Original research

COMPARATIVE ANALYSIS OF ACID-BASE PARAMETERS IN NEWBORNS AND INFANTS WITH CONGENITAL MALFORMATIONS DURING PERIOPERATIVE CARE BASED ON TYPES OF ANESTHESIA

Vlasov O.O.[1*]

Author information: [1]MI «Dnepropetrovsk Regional Children's Clinical Hospital» Dnepropetrovsk Regional Council», Dnipro, Ukraine

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Abstract: *Introduction:* Congenital malformations (CM) are most common in newborns and infants in the first year of life and require surgical correction in the first hours, days, months of life. Surgical interventions in severely ill babies with malformations can lead to catabolic stress, circulatory and respiratory disorders, metabolism shifts, water-electrolyte, protein, and acid-base status disorders.

This study aimed to compare acid-base status in newborns and infants with congenital surgical pathology under different types of combined anesthesia.

Materials and methods: This retrospective study included 150 newborns and infants with CM who required surgery. The patients were divided into three groups based on types of provided anesthesia: inhalation by Sevoran (sevoflurane) and regional anesthesia (group I); inhalation of Sevoran and intravenous anesthesia by Fentanyl (group II); and intravenous combination of Fentanyl and 20% Sodium Oxybutyrate (group III). The analysis included: acid-base status, peripheral oximetry, and the need for an oxygen mixture inhaled by the patient.

Results In group I, there was a significant reduction in partial tension of CO_2 and increased pH from the pre-surgical status, at the time of induction of anesthesia, during the most painful, traumatic stage, and after surgery compared to group II and III. Peripheral O_2 saturation was not critically reduced at all stages of observation except in babies of group I compared to group III at the stage of induction of anesthesia (97.79 ± 2.45 vs. 98.79 ± 1.63, p = 0.0194) and at the most painful period of surgery (96.29 ± 3.47 vs. 98.10 ± 2.47, p = 0.0368). In group I, newborns and infants required higher oxygen concentrations in the inhalation mixture. There was a significant difference in FiO_2 between groups I and III during the most painful stage of surgery (0.47 ± 0.29 and 0.33 ± 0.2, p = 0.0071), and immediately after surgery (0.34 ± 0, 19 and 0.26 ± 0.13, p = 0.0246).

Conclusion: Among the newborns and infants with CM requiring surgical intervention and combined anesthesia, the most substantial acid-base status changes were observed in the group where anesthesia was provided by Sevoran (sevoflurane) and regional anesthesia (Group I).

Keywords: Newborns, infants, congenital malformations, combined anesthesia, parameters

INTRODUCTION Congenital malformations (CM) are the most common pathology in newborns and infants in the first year of life. A surgery allows radical or gradual correction of developmental abnormalities, restores the viability of organs, and improves the patient's condition [1,2].

The surgery outcome depends on the severity of the defect, comorbidities, and the qualifications of a pediatric surgeon and anesthesiologist. The chosen type of anesthesia and the quality of its implementation is based on the baby's condition before, during, and after the surgery, recovery rate, and impacts follow-up prognosis after discharge from hospital.

Corresponding Author: Vlasov O.O. Kosmicheskaya str., 13, Dnipro, Dnipropetrovsk region, 49000
Contact phone: +38 (050) 362 68 68
e-mail: vlasovalexey75@gmail.com
ResearcherID: https://publons.com/researcher/AAI-2190-2020
ORCID: https://orcid.org/0000-0003-1575-9872

Newborns and infants are at high risk for hypoxemia of organs and tissues, hypotension, and decreased cardiac output during anesthesia due to the effects of analgesics on the respiratory center, poor ventricular elasticity, inadequate sympathetic nervous system response, and increased susceptibility to the action of myocardial depressants of inhaled anesthetics [3,4]. As a result, surgery in newborns and infants, in addition to serious diseases and malformations, can lead to catabolic stress, circulatory, and respiratory disorders, shift of metabolism, water-electrolyte, protein, and acid-base state.

Blood gas assessment is a standard to evaluate a state of pulmonary gas exchange in an intensive care unit. During respiratory support, this study aims to minimize the risk of potential hypoxemia, hyperoxemia, hypocapnia, hypercapnia, and acid-base disorders (ABD) [5]. The correction of the shifted parameters should be done as soon as possible to restore homeostasis. Monitoring the blood gas parameters in the dynamics of anesthesia allows indirect judgment about the quality of anesthesia, surgical treatment, and the adequacy of therapeutic interventions, thus minimizing the occurrence of possible complications [6,7]. Therefore, it is important for a pediatric anesthesiologist to have information that reflects ventilation and oxygenation adequacy by assessing the acid-base status and blood gas levels. It is essential to assess and analyze the acid-base status and blood gas levels in newborns and infants with CM during surgery to improve medical care quality.

