n=50)	II (n=50)	III (n=50)
Mass, g	3185.5±1173.3	3019.9±896.4	3202.1±816.2
Age, age of life	14.3±23.9	15.9±17.4	12.8±18.9

When analyzing the state of peripheral oxygenation in the examined groups of children with different types of combined anesthesia, no significant pathological abnormalities were obtained. The data are presented in Table 3.

Table 3

Indicators of pulse oximetry (SpO_2) in children with different types of anesthesia depending on the stages of the operation, %, M±m

Stages of the operation	Groups		
	I (n=50)	II (n=50)	III (n=50)
Beginning	98.3±2.0	98.3±1.9	96.8±1.2
Induction	97.8±2.5	98.4±1.7	98.8±1.6
Traumatic	96.3±3.5	97.4±3.4	98.1±2.5
After the operation	95.8±3.4	95.6±3.5	96.9±2.9
24 hours after surgery	96.9±2.8	96.4±2.8	96.8±3.7

In general, peripheral saturation of neonates and infants with CM was not critically reduced at all stages of observation except for the obtained reduction of SpO2 in children of group I compared with group III at the stage of induction of anesthesia (97.8±2.5 vs. 98.8±1, 6, at $p<0.05$, respectively), at the most painful moment of surgery (96.3±3.5 vs. 98.1±2.5, at $p<0.05$), as well as in children of group II in comparison with group III after surgery (95.6±3.5 vs. 96.9±2.9, respectively, at $p>0.05$) (Table 3). The presented results of group I indicate a greater oxygen dependence of children with analgesia with sevoflurane in combination with regional anesthesia, due to the mechanism of action of anesthesia on the child's body, hypoxia, but does not exclude the presence of pain during surgery.

At the same time, HR monitors of children of all groups were monitored on the pulse oximeter monitor during all stages of observation. It should be noted that significant differences in indicators were not found when evaluating the results of HR in children of the surveyed groups. Only in two cases a significant dependence of the indicator on the type of anesthesia and the stage of surgery. At the time of induction of anesthesia in children of group III there was a decrease in HR relative to the rate of cardiac activity in infants of group I (131.9±17.4 – in group III against 132.0±13.9 – in group I, at $p<0.05$). While at the most painful moment of the operation it was in children of group I that a drop in HR was observed in comparison with group III (127.9±13.8 and 136.1±15.4, respectively, at $p<0.05$) and group II (134.0±18.4, at $p>0.05$) against the background of a decrease in SpO_2.

In analyzing the trend, we further assessed the need for oxygen in the respiratory mixture during ventilation support for children of all groups. The data are presented in Table 4.

When assessing the oxygen demand of children with CM during the observation, depending on the types of anesthesia, attention is paid to the value of FiO_2 in group I. It is with combined analgesia by inhalation and regional methods that newborns and infants needed higher concentrations of oxygen in the respiratory mixture (Table 4). A significant difference in the indicator is observed between groups I and III during the most painful stage – 0.5±0.2 and 0.3±0.2, at $p<0.05$, respectively, and immediately after surgery – 0.3±0.2 and 0.3±0.1, at $p<0.05$, respectively.

Insignificant oxygen demand was found in children of group II during combined anesthesia by inhalation with intravenous anesthesia. Moreover, higher concentrations of oxygen were needed by newborns and infants at the time of induction of anesthesia and during the most traumatic period of the operation ($p>0.05$). It should be noted that the minimum oxygen dependence was observed in children of group III (Table 4).

Table 4

FiO_2 in children with different types of anesthesia depending on the stages of the operation, absolute number, M±m

Stages of the operation	Groups		
	I (n=50)	II (n=50)	III (n=50)
Beginning	0.4±0.3	0.4±0.2	0.4±0.3
Induction	0.4±0.3	0.4±0.3	0.4±0.2
Traumatic	0.5±0.3*	0.4±0.2	0.3±0.2*
After the operation	0.3±0.2*	0.3±0.1*	0.3±0.1
24 hours after surgery	0.3±0.1	0.3±0.1	0.2±0.1

*Note: * – the difference between groups I and III, $p<0.05$.*

5. Discussion of research results

According to the latest international clinical guidelines, conventional pulse oximetry is used to screen for congenital heart defects in newborns in the first hours of life. A systematic review of clinical trials has shown that this method has proven to be safe, effective and appropriate in neonatal practice [10]. Pulse oximetry is a highly specific and moderately sensitive test to detect birth defects with very low false positives. Current data confirm the introduction of regular screening for congenital heart defects in asymptomatic newborns before discharge from the hospital [10].

The given data of own research confirmed expediency of its use during surgical treatment and carrying out anesthesia to children with CM for control of a condition of the child and timely correction of pathological changes. In the future it is planned to conduct a correlation analysis between the main clinical indicators and SpO_2.

Study limitations. Children with urgent surgical pathology, as well as in the agonal state were excluded from the retrospective analysis.

Prospects for further research. In the future research it is planned to conduct a correlation of clinical indicators.

6. Conclusions

Thus, the study confirmed the feasibility and effectiveness of pulse oximetry in children with congenital malformations at all stages of anesthesia during surgical treatment as part of additional observation parameters.

According to the obtained data of peripheral oxygenation, HR, the need for oxygen respiratory support by the risk group of oxygen deficiency in organs and tissues, the occurrence of pain during surgery there were newborns and infants who underwent combined anesthesia in the form of inhalation and regional anesthesia. In the case of prescribing this type of anesthesia, it is necessary to more carefully monitor the vital signs and timely correct the deterioration of the child's condition.

Conflict of interests

The authors declare that they have no conflicts of interest.

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