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THE INFLUENCE OF BIOCOMPATIBILITY OF THE EXTRACORPOREAL OXYGENATOR CIRCUIT ON THE DEGREE OF HEMOLYSIS AND OPTIMIZATION OF OXYGEN STATUS IN MINIMALLY INVASIVE CORONARY ARTERY BYPASS GRAFTING

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Summary

Introduction. A distinctive feature of cardiopulmonary bypass in minimally invasive coronary artery bypass grafting (CABG) is the significantly longer perfusion time, involving active blood drainage from the vein to the cardiotomy reservoir, which carries the risk of hemolysis development. In this context, mechanical hemolysis disrupts the gas transport function of the blood.
The aim of the research. Reducing hemolysis and optimizing oxygen status of patients during minimally invasive coronary artery bypass grafting surgeries.
Materials and methods. The study included 60 patients, who underwent minimally invasive coronary artery bypass grafting (CABG) with cardiopulmonary bypass (CPB) under moderate hypothermia. The patients were divided into two groups of 30 individuals each. To improve the biocompatibility of the oxygenator, the circuit in Group 1 (Gr1) was treated with an adaptive composition, while in Group 2 (Gr2), the oxygenator circuit remained untreated. The following parameters were examined: hemoglobin (Hb), hematocrit (Ht), red blood cell count (RBC), oxygen delivery index (DO2I), oxygen consumption index (VO2I), oxygen extraction ratio (O2ER%), oxygen extraction index (O2EI%), venous (SpvO2), and arterial (SpaO2) oxygen saturation, oxygen tension in arterial (PaO2) and venous blood (PvO2), acid-base status of the blood (pH, pCO2, $HCO3^-$, BE), and the degree of hemolysis.
Results. Before initiation of cardiopulmonary bypass (CPB), an insignificant increase in O2IE% was observed in Gr1 (26.07±1.57) and Gr2 (27.11±0.81); p=0.875, indicating an increase in tissue oxygen consumption. At the hypothermic stage CPB, both Gr1 and Gr2 demonstrated a statistically significant decrease in Hb, Ht, and RBC levels ($p<0.05$) due to hemodilution, accompanied by a decrease in IDO2, IVO2, O2IE%, and O2ER% in both groups due to hypothermia. After rewarming, O2ER% in Gr1 (22.91±2.68) and Gr2 (24.59±2.02); p=0.191, and O2EI% in Gr1 (22.92±2.44) and Gr2 (24.61±2.01); p=0.215, were in the normal range. After weaning off cardiopulmonary bypassin Gr2, O2EI% was 27.34±1.97, indicating an increase in oxygen consumption and oxygen extraction. Upon separation from CPB, Gr2 showed a tendency to mild compensated metabolic acidosis, mainly due to $HCO3^-$ 21.9±0.3. During the rewarming stage, the hemolysis value was 0.36±0.09in Gr1 and 0.45±0.17 in Gr2 ($p<0.001$). After CPB, hemolysis was 0.41±0.15 in Gr1 and 0.61±0.22 in Gr2 ($p<0.001$).
Conclusions. Improving the biocompatibility of the extracorporeal oxygenatorcircuit makes it possible to reduce hemolysis and optimise the patient's oxygen status after cardiopulmonary bypass in minimally invasive coronary artery bypass grafting.

Keywords: **treatment, cardiopulmonary bypass, biocompatibility, hemolysis, coronary artery bypass grafting, oxygen delivery, oxygen consumption**

INTRODUCTION

Highly traumatic coronary artery bypass grafting (CABG) by sternotomy, both with and without cardiopulmonary bypass (CPB), is associated with an increased risk of complications. The search for methods to reduce surgical trauma has led to the development of a promising direction known as minimally invasive coronary artery revascularization under cardiopulmonary bypass.

