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Myocardial Protection in Combined Mitral-Aortic-Tricuspid Valve Diseases Correction under Cardiopulmonary Bypass

Abstract

The aim. To determine the optimal option for administering cardioplegic solution for myocardial protection in the correction of combined mitral-aortic-tricuspid valve diseases (CMAT) under cardiopulmonary bypass.

Materials and methods. We analyzed the results of surgical treatment of 251 patients with CMAT who were operated on at the National Amosov Institute of Cardiovascular Surgery from 01/01/2010 to 01/01/2023 and in whom 3 ways of applying crystalloid cardioplegic solution was used. There were three comparison groups: group A with antegrade (n = 47), group B with retrograde (n = 56), and group C with combined ante-retrograde administration of crystalloid cardioplegic solution (n = 148).

Results. Of the 251 operated patients, 10 died at the hospital stage (mortality rate 3.9%). The level of creatine kinase-MB (CK-MB) (U/L) at cross-clamping time ≤90 minutes for the groups was as follows: 72.3 ± 7.1 ($p < 0.05$) in group A, 64.0 ± 8.2 in group B, 67.5 ± 7.7 in group C. The level of CK-MB (U/L) at cross-clamping time ≥151 minutes for the groups was as follows: 115.2 ± 18.7 in group A, 97.4 ± 15.8 in group B, 96.3 ± 16.2 in group C.

The dynamics of echocardiographic parameters at the stages of treatment were as follows. Group A (mortality rate 4.3%): left ventricular (LV) end-systolic index (mL/m^2): 69.1 ± 13.5 (before surgery), 60.3 ± 9.7 (after surgery); left ventricular ejection fraction (LVEF): 51% ± 9% (before surgery), 54% ± 7% (after surgery). Group B (mortality rate 3.6%): LV end-systolic index (mL/m^2) 66.5 ± 12.1 (before surgery), 57.4 ± 8.6 (after surgery); LVEF: 50% ± 8% (before surgery), 56% ± 7% (after surgery). Group C (mortality rate 4.1%): LV end-systolic index (mL/m^2) 67.8 ± 11.3 (before surgery), 56.2 ± 8.9 (after surgery); LVEF: 50% ± 7% (before surgery), 56% ± 7% (after surgery).

The dynamics of echocardiographic parameters at the stages of treatment were better in groups B and C than in group A ($p < 0.05$). Hospital mortality was lower in groups B and C than in group A ($p > 0.05$).

Conclusions. The three types of cardioplegic solution delivery used in complex pathology of surgical treatment of CMAT demonstrated the adequacy of heart protection using crystalloid cardioplegia. Taking into account certain advantages in the dynamics of restoration of the LV contractility and increase in the level of CK-MB (U/L) on the second day after surgery, groups C and B should be considered optimal compared to group A ($p < 0.05$). The widespread, branched venous system of the heart allows for adequate use of the retrograde route of cardioplegia delivery and complete penetration of cardioplegic solution into the heart cells, which provides a better clinical effect compared to the isolated antegrade route of crystalloid cardioplegia delivery.

Keywords: *antegrade, retrograde crystalloid cardioplegia, mitral and aortic valve replacement, tricuspid valve repair, mitral valve repair.*

Introduction. Surgical correction of combined mitral-aortic-tricuspid valve diseases (CMAT) under cardiopulmonary bypass (CPB) is one of the most difficult surgical interventions in modern cardiac surgery [1,2,3,4]. Multivalve corrections are accompanied by prolonged CPB, cross-clamping, a large surgical trauma against the background of the initially severe condition of patients [5,6,7,8,9,10]. In the vast majority of cases (from 70 to 90%), combined mitral-aortic valve diseases were eliminated by the prosthetics of both valves and with tricuspid valve repair [11,12,13,14,15,16]. Nevertheless, despite the success in solving the problem of intraoperative myocardium protection, some of the questions still require additional research.

The aim. To conduct a comparative analysis of myocardial protection techniques in the correction of CMAT.

