Cardiovasc Surg Int 2025;12(2):i-xi
http://dx.doi.org/DOI: 10.5606/e-cvsi.2025.1822
www.e-cvsi.org

Cardiovascular Surgery and Interventions

Original Article Open Access

The effect of cardioplegia techniques on left ventricular functions in coronary artery bypass grafting: A comparison with tissue Doppler echocardiography

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Received: January 18, 2025 ***Accepted:*** March 27, 2025 ***Published online:*** May 27, 2025

ABSTRACT

Objectives: This study aims to evaluate the effects of antegrade cardioplegia (ACP) and combined antegrade/retrograde cardioplegia (ARCP) on left ventricular systolic and diastolic function in patients undergoing elective coronary artery bypass grafting (CABG) using tissue Doppler echocardiography (TDE).

Patients and methods: Between September 2010 and September 2012, a total of 40 patients (29 males, 11 females; mean age: 62±1.45 years; range, 27 to 78 years) who underwent elective isolated CABG under cardiopulmonary bypass were included. The patients were equally divided into two groups (n=20). Group 1: Antegrade cold blood cardioplegia (0-6°C), Group 2: Antegrade + retrograde cold blood cardioplegia (0-6°C). The TDE was performed preoperatively and was repeated at Weeks 1 and 4 postoperatively. Isovolumetric contraction time (IVCT), isovolumetric relaxation time (IVRT), ejection time (ET), mitral annular waves, and diastolic velocity/myocardial E velocity (E/Em), late diastolic velocity (A) ratios were measured using TDE. The Tei index was calculated to assess the global function.

Results: The transmitral (E), E/A ratio, ejection fraction (EF), IVRT, IVCT, and myocardial performance index (MPI) significantly increased, whereas the transmitral (A), E wave deceleration time (EDT), and ET decreased. In the ARCP group, (E), the E/A ratio, EF, IVRT, IVCT, and MPI increased and ET decreased; however, (A) and EDT did not change. Both groups showed an improvement in cardiac function after revascularization.

Conclusion: Our study results show that both ACP and ARCP yield similar outcomes on cardiac systolic, diastolic, conduction system, and left ventricular functions. Revascularization has positive effects on systolic, diastolic, left ventricular, and conduction system function, leading to a significant improvement in segmental systolic and diastolic functions of the heart in the first month postoperatively.

Keywords: Coronary artery bypass grafting, myocardial protection, tissue Doppler echocardiography.

For optimal myocardial protection, homogeneous distribution of the cardioplegic solution is critical. This is mostly dependent on the way cardioplegia is delivered. Each technique offers different advantages according to the individual patient and procedural characteristics. The most common use in practice is antegrade delivery of cardioplegia via the aortic root, as it is simple to perform and causes rapid diastolic cardiac arrest.[1] However, several studies have suggested that combined cardioplegia offers distinct advantages over antegrade cardioplegia (ACP) in terms of preservation of myocardial function and reduction of ischemic injury.[2] Assessment of myocardial function after coronary artery bypass grafting (CABG) is critical for determining the efficacy and safety of cardioplegia strategies. Reperfusion after CABG is expected to improve left ventricular (LV) systolic and diastolic function and increase long-term survival.[3] Wall motion abnormalities observed early after CABG are among the most important indicators of myocardial

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Citation:
Yucel M, Turan SA, Uğuz E, Karabağ T. The effect of cardioplegia techniques on left ventricular functions in coronary artery bypass grafting: A comparison with tissue Doppler echocardiography. Cardiovasc Surg Int 2025;12(2):i-xi. doi: 10.5606/e-cvsi.2025.1822.

ischemia. This is because, during ischemia, significant changes in systolic and diastolic function occur both regionally and globally in the LV.[4] By evaluating myocardial functional recovery in the early postoperative period, we attempt to contribute to a better understanding of the effects of myocardial conduction strategies on clinical outcomes and functional recovery and to guide the selection of cardioplegia strategies in clinical practice.