Aim of the study

To analyze acid-base status in newborns and infants with congenital surgical pathology under different types of combined anesthesia.

MATERIALS AND METHODS The retrospective study was based on a chart review of 150 newborns and infants with CM who received surgical treatment in a Dnipro pediatric hospital (Ukraine) 2015- 2019 (Table 1).

According to the nature of CM, the study involved babies with the pathology presented in Table 1. The most common among CM were intestinal obstruction (24%) and tumors (21.3%).

Patients were randomly divided into the three groups with an equal number of babies in each group, based on the type of anesthesia: group I was provided with inhalational (Sevoran/sevoflurane) and regional anesthesia; group II with inhalational (Sevoran/sevoflurane) and intravenous anesthesia (Fentanyl); group III received intravenous anesthesia with 2 drugs: analgesic (Fentanyl) and hypnotics (20% Sodium Oxybutyrate). Surgeries performed: thoracic, urological, abdominal.

The distribution of children by body weight and age at the time of hospitalization for surgical treatment is presented in Table 2.

No significant differences in age and weight between groups were found. In all groups of babies, a bodyweight of more than 3000 g prevailed, and the postnatal age at admission in a children's surgical hospital reached an average of two weeks.

Data were retrospectively extracted from patient charts:

1. Before surgery and anesthesia (pre-surgical period)
2. Induction of the newborn or infant into anesthesia
3. Traumatic stage of the surgery: the middle of the surgery or the most painful stage of surgery
4. Postoperative period (1 hour after the transfer of a baby to the intensive care unit)
5. Twenty-four hours after the surgery

During all stages, the following parameters were investigated: concentration of hydrogen ions (pH), the partial pressure of carbon dioxide in venous blood ($PvCO_2$), the partial pressure of oxygen (PvO_2), blood base excess (BE), base excess in extracellular fluids (BEe), standard bicarbonate (SBC), the percentage of blood oxygen

Congenital malformations	Malformations of esophagus	Intestinal obstruction		Gastroschisis	Tumors	Intestinal malformations	Ano-rectal malformations	Pulmonary malformations	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)

Table 1. Types of congenital malformations in examined newborns and infants, n (%)

saturation (SrO_2). All acid-base status studies were performed using an ion-selective ionizer of electrolytes and blood gases "Medica Easy Lyte," USA. Hemoglobin of the newborn and the oxygen content in the air inhaled by the patients (FiO_2) were also considered.

Bonferroni's corrections were used to resolve multiple comparisons.

Statistical analysis was done using the software product STATISTICA 6.1® (StatSoft Inc., serial № AGAR909E415822FA).

Parameter	Groups			P
	I (n = 50)	II (n = 50)	III (n = 50)	
Body weight, g	3185.53 ± 1173.27	3019.88 ± 896.38	3202.06 ± 816.17	0.4342* 0.9356** 0.2954***
Age, day of life	14.33 ± 23.95	15.89 ± 17.39	12.84 ± 18.97	0.7109* 0.7336** 0.4071***

Note: * *p* between groups I and II; ** *p* between groups I and III; *** *p* between groups II and III

Table 2. Body weight and age of examined newborns and infants on the moment of hospitalization for surgical treatment, M±SD

Time of the study	Groups of examined children			P
	I (n = 50)	II (n = 50	III (n = 50)	
Pre-surgery	52.7 ± 12.2	50.9 ± 7.8	49.9 ± 6.4	0.4032* 0.1559** 0.4551***
Induction of anesthesia	51.5 ± 12.1	51.2 ± 7.9	50.4 ± 5.3	0.8905* 0.5469** 0.5294***
Traumatic stage	50.2 ± 12.1	50.7 ± 7.5	51.1 ± 7.3	0.8099* 0.6499** 0.7759***
After the surgery	51.4 ± 15.1	50.0 ± 10.1	49.8 ±9.4	0.5949* 0.5176** 0.8936***
24 hours after the surgery	50.0 ± 11.4	47.6 ± 7.1	47.8 ± 8.7	0.2076* 0.2796** 0.8975***

Note: * *p* - between groups I and II; ** p - between groups I and III; *** *p* - between groups II and III

Table 3. Partial pressure of O_2 in venous blood (PvO_2) parameters in newborns and infants at different types of anesthesia depending on the surgery stage, M±SD

Groups were first analyzed by descriptive statistics, presenting the data as mean (M) and standard deviation (SD). For multiple comparisons, a two-sided Newman-Keuls test was used. Alpha was set for $p < 0.05$.