The special feature of minimally invasive cardiac surgery is a significantly longer perfusion time, which carries the risk of developing mechanical hemolysis. Another peculiarity of this type of surgery is the need to cannulate the femoral artery and vein with smaller diameter cannulas, which impedes blood flow into the cardiotomy reservoir. Under these conditions, adequate drainage of the heart is a critical factor for good visualization of the surgical field and crucial for the quality of the surgical treatment.

Vacuum-assisted venous drainage (VAVD) provides a remedy here by increasing the flow of venous blood into the oxygenator. This technique actively drains the blood from the vein by creating a negative pressure in the venous reservoir, which can cause additional damage to the blood cells [1, 2].

Another cause of intraoperative hemolysis is the initial structural-metabolic state of the erythrocytes and their contact with the artificial surfaces of the oxygenator, which leads to the formation of varying degrees of post-perfusion hemoglobinemia [3]. The degree of deformability of erythrocytes determines their ability to pass through the smallest capillaries and thus ensure adequate gas transport in the blood, sufficient nutrient supply and effective removal of metabolic by-products. Impaired deformability of erythrocytes reduces the number of functioning capillaries, which leads to tissue ischemia, worsens oxygen status and disrupts metabolism in the body.

Adequate oxygen delivery (DO2) is a key factor in sustaining life, and actual tissue oxygen consumption (VO2) reflects the body's metabolic needs. However, the values of DO2 and VO2 do not always reflect the intensity of the general metabolism, as they depend on the state of the blood circulation. Calculating the values of DO2 and VO2 alone cannot provide information on how internal respiration changes at the level of the individual target organs. Nevertheless, assessing the imbalance between oxygen delivery and consumption is crucial as it allows early detection and assessment of the severity of global dysoxia. This process can be characterized by indicators such as the oxygen extraction ratio (O2ER%) and the oxygen extraction index (O2EI%).

Many studies have reported a decrease in the deformability of erythrocytes after mechanical stress [4, 5]. Hemolysis is a significant complication that increases erythrocyte aggregation, and mechanical trauma causes sublethal cell damage [6]. The extent of hemolysis depends not only on the mechanical trauma to the erythrocytes, but also on the state of the erythrocyte membrane during CPB [7]. One way to tackle the complex problem of hemolysis could be to improve the biocompatibility of the extracorporeal oxygenator circuit [8].

The aim of the research was to reduce hemolysis and optimize the oxygen status of patients undergoing minimally invasive coronary artery bypass grafting surgery.

MATERIALS AND METHODS

The study included 60 patients who underwent minimally invasive coronary artery bypass grafting with three anastomoses with CPB. The patients were divided into two groups of 30 patients each. In Group 1 (Gr1), the oxygenator circuit was treated with an adaptive composition (AdC), while in Group 2 (Gr2), the oxygenator circuit was not treated with Ad C.

Exclusion criteria for the study were patients with a body weight of more than 90 kg, diabetes mellitus anamnesis, creatinine clearance of less than 50 ml/min, cardiopulmonary bypass duration of more than 150 minutes, the need for a blood transfusion, and the patient's unwillingness to participate in the research study.

The groups were homogeneous and statistically comparable according to age, gender, body surface area and functional class of chronic heart failure (NYHA) ($p>0.05$ for each parameter). Laboratory methods were used to assess the oxygen transport function of the blood. Hemoglobin (Hb), hematocrit (Ht), red blood cell count (RBC), oxygen delivery index (IDO2) and oxygen consumption index (IVO2), oxygen extraction ratio (O2ER%) were determined, the oxygen extraction index (O2EI%), the venous (SpvO2) and arterial (SpaO2) saturation, the oxygen tension in the arterial (PaO2) and venous blood (PvO2), the acid-base status (ABS) of the blood (pH, PCO2, HCO^{-}, VE), hemolysis level. Calculative methods of research were used to determine cardiac output (CO) and the expected degree of hemodilution during CPB. Invasive monitoring of arterial and central venous pressure, mean perfusion pressure, ECG, ultrasound of the vessels and transesophageal ECHO-CG was performed using instrumental examination methods.