Tissue Doppler echocardiography (TDE) is an imaging modality which allows quantitative assessment of myocardial motion. It was first described in 1989.[5] It uses early diastolic velocity (E), late diastolic velocity (A), E/A ratio, myocardial performance index (MPI), isovolumic relaxation time (IVRT), and isovolumic contraction time (IVCT) to analyze LV function. Unlike conventional echocardiography, it can provide more detailed information on regional myocardial systolic and diastolic functions based on detailed analysis of myocardial velocities.

Although many studies have examined LV function in the post-CABG period, early and late TDE studies are limited. In addition, existing studies have mostly focused on the changes in LV systolic function after CABG. However, LV diastolic dysfunction is directly related to perioperative outcomes in patients undergoing cardiac surgery.[6,7]

Although ACP is a safe and effective method of myocardial protection, aortic regurgitation in the presence of severe coronary stenosis can result in an inhomogeneous, inadequate distribution. Therefore, myocardial areas distal to the lesion are poorly protected, resulting in myocardial injury and delayed functional recovery.[8] Although the combined cardioplegia technique is widely used currently, the comparative effects of these techniques on LV function remain a matter of debate in cardiac surgery literature. This dual approach is hypothesized to enhance myocardial protection by providing comprehensive perfusion in all myocardial layers, even in patients with advanced coronary pathology.[9] In the present study, we, therefore, aimed to objectively evaluate the effect of reperfusion provided by different cardioplegia strategies on myocardial systolic and diastolic performance in CABG and to reveal potential differences in the postoperative period.

PATIENTS AND METHODS

This single-center, prospective study was conducted at Bülent Ecevit University, Faculty of Medicine, Department of Cardiovascular Surgery between September 2010 and September 2012. A total of 40 patients (29 males, 11 females; mean age: 62±1.45 years; range, 27 to 78 years) who underwent elective isolated CABG under cardiopulmonary bypass (CPB) were included. Inclusion criteria were as follows: *(i)* 18-80 years of age, *(ii)* Elective, isolated coronary bypass surgery. Exclusion criteria were as follows: *(i)* Congenital or acquired valve disease, *(ii)* Hypertrophic, restrictive or dilate cardiomyopathy, *(iii)* History of atrial fibrillation or ventricular arrhythmia, *(iv)* QRS duration >120 ms, *(v)* Pulmonary hypertension, ventricular aneurysm or valvular/congenital heart disease, *(vi)* Non coronary artery bypass surgery, *(vii)* Redo coronary artery bypass surgery, *(viii)* Need for urgent surgery, *(ix)* Cases where postoperative intra-aortic balloon is used or complications develop, *(x)*Patients with EF-30. To ensure homogeneity in the study and minimize possible biases, the patients were divided into two equal groups (n=20) using a computer-assisted random assignment method: Group 1: those who received ACP only and Group 2: those who received a combination of antegrade/retrograde cardioplegia (ARCP). Randomization was independently performed using the cardioplegia method. The study flowchart is shown in Figure 1. A written informed consent was obtained from each patient. The study protocol was approved by the Bülent Ecevit University Health Sciences Research Ethics Committee (date: 20.06.2010, no: 2010/17). The study was conducted in accordance with the principles of the Declaration of Helsinki.

All patients underwent a standard general anesthesia protocol for CABG. All surgical procedures were performed by three experienced surgeons working in the same center according to standard protocols. There were no technical differences between the surgeons. After median sternotomy, the left internal mammary artery (LIMA) was prepared and anticoagulated with heparin (300 U/kg). Cannulation was performed from the aorta and right atrium. A roll pump (Jostra Lund, Sweden) and membrane oxygenator (Compactflo Evo, Dideco, Italy) were used for CPB. Rectal temperature was maintained between 32 and 33°C

