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Original Article

Comparison of metabolic effects of del Nido cardioplegia, blood cardioplegia, and St. Thomas cardioplegia solutions in adult patients undergoing isolated minimally invasive aortic valve replacement surgery

Minimal invaziv aort kapak replasmanı yapılan erişkin hastalarda del Nido kardiyopleji solüsyonu, kan kardiyoplejisi ve St. Thomas kardiyopleji solüsyonunun metabolik etkilerinin karşılaştırılması

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ABSTRACT

Aim: Cardiac arrest during cardiopulmonary bypass (CPBP) is achieved using cardioplegia solutions for myocardial protection. There are limited data about the systemic biochemical effects of cardioplegia solutions. This study aimed to compare the biochemical effects of del Nido cardioplegia, blood cardioplegia, and St. Thomas cardioplegia solutions.

Material and Methods: This retrospective study included patients that underwent isolated Aortic valve replacement between 1 August 2017 and 31 July 2018. The medical records of patients reviewed after ethical approval of the protocol. Patients were divided into 3 groups according to the cardioplegia solution used during surgery, as follows: the del Nido cardioplegia group (dNC group); the blood cardioplegia group (BC group); the St. Thomas cardioplegia group (STC group). Perioperative clinical outcomes and laboratory findings were compared between groups.

Results: The study included 26 patients that underwent minimally invasive aortic valve replacement. Fewer patients in the dNC group required inotropic agents than in the other 2 groups, but the difference was not significant ($P = 0.844$). There wasn't a significant difference between the groups in the change in the troponin t level from the preoperative to postoperative period ($P = 0.148$). The difference in the arterial glucose and insulin levels was similar in all 3 groups ($P = 0.372$ and $P = 0.258$, respectively). Thyroid, liver, and renal function were also similar in all 3 groups.

Conclusion: dNC solution is a safe alternative to BC and STC solutions during isolated minimally invasive aortic valve replacement surgery, in terms of myocardial protection and biochemical parameters.

Keywords: Minimally invasive; aortic valve replacement; del Nido cardioplegia solution; blood cardioplegia solution; St. Thomas cardioplegia solution.

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ÖZ

Amaç: Kardiyopulmoner baypas (CPBP) sırasında kardiyak arrest, miyokardiyal koruma için kardiyoplejik solüsyonlar kullanılarak sağlanır. Kardiyopleji solüsyonlarının sistemik biyokimyasal etkileri hakkında sınırlı veri bulunmaktadır. Bu çalışma, del Nido kardiyopleji, kan kardiyopleji ve St. Thomas kardiyopleji solüsyonlarının biyokimyasal etkilerini karşılaştırmayı amaçlamıştır.

Gereç ve Yöntemler: Bu retrospektif çalışma, 1 Ağustos 2017 – 31 Temmuz 2018 tarihleri arasında minimal invaziv aort kapak replasmanı yapılan hastaları içermektedir. Etik kurul onayı alındıktan sonra hastaların tıbbi kayıtları gözden geçirildi. Hastalar ameliyat sırasında kullanılan kardiyoplejiye göre 3 gruba ayrıldı: del Nido cardioplegia grubu (dNC grubu); kan kardiyopleji grubu (BC grubu); St Thomas kardiyopleji grubu (STC grubu). Perioperatif klinik sonuçlar ve laboratuvar bulguları gruplar arasında karşılaştırıldı.

Bulgular: Çalışmaya minimal invaziv aort kapak replasmanı yapılan 26 hasta dahil edildi. DNC grubundaki hastalar, diğer 2 gruptan daha az inotropik ajan gerektirdi, ancak fark anlamlı değildi ($P = 0.844$). Preoperatif ve postoperatif troponin t düzeyi değişikliklerinde gruplar arasında anlamlı fark yoktu ($P = 0.148$). Arteryel glukoz ve insülin düzeylerindeki fark 3 grubun hepsinde benzerdi (sırasıyla $P = 0.372$ ve $P = 0.258$). Tiroid, karaciğer ve böbrek fonksiyonları da 3 grupta benzerdi.

Sonuç: dNC solüsyonu, minimal invaziv aort kapak replasmanı ameliyatında miyokardiyal koruma ve biyokimyasal parametreler açısından kan kardiyopleji ve St. Thomas kardiyopleji solüsyonlarına güvenli bir alternatiftir.