Anesthesiologic and perfusiologic support for minimally invasive surgery has several special features. These include careful preoperative patient selection with prediction of surgical anesthesiologic risk, one-lung ventilation, control of oxygen delivery in the basin of the aortic arch branches, and cannulation of the femoral artery and vein for cardiopulmonary bypass [9].

All patients underwent a preoperative examination protocol, which included a computed tomography

angiography of the great vessels with contrast enhancement. The aim was to timely detect plaques, aneurysms, dissections, tortuosities, and foreign materials for safe vascular cannulation [10].

The Enhanced Recovery After Surgery (ERAS) protocol avoids preoperative anxiolytic therapy. Therefore, pharmacological premedication was not administered to facilitate faster postoperative rehabilitation. Anesthetic induction was carried out using fentanyl at a dose of 0.05-0.1 mg intravenously, and propofol was administered at a dose of 1.5-2.5 mg/kg until the desired effect was achieved. Atracurium at a dose of 0.5 mg/kg was used to induce neuromuscular relaxation. The right bronchus was intubated under the guidance of auscultation and capnography. In case of suspected ventilation of both lungs, a bronchoscopy was performed. Mechanical ventilation of the lung (MVL) was conducted in Volume Control mode with target parameters of tidal volume (TV) of 4 ml/kg, respiratory rate (RR) of 20-25/min, positive end-expiratory pressure (PEEP) of2 cmH2O, FIO2-100 %. If the patient's oxygenation level dropped below 90 % during one-lung ventilation, it was recommended to switch to two-lung ventilation in Volume Control mode. Used a tidal volume of 5-6 ml/kg, respiratory rate of 10-12/min, and ensured capnography etCO2 levels were maintained at 32-35 mmHg. Set PEEP at 3 cmH2O and FIO2 at 100 %. Neuromuscular blockade was achieved with atracurium at a dose of 0.1-0.2 mg/kg. Anesthesia maintenance until the start of cardiopulmonary bypass was done with low-flow inhalation anesthesia using sevoflurane. The flow rate used was 1 L/min, with an end-tidal concentration of sevoflurane (etSev) ranging from 1.4 % to 1.6 %. The minimum alveolar concentration (MAC) was between 1.0 % and 1.2 %. To connect the extracorporeal circuit to the patient, heparinization was performed with an intravenous dose of 300 IU per kg. During the cardiopulmonary bypass, anesthesia was maintained with a propofol infusion of 5 to 10 mg/kg/min, along with bolus administration of fentanyl at a dose of 0.1 mg/kg, and atracurium at a dose of 0.1 to 0.2 mg /kg as needed. The ventilator was in Man/Spont mode, FiO2 was set to 0.21, and PEEP was 3 cmH2O. After CPB, anesthesia maintenance was carried out with low-flow inhalation anesthesia using sevoflurane. The flow rate was 1 L/min, and etSev was between 0.8 % and 1.0 %. The MAC was between 0.6 % and 1.0 %. Analgesia was provided with bolus administration of fentanyl at a dose of 0.1 mg/kg. Neuromuscular relaxation was achieved with atracurium at a dose of 0.1 to 0.2 mg/kg as the need required. To enhance the biocompatibility of the internal surface of the oxygenator in Gr1, the extracorporeal circuit was treated with AdC using the following protocol: before the surgery, 20 ml of the patient's blood was collected from a subclavian vein. The collected blood was left to settle for 15 minutes and after clot formation, the serum was centrifuged using the NF 200 centrifuge (Nuve, Turkey) for 7 minutes at 3500 rpm. The obtained serum of 5-10 ml was taken with a sterile syringe, adjusted to a volume of 20 ml with saline (0.9 % NaCl), and added to the oxygenator, which was pre-filled with 0.9 % NaCl in a volume of 1000 ml, through a disposable membrane filter with 0.22 μm pores (Minisart, Sartoriusstedium, Biotech corp.). Subsequently, the AdC was circulated at idle operating mode for 5-7 minutes [12]. Afterward, the oxygenator was completely drained, and the standard procedure of filling the oxygenator with corresponding solutions. A standardized multicomponent prime was used to fill the oxygenator circuit. This prime consisted of 4 % succinylated gelatin, 15 % Mannitol, 4.2 % Soda-buffer, Rheosorbilact, and heparin. In the case of metabolic acidosis, a dose of 4.2 % sodium bicarbonate was calculated using a specific formula:

$$NaHCO3\ 4.2\ \%\ (ml) = 0.6 \times (-BE) \times m\ (kg),$$

where **ml** is the volume of the sodium bicarbonate solution used for correction;
m is the patient's body mass
BE is the base excess of blood buffers (mmol/L) [13].

Perfusion was carried out using a membrane oxygenator in a non-pulsatile blood flow mode with a prime volume of 1300-1500 ml. The cardiopulmonary bypass was performed under conditions of moderate hypothermia (32-33 °C). During the hypothermic phase, moderate hemodilution was achieved, aiming for a hematocrit of 25 g/L. The target mean flow index and mean perfusion pressure were set at 2.5-2.8 L/min/m² and 60-80 mmHg, respectively.

The research results were collected and stored in a database created in MS Excel 2013. The obtained results were analyzed using the MedStat program (license v. 4, MS 000070-06.07.2009, Yu. Yu. Lyakh, V. G. Guryanov). For normally distributed data, mean values, standard error, Student's t-test, and the Scheffé multiple comparisons method were used. Statistical significance was considered when $p<0.05$.

RESULTS AND DISCUSSION

The time-CPB was 113.9±12.4 minutes in Gr1 and 115.6±9.8 minutes in Gr2 (p=0.503). The mean time for anastomosis formation was 12.3±1.8 min in Gr1 and 12.9±1.4 min in Gr2, with no significant difference between the two groups (p=0.780).

The results of the study showed a statistically significant decrease in Hb, Ht, and RBC parameters in both groups at the beginning of CPB (stage I) (table 1).

Such a decrease in hematological parameters is associated with hemodilution at the beginning of CPB. The prime volume was calculated based on the patient's initial hemoglobin levels and the target hemoglobin levels after dilution with the solutions included in the prime. As a result, we did not research the fact of a critical decrease in Hb, Ht, and RBC in the groups. There was no statistical difference in these parameters at Stages I and II of the study.

Table 1

Dynamics of hematological blood parameters and hemolysis at stages of cardiopulmonary bypass study (n=60)

Parameters/ Stage	Arithmetic mean± SD			
	Hb, g/l	RBC x 10^{12}	Ht,%	Hemolysis
Before CPB (I)				
Gr 1	131.8±18.25#&$	4.51±0.62#&$	39.3±5.2#&$	0,16±0,07&$
Gr2	134.4±16.50#&$	4.58±0.59#&$	40.1±4.9#&$	0,15±0,09&$
p	0.901	0.877	0.619	0.185
Hypothermic stage (II)				
Gr 1	85.19±14,12*$	3.19±0,61*$	26.05±4,56*$	0.17±0,14&$
Gr2	83.59±16,64*$	3.14±0,48*$	25.85±3,73*$	0.18±0,09&$
p	0.428	0.789	0.884	0,678
Rewarming stage (III)				
Gr 1	91.88±12.89*$	3.07±0.53*$	27.51±4,17*$	0.36±0.09*#$
Gr2	84.57±11.52*$	2.89±0.49*$	25.37±3.13*$	0.45±0.17*#$
p	0.041	0.012	0.035	<0.001
After CPB (IV)				
Gr 1	115.8±16.95*#&	3.89±0.47*#&	34.54±2.28*#&	0.41±0.15*#&
Gr2	91.2±8.41*#&	3.03±0.29*#&	27.35±3.66*#&	0.61±0.22*#&
p	0.021	0.011	< 0.001	<0.001

