

Cardioplegia Practices in Elective Adult Coronary Artery Bypass Surgery: A National Survey

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Abstract

Objective: This study aimed to determine current cardioplegia practices in coronary artery bypass grafting surgery in Türkiye and variations according to the preferred cardioplegia type.

Methods: A 16-item questionnaire was distributed to members of the Turkish Society of Cardiovascular Surgery involved in adult cardiac surgery between November 2023 and February 2024. The questions addressed cardioplegia type, temperature, dose, delivery method, redosing interval, topical cooling, and hot-shot use.

Results: A total of 204 responses were analyzed. Blood cardioplegia was used by 69 (33.8%) participants, microplegia by 68 (33.3%), and Del Nido cardioplegia by 60 (29.4%). Most participants preferred a cardioplegia temperature of 4–10 °C (56.4%). Topical cardiac cooling was routinely used by 41.7%, and hot-shot administration by 47.1%. Antegrade cardioplegia alone was used by 59.3%, whereas 40.7% used combined antegrade and retrograde delivery. The roller pump was the most frequently preferred delivery technique (51.0%). The most common redosing interval was 15–20 minutes for blood cardioplegia (60.9%) and 60–90 minutes for Del Nido cardioplegia (71.7%). The most common blood-to-crystalloid ratios were 4:1 for blood cardioplegia (92.8%) and 1:4 for Del Nido cardioplegia (61.7%).

Conclusion: Cardioplegia practices in adult coronary artery bypass surgery vary considerably in Türkiye. Blood-based cardioplegia remains the predominant strategy. Further studies should investigate the associations between cardioplegia practices, myocardial protection markers, and postoperative outcomes.

Keywords: Cardioplegia; cabg; myocardial protection questionnaire.

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Elektif Yetişkin Koroner Arter Bypass Cerrahisinde Kardiyopleji Uygulamaları: Ulusal Bir Anket

Özet

Amaç: Bu çalışmanın amacı, Türkiye’de koroner arter baypas greftleme cerrahisinde güncel kardiyopleji uygulamalarını ve tercih edilen kardiyopleji türüne göre uygulama farklılıklarını belirlemektir.

Yöntem: Kasım 2023–Şubat 2024 tarihleri arasında, Türk Kalp ve Damar Cerrahisi Derneğine kayıtlı ve erişkin kalp cerrahisi alanında çalışan üyelere 16 maddelik bir anket gönderildi. Sorular kardiyopleji türü, sıcaklığı, dozu, uygulama yöntemi, tekrar doz aralığı, topikal soğutma ve hot-shot kullanımına yönelikti.

Bulgular: Toplam 204 yanıt analiz edildi. Katılımcıların 69’u (%33,8) kan kardiyoplejisi, 68’i (%33,3) mikrokardiyopleji ve 60’ı (%29,4) Del Nido kardiyoplejisi kullanmaktaydı. Katılımcıların çoğu kardiyopleji sıcaklığı olarak 4–10 °C’yi tercih etti (%56,4). Topikal kardiyak soğutma katılımcıların %41,7’si, hot-shot uygulaması ise %47,1’i tarafından rutin olarak kullanılıyordu. Katılımcıların %59,3’ü yalnızca antegrad, %40,7’si ise kombine antegrad ve retrograd uygulamayı tercih etti. En sık tercih edilen uygulama tekniği roller pompaydı (%51,0). En yaygın tekrar doz aralığı kan kardiyoplejisinde 15–20 dakika (%60,9), Del Nido kardiyoplejisinde ise 60–90 dakikaydı (%71,7). En sık kullanılan kan:kristalloid oranları kan kardiyoplejisinde 4:1 (%92,8), Del Nido kardiyoplejisinde ise 1:4’tü (%61,7).

Sonuç: Türkiye’de erişkin koroner arter baypas cerrahisindeki kardiyopleji uygulamaları önemli ölçüde farklılık göstermektedir. Kan temelli kardiyopleji halen baskın stratejidir. Kardiyopleji uygulamaları ile miyokardiyal koruma belirteçleri ve postoperatif sonuçlar arasındaki ilişkileri araştırılan ileri çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Kardiyopleji; cabg; miyokardiyal koruma.