Anahtar Kelimeler: Minimal invaziv; aort kapak replasmanı; del Nido kardiyopleji solüsyonu; kan kardiyopleji solüsyonu; St. Thomas kardiyopleji solüsyonu.

Introduction

Use of cardiopulmonary bypass (CPBP) and elective cardiac arrest during open cardiac surgery offers surgeons a blood-free surgical field. During aortic cross-clamping, however, myocardial injury of varying extent can occur, but can be prevented via appropriate protective techniques. All cardioplegia methods are used for cardioprotective purposes. Cardioplegia solutions contain various chemical agents that rapidly arrest the heart at diastole. Many myocardial protection methods are used in adults, especially St. Thomas cardioplegia (STC) solution and blood cardioplegia (BC) [1-3]. del Nido cardioplegic (dNC) solution, which has been used in recent years, is increasing in popularity for use in adult patients. dNC solution differs from other cardioplegia solutions, as it is not only non-glucose-based and calcium free, but is also inexpensive and usually administered as a single dose [4,5].

Regarding the cardioprotective effects of dNC solution in pediatric patients, it increases tolerance to an elevated intracellular calcium level that causes irreversible myocyte injury [6]. In adults, dNC solution was suggested to distribute to the myocardium uniformly, providing adequate protection with a single dose [7-9]. When used during mitral and aortic valve surgery (as a non-glucose-based solution), dNC solution improves intraoperative blood glucose control and decreases the need for insulin [10]. Despite these reports, data on the effects of cardioplegia solutions on the blood insulin level are limited. Use of dNC solution in adults is not as common as in pediatric patients and therefore, little is known about its metabolic and biochemical effects in adults, especially on thyroid, liver, and kidney function. As such, the present study aimed to compare the biochemical and metabolic effects of dNC, BC, and STC, solutions in adults.

Material and Methods

This retrospective cohort study included patients that underwent minimal invasive aortic valve replacement and received dNC, BC, or STC solution between 1 August 2017 and 31 July 2018 at tertiary care hospital. Patients with unavailable or incomplete data were excluded.

Patients were divided into 3 groups according to the cardioplegia solution used during surgery, as follows: the dNC group; the BC group; the STC group. The premedication and anesthesia protocols were the same in all 3 these groups: All patients received oral diazepam 5 mg 8 h before surgery and intramuscular morphine 0.1 mg kg^{-1} 30 min before surgery. ECG leads II and V, pulse oximetry, bispectral index, and invasive arterial blood pressure were used to monitor the patients. Orotracheal intubation was performed following induction of anesthesia via midazolam 0.04 mg kg^{-1}, fentanyl 10 µg kg^{-1}, propofol 1 mg kg^{-1}, and rocuronium 0.5 mg kg^{-1}. Anesthesia was maintained using sevoflurane 0.5%-2% and a mixture of 50% oxygen and 50% air. Rocuronium and fentanyl were administered as intravenous bolus every 45 min.

All patients underwent standard surgery. CPBP was performed using a roller pump with a non-pulsatile flow of 2.4 L m^{-2} min^{-1}. Patients received heparin 300 IU kg^{-1} to ensure an activated clotting time >400 s. Systemic hypothermia during CPBP was provided at 30-32 °C. Following placement of aortic cross-clamp, cardiac arrest was achieved via anterograde administration of dNC, BC, or STC solution, all of which were routinely used at our clinic. The composition of each cardioplegia solution is shown in Table 1. dNC solution [4] and BC solution [4] were prepared at our hospital, whereas the STC solution used was as a ready-to-use preparation (Plegisol® 1000 mL; Pfizer, New York, US). In patients in which the duration of cross-clamping did not exceed 120 min dNC solution was administered as a single dose. BC and STC solutions were administered every 20 min. Patients were warmed to 37 °C following removal of cross-clamp.

Table 1: The composition of dNC, BC, and STC solutions

	dNC	BC	STC
Formulation	Plasma-Lyte A	Mixed 4:1 BC	
Total volume	1000 mL	1000 mL	1000 mL
Additive			
Mannitol	3.26 g	10 g	
K+	26 mEq	46 mEq	16 mmol L–1
Mg2+	2 g	2.5 g	16 mmol L–1
Lidocaine	130 mg	40 mg	
NaHCO3-	13 mEq	1 mEq	
Na+			110 mmol L–1
Ca2+			1.2 mmol L–1

