

Enhanced myocardial protection in failing hearts: comparative outcomes of single-dose Del Nido and conventional blood cardioplegia in emergency low-ejection fraction coronary artery bypass grafting (CABG)

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ABSTRACT

Background: Optimal myocardial protection remains challenging in emergency coronary revascularization, especially in patients with severely reduced left ventricular function. Contemporary cardioplegia strategies aim to limit ischemia–reperfusion injury and enhance postoperative ventricular recovery. The aim of this study was to compare operative parameters, early postoperative outcomes, and myocardial functional recovery between single-dose Del Nido cardioplegia and conventional blood cardioplegia in adults with left ventricular ejection fraction (LVEF) $\leq 40\%$ undergoing emergency isolated coronary artery bypass grafting (CABG).

Methods: This retrospective study included 150 consecutive patients with left ventricular ejection fraction (LVEF) $\leq 40\%$ who underwent emergency isolated CABG between 2022 and 2024. Patients were assigned to either the Del Nido group (n=80) or the conventional blood cardioplegia group (n=70). Demographics, operative variables, postoperative complications, ventricular function changes, and short-term mortality were analysed. Myocardial recovery was assessed using Δ EF (postoperative minus preoperative LVEF).

Results: The Del Nido group demonstrated significantly shorter aortic cross-clamp and cardiopulmonary bypass times and required less intraoperative defibrillation. The incidence of postoperative atrial fibrillation was lower in the Del Nido group (18%) compared with conventional blood cardioplegia (29%). Improvement in ventricular function was greater with Del Nido (Δ EF $+5.8 \pm 2.1\%$) than with blood cardioplegia ($+3.2 \pm 2.4\%$). Rates of stroke, perioperative myocardial infarction, and early mortality were comparable between the groups.

Conclusion: Single-dose Del Nido cardioplegia provides effective and safe myocardial protection in emergency low-EF CABG, offering improved operative efficiency and superior early ventricular recovery without increasing perioperative complications.

Keywords: cardiopulmonary bypass, cardioplegic solutions, coronary artery bypass, heart ventricles, myocardial reperfusion injury

INTRODUCTION

Myocardial protection remains a central determinant of outcomes in coronary artery bypass grafting (CABG), particularly in patients with severely reduced left ventricular ejection fraction (LVEF). Despite advances in myocardial preservation and surgical techniques, patients with low LVEF continue to face in-

creased perioperative morbidity and mortality due to ischemia–reperfusion injury and poor ventricular recovery (1,4). The optimal cardioplegia strategy in this high-risk population, especially in emergency CABG, remains a subject of ongoing debate. Del Nido (DN) cardioplegia, originally developed for paediatric cardiac surgery, has recently gained wide application in adults because of its simplicity, single-dose administration, and prolonged myocardial protection duration (5,6,7). Current evidence suggests that DN may offer comparable or superior myocardial protection compared with conventional blood cardioplegia (BC), potentially reducing cross-clamp time, postoperative arrhythmias, and myocardial injury markers (8-9). However, most available studies are limited to elective procedures, and data in emergency settings or among patients with severely depressed ventricular function remain scarce (10-12).

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| Submitted: 10. Nov 2025. Revised: 05. Dec 2025, Accepted: 08. Dec 2025.

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Recent investigations have highlighted that improving myocardial protection in this subgroup could directly influence early ventricular recovery and postoperative outcomes (13,14). Given the ongoing evolution of myocardial protection strategies, evaluating the effectiveness of single-dose DN cardioplegia in emergency CABG for low LVEF patients is both clinically and scientifically relevant. Initially developed for paediatric cardiac surgery, Del Nido (DN) cardioplegia has become increasingly popular in adults due to its single-dose administration, extended arrest duration (up to 90 minutes), and ability to mitigate calcium overload. However, most evidence concerns elective, lower-risk populations, leaving uncertainty about its safety and efficacy in emergency cases and failing myocardium (15-16). Furthermore, prolonged cross-clamp duration is independently associated with adverse outcomes, emphasizing the need for efficient myocardial protection (17).

Patients undergoing emergency coronary artery bypass grafting (CABG) with severely reduced left ventricular ejection fraction (LVEF) represent one of the highest-risk groups in contemporary cardiac surgery, with myocardial ischemia-reperfusion injury and impaired contractile reserve contributing to significant perioperative morbidity (18). Therefore, selecting an effective cardioplegia strategy is essential for optimizing myocardial protection and postoperative recovery in this vulnerable population. Recent evidence has increasingly focused on optimizing myocardial protection strategies in high-risk coronary bypass populations. Several contemporary meta-analyses and large cohort studies have demonstrated that Del Nido cardioplegia provides comparable or superior myocardial protection compared with conventional blood cardioplegia in adult cardiac surgery, including CABG (19-21). Del Nido's extended arrest duration, lower calcium load, and simplified single-dose administration have been associated with reduced ischemia-reperfusion injury and improved early myocardial recovery, particularly in patients with ventricular dysfunction (18,19). Moreover, a comprehensive 2025 narrative review confirmed the safety and expanding use of Del Nido cardioplegia in adults, including those with low EF and complex surgical profiles (21). Despite these advances, most of the current evidence is derived from elective or mixed surgical cohorts, and the applicability of Del Nido cardioplegia in urgent settings with severely impaired ventricular function remains uncertain. A notable gap persists in the literature regarding its effectiveness in emergency CABG among patients with low LVEF, a subgroup in whom ischemic tolerance is significantly reduced and operative risk elevated (11).