Introduction

Advances in cardiac physiology and myocardial protection have played an important role in the development of cardiac surgery. Various practices and approaches have been developed to ensure optimal preservation of myocardial function and reserves. Cardioplegia is one of these approaches and is an essential component for the safe performing of procedures on the heart. Cardioplegia provides myocardial protection against ischemia-reperfusion injury during cardiac surgery and provides access to an immobilized and bloodless area through electromechanical arrest.^[1]

At present, there are differences in the cardioplegia techniques used in myocardial protection. Potassium-based cold blood cardioplegia and Del Nido cardioplegia with 1:4 blood crystalloid mixture are extracellular cardioplegia and show a depolarizing effect. Intracellular cardioplegia types containing low sodium levels show their effects by hyperpolarization.^[2] There is no standard in terms of optimal formula and delivery technique for cardioplegia.^[3]

In this study, we conducted a survey to evaluate in detail the current cardioplegia practices in adult coronary artery bypass grafting (CABG) procedures in various cardiac surgery clinics in Türkiye.

Materials and Methods

We designed a descriptive cross-sectional study approved by the Non-Interventional Research Ethics Committee of Bandırma 17 Eylül University (Document Date and Number: 10.11.2023-553). Between December 2023 and February 2024, we conducted a 16-question survey sent to participants working in adult cardiac surgery in various centers in Türkiye and registered with the Turkish Society of Thoracic and Cardiovascular Surgery. The survey was created with the help of Google Forms (Google LLC, MountainView, CA) to cover common variations in cardioplegia applications in isolated coronary artery bypass surgery. The design of the survey was based on the cardioplegia study by Drury et al.^[4] in the United Kingdom. The questions were developed through multiple iterations by cardiovascular surgical specialists. The technical functionality of the questionnaire was extensively tested before distribution.

Each participant was asked to provide demographic information and data on current cardioplegia practices in isolated CABG surgery, including the type of cardioplegia, initial dose, redosing interval, and delivery characteristics. Cardioplegia strategies were categorized according to their blood and crystalloid composition as conventional blood cardioplegia (blood diluted with crystalloid solution), microplegia (a predominantly whole-blood technique using concentrated cardioplegic agents with minimal crystalloid volume), Del Nido cardioplegia (blood mixed with Del Nido crystalloid solution), and crystalloid cardioplegia administered without added blood, including St. Thomas solution (Plegisol; Pfizer, New York, NY, USA) and Histidine-Tryptophan-Ketoglutarate (HTK) solution (Custodiol; Dr. Franz Köhler Chemie GmbH, Frankfurt, Germany). Exclusion crite-

ria included incomplete questionnaires and multiple responses from the same internet protocol or email address. Identical responses from the same center were also excluded. Participant anonymity and confidentiality were ensured by design.

Responses were collected anonymously in Google Forms to protect participant identities from being seen. After all questionnaires were completed, responses were exported in Microsoft Excel format to IBM Statistical Package for the Social Sciences ver. 27.0 (IBM Corp., Armonk, NY, USA) for statistical analysis. Due to the nature of this research, most of the analyses performed were descriptive in nature. Categorical data were expressed as numbers and percentages. Multiple-choice items were represented by bar and pie charts. $p < 0.05$ was considered statistically significant.

Results

Two hundred and forty-two responses were received. It was determined that 23 of these responses came from the same centers and contained the same answers, and 15 responses contained missing data. The remaining 204 responses were included in the final analysis. The most frequent responses were received from Education and Research Hospital (34.3%) and University Hospital (23.5%) (Table 1).

Of the participants, 33.8% ($n=69$) reported using blood cardioplegia, 33.3% ($n=68$) microplegia, 29.4% ($n=60$) Del Nido cardioplegia, 2% ($n=4$) HTK cardioplegia, and 1.5% ($n=3$) St. Thomas cardioplegia (Fig. 1).