Age, gender, body mass index (BMI), New York Heart Association (NYHA) classification, Euroscore II, the preoperative ejection fraction, comorbidities, and smoking status were obtained from the patients' medical records and anesthesia forms. CPBP time and cross-clamp time, and any ventricular fibrillation during the intraoperative period were recorded. Perioperative use of positive inotropic agents, insulin infusion, erythrocyte suspension (RBC), platelet suspension, and fresh frozen plasma (FFP) was recorded. The troponin T level before and after aortic cross-clamping was recorded. Preoperative and postoperative hematocrit values were also recorded. In addition, the plasma glucose, potassium, urea, creatinine, AST, ALT, LDH, insulin, TSH, T3, and T4 levels were recorded at the pre- and post-surgery. The need for an intra-aortic balloon pump (IABP) or extracorporeal membrane oxygenation (ECMO) was noted. The number re-exploration for bleeding in each patient was recorded. The study protocol was approved by the Hospital Ethics Committee.

Statistical analysis

Data were analyzed using IBM SPSS Statistics for Windows v.20.0 (IBM Corp., Armonk, NY). A two-sided P value ≤0.05 was considered statistically significant. The normality of each continuous variable was determined using the Shapiro-Wilk test. Variance homogeneity between groups was determined using the Levene test. Kruskal-Wallis test was used to compare continuous variables between groups and the results are shown as median (range). Pearson's chi-square test was used to compare categorical variables between groups and the results are shown as frequency (percentage).

Results

In total, 26 patients were analyzed: 9 in the dNC group, 8 in the BC group, and 9 in the STC group. Baseline characteristics of the patients are presented in Table 2. There weren't any differences in age, gender, BMI, NYHA class, Euroscore II, comorbidity, smoking status, or the left ventricular ejection fraction between the groups (Table 2).

Table 2: Patient characteristics

	dNC Group (n = 9)	BC Group (n = 8)	STC Group (n = 9)	P
Mean age, years (range)	66 (57-71)	64.5 (45-71)	62 (52-70)	0.675a
Male, n (%)	5 (56)	6 (75)	7 (78)	0.542b
Female, n (%)	4 (44)	2 (25)	2 (22)	
Mean BMI, kg m–2 (range)	2 (1.64-2)	2 (1.77-2)	1.9 (1.6-2.03)	0.274a
NYHA class, n (%)				
I	1 (11)	1 (12)	0 (0)	0.860b
II	6 (67)	5 (63)	6 (67)	
III	2 (22)	2 (25)	3 (33)	
IV	0 (0)	0 (0)	0 (0)	
Arterial hypertension, n (%)	6 (67)	7 (88)	6 (67)	0.543b
Dyslipidemia, n (%)	6 (67)	4 (50)	5 (56)	0.543b
Diabetes mellitus, n (%)	3 (33)	5 (63)	4 (44)	0.480b
History of atrial fibrillation, n (%)	2 (22)	2 (25)	1 (11)	0.739b
Chronic pulmonary disease, n (%)	4 (44)	2 (25)	3 (33)	0.699b
Peripheral vascular disease, n (%)	8 (89)	8 (100)	8 (89)	0.618b
Chronic kidney disease, n (%)	3 (33)	1 (13)	1 (11)	0.413b
Smoking, n (%)	5 (56)	4 (50)	5 (56)	0.966b
Left ventricular ejection fraction, n (%)				
<30	0 (0)	0 (0)	0 (0)	0.355b
30-50	6 (67)	7 (88)	5 (56)	
>50	3 (33)	1 (12)	4 (44)	
Euroscore II, (range)	2 (0.62, 8.05)	1.82 (1, 10)	1.79 (0.84, 5.08)	0.975a

Note: Pa: Obtained via the Kruskal-Wallis test; Pb: Obtained via Pearson's chi-square test.
Values are displayed as median (range) or number (%).

Perioperative clinical data according to group are shown in Table 3. Median CPBP time was 99 min in the dNC group (range: 55-132 min), 101.5 min (range: 76-130 min) in the BC group, and 98 min (range: 63-106 min) in the STC group; the difference between groups was not significant (P = 0.479). Median aortic cross-clamp time was shorter in the dNC group than in the BC and STC groups, but not significantly (P = 0.931). Only 1 (11%) patient in the dNC group developed ventricular fibrillation after removal of the aortic cross-clamp, versus 4 (50%) in the BC group and 6 (67%) in the STC group. Fewer patients in the dNC group required inotropic agents than in the BC and STC groups, but the difference was not significant (P = 0.844). The number of perioperative RBC, platelet, and FFP transfusions was similar in all 3 groups (P = 0.433, P = 0.403, and P = 0.423, respectively).