RESULTS AND DISCUSSION Oxygen saturation of the blood is extremely important in any surgery, especially in pediatric patients. Reduced volume of circulating blood in the tissue (ischemia) or reduced oxygen saturation in the arterial blood (hypoxia) affects the newborn and infants’ organs and systems. Especially vulnerable to ischemia and hypoxia are the kidneys, intestines, and brain. One of the first compensatory mechanisms to compensate for a tissue's O_2 deficiency is to increase its extraction from the blood, which leads to a decrease in the oxygen content in the venous blood. Given the importance of these pathophysiological processes and their significance to CM surgical correction outcomes, it is mandatory to monitor acid-base status and peripheral oximetry by pulse oximetry [5-7].

No significant pathological changes in acid-base status during all periods were found within and between the groups in our study, but some tendency was noticed in **the** reduction of PvO_2 in the third group during after surgery period ($p \geq 0.05$). The data are presented in Table 3.

$PvCO_2$ parameters in group I were significantly lower than the other groups in the surgery initiation period (pre-surgery), at the time of induction of anesthesia, during the most painful/ traumatic stage, and after surgery (Table 4). The $PvCO_2$ index in group I was restored only 24 hours after surgical treatment, which may be explained by respiratory alkalosis due to hyperventilation and increased respiratory rate during the ventilatory respiratory support.

Surgery stage	Groups of examined children			P
	I (n = 50)	II (n = 50	III (n = 50)	
Pre-surgery	31.3 ± 6.5	33.8 ± 7.1	36.0 ± 7.4	0.0724* 0.0013** 0.1398***
Induction of anesthesia	31.3 ± 6.2	36.1 ± 6.9	36.3 ± 6.7	0.0005* 0.0003** 0.8916***
Traumatic	30.6 ± 6.7	35.2 ± 6.7	35.9 ± 6.7	0.001* 0.0001** 0.5484***
After the surgery	31.0 ± 9.2	36.9 ± 8.01	35.4 ±7.2	0.001* 0.0109** 0.3079***
24 hours after the surgery	36.4 ± 9.8	39.4 ± 6.7	38.4 ± 7.5	0.0768* 0.2577** 0.4797***

Note: * *p* - between groups I and II; ** *p* - between groups I and III; *** *p* - between groups II and III

Table 4. Partial pressure of CO_2 in venous blood ($PvCO_2$) parameters in newborns and infants at different anesthesia types depending on surgery stage, M±SD

Confirmation of hypocapnia and the presence of respiratory alkalosis reflected pH parameters in children of group I (Table 5). In this group, we observed that pH level was slightly elevated and ranged from 7.41 ± 0.08 - 7.44 ± 0.12 from the beginning until the postoperative periods. Moreover, when comparing the pH immediately after surgery in children of group I –(7.44 ± 0.12) with other types of combined anesthesia in groups II (7.39 ± 0.08) and III (7.38 ± 0.08) there was a significant difference (p = 0.0094; p = 0.0084, respectively).

It is known that in alkalosis (pH increase), the dissociation curve of hemoglobin with oxygen or carbon dioxide shifts to the left [5]. This reaction occurs when blood flows to the lungs and hemoglobin carries less oxygen or carbon dioxide than normal blood. In the latter, oxygen dissolved in large quantities of blood cannot be utilized by the body's cells and tissues. As a result, respiratory deficits emerge. On the other hand, increased pH of the blood prevents the binding of hemoglobin to carbon dioxide and its excretion from the body, which in turn, increases the manifestation of alkalosis. It should be noted that this condition can also occur when a child has hypothermia.

Therefore, when an anesthesiologist chooses to combine anesthesia with inhalation and regional anesthesia in pediatric patients (newborns and infants) during a surgical correction, caution should be taken against hyperventilation, which should be controlled by acid-base status and timely adjustment of ventilation parameters.