The centers where the respondents work are shown in Table 1. Regardless of the type of cardioplegia, the most frequently preferred temperature value for cardioplegia temperature ($n=115$; 56.4%) was 4–10°. While 41.7% ($n=85$) of the participants preferred topical cooling of the heart, 30.4% ($n=62$) stated that they did not use topical cooling. While 47.1% ($n=96$) of the participants stated that they used hot-shot, 20.1% ($n=41$) stated that they did not. While 59.3% ($n=121$) of the participants preferred only an antegrade delivery route, 40.7% ($n=83$) reported using both an antegrade and retrograde delivery route. Among the participants, 51% ($n=104$) preferred roller pump and 49% ($n=100$) preferred pressure bag for cardioplegia delivery technique. The most preferred antegrade cardioplegia delivery pressure was 150–180 mmHg (30.9%; $n=63$), while the most preferred retrograde cardioplegia delivery pressure was 35–50 mmHg (63.2%; $n=129$) (Table 2).

When the participants were asked about the preferred time interval between doses of cardioplegia, the most common intervals were 15–20 min for blood cardioplegia (60.9%), 60–90 min for Del Nido cardioplegia (71.7%), and 15–20 min for microplegia (55.9%) (Table 3).

Regarding cardioplegia mixing ratios, all participants using microplegia reported using it undiluted (100.0%). The most common blood-to-crystalloid ratio was 4:1 for conventional blood cardioplegia (92.8%) and 1:4 for Del Nido cardioplegia (61.7%). All participants using St. Thomas and HTK solutions reported administering them without added blood (Table 4).

Table 1. Distribution of participants by institution type

Institutions	n	%
State hospital	21	10.3
Training and research hospital	70	34.3
City hospital	20	9.8
University hospital	48	23.5
Private hospital	45	22.1
Total	204	100.0

Participants' induction dose preferences according to the type of cardioplegia used were found to be 10 mL/kg most frequently (39.1%) for blood cardioplegia, 10 mL/kg (45%) and 20 mL/kg (41.7%) for Del Nido cardioplegia, and 10 mL/kg most frequently (77.9%) for microplegia (Table 5).

Discussion

Cardiopulmonary bypass is widely used in cardiac surgery. Cardioplegia is an essential component of cardiac surgery procedures. Cardioplegia is necessary to eliminate global ischemia during aortic crossing and to achieve a bloodless and immobilized surgical field. There are various approaches associated with cardioplegia applications. Cardioplegia applications vary according to adult and pediatric patient profiles and may vary from institution to institution. Cardioplegia varies according to the composition, application methods, temperature and added substances; however, all available solutions contain potassium chloride (15–35 meq/L) to induce cardiac arrest.^[5]

The use of single-dose cardioplegia in CABG procedures is becoming widespread. The benefits of single-dose cardioplegia include reduced aortic cross-clamp time, fewer intraoperative interruptions, and reduced incidence of post-operative myocardial dysfunction. Del Nido solution, originally developed for neonates and immature hearts, is one such cardioplegia and contains mannitol for cell membrane regulation, magnesium sulfate as a calcium channel blocker, sodium bicarbonate buffer, potassium chloride, and lidocaine as a sodium channel blocker. This solution is administered as 1:4 blood crystalloid.^[6] St. Thomas cardioplegia is an extracellular crystalloid-based solution containing 16 mmol/L potassium and requiring repeat dosing for ~20 min.^[6] Blood-based cardioplegia diluted with crystalloid in various ratios is frequently preferred because it provides a natural buffering system, normal oncotic pressure, improved oxygen delivery, and a natural free radical scavenging mechanism. Predominantly, 4:1 blood-crystalloid dilution is preferred.^[7] Another solution defined as microplegia is a condensed version using whole blood cardioplegia. This solution offers all the advantages of blood cardioplegia without the potential disadvantages of hemodilution (such as myocardial edema).^[8]

Crystalloid and blood-based cardioplegic solutions have been used together for many years for myocardial protection in cardiac surgery. However, the use of Del Nido cardioplegia solution, which can provide protection for up to 90 min in a single dose, has become popular in recent years.^[9]

In our study, we determined that 33.8% of the participants preferred blood-based cardioplegia and 33.3% preferred microp-