Table 3: Patient perioperative clinical data

	dNC Group (n = 9)	BC Group (n = 8)	STC Group (n = 9)	P value
Cardiopulmonary bypass time, min	99 (55-132)	101.5 (76-130)	98 (63-106)	0.479a
Aortic cross-clamp time, min	82 (46-113)	84.5 (47-135)	87 (44-120)	0.931a
Ventricular fibrillation, n (%)	1 (11)	4 (50)	6 (67)	0.051b
Length of ICU stay, h	66 (50-85)	64 (48-80)	56 (48-84)	0.682a
Need of inotropic agents, h	10 (0-48)	24 (0-45)	24 (0-48)	0.844a
Need for intravenous insulin, n (%)	8(89)	7(88)	7(78)	0.779b
Re-exploration for bleeding, n (%)	1(11)	2(25)	2(22)	0.739b
Intra-aortic balloon pump, n (%)	1(11)	0(0)	0(0)	-
ECMO, n (%)	0/9	0/8	0/9	-
RBC transfusions	4 (0, 10)	4 (2, 6)	6 (2, 9)	0.433a
Platelet transfusions	0 (0, 1)	0 (0, 0)	0 (0, 3)	0.403a
FFP transfusions	8 (0, 16)	6.5 (3, 13)	6 (3, 14)	0.423a

Note: Pa: Obtained via the Kruskal-Wallis test; Pb: Obtained via Pearson's chi-square test.
Values are displayed as median (range) or number (%).

There wasn't a significant difference between the groups in the change in the troponin T level from before to after aortic cross-clamping (P = 0.148). The difference between preoperative and postoperative arterial blood glucose and insulin levels was similar in all the groups (P = 0.372 and P = 0.258, respectively). In addition, preoperative-postoperative change in thyroid, liver, and kidney function did not differ significantly between the groups (P < 0.05), although the decrease in the glomerular filtration rate was greater in the STC group (Table 4).

Discussion

The present findings show that dNC solution is as safe as BC and STC solutions in adult patients undergoing minimally invasive aortic valve replacement. To the best of our knowledge the present study is the first to compare the effects of these 3 cardioplegia solutions on myocardial protection and biochemical parameters in adults. Mishra et al.,[1] studied adult patients undergoing open heart surgery and reported that dNC solution provides better myocardial protection than STC solution. They also reported that the left ventricular ejection fraction decreased from 53.80% ± 9.60% preoperatively to 52.00% ± 10.41% postoperatively in their STC group, whereas it increased from 50.00% ± 12.86% preoperatively to 51.25% ± 11.02% preoperatively in their dNC group, which is a significant difference (P < 0.05). Yerebakan et al.[8] reported that the myocardial protective effect of dNC and BC solutions was similar. Their patients were high-risk CABG patients and they did not observe any negative inotropic effects associated with dNC solution. Moreover, they noted that dNC solution was more effective than BC solution in terms of eliminating contractions and elevating intracellular calcium in isolated aged cardiomyocytes during ischemic arrest. This effect was posited to be due to the high potassium concentration and lidocaine in dNC solution [5].

Studies that compared dNC and BC solutions reported that they offer similar myocardial protection [6,12] or that dNC solution was provides greater myocardial protection [9]. Kim et al.[9] studied patients undergoing open heart surgery, reporting that spontaneous defibrillation occurred in 94.9% of patients administered dNC solution, versus in 30.8% of those administered BC solution. In addition, the incidence of postoperative atrial fibrillation in their study was 35.9% and 30.8% in the dNC and BC groups, respectively—not a significant difference (P = 0.804). In the present study, 11% of patients in the dNC group had had ventricular fibrillation, as compared to 50% and 67% in the BC and STC groups, respectively. Furthermore, the need for inotropic agents was 50% lower in the dNC group than in the BC and STC groups. The lower incidence of ventricular fibrillation and need for inotropic agents in the present study's dNC group might have been due to dNC solution's more robust myocardial protection.

Single-dose administration of dNC solution appears to be advantageous in terms of aortic cross-clamp time, yet there may be delays due to other factors prolonging the duration of surgery. Some studies reported that aortic cross-clamp time was shorter in patients receiving dNC solution than in those receiving other conventional cardioplegic solutions [1, 2]. In contrast, a recent study showed that dNC solution did not decrease aortic cross-clamp time [12].