Notes: * – statistical difference compared to Stage I (p <0.05); # – statistical difference compared to Stage II (p <0.05); & – statistical difference compared to Stage III (p <0.05); $ – statistical difference compared to Stage IV (p <0.05)

After the rewarming process (Stage III), there was a tendency towards higher values of Hb, Ht, and RBC values in Gr1, which persisted after weaning off CPB (table 1). The obtained results correspond to the dynamics of changes in hemolysis parameters. During Stages I and II of the study, there was no statistical difference in hemolysis parameters between the groups. From Stage III (which corresponds to CPB-time in Gr1 89.3±17.1 min and 87.7±13.2 in Gr2, p=0.192), hemolysis increased in both Gr1 and Gr2 (p < 0.001). When comparing the groups, it was found that hemolysis in Gr1 was lower than in Gr2. This tendency persisted even after CPB, as shown in table 1.

Before CPB and at Stage II of the study, the use of the multi-component prime volume prevented any abnormalities in acid-base balance parameters in both Gr1 and Gr2. While rewarming, metabolic acidosis was corrected by administering an additional volume of 4.2 % Soda Buffer, and acid-base balance parameters were restored to physiological values in both Gr1 and Gr2. After weaning off CPB, there was a tendency towards a slight compensated metabolic acidosis in Gr2, mainly due to $HCO3^{-}$, a parameter that shows the metabolic component of pH changes, including disruptions in buffer system function (table 2).

Table 2

Dynamics of acid-base balance parameters in venous blood during CPB stage (n=60)

Parameters/Stage	Arithmetic mean± SD		
	pH	$HCO3^{-}$, mmol/L	pCO2, mmHg
Before CPB (I)			
Gr 1	7.375±0.024$	22.7±1.8$#	39.9±2.5&
Gr2	7.389±0.019	24.1±1.2$	39.7±2.3
p	0.662	0.213	0.851
Hypothermic stage (II)			
Gr 1	7.401±0.012	24.9±1.7*	41.1±1.8
Gr2	7.398±0.018	23.8±0.8$	39.8±2.4
p	0.129	0.09	0.564
Rewarming stage (III)			
Gr 1	7.368±0.028	24.3±0.9	43.7±1.8*
Gr2	7.359±0.016	23.9±1.4$	44.0±1.3
p	0.118	0.259	0.876
After CPB (IV)			
Gr 1	7.409±0.012*	24.5±1.6*	39.8±1.2
Gr2	7.356±0.017	21.9±0.3	41.8±1.6
p	0.075	0.001	0.138

Notes: * – statistical difference compared to stage I (p<0.05); # – statistical difference compared to stage II (p<0.05); & – statistical difference compared to stage III (p<0.05); $ – statistical difference compared to stage IV (p<0.05)

To assess metabolism, the mean flow index must be the same at all stages of the operation in both groups (p=0.795). An analysis of the oxygen transport function of the circulatory system revealed no statistical difference in the parameters of IDO2 and IVO2 at stage I of the research (table 3). However, these rates were slightly reduced compared to the physiologically normal state of an awake person, due to the vasodilatory effect of sevoflurane and a decrease in total peripheral resistance, a decrease in the intensity of general metabolism as a result of anesthesia, and the spontaneous cooling of patients on the operating table. The patients in both groups had a body temperature of 35.9 ± 0.4 °C at the beginning of CPB. Many researchers have shown that total myoplegia during anesthesia can reduce oxygen consumption and extracorporeal circulationas an effect of the redistribution of blood flow, cooling, and exclusion of the heart from circulation, it can further reduce oxygen consumption by another 20 % from normal [14].

Parameters such as SaO2 %, SvO2 %, DO2 index (IDO2), VO2 index (IVO2), oxygen extraction ratio (O2ER%), and oxygen extraction index (O2EI%) were investigated as markers of blood gas transport function at all stages.