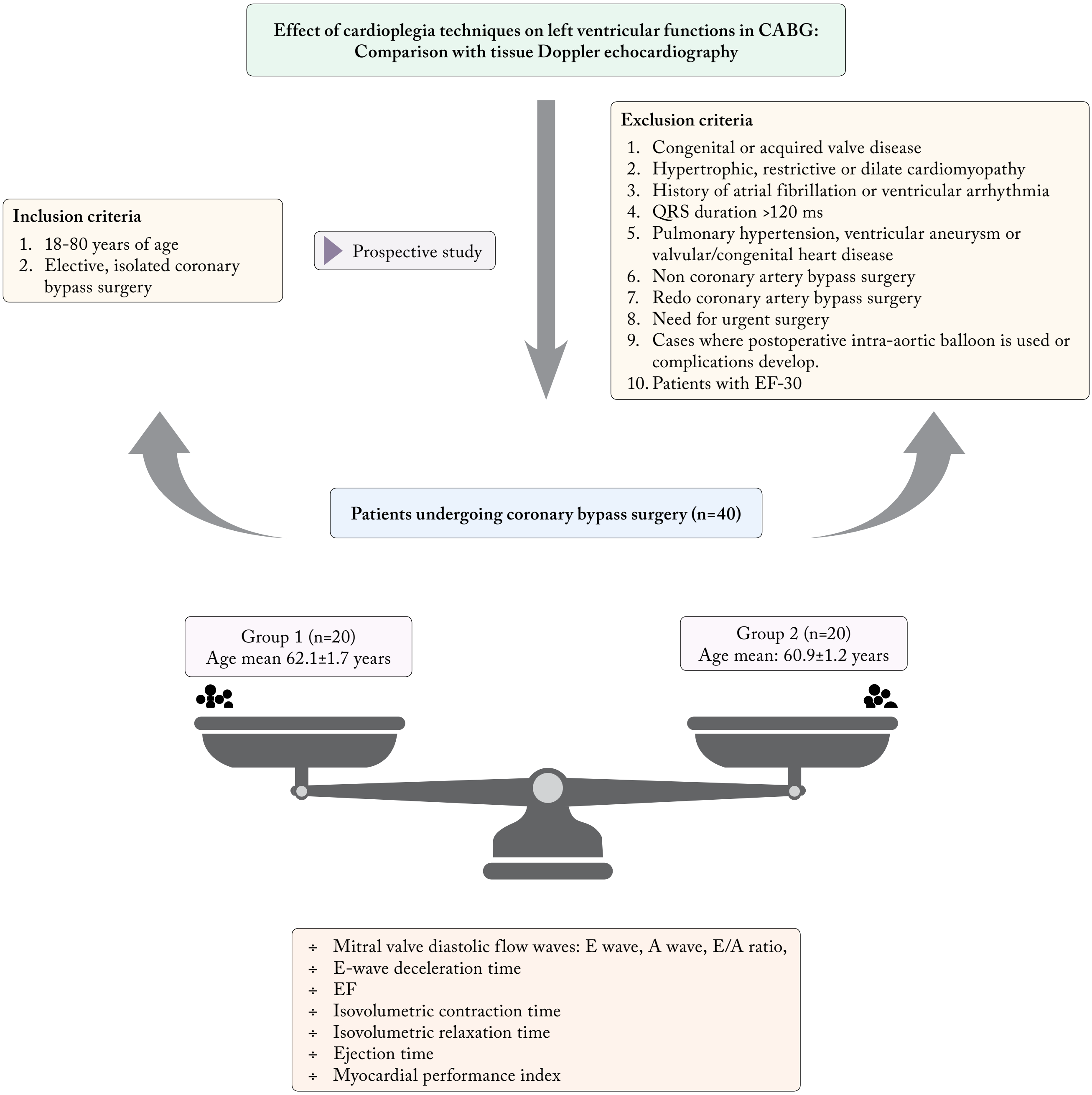

Figure 1. Study flowchart.
CABG: Coronary artery bypass grafting; QRS: QRS complex; E: Transmitral early diastolic velocity; A: Transmitral late diastolic velocity; EF: Ejection fraction.

throughout the operation. For myocardial protection, systemic moderate hypothermia (30 to 33°C) was maintained and cold blood cardioplegia (0 to 6°C) was administered. The ACP was administered at a flow rate of 250 to 350 mL/min, under a line pressure of 150 to 200 mmHg, at a mean dose of 15 to 20 mL/kg. The ARCP was administered with 2/3 of the total cardioplegia delivered antegrade and 1/3 retrograde. Retrograde cardioplegia was administered at a flow rate of 200-250 mL/min with a coronary sinus pressure of 30-40 mmHg. The cardioplegia solution was blood-based and contained potassium chloride, magnesium sulfate, and lidocaine. Warm blood cardioplegia (36°C) was induced after CPB. After the completion of surgery, heparin was neutralized with protamine hydrochloride at a 1:1 to 1.3 ratio. Following CPB, the heart was started spontaneously or by defibrillation, and CPB was terminated after hemodynamic stability was achieved. The LIMA and left anterior descending artery (LAD) anastomosis was performed in all the patients, and complete revascularization was achieved.