Table 2. Participants' responses regarding cardioplegia practices

Variables	n	%
Cardioplegia temperature		
4–10°	115	56.4
11–20°	25	12.3
21–30°	25	12.3
Isothermic	39	19.1
Topical cooling of the heart		
Yes	85	41.7
No	62	30.4
Sometimes	57	27.9
Cardioplegia delivery route		
Only antegrade	121	59.3
Antegrade-retrograde	83	40.7
Antegrade pressure		
80–120 mmHg	37	18.1
120–150 mmHg	60	29.4
150–180 mmHg	63	30.9
Above 180 mmHg	44	21.6
Retrograde pressure		
35–50 mmHg	129	63.2
55–70 mmHg	48	23.5
75–90 mmHg	21	10.3
Above 90 mmHg	6	2.9
Cardioplegia delivery technique		
Roller pump	104	51
Pressure bag	100	49
Hot-Shot application		
Yes	96	47.1
No	41	20.1
Sometimes	67	32.8

legia. Del Nido cardioplegia (29.4%) was the most preferred solution after blood-based cardioplegia. Other solutions were HTK (2%) and St Thomas (1.5%).

Cold blood cardioplegia was first introduced in 1978,^[10] and since then there has been ongoing debate about the optimal temperature for cardioplegic solutions. Cold cardioplegia has been used to maximise myocardial cooling and metabolic inhibition. However, some investigators recommend warm cardioplegia because it reduces the risks of membrane destabilization, intracellular edema, and the time required for rewarming of the heart.^[11] In our study, 56.4% of the participants reported that they preferred a temperature of 4–10°C in cardioplegia solutions. However, 41.7% of the participants stated that they used topical cooling in addition to cardioplegia. In addition, 47.1% of the participants stated that they used Hot-Shot.

Retrograde coronary sinus perfusion is one of the techniques used to deliver cardioplegic solution during myocardial revascularization. It is unclear whether the combined antegrade/retrograde approach to myocardial protection provides significant clinical benefits. In a study comparing the efficacy of isolated