Charette et al.[13] compared dextrose-based cardioplegic solution (5% dextrose in water) to dNC solution in a 2011 study that included 34 pediatric patients undergoing congenital heart surgery. The mean blood glucose level was 314.12 ± 102.92 mg dL–1 and 209.65 ± 61.48 mg dL–1 in the dextrose-based and dNC groups, respectively, and the difference was significant. Similarly, a study that compared dNC solution and modified Buckberg cardioplegia solution reported that dNC solution provided better blood glucose regulation due to the fact that Buckberg cardioplegia solution contains dextrose and dNC solution does not [7].

Mick et al.[10] observed a significant difference in the intraoperative blood glucose level between adult patients undergoing aortic valve surgery that received Buckberg cardioplegia solution (240 ± 41 mg dL–1) and dNC solution (170 ± 31 mg dL–1) (P < 0.0001). The researchers also noted that in patients undergoing mitral valve surgery the blood glucose level was significantly higher and more patients required insulin in the Buckberg cardioplegia group than in the dNC group. Another study observed that there wasn't a significant difference in the intraoperative and postoperative blood glucose levels in adult patients undergoing minimal invasive aortic valve surgery that received dNC solution versus Ringer lactate-based BC solution [12]. In the present study none

Table 4: Preoperative-postoperative change in laboratory findings, according to group

		Hemoglobin (gL–1)	P-value	Hematocrit (%)	P-value	Glucose (mgdL–1)	P-value
dNC Group (n = 9)	Pre	13.2 (8.8-16)		39.3 (25.6-45)		125 (95-180)	
	Post	9.2 (8.7-13)		27.4 (25.6-38)		187 (128-259)	
	Change	–3.3 (–6-–0.1)		–9.5 (–16-0)		42 (–11-110)	
BC Group (n = 8)	Pre	13.6 (12-15.3)		41 (36-43)		156.5 (93-230)	
	Post	9.45 (8-11)	0.421	27.45 (25-32)	0.304	195 (103-221)	0.372
	Change	–4 (–6-–1)		–14.3 (–16-–4)		33.5 (–19-97)	
STC Group (n = 9)	Pre	13.4 (8.9-15.3)		39.2 (25.9-44)		132 (96-246)	
	Post	8.8 (8-9.5)		25.5 (23.2-27.6)		177 (132-316)	
	Change	–3.9 (–7-–0.2)		–12.3 (–20.2-–0.9)		47 (–20-134)	
		Insulin (µUmL–1)		Troponin T (ngmL–1)		LDH (UL–1)	
dNC Group (n = 9)	Pre	3.04 (1.27-156)		0.06 (0-0.18)		224 (172-408)	
	Post	21 (7.33-87)		2.13 (0-9.27)		415 (182-858)	
	Change	15.97 (–69-44.98)		2.07 (0-9.11)		193 (10-522)	
BC Group (n = 8)	Pre	4.5 (2-171)		0 (0-4)		190.5 (151-513)	
	Post	36.07 (18-62)	0.258	1.02 (0-4)	0.148	417.5 (219-686)	0.570
	Change	29.5 (–109-40)		0.5 (0-2.07)		202.5 (–172-493)	
STC Group (n = 9)	Pre	8 (1.39-167.2)		0.09 (0-0.25)		186 (114-272)	
	Post	21.52 (5.25-90.91)		0.36 (0.09-1.04)		290 (224-487)	
	Change	13.87 (–124.47-84.1)		0.32 (0.02-1)		133 (–48-261)	
		TSH (µIUmL–1)		T3 (ngdL–1)		T4 (pgmL–1)	
dNC Group (n = 9)	Pre	1 (0-3.42)		3 (2.4-3.72)		1 (0.91-1.5)	
	Post	0.11 (0-0.95)		2.76 (1.47-3)		1.21 (0.83-2)	
	Change	–0.95 (–2.98-0)		–0.57 (–2.25-0.43)		0 (–0.09-1)	
BC Group (n = 8)	Pre	1.38 (0-4)		3.48 (3-4)		1 (0.97-1.65)	
	Post	0.27 (0-4)	0.679	2.57 (2-3)	0.218	1.14 (1-2)	0.665
	Change	–0.5 (–3.43-1)		–1 (–2-0)		0 (–0.28-1)	
STC Group (n = 9)	Pre	1.12 (0.84-1.78)		3.32 (2.86-4)		0.91 (0.78-1.05)	
	Post	0.34 (0-1.39)		2.69 (1.99-3)		1.15 (0.79-1.58)	
	Change	–0.96 (–1.11-–0.39)		–0.84 (–1.21-–0.17)		0.37 (–0.12-0.53)	
		AST (UL–1)		ALT (UL–1)		Potassium (mmolL–1)	
dNC Group (n = 9)	Pre	17 (12-106)		15 (7-70)		4.03 (3.9-4.95)	
	Post	60 (43-150)		20 (10-148)		4 (3-4.33)	
	Change	41 (–29-110)		3 (–9-78)		0 (–1-0.4)	
BC Group (n = 8)	Pre	19.5 (11-46)		18.5 (7-45)		4 (3-5)	
	Post	39.5 (19-187)	0.814	22 (11-50)	0.558	4 (3-4.52)	0.077
	Change	23.5 (–10-172)		4 (–13-25)		0 (–1-0.54)	
STC Group (n = 9)	Pre	19 (17-60)		22 (13-43)		4.08 (3.53-4.5)	
	Post	61 (12-222)		31 (16-53)		4.27 (4-5.66)	
	Change	30 (–8-204)		7 (–4-36)		0.21 (–0.3-1.39)	
		Urea (mgdL–1)		Creatinine (mgdL–1)		GFR	
dNC Group (n = 9)	Pre	38 (27-76)		1 (0.73-1.88)		70 (28.46-78)	
	Post	50 (29-102)		1 (0.8-2.52)		70 (20.29-81)	
	Change	11 (2-47)		0 (–0.14-1)		–3 (–31-10)	
BC Group (n = 8)	Pre	40.5 (27-63)		1 (1-2)		80 (43-89)	
	Post	46 (30-59)	0.067	1 (0.97-2)	0.111	76.5 (45-99)	0.047
	Change	2.5 (–13-19)		0 (–0.11-0.22)		–1.5 (–13-10)	
STC Group (n = 9)	Pre	38 (32-67)		1.02 (0.74-1.45)		80 (51.75-89)	
	Post	58 (36-88)		1.25 (0.77-1.87)		59 (38.59-85)	
		21 (–7-41)		0.11 (–0.08-0.42)		–15.78 (–31.82-10)	