A 12-lead surface electrocardiogram (ECG) was obtained from all patients. Heart rate, R-R interval, QRS and QT intervals were measured manually, and the QT interval was corrected with Bazett's formula (QTc = QT/√R-R).

Time points of Weeks 1 and 4 were selected for TDE. In the first week measurement, myocardial function changes in the early postoperative period due to ischemia-reperfusion were observed.[9,10] In the fourth week measurement, the mid-term myocardial recovery process was evaluated. In previous studies in literature, Week 4 is recommended as an optimal time frame for early myocardial recovery.[11,12] Echocardiography was performed using the General Electric Vivid Five (GE Vingmed Ultrasound AS, Horten, Norway) device. Two-dimensional (2D) images were obtained from standard parasternal long and short axes and apical four- and two-space slices. Left ventricular ejection fraction (EF) was calculated using the modified Simpson method. Using TDE, the mitral annular waves (myocardial E velocity [Em], myocardial A velocity [Am], and mitral peak systolic velocity [Sm]), E/Em ratios, IVCT, isovolumetric relaxation time IVRT, and ejection time (ET) were measured. All TDE measurements were performed by an experienced cardiologist with a single rater to avoid interobserver variability. Measurements were performed using the blinded observer method.

Statistical analysis

Statistical analysis was performed using the PASW version 18.0 software (SPSS Inc., Chicago, IL, USA). Continuous data were expressed in mean ± standard deviation (SD) or median (min-max), while categorical data were expressed in number and frequency. The distribution of quantitative variables was evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests. An independent sample t-test was applied for independent quantitative variables with a normal distribution, while the Mann-Whitney U test was applied for independent quantitative variables without a normal distribution. The chi-square test or Fisher exact test was used to compare categorical variables. For repeated measures, one-way analysis of variance (ANOVA) was used for normally distributed data, and Friedman's test was used for non-normally distributed data. A p value of <0.05 was considered statistically significant with 95% confidence interval (CI).

RESULTS

Of a total of 40 patients included in the study, there were 20 patients in Group 1 and 20 patients in Group 2. There was no significant difference in the mean age between the groups (p=0.666). The clinical characteristics of the patients are summarized in Table 1.

Table 1
Baseline characteristics of the patients

	Group 1 (n=20)			Group 2 (n=20)			
	n	%	Mean±SD	n	%	Mean±SD	p
Age (year)			62.1±1.7			60.9±1.2	0.912
Sex							0.808
Female	3	15		8	40		
Male	17	85		12	60		
Hypertension	6	30		6	30		0.098
Diabetes mellitus	8	40.0		14	70.0		0.476
Hypercholesterolemia	9	45.0		12	60.0		0.421

SD: Standard deviation.

Table 2

Comparative analysis of tissue Doppler echocardiographic parameters before and after coronary artery bypass grafting in patients undergoing antegrade cardioplegia

	Preoperative	Postoperative 1st week	Postoperative 1st month	
	Mean±SD	Mean±SD	Mean±SD	*p*
E (mm/s)	0.70±0.03	0.70±0.03	0.80±0.02	<0.05
A (mm/s)	0.88±0.03	0.85±0.05	0.92±0.04	<0.05
E/A	0.83±0.05	0.85±0.03	0.90±0.02	<0.05
EDT (s)	244.2±9.81	234.4±9.14	214.3±7.78	<0.05
IVRT (s)	103.1±3.91	105.2±4.02	109.00±3.71	<0.05
IVCT (s)	64.8±2.11	69.3±2.09	72.1±2.10	<0.05
ET (s)	239.3±5.92	242.5±5.99	224.0±5.26	<0.05
MPI	0.71±0.03	0.73±0.03	0.82±0.02	<0.05
EF	57.60±1.62	58.85±1.64	62.00±1.34	<0.05

SD: Standard deviation; E: Transmitral early diastolic velocity; A: Transmitral late diastolic velocity; EDT: E Wave deceleration time; IVRT: Isovolumic relaxation time; IVCT: Isovolumic contraction time; ET: Ejection time; MPI: Myocardial performance index; EF: Ejection fraction.