Material and methods. We analyzed data from 251 patients with CMAT who were operated on at the National Amosov Institute of Cardiovascular Surgery of the National Academy of Medical Sciences of Ukraine from 01/01/2010 to 01/01/2023. All the patients were diagnosed with CMAT requiring surgical correction. The leading etiologic cause of valve damage was rheumatism combined with lipoidosis. The mean age of the operated patients was 57.8 ± 9.3 years. There were 124 (49.4%) women, 127 (50.6%) men. The distribution of patients depending on the initial New York Heart Association (NYHA) functional class was as follows: 105 (41.8%) in class III, 146 (58.2%) in class IV. Atrial fibrillation was present in 57% of the patients. Patients with concomitant aorto-coronary bypass grafting were excluded from the study. All the surgical interventions were performed under CPB and moderate hypothermia (32-34 °C). Myocardium protection was carried out in the conditions of permanent cardioplegia with Custodiol solution at 20 mL per each kg of body weight. Heart external cooling was an obligatory condition of myocardium protection procedure. We studied 3 ways of supplying crystalloid cardioplegic solution to the heart; hence, there were three comparison groups: group A with antegrade (n = 47), group B with retrograde (n = 56), and group C with combined ante-retrograde administration (n = 148).

In group C, Custodiol antegrade intake was introduced by 1/3 of calculated volume under pressure of 60 mmHg after aorta compression into the orifices of the coronary arteries, and then the remaining 2/3 of the volume was introduced by retrograde intake under pressure of about 35 mmHg. Retrograde cannula installation was made under finger control at sufficient depth in coronary sinus system prior to artificial blood circulation. Surgical manipulations started together with retrograde intake. Control of cardioplegia solution retrograde intake was performed by: 1) pressure checks at the coronary sinus inlet, 2) visual inspection of Custodiol efflux out of left ventricle.

The preoperative echocardiographic parameters at the stages of treatment were as follows: group A: left ventricular (LV) end-systolic index (mL/m^2) 69.1 ± 13.5, left ventricular ejection fraction (LVEF) 51% ± 9%; group B: LV end-systolic index (mL/m^2) 66.5 ± 12.1, LVEF 50% ± 8%; group C: LV end-systolic index (mL/m^2) 67.8 ± 11.3, LVEF 50% ± 7%.

Combined mitral and aortic valve replacement was used in most cases (179 [71.3%]). Mitral valve replacement with aortic valve repair was performed in 13 (5.2%) patients. Aortic valve replacement with mitral valve repair (support rings for mitral valve plastic surgery) was performed in 56 (22.3%) patients. Both valves were repaired in 3 (1.2%) patients. Tricuspid valve plastic surgery was performed with the help of support ring (n = 55) and Amosov-De Vega suture plastic surgery (n = 196). Left atrial fragmentation operation (Maze) to restore sinus rhythm was performed in 57 (19.8%) patients.

The aortic clamping time was: 148.9 ± 25.5 minutes ($p < 0.05$) in group A, 123.6 ± 13.3 minutes in group B, 138.9 ± 25.5 minutes ($p < 0.05$) in group C. Cardiac activity spontaneous recovery was observed in 63.4% cases ($p < 0.05$) in group A, 79.5% cases in group B, 81.6% cases in group C.

Short time of aortic compression allows lowering of reperfusion period basically without hypothermia use. Adequate reperfusion period is a significant element of cardiomyocyte preservation. Right before forceps removal from aorta, perfusionist lovers CPB pump capacity to 300 mL/min. After this forceps are removed from aorta. Within the next 5 minutes CPB pump perfusion volume speed is increased by adding 100-150 mL/min every 10 seconds, thus recovering the initial capacity. This element is very important since it excludes the hemodynamic and thermal shock on coronary bed and hibernating myocardium, caused by cardioplegia solution and hypothermia impact.

Results. Of the 251 operated patients, 10 died at the hospital stage (mortality rate 3.9%). In the group A, 2 out of 47 patients died at the hospital stage (hospital mortality 4.2%). The cause of death was heart failure (n = 2). The dynamics of echocardiographic parameters at the stages of treatment were as follows. Group A: LV end-systolic index (mL/m^2) 69.1 ± 13.5 (before surgery), 60.3 ± 9.7 (after surgery), LVEF: 51% ± 9% (before surgery), 54% ± 7% (after surgery).

In group A, the level of creatine kinase-MB (CK-MB) (U/L) was 72.3 ± 7.1 at cross-clamping time ≤90 minutes and 115.2 ± 18.7 at ≥151 minutes, which indicates manifestations of myocardial anoxia depending on the duration of aortic clamping.

In group B, 2 out of 56 patients died at the hospital stage (hospital mortality 3.6%). The causes of deaths were pneumonia (n = 1) and multiple organ failure (n = 1).