Table 3

Blood oxygen transport function indices at different stages of CPB research (n=60)

Parameters/ Stage	Arithmetic mean± SD					
	SaO2, %	SvO2, %	IDO2, ml/ (min·m²)	IVO2, ml/(min·m²)	O2ER, %	O2IE, %
Before CPB (I)						
Gr 1	97.8±1.1	72.3±0.9#	449.07±52.4 #&$	117.07±12.81#&$	26.06±1.80#&$	26.07±1.57#&$
Gr2	98.1±0.9	71.5±1.1#	459.34±53.2 #&$	124.56±16.34#&$	27.12±0.70#&	27.11±0.81#&
p	0.997	0.684	0.842	0.137	0.899	0.875
Hypothermic stage (II)						
Gr 1	99.9±0.1	89.5±0.6*&$	285.0±47.5*	29.75±3.0*&$	10.40±0.61*&$	10.41±0.51*&$
Gr2	99.8±0.1	88.1±1.3*&$	279.5±55.5*	33.0±1.9*&$	11.80±1.40*&$	11.81±1.31*&$
p	0.998	0.977	0.813	0.716	0.984	0.851
Rewarming stage (III)						
Gr 1	99.8±0.1	76.92±2.4#	307.17±32.87*	70.42±2.53*#	22.91±2.68*#	22.92±2.44*#
Gr2	99.9±0.1	75.33±1.92#	283.20±27.25*	68.62±3.05*#	24.59±2.02*$	24.61±2.01*$
p	0.998	0.598	0.197	0.226	0.191	0.215
After CPB (IV)						
Gr 1	96.1±1.8	74.3±2.2#	328.06±37.45*	74.42±5.13*#	22.68±0.79*#	22.67±0.82*#
Gr2	96.9±1.1	70.4±2.8#	260.51±26.27*	71.23±5.71*#	27.35±1.93#&	27.34±1.97#&
p	0.997	0.07	0.413	0.117	<0.001	0.001

Notes: * – statistical difference compared to stage I (p<0.05); #– statistical difference compared to stage II (p<0.05); & – statistical difference compared to stage III (p<0.05); $ – statistical difference compared to stage IV (p<0.05)

During the hypothermic stage, IDO2 decreased in both groups (Gr1 and Gr2) due to a decrease in Hb levels caused by hemodilution. The dynamic of IDO2 is indicative of acute hemodilution in new hemodynamic conditions associated with extracorporeal circulation. The critical level of IDO2 during hypothermic conditions is not clearly defined. Some researchers have identified a level of IDO2 below which IVO2 begins to critically decrease, which is about 280-300 ml/(min·m²) [15]. The IVO2 level in the research groups at this stage was reduced due to the subnormal temperature patient's body. After rewarming, there is a predictable increase in metabolism and, accordingly, tissue oxygen consumption, against a stable level of IDO2. To prevent any derangement of DO2 to the tissues, with a decrease in Hb and an increase in the patient's body temperature, the mean flow index was increased by 10-15 % from the calculated rate. At Stage III, the O2ER% and O2EI% values were within the normal range in both Gr1 and Gr2, and these data are indirect criteria for adequate perfusion.

After CPB, IDO2 and IVO2 values in both Gr1 and Gr2 were statistically significantly lower than before CPB. We associate this with a decrease in Hb and a decrease in cardiac output. In Gr2, the O2IE% index tended to be higher than before CPB (p=0.05), indicating increased O2 extraction and increased metabolic demand. Thus, despite patients being pharmacologically paralyzed during surgery and their reduced oxygen needs, in Gr2, an oxygen debt was formed during the CPB stage. This is evidenced by increased oxygen consumption and extraction after perfusion.

CONCLUSIONS

Minimally invasive aortocoronary bypass surgeries performed using extracorporeal circulation carry the risk factors for hemolysis development due to the technical features of the surgeries. Improving the biocompatibility of the extracorporeal circuit's oxygenator helps reduce the

level of hemolysis and optimize the patient's oxygen status after extracorporeal circulation.