A statistically significant increase was found in transmitral (E), E/A ratio, EF, IVRT, IVCT, and MPI values ($p<0.005$), whereas a statistically significant decrease was observed in transmitral (A)A, E wave deceleration time (EDT), and ET ($p<0.005$) (Table 2).

As shown in Table 2, there was a statistically significant increase in the transmitral (E), E/A ratio, EF, IVRT, IVCT, and MPI ($p<0.005$). A statistically significant decrease was observed in transmitral (A), EDT, and ET measurements ($p<0.005$).

Table 3 shows that there was a statistically significant increase in (E), E/A ratio, IVRT, ICT, EF, and MPI values in the TDE measurements performed preoperatively and on postoperative Days 7 and 30 in the ARCP group ($p<0.005$). A statistically significant decrease was also observed in the ET values ($p<0.05$). No significant changes were observed in A and EDT values ($p>0.05$).

Table 3

Comparison of tissue Doppler echocardiography parameters before and after coronary artery bypass grafting in patients with combined antegrade and retrograde cardioplegia

	Preoperative	Postoperative 1st week	Postoperative 1st month	
	Mean±SD	Mean±SD	Mean±SD	*p*
E (mm/s)	0.67±0.03	0.67±0.03	0.76±0.02	<0.005
A (mm/s)	0.83±0.05	0.80±0.05	0.84±0.03	>0.005
E/A	0.83±0.05	0.85±0.05	0.92±0.04	<0.005
EDT (s)	244.2±9.81	234.4±9.14	214.03±7.78	>0.005
IVRT (s)	103.1±3.92	105.2±4.02	109.0±3.70	<0.005
IVCT (s)	64.80±2.10	69.35±2.09	72.10±2.10	<0.005
ET (s)	239.30±5.91	242.55±5.99	224.05±5.26	<0.005
MPI	0.71±0.03	0.73±0.03	0.83±0.02	<0.005
EF	57.60±1.62	58.85±1.64	62.00±1.34	<0.005

SD: Standard deviation; E: Transmitral early diastolic velocity; A: Transmitral late diastolic velocity; EDT: E Wave Deceleration time; IVRT: Isovolumic relaxation time; IVCT: Isovolumic contraction time; ET: Ejection time; MPI: Myocardial performance index; EF: Ejection fraction.

Table 4
Comparison of tissue Doppler segmentary region parameters before and after coronary artery bypass grafting in patients with antegrade cardioplegia

	Preoperative	Postoperative 1st week	Postoperative 1st month	
	Mean±SD	Mean±SD	Mean±SD	*p*
Basal septum				
Em (cm/s)	5.95±0.23	5.00±0.23	4.96±0.24	0.165
Am (cm/s)	8.54±0.43	8.70±0.43	8.70±0.42	0.352
S (cm/s)	6.30±0.25	6.09±0.27	6.09±0.27	**0.047**
Em/Am	0.72±0.44	0.60±0.41	0.60±0.41	**0.037**
Septal annulus				
Em (cm/s)	6.36±0.30	6.03±0.32	6.04±0.32	0.154
Am (cm/s)	8.01±0.34	8.18±0.32	8.16±0.31	0.546
S (cm/s)	6.24±0.32	6.22±0.28	6.23±0.28	0.618
Em/Am	0.82±0.50	0.76±0.55	0.77±0.55	0.123
Basal lateral				
Em (cm/s)	6.38±0.38	5.91±0.44	5.95±0.43	**0.026**
Am (cm/s)	7.73±0.56	7.68±0.54	7.67±0.55	0.873
S (cm/s)	6.06±0.38	6.01±0.44	6.06±0.38	0.765
Em/Am	0.92±010	0.84±0.10	0.88±0.10	0.265
Lateral annulus				
Em (cm/s)	6.60±0.48	6.30±0.57	6.27±0.55	**0.004**
Am (cm/s)	7.95±0.50	8.39±0.55	8.42±0.53	0.06
S (cm/s)	6.75±0.33	6.72±0.40	6.70±0.40	0.903
Em/Am	0.86±0.06	0.79±0.08	0.78±0.07	**0.015**

SD: Standard deviation; Em: Myocardial E velocity; Am: Myocardial A velocity; S: Mitral peak systolic velocity.