The dynamics of echocardiographic parameters at the stages of treatment were as follows: LV end-systolic index (mL/m^2) 66.5 ± 12.1 (before surgery), 57.4 ± 8.6 (after

surgery), LVEF: 50% ± 8% (before surgery), 56% ± 7% (after surgery).

In group B, the level of CK-MB (U/L) was 64.0 ± 8.2 at cross-clamping time ≤90 minutes and 97.4 ± 15.8 at ≥151 minutes.

In group C, 6 out of 148 patients died at the hospital stage (hospital mortality 4.1%). The causes of deaths were arrythmia (n = 1), multiple organ failure (n = 4), and bleeding (n = 1). The dynamics of echocardiographic parameters at the stages of treatment were as follows: LV end-systolic index (mL/m^2) 67.8 ± 11.3 (before surgery), 56.2 ± 8.9 (after surgery), LVEF: 50% ± 7% (before surgery), 56% ± 7% (after surgery).

In group C, the level of CK-MB (U/L) was 67.5 ± 7.7 at cross-clamping time ≤90 minutes and 96.3 ± 16.2 at ≥151 minutes.

The dependence of the length of aortic clamping and the level of in-hospital mortality is presented in Table 1.

The highest level of increase in hospital mortality is noted in all groups when the aorta is clamped for more than 120 minutes: 4.6% (9 of 193 patients) compared to that for ≤120 minutes: 1.7% (1 of 58 patients) ($p < 0.05$).

The dependence of the length of aortic clamping and the level of CK-MB (U/L) is presented in Table 2.

The level of CK-MB (U/L) at cross-clamping time ≤90 minutes for the groups was as follows: 72.3 ± 7.1 in group A, 64.0 ± 8.2 in group B, and 67.5 ± 7.7 in group C, which reveals better indicators of myocardial protection in groups B and C compared to group A.

The level of CK-MB (U/L) at cross-clamping time ≥151 minutes for the groups was as follows: 115.2 ± 18.7 in group A, 97.4 ± 15.8 in group B, and 96.3 ± 16.2 in group C, which reveals better indicators of myocardial protection in groups B and C compared to group A.

The dynamics of echocardiographic parameters at the stages of treatment were better in groups B and C than in group A ($p < 0.05$). Hospital mortality was lower in groups B and C than in group A ($p > 0.05$).

Discussion. The complexity of surgical correction of CMAT is associated with prolonged clamping of the aorta, which, in turn, predetermines possible conditions for the development of hypoxia of the heart muscle due to the inadequacy of the method of its protection [1,2,3,4,5]. In this regard, the relevance of the choice of the method of delivering crystalloid cardioplegia is extremely important [9,13]. Our proposed results obtained for a large series of clinically complex patients indicate the feasibility of using a combined method of delivering cardioplegic solution, which coincides with the exact view of a number of clinics [1,2,13,16]. According to our study, the isolated retrograde method of delivering cardioplegia has undoubted advantages over the isolated antegrade method, especially in cases of prolonged clamping of the aorta [2,3].

We proposed correction of CMAT using various methods of supplying crystalloid cardioplegia (Custadiol). These developments have proven themselves to be a low-traumatic and effective intervention. At the same time, they allowed to significantly improve the contractility of the LV in the postoperative period. In addition, retrograde and ante-retrograde way of delivery are accompanied by a low risk of hospital mortality and heart failure complications in the hospital period.

Table 1

The dependence of the length of aortic clamping and the level of in-hospital mortality

		Number of operated/deceased patients depending on cross-clamping time, N/n				Total mortality, n (%)
Type of cardioplegia	**N**	**≤90 min**	**91-120 min**	**121-150 min**	**≥151 min**	
Antegrade	47	0/0	11/0	23/1	13/1	2 (4.3)
Retrograde	56	5/0	15/0	17/1	19/1	2 (3.6)
Combined ante-retrograde	148	0/0	27/1	58/2	63/3	6 (4.1)
All the subjects	251	5/0	53/1	98/4	95/5	10 (3.9)

N, number of operated patients; n, number of deceased patients.