Pulse oximetry is the optical method of determination of the saturation percentage of hemoglobin with oxygen. It is based on 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 and measurement error usually does not exceed 2-3%. It takes 23 seconds to 1.5 minutes to measure SpO_2 depending on the correct installation of the sensor, monitor model (ability to record the signal and duration of data update on the screen), and specifics of blood circulation in a patient [6,7].

approximately 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% may be acceptable, and, accordingly, PaO_2 from 45 to 90 mm Hg. 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 [5].

In our study, peripheral saturation parameters exceeded 97%, which was probably determined by the doctor's desire to maintain oxygenation of all tissues of the baby's body at a sufficient level (Table 6). In general, peripheral saturation of neonates and infants with CM was not critically reduced at all stages of observation except decreased SpO_2 in children of group I compared with group III at the stage of induction of anesthesia (97.79 ± 2.45 vs. 98.79 ± 1.63, p = 0.0194), at the most painful moment of surgery (96.29 ± 3.47 vs. 98.10 ± 2.47, p = 0.0368); and in the newborns of the group II compared with group III after

Surgery stage	Groups of examined children			P
	I (n = 50)	II (n = 50	III (n = 50)	
Pre-surgery	7.41 ± 0.08	7.41 ± 0.08	7.40 ± 2.92	0.6061* 0.4827** 0.8379***
Induction of anesthesia	7.41 ± 0.07	7.39 ± 0.09	7.40 ± 0.08	0.1644* 0.4938** 0.4799***
Traumatic	7.41 ± 0.09	7.39 ± 0.07	7.35 ± 0.43	0.4244* 0.3288** 0.4359***
After the surgery	7.44 ± 0.12	7.39 ± 0.08	7.38 ±0.08	0.0094* 0.0084** 0.9081***
24 hours after the surgery	7.39 ± 0.07	7.33 ± 0.42	7.36 ± 0.08	0.4132* 0.1027** 0.6894***

Note: * *p* - between groups I and II; ** *p* - between groups I and III; *** *p* - between groups II and III

Table 5. Venous blood pH parameters in newborn and infants at different anesthesia types depending on surgery stage, M±SD

The oxyhemoglobin dissociation curve determines the relationship between PaO_2 and SpO_2, the shape and displacement of which depends on pH, temperature, pCO_2, and 2,3-diphosphoglycerate in erythrocytes and the ratio of fetal and adult hemoglobin. In a full-term newborn, the range of PaO_2 is from 60 to 90 mm Hg, which

surgery (95.63 ± 3.47 vs. 96.92 ± 2.94, respectively, p = 0.0507). Probably, to increase the parameters of peripheral saturation, physicians prescribed a correction of lung ventilation, which, in turn, led to hyperventilation and respiratory alkalosis.

Newborn in group I showed a greater oxygen dependence. That may relate to the mechanism of action of anesthesia on the baby's body but does not exclude the presence of pain during surgery.

Analysis of BE parameters in babies' venous blood with CM during surgical treatment with different types of combined anesthesia did not reveal any significant differences between the groups and time of measurements (Table 7).

Surgery stage	Groups of examined children			P
	I (n = 50)	II (n = 50)	III (n = 50)	
Pre-surgery	98.27 ± 2.01	98.31 ± 1.97	96.82 ± 1.23	0.9193* 0.4832** 0.4708***
Induction of anesthesia	97.79 ± 2.45	98.39 ± 1.69	98.79 ± 1.63	0.1673* 0.0194** 0.2275***
Traumatic	96.29 ± 3.47	97.37 ± 3.4	98.10 ± 2.47	0.2837* 0.0368** 0.3106***
After the surgery	95.76 ± 3.41	95.63 ± 3.47	96.92 ± 2.94	0.8607* 0.0736** 0.0507***
24 hours after the surgery	96.88 ± 2.77	96.39 ± 2.75	96.79 ± 3.66	0.3818* 0.9011** 0.5339***

Note: * *p* - between groups I and II; ** *p* - between groups I and III; *** *p* - between groups II and III

Table 6. Pulse oximeter parameters (SpO_2) in children at different anesthesia types depending on surgery stage, M±SD