In the segmental regional analysis of ACP patients using TDE, pre- and postoperative myocardial Em, Am, Sm waves, and Em/Am values were measured, and measurements were taken from four different regions: basal and annulus of the septum and lateral wall. A significant decrease was observed in the postoperative Em value of the basal septum (p=0.001). There was no significant difference between the postoperative Day 7 and 30. A slight increase in Am was observed; however, this difference was not statistically significant (p=0.540). A statistically significant decrease was also observed in Em/Am values during the postoperative period (p=0.01). No significant changes were observed in the Sm values (p=0.280). These changes were similar in all measured regions of the myocardial wall (basal and annulus of the septum, and basal and annulus of the lateral septum) (Table 4).

As shown in Table 5, a statistically significant decrease was observed in the Em/Am values for the basal septum in the postoperative period in the segmental analysis performed with TDE in Group 2 (p=0.037). Changes over time were not significant for any of the septal annulus measurements. A statistically significant decrease in Em values was observed in measurements taken from the basal septum and annulus of the lateral septum in the postoperative period (p=0.026 and p=0.004, respectively). The change in Am value was not significant in either segment. The Em/Am values were significantly lower in the postoperative period (p=0.015). In all analyzed TDE segments, the measurement values obtained between Days 7 and

Table 5

Comparison of tissue Doppler parameters before and after coronary artery bypass grafting in patients with combined antegrade and retrograde cardioplegia

	Preoperative	Postoperative 1st week	Postoperative 1st month	
	Mean±SD	Mean±SD	Mean±SD	*p*
Basal septum				
Em (cm/s)	5.46±0.32	5.15±0.38	5.15±0.37	0.165
Am (cm/s)	7.26±0.39	7.59±0.36	7.57±0.35	0.352
S (cm/s)	5.61±0.30	5.87±0.24	5.89±0.24	**0.047**
Em/Am	0.82±0.85	0.73±0.77	0.73±0.78	**0.037**
Septal annulus				
Em (cm/s)	6.79±0.33	5.63±0.20	5.65±0.20	**0.031**
Am (cm/s)	9.21±0.33	9.50±0.34	9.51±0.34	0.163
S (cm/s)	6.92±0.32	6.76±0.23	6.69±0.23	0.394
Em/Am	0.75±0.44	0.61±0.32	0.61±0.33	**0.024**
Basal lateral				
Em (cm/s)	5.68±0.32	5.08±0.36	5.13±0.36	**0.003**
Am (cm/s)	7.56±0.38	8.76±0.60	8.83±0.59	**0.018**
S (cm/s)	5.59±0.33	5.76±0.33	5.60±0.33	0.051
Em/Am	0.76±0.06	0.63±0.05	0.60±0.05	**0.006**
Lateral annulus				
Em (cm/s)	6.73±0.44	6.07±0.36	6.06±0.35	**0.019**
Am (cm/s)	9.14±0.41	9.63±0.42	9.60±0.43	0.226
S (cm/s)	7.32±0.42	7.30±0.43	7.28±0.45	0.891
Em/Am	0.76±0.06	0.65±0.05	0.65±0.05	**0.009**

SD: Standard deviation; Em: Myocardial E velocity; Am: Myocardial A velocity; S: Mitral peak systolic velocity.