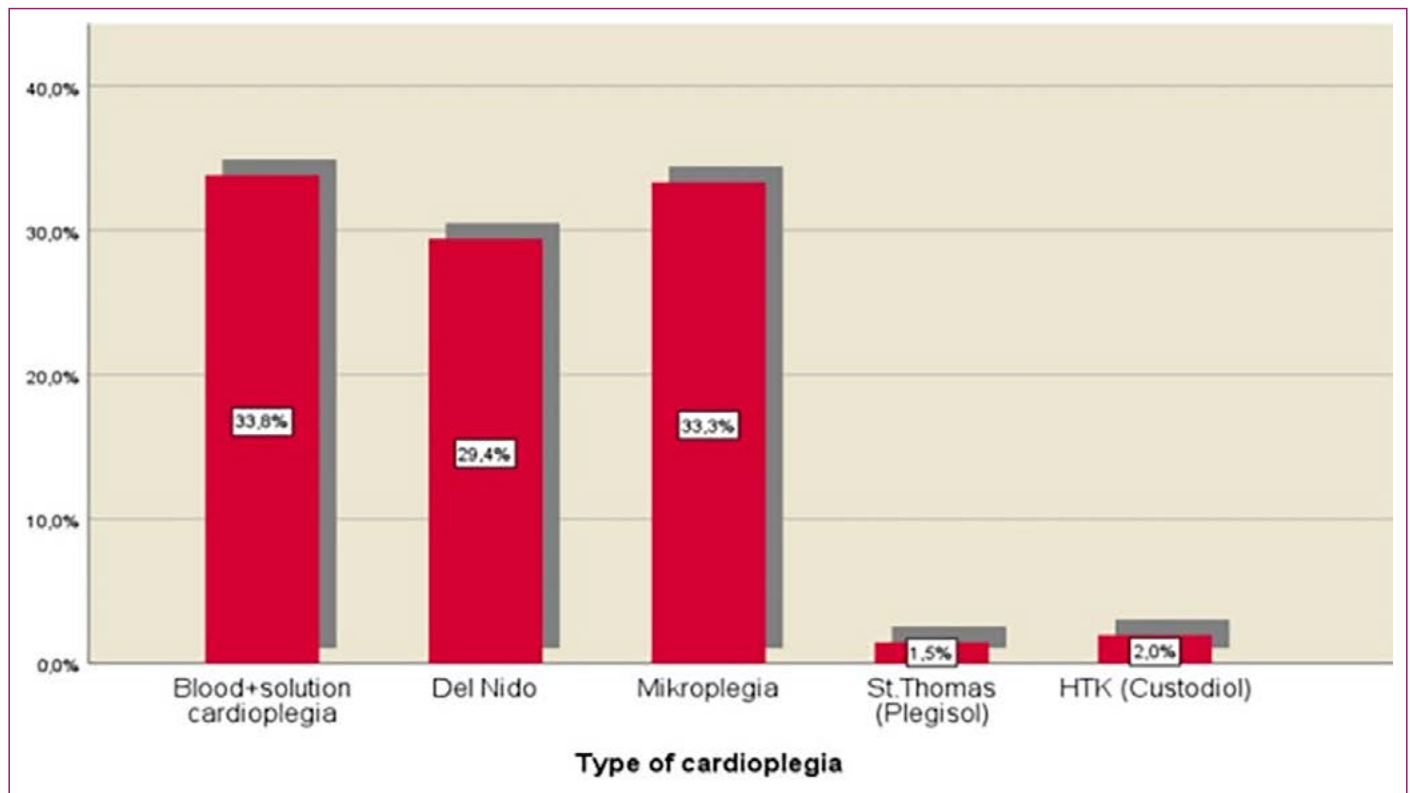


Figure 1. Preferred types of cardioplegia.

HTK: Histidine–tryptophan–ketoglutarate.

antegrade and combined antegrade/retrograde approaches in CABG procedure, it was reported that postoperative cardiac output, electrophysiological and biochemical evidence of ischemia, need for temporary pacing and 30-day morbidity were similar between the groups.^[12]

In our study, we found that the majority of the participants (59.3%) used the isolated antegrade cardioplegia method. Estimation of the pressure of the infusion during antegrade cardioplegia is based on measurement of the pressure at the initial part of the aorta. Aortic pressure is measured directly intra-

Table 3. Cardioplegia redosing intervals according to cardioplegia type

Cardioplegia type	15–20 min n (%)	20–30 min n (%)	30–60 min n (%)	60–90 min n (%)	Single dose n (%)	Total n (%)
Blood-based cardioplegia	42 (60.9)	26 (37.7)	0 (0.0)	1 (1.4)	0 (0.0)	69 (100.0)
Del Nido cardioplegia	3 (5.0)	1 (1.7)	3 (5.0)	43 (71.7)	10 (16.7)	60 (100.0)
Microplegia	38 (55.9)	25 (36.8)	3 (4.4)	2 (2.9)	0 (0.0)	68 (100.0)
St. Thomas cardioplegia (Plegisol)	1 (33.3)	1 (33.3)	0 (0.0)	1 (33.3)	0 (0.0)	3 (100.0)
HTK solution (Custodiol)	1 (25.0)	0 (0.0)	0 (0.0)	1 (25.0)	2 (50.0)	4 (100.0)
Total	85 (41.7)	53 (26.0)	6 (2.9)	48 (23.5)	12 (5.9)	204 (100.0)

Data are presented as n (row percentage). HTK: Histidine–tryptophan–ketoglutarate.

Table 4. Cardioplegia mixing ratios according to cardioplegia type

Cardioplegia type	4=1, n (%)	1=4, n (%)	Undiluted, n (%)	Total, n (%)
Blood-based cardioplegia	64 (92.8)	3 (4.3)	2 (2.9)	69 (100.0)
Del Nido cardioplegia	21 (35.0)	37 (61.7)	2 (3.3)	60 (100.0)
Microplegia	0 (0.0)	0 (0.0)	68 (100.0)	68 (100.0)
St. Thomas cardioplegia (Plegisol)	0 (0.0)	0 (0.0)	3 (100.0)	3 (100.0)
HTK solution (Custodiol)	0 (0.0)	0 (0.0)	4 (100.0)	4 (100.0)
Total	85 (41.7)	41 (20.1)	78 (38.2)	204 (100.0)

Data are presented as n (row percentage). Mixing ratios indicate the blood-to-crystalloid ratio. Undiluted indicates cardioplegia administered without mixing with an additional component. HTK: Histidine–tryptophan–ketoglutarate.