Surgery stage	Groups			P
	I (n = 50)	II (n = 50)	III (n = 50)	
Pre-surgery	-4.58 ± 1.50	3.05 ± 2.44	-3.11 ± 2.17	0.3158* 0.4853** 0.2143***
Induction of anesthesia	-2.40 ± 2.79	-2.62 ± 2.87	-3.17 ± 1.74	0.7078* 0.1036** 0.2485***
Traumatic	2.42 ± 2.51	-2.22 ± 2.61	-2.98 ± 1.74	0.6978* 0.1989** 0.0905***
After the surgery	-2.65 ± 2.63	-2.46 ± 2.94	-3.03 ± 2.39	0.7359* 0.4507** 0.2903***
24 hours after the surgery	-2.52 ± 2.79	-1.89 ± 2.32	-2.97 ± 2.41	0.2221* 0.3997** 0.0258***

Note: * *p* - between groups I and II; ** *p* - between groups I and III; *** *p* - between groups II and III

Table 7. BE parameters in the venous blood in newborns and infants at different anesthesia types depending on surgery stage, M±SD

We noticed that babies from group I needed higher concentrations of oxygen in the inhaled mixture (Table 8). A significant difference in this parameter is observed between groups I and III during the most painful stage of surgery (0.47 ± 0.29 and 0.33 ± 0.2, p = 0.0071) and immediately after the surgery (0.34 ± 0.19 and 0.26 ± 0.13, p = 0.0246).

Insignificant oxygen demand was found in children of group II during combined inhalational and intravenous anesthesia. Moreover, higher concentrations of oxygen were required in newborns and infants when anesthesia was inducted and during the most traumatic period of the surgery (p ≥0.05). Minimal oxygen dependence was observed in group III (Table 8).

that in group I, reduced partial pressure of CO_2 and increased pH were present from the pre-surgical preparation, at the time of induction of anesthesia, during the most painful period (traumatic stage), and until after surgery. Moreover, the obtained values are significantly different from other types of combined anesthesia. Observed respiratory alkalosis was most likely due to hyperventilation and increased respiratory rate during the correction of the babies' respiratory support parameters by physicians. Moreover, peripheral oxygen saturation in neonates and infants with CM was not reduced at all stages of observation except in group I compared with group III during anesthesia induction (97.79 ± 2.45 vs. 98.79 ± 1.63, p = 0.0194), at the most painful moment of surgical intervention (96.29 ± 3.47 vs. 98.10 ± 2,47, p = 0.0368).

Surgery stage	Groups			P
	I (n = 50)	II (n = 50)	III (n = 50)	
Pre-surgery	0.36 ± 0.26	0.37 ± 0.22	0.39 ± 0.27	0.7750* 0.5457** 0.3545***
Induction of anesthesia	0.39 ± 0.267	0.44 ± 0.26	0.38 ± 0.24	0.4268* 0.8259** 0.2887***
Traumatic	0.47 ± 0.29	0.40 ± 0.24	0.33 ± 0.2	0.2175* 0.0071** 0.0997***
After the surgery	0.34 ± 0.19	0.29 ± 0.14	0.26 ± 0.13	0.1932* 0.0246** 0.2555***
24 hours after surgery	0.29 ± 0.14	0.25 ± 0.1	0.23 ± 0.11	0.4773* 0.1498** 0.3592***

Note: * p - between groups I and II; ** p - between groups I and III; *** p - between groups II and III

Table 8. FiO_2 in newborns and infants at different anesthesia types depending on surgery stage, M±SD

CONCLUSION Among the examined groups of newborns and infants with CM requiring surgical intervention and combined anesthesia, the most volatile acid-base status parameters were peripheral oxygen saturation and oxygen demand in group I anesthetized by inhalational anesthesia with Sevoran and regional anesthesia. That indicated a greater oxygen dependency of those babies and did not exclude the presence of pain and/or hypothermia. We also noted that patients in Group I were the most vulnerable to blood gas disorders. Assessment of $PvCO_2$ and pH showed

We observed that with combined inhalational and regional anesthesia, newborns and infants required higher oxygen concentrations in the inhalation mixture. Furthermore, there was a significant difference in this parameter between Groups I and III during the most painful stage of surgery (0.47 ± 0.29 and 0.33 ± 0.2; p = 0.0071), and immediately after surgery (0.34 ± 0.19 and 0.26 ± 0.13, at p = 0.0246). Our findings suggest that when choosing inhalational and regional anesthesia for surgical correction, an anesthesiologist should be aware of oxygen dependence in a baby. Newborns and infants could have a drop in peripheral oxygenation because of hyperventilation during ventilatory support and respiratory alkalosis. The changes are predictable, and it is necessary to monitor the acid-base status constantly and adjust ventilatory support settings.

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