Table 6

Comparison of QRS and QTC values on ECG before and after CABG depending on the method of cardioplegia administration

	Preoperative	Postoperative 1st week	Postoperative 1st month	
Cardioplegia method	Mean±SD	Mean±SD	Mean±SD	*p*
Antegrade cardioplegia				
QTC (ms)	413.5±4.42	423.95±4.68	414.35±6.40	0.086
QRS (ms)	90.15±3.04	91.50±3.26	87.95±3.59	0.335
Antegrad/retrograd cardioplegia				
QTC (ms)	410.5±6.50	414.35±6.40	413.50±6.48	0.143
QRS (ms)	85.90±3.85	87.95±3.59	86.60±3.72	0.835

SD: Standard deviation; QRS: QRS complex; QTc: Corrected QT interval; ECG: Electrocardiogram; CABG: Coronary artery bypass grafting.

30 in the postoperative period were not statistically different.

Comparison of the pre- and postoperative Week 1 and 4 TDE measurements revealed no statistically significant differences in the E, A, E/A ratio, ET, EF, and MPI values between the groups (p>0.05).

Depending on the method of cardioplegia administration, the QRS and QTC values on ECG were compared before CABG and on Days 7 and

30. The change in these values over time was not statistically significant in either patient group ($p>0.05$) (Table 6).

DISCUSSION

Myocardial protection methods used during cardiac surgery directly affect surgical success and postoperative myocardial function. Diastolic dysfunction is one of the earliest signs of myocardial ischemia. In coronary artery disease, diastolic function deteriorates or improves before systolic function does.[6] In ischemic heart disease, decreased E wave and E/A ratio, which indicate diastolic dysfunction in ischemic myocardial segments with TDE, and prolonged IVRT and EDT parameters have been reported.[13]

In this study, significant increases in the early diastolic flow velocity (E), E/A ratio, and EF values were observed on postoperative Day 30, whereas decreases in the (A) and ET values were found in the ACP group, which is consistent with the literature. These findings suggest that a certain time period is required for the regulation of myocardial function. Increases in EF, E/A ratio, and (E) wave on postoperative Day 30 indicated that ventricular relaxation recovered after surgery, and systolic and diastolic functions tended to improve. A decrease in the (A) wave indicates a decrease in active atrial filling and an increase in the relaxation capacity of the ventricle, leading to passive filling.[14] The decrease in ET may be associated with revascularization after CABG, optimization of myocardial contraction time, and more efficient filling dynamics due to the reduction in ischemic regions. In contrast, a statistically significant increase in the E value on postoperative Day 30 was observed in the combined cardioplegia group. However, the E/A ratio differed among the three time periods, and the postoperative Day 30 values were higher than the preoperative and postoperative Day 7 values. This periodic difference in our findings was interpreted to be compatible with data in the literature regarding early diastolic dysfunction in ischemic myocardial segments.[14] In addition, in our study, the increases in time parameters, such as IVRT and IVCT, which were common in both cases, were evaluated as changes due to the short-term adaptation process of the myocardium. The effect of ACP on diastolic improvement is similarly emphasized in the literature.[15]

When TDE segmental myocardial analyses of both groups were performed, the Em and Am values in the ACP group mostly showed no significant postoperative change, whereas the Em/Am ratios decreased in all segments. This decrease was statistically significant for both basal and lateral walls. In the ARCP group, there was a significant decrease in the Em/Am ratio in all the segments. This suggests that the effects of cardioplegia may differ depending on the myocardial region, and that combined cardioplegia administration may produce more specific effects at the segmental level.[15] In addition, the segmental myocardial velocity differences observed in both groups were considered to be indicators of myocardial fibrosis or ischemia in the early postoperative period. However, the stabilization of these values at follow-up suggests that this process is reversible and that both cardioplegia methods preserve myocardial function.

However, studies have demonstrated that right ventricular recovery can be achieved more effectively with combined cardioplegia and that it is superior in terms of postoperative inotrope use and the need for mechanical support.[16] These findings may explain the myocardial segmental differences between the two cardioplegia methods used in our study.

The MPI is a global indicator of LV systolic and diastolic dysfunctions. An increase in MPI is important for assessing global cardiac function and myocardial recovery after CABG. In our study, significant increases in the postoperative MPI and EF values indicated that both methods supported myocardial function. However, this increase was more pronounced in Group 2. This finding suggests that combined cardioplegia may provide a more extensive and balanced myocardial protection.