COMPLIANCE WITH ETHICAL REQUIREMENTS

The study was conducted in accordance with the principles of the Helsinki Declaration of the World Medical Association «Ethical principles of medical research involving a person as an object of research». All study participants provided informed consent in writing to participatein the study.

FUNDING AND CONFLICT OF INTEREST

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The Authors declare no conflict of interest.

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Резюме

ВПЛИВ БІОСУМІСНОСТІ ЕКСТРАКОРПОРАЛЬНОГО КОНТУРУ ОКСИГЕНАТОРА НА РІВЕНЬ ГЕМОЛІЗУ ТА ОПТИМІЗАЦІЮ КИСНЕВОГО СТАТУСУ ПІД ЧАС МІНІІНВАЗИВНОГО АОРТО-КОРОНАРНОГО ШУНТУВАННЯ

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Вступ. Особливістю штучного кровообігу при мініінвазивному аорто-коронарному шунтуванні (АКШ) є значне збільшення тривалості перфузії та використання активного дренування крові з вени до кардіотомічного резервуару, що є ризиком розвитку гемолізу. На тлі механічного гемолізу порушується газотранспортна функція крові.

Мета дослідження. Зниження рівня гемолізу та оптимізація кисневого статусу пацієнтів під час операцій мініінвазивного аорто-коронарного шунтування.

Матеріали та методи. У дослідженні взяли участь 60 осіб, яким було проведеномініінвазивне АКШ з штучним кровообігом в режимі помірної гіпотермії. Пацієнтів було розділено на 2 групи по 30 осіб. Для покращення біосумісності оксигенатора в групі 1 (Gr1) контур оброблявся адаптуючою композицією, а в групі 2 (Gr2) контур оксигенатора залишався без обробки. Досліджено гемоглобін (Hb), гематокрит (Ht), кількість еритроцитів (RBC), індекс доставки кисню (IDO2), індекс споживання кисню (IVO2), коефіцієнт екстракції кисню (O2ER%), індекс екстракції кисню (O2EI%), венозну (SpvO2) та артеріальну (SpaO2) сатурацію, напруження кисню в артеріальній (PaO2) і венозній крові (PvO2), кислотно-основний стан крові (pH, pCO2, $HCO3^-$, BE), рівень гемолізу.

Результати дослідження. До штучного кровообігу відмічається невелике підвищення O2IE% в Gr1 (26.07±1.57) і в Gr 2 (27.11±0.81); p=0.875, що свідчить про збільшення потреби тканин в кисні. З початком ШК на етапі охолодження в Gr1 і в Gr2 відбувається статистично значуще зниження показників Hb, Ht і RBC (p<0.05) за рахунок гемодилюції, при цьому спостерігалося зниження рівня IDO2, IVO2, O2IE% і O2ER% у двох групах через зниження температури тіла. Після зігрівання показник O2ER% в Gr1 (22.91±2.68) і в Gr2 (24.59±2.02); p=0.191 і O2EI% в Gr1 (22.92±2.44) і в Gr 2 (24.61±2.01); p=0.215 були в межах норми. Після зупинки ШК в Gr2 значення O2EI% склало 27.34±1.97, що свідчить про збільшення споживання та екстракції кисню після перфузії у цій групі хворих. Після зупинки ШК в Gr 2 спостерігалась тенденція до невеликого компенсованого метаболічного ацидозу, головним чином за рахунок $HCO3^-$ 21.9±0.3. На етапі зігрівання рівень гемолізу в Gr1 був 0.36±0.09, в Gr2 0.45±0.17 (p<0.001). Після ШК гемоліз в Gr1 був 0.41±0.15, в Gr2 0.61±0.22 (p<0.001).

Висновки. Поліпшення біосумісності екстракорпорального контуру оксигенатора дають змогу зменшити рівень гемолізу та оптимізувати кисневий статус пацієнта після штучного кровообігу при мініінвазивному аорто-коронарному шунтуванні.

Ключові слова: **лікування, штучний кровообіг, біосумісність, гемоліз, аорто-коронарне шунтування, доставка кисню, споживання кисню**