Table 5. Initial cardioplegia dose according to cardioplegia type

Cardioplegia type	5 mL/kg, n (%)	10 mL/kg, n (%)	15 mL/kg, n (%)	20 mL/kg, n (%)	Total, n (%)
Blood-based cardioplegia	3 (4.3)	27 (39.1)	18 (26.1)	21 (30.4)	69 (100.0)
Del Nido cardioplegia	1 (1.7)	27 (45.0)	7 (11.7)	25 (41.7)	60 (100.0)
Microplegia	2 (2.9)	53 (77.9)	3 (4.4)	10 (14.7)	68 (100.0)
St. Thomas cardioplegia (Plegisol)	0 (0.0)	1 (33.3)	1 (33.3)	1 (33.3)	3 (100.0)
HTK solution (Custodiol)	0 (0.0)	0 (0.0)	0 (0.0)	4 (100.0)	4 (100.0)
Total	6 (2.9)	108 (52.9)	29 (14.2)	61 (29.9)	204 (100.0)

Data are presented as n (row percentage). HTK: Histidine–tryptophan–ketoglutarate.

luminally using a pressure monitoring line attached to the cardioplegia cannula.^[13] In our study, differences were determined between the participants' responses to cardioplegia conduction pressure. According to the data we obtained, 30.9% of the participants stated that they preferred 150–180 mmHg pressure, 29.4% 120–150 mmHg pressure, 21.6% 180 mmHg pressure, and 18.1% 80–120 mmHg pressure. In addition, the most common (63.2%) retrograde cardioplegia pressure preferred by the participants was 35–50 mmHg.

In various centers, antegrade cardioplegia can be administered with the help of a roller pump from a heart-lung machine or with a manually squeezed pressure bag. In a study in which both techniques were compared, it was reported that cardioplegia given with a roller pump of the heart-lung machine and cardioplegia given with a pressure bag did not differ in terms of myocardial protection.^[14] Another question of our study was by which method cardioplegia was administered. Of the participants who responded, 51% stated that cardioplegia was administered with the help of a heart-lung machine roller pump and 49% stated that cardioplegia was administered with a pressure bag.

During coronary artery surgery, redosing of cardioplegia is usually performed after each distal anastomosis, that is, every 10±5 min, but redosing intervals of 60 min have also been described.^[15] However, the optimal redosing strategy of Del Nido cardioplegia is unclear. In our study, the participants who responded to the question about redosing frequently preferred intervals of 15–20 min for blood cardioplegia (60.9%), 15–20 min for microplegia (55.9%), and 60–90 min for Del Nido (71.7%).

Cardioplegia strategies can broadly be categorized as conventional blood cardioplegia consisting of blood diluted with crystalloid solution, microplegia using predominantly whole blood with minimal crystalloid volume, and crystalloid cardioplegia administered without added blood. Del Nido cardioplegia represents a blood–crystalloid strategy characterized by a higher crystalloid-to-blood ratio. In our study, the reported mixing ratios varied according to the cardioplegia strategy. Among participants using conventional blood cardioplegia, 92.8% reported a blood-to-crystalloid ratio of 4:1, whereas 61.7% of those using Del Nido cardioplegia reported a ratio of 1:4. All participants using microplegia reported using it undiluted (100.0%). Similarly, all participants using St. Thomas and HTK solutions reported administering these crystalloid solutions without added blood.

The strengths of this study include a high response rate and complete response rate from coronary artery surgery centers

in Türkiye. However, limitations include the lack of a study evaluating the effectiveness of myocardial protection and the inability to determine whether the variety of responses given by the participants had an effect on patient outcomes.

Conclusion

This study on current cardioplegia practices in adult coronary artery surgery in Türkiye shows that there is heterogeneity in the cardioplegia approaches of the participants. We think that the main reason for this situation is the experience of surgeons in different ecoles. As shown in different studies,^[16,17] most surgeons in our study used blood-based cardioplegia, while there are differences in the temperature of the solutions, delivery techniques, delivery routes and preferred delivery pressures. In the light of the data obtained in this study, we think that targeted, randomized studies designed to examine the effects of cardioplegia choices on clinical outcomes after cardiac surgery should be conducted.

Disclosures

Ethics Committee Approval: The study was approved by the Bandırma 17 Eylül University Non-Interventional Research Ethics Committee (no: 553, date: 10/11/2023).

Informed Consent: Informed consent was obtained from all participants.

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