In the literature, there are studies emphasizing the advantages of combined cardioplegia in providing more uniform, which found that the improvement in EF in the postoperative period was better with high-risk CABG.[17] In our study, although there was no significant difference in EF values between the preoperative and early postoperative periods, the significant increase in the first postoperative month may be due to adaptive changes in the hibernating myocardium after revascularization. Simultaneously, surgery-induced inflammation and myocardial edema in the early postoperative period after CABG may have had transient adverse effects on LV function. Medical therapies administered in the postoperative period, such as beta-blockers,[18] angiotensin-converting enzyme (ACE) inhibitors, and angiotensin receptor blockers (ARBs),[19] may contribute to the improvement of LV function by reducing the load on the myocardium.

The similar QTc and QRS durations on preoperative and postoperative ECG in both groups suggest that the effects of cardioplegia methods on myocardial electrical stability were minimal. It has been reported in the literature that cardioplegia-induced hyperkalemia may cause the prolongation of QTc duration.[20] In addition, QTc prolongation due to prolonged operation times has been reported in some studies.[21] The non-significant prolongation of QTc duration observed in our study may be due to cardioplegia-induced hyperkalemia or prolonged surgery, similar to the findings of previous studies.

In the current study, similar results were found in the myocardial recovery processes in the first month after CABG using both the methods. However, it is frequently reported that combined cardioplegia provides significant advantages in terms of myocardial protection compared with ACP.[16] Therefore, it is emphasized that it may be a more favorable option, particularly in patients with complex coronary artery disease,[22] hypertrophic myocardial tissue,[23] redo-CABG,[24] and high-risk patients with low preoperative EF.[17] Taken together, each method has its advantages and disadvantages. Therefore, the cardioplegia strategy should be individualized based on the clinical characteristics of the patient and experience of the surgeon. In the future, prospective studies involving larger patient groups and the evaluation of long-term outcomes would make important contributions to the optimization of cardioplegia methods. Based on the findings of our study, cardioplegia strategies should be individualized on a patient-by-patient basis. In addition, TDE and other advanced imaging modalities should be used both in the decision-making process for preoperative myocardial protection techniques and in the establishment of myocardial rehabilitation and pharmacological support protocols in the early postoperative period.

Nonetheless, this study has some limitations. First, the relatively small number of patients and single-center design limit the generalizability of the results. Studies evaluating changes in myocardial function after CABG often require long-term follow-ups. However, our study focused on early postoperative myocardial recovery, and the first month results were evaluated in terms of the number of patients and follow-up period. Studies evaluating changes in myocardial function after CABG often require long-term follow-ups. However, our study focused on early postoperative myocardial recovery and evaluated the results in the first month in terms of the number of patients and the follow-up time. Considering that the myocardial healing process may take weeks, long-term results may have been underestimated. Furthermore, the correlation of regional strain parameters assessed by TDE with coronary stenosis was not analyzed. Furthermore, biomarkers such as troponin levels were not analyzed, which may provide additional information for evaluating the effectiveness of myocardial protection strategies. On the other hand, although TDE parameters were less affected by changes in LV preload and afterload compared to conventional Doppler parameters, inotropic, vasodilator and diuretic therapies initiated after CABG may have affected these parameters to some extent. The Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery (SYNTAX) score, an important prognostic tool for assessing the anatomical complexity of coronary artery disease, was not used in this study. This limitation limits the generalizability of the results obtained, particularly for patients with complex coronary lesions. In our study, patients in both groups had similar demographic and clinical characteristics, and showed a homogeneous distribution in terms of preoperative EF, New York Heart Association (NYHA) functional class, LV diastolic function, and other hemodynamic parameters. However, the lack of consideration of more specific anatomical variables, such as the SYNTAX score, is a significant limitation. Further large-scale, long-term, prospective studies are warranted to confirm these findings.

In conclusion, both antegrade and combined cardioplegia techniques demonstrated equivalent early improvements in left ventricular function after CABG, supporting prior evidence on their myocardial protective efficacy.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Conceptualization, investigation, writing-original draft, data curation: M.Y.; Review, and editing, formal analysis, supervision: S.A.T.; Investigation, methodology, review and editing: T.K.; Methodology, writing-review and editing: E.U.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

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