Table 2

The dependence of the length of aortic clamping and the level of CK-MB (U/L)

		Level of CK-MB depending on cross-clamping time, U/L			
Type of cardioplegia	**N**	**≤90 min**	**91-120 min**	**121-150 min**	**≥151 min**
Antegrade	47	72.3 ± 7.1	78.3 ± 9.3	95.1 ± 13.7	115.2 ± 18.7
Retrograde	56	64.0 ± 8.2	72.5 ± 10.4	85.5 ± 14.5	97.4 ± 15.8
Combined ante-retrograde	148	67.5 ± 7.7	73.4 ± 8.8	83.4 ± 15.6	96.3 ± 16.2

Conclusion. The three types of cardioplegic solution delivery used in complex pathology of surgical treatment of CMAT demonstrated the adequacy of heart protection using crystalloid cardioplegia. Taking into account certain advantages in the dynamics of restoration of the LV contractility, the level of increase in CK-MB (U/L) on the second day after surgery, groups C and B should be considered optimal compared to group A ($p < 0.05$).

The widespread, branched venous system of the heart allows for adequate use of the retrograde route of cardioplegia delivery and complete penetration of cardioplegic solution into the heart cells, which provides a better clinical effect compared to the isolated antegrade route of crystalloid cardioplegia delivery.

Conflicts of interest. None declared.

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Захист міокарда при корекції поєднаних мітрально-аортально-тристулкових вад в умовах штучного кровообігу

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Резюме

Мета – визначити оптимальний спосіб введення кардіоплегічного розчину для захисту міокарда при корекції поєднаних мітрально-аортально-тристулкових вад в умовах штучного кровообігу.

Матеріали та методи. Проведено порівняльний аналіз результатів хірургічного лікування 251 хворого з поєднаною мітрально-аортально-тристулковою вадою серця, прооперованого у НІССХ ім. М. М. Амосова з 01.01.2010 по 01.01.2023 р. У хворих застосовано 3 способи введення кристалоїдного кардіоплегічного розчину для захисту міокарда. Групи порівняння подачі кардіоплегічного розчину: група А – антеградна (n = 47), група В – ретроградна (n = 56), група С – комбінована антеретроградна (n = 148).

Результати. Загалом із 251 оперованого на госпітальному етапі померли 10 (шпитальна летальність – 3,9 %). Шпитальна летальність за групами склала такі показники: група А – 4,3 %, група В – 3,6 %, група С – 4,1 %. Рівень МВ-фракції креатинкінази (МВ-КК) гормону, що обумовлює рівень гіпоксії, серцевої недостатності (U/L) при перетисканні аорти ≤ 90 хвилин у групах сягав: група А – 72,3 ± 7,1 ($p < 0,05$); група Б – 64,0 ± 8,2; група С – 67,5 ± 7,7. Рівень МВ-КК (U/L) при перетисканні аорти ≤ 151 хвилин у групах становив: група А – 115,2 ± 18,7 ($p < 0,05$); група Б – 97,4 ± 15,8; група С – 96,3 ± 16,2.

Динаміка ехокардіографічних показників на етапах лікування була такою. Група А: кінцево-систолічний індекс лівого шлуночка (ЛШ) (мл/м^2) – 69,1 ± 13,5 (до операції), 60,3 ± 9,7 (після операції), фракція викиду ЛШ – 51 ± 9 % (до операції), 54 ± 7 % (після операції). Група В: кінцево-систолічний індекс ЛШ (мл/м^2) – 66,5 ± 12,1 (до операції), 57,4 ± 8,6 (після операції), фракція викиду ЛШ – 50 ± 8 % (до операції), 56 ± 7 % (після операції). Група С: кінцево-систолічний індекс лівого шлуночка (мл/м^2) – 67,8 ± 11,3 (до операції), 56,2 ± 8,9 (після операції), фракція викиду ЛШ – 50 ± 7 % (до операції), 56 ± 7 % (після операції).

Динаміка ехокардіографічних показників на етапах лікування була кращою в групі В і С порівняно з групою А ($p < 0,05$). Шпитальна летальність краща в групах В і С, ніж в А ($p > 0,05$).

Висновки. Застосовано 3 види подачі кардіоплегічного розчину при складній патології хірургічного лікування поєднаних мітрально-аортально-тристулкових вад показали адекватність захисту серця із використанням кристалоїдної кардіоплегії. З урахуванням певних переваг у динаміці відновлення рівня скоротливості лівого шлуночка та рівня підйому МВ-КК (U/L) на другу добу після операції слід вважати оптимальними групи С та В порівняно з групою А ($p < 0,05$).

***Ключові слова**: антеградна, ретроградна кристалоїдна кардіоплегія, протезування мітрального та аортального клапанів, пластика тристулкового клапана, пластика мітрального клапана, штучний кровообіг.*

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