Note: Data are shown as median (range) for continuous variables.P values were obtained via the Kruskal-Wallis test, which was performed to compare change in the corresponding variables between groups.

of the 3 cardioplegia solutions used contained dextrose and the 3 groups did not differ significantly in preoperative-postoperative change in the blood glucose level. The need for insulin infusion and preoperative-postoperative blood insulin level change were also similar in the 3 groups. Based on the present findings, we think that peaks in the blood glucose level can be prevented and that blood glucose regulation can be established if dextrose-based cardioplegia solutions are not used.

In pediatric patients undergoing CPBP during elective repair of congenital heart defects T3, T4, and TSH levels were lower post surgery than presurgery [14]. Similarly, T3, T4, and TSH levels were lower postoperatively than preoperatively in all 3 of the present study's groups, but not significantly. An earlier study reported that the plasma ALT, AST, and LDH levels were similar in patients that underwent open heart surgery for valve replacement that received STC solution versus and warm BC solution [15]. In the present study patients in all 3 groups had elevated ALT, AST, and LDH levels at the postoperative period.

Renal injury varying in degree can develop secondary to such factors as hypothermia, inflammatory response, and decreased renal perfusion during CPBP [17]. Kim et al.[9] reported that the incidence of acute renal failure (10.3%) during the early postoperative period in adult patients that underwent open heart surgery was similar in those that received dNC solution and BC solution. In the present study urea and creatinine were higher postoperatively than preoperatively in all 3 groups, and did differ significantly between groups. In addition, the decrease in the GFR was significantly greater in the present study's STC group than in the dNC and BC groups ($P < 0.05$).

dNC solution is less expensive and more cost effective than BC and STC solutions, because unlike BC and STC solutions, which are repeatedly administered every 20 min, dNC solution is used as a single dose when aortic cross-clamp time does not exceeding 120 min [12].

The present study has some limitations; its retrospective design and small sample size.

Conclusion

dNC solution provides effective myocardial protection comparable to that of BC and STC solutions, with similar effects on blood biochemical parameters in adult patients undergoing isolated minimally invasive aortic valve replacement surgery.

Declaration of conflict of interest

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