The aim of this study was to compare intraoperative characteristics, myocardial recovery, and early postoperative outcomes between single-dose Del Nido and conventional blood cardioplegia in adults undergoing emergency CABG with reduced LVEF.

MATERIAL AND METHODS

Patients and study design

This retrospective single-centre study included 150 consecutive patients who underwent emergency isolated coronary artery bypass grafting (CABG) at the Trabzon Ahi Evren Thoracic and Cardiovascular Surgery Training and Research Hospital (Turkey) between October 2022 and September 2024.

All patients had preoperative left ventricular ejection fraction (LVEF) $\leq 40\%$ and required urgent surgical revascularization for acute coronary syndromes (11-13). Patients with previous cardiac surgery, combined valve or aortic procedures, or incomplete perioperative data were excluded.

Demographic variables, comorbidities, preoperative LVEF, intraoperative parameters (cross-clamp time, CPB duration, number of grafts, defibrillation requirement), and postoperative outcomes (atrial fibrillation, stroke, myocardial infarction, ICU stay, hospital stay, and 30-day mortality) were collected from institutional databases. Myocardial recovery was assessed by calculating the change in LVEF ($\Delta\text{EF} = \text{postoperative} - \text{preoperative}$).

Patients were divided into two groups according to the cardioplegia strategy used during surgery: the Del Nido group (DN group, $n=80$), who received single-dose Del Nido cardioplegia, and the blood cardioplegia group (BC group, $n=70$), who received conventional multidose blood cardioplegia.

Written informed consent was obtained from all participants or their legal representatives prior to surgery.

Ethical approval for the study was obtained from the relevant ethics committee (approval number: 2022/54).

Methods

Surgical technique and cardioplegia protocol. All procedures were performed via median sternotomy under moderate hypothermia ($32-34\text{ }^{\circ}\text{C}$) using standard cardiopulmonary bypass (CPB) with a membrane oxygenator and roller pump (6,7). Distal anastomoses were completed during aortic cross-clamping, followed by proximal anastomoses performed under partial clamping. In the Del Nido (DN) group, the cardioplegic solution was prepared with a 1:4 blood-to-crystalloid ratio using Plasma-Lyte A as a base, administered as a single 1200 mL dose at $4\text{ }^{\circ}\text{C}$. Supplemental doses (200-300 mL) were given only if cross-clamp time exceeded 90 minutes. In the blood cardioplegia (BC) group, a 4:1 blood-to-crystalloid mixture was used (2.6) (initial 1000 mL, then 200 mL every 15-20 minutes) at $4-8\text{ }^{\circ}\text{C}$. Cardioplegia was delivered antegrade through the aortic root in all cases. Myocardial temperature, arrest time, and hemodynamic stability were monitored continuously. Rewarming and weaning from cardiopulmonary bypass (CPB) were performed under standardized institutional protocols.

Statistical analysis

Continuous variables were expressed as mean \pm standard deviation and compared using Student's t-test or Mann-Whitney U-test, depending on distribution. Categorical variables were compared using Chi-square or Fisher's exact test. Two-tailed p-values <0.05 were considered statistically significant.

RESULTS

A total of 150 patients were included: 80 received DN cardioplegia and 70 received BC. Baseline demographic and clinical characteristics were comparable between the two groups, including age, sex distribution, prevalence of diabetes and hypertension, chronic kidney disease, and preoperative LVEF (Table 1).

Intraoperative Outcomes: Del Nido cardioplegia was associated with shorter aortic cross-clamp duration (81.8 ± 17.3 vs.

Table 1. Baseline demographic and preoperative clinical characteristics of patients undergoing isolated CABG receiving Del Nido versus blood cardioplegia

Variable	Del Nido (n=80)	Blood Cardioplegia (n=70)	p-value
Age (years)	64.8 ± 9.1	65.3 ± 8.7	0.72
Male sex (%)	62 (77.5%)	52 (74.2%)	0.64
Hypertension (%)	49 (61.3%)	45 (64.2%)	0.71
Diabetes mellitus (%)	32 (40.0%)	30 (42.8%)	0.75
Chronic kidney disease (%)	12 (15.0%)	10 (14.2%)	0.89
Preoperative LVEF (%)	32.1 ± 5.2	32.4 ± 4.9	0.78

94.2±19.1 minutes) and shorter cardiopulmonary bypass time (111.9 ± 22.8 vs. 128.3 ± 25.6 minutes). The need for intraoperative defibrillation was also lower in the Del Nido group compared with conventional blood cardioplegia (11.3% vs. 27.1%) (Table 2, Figure 1).

Table 2. Intraoperative outcomes of patients undergoing isolated CABG receiving Del Nido versus blood cardioplegia

Outcome	Del Nido (n=80)	Blood Cardioplegia (n=70)	p-value
Cross-clamp time (min)	81.8 ± 17.3	94.2 ± 19.1	0.001
CPB time (min)	111.9 ± 22.8	128.3 ± 25.6	0.002
Number of grafts	3.1 ± 0.9	3.2 ± 1.0	0.54
Need for defibrillation (%)	9 (11.3%)	19 (27.1%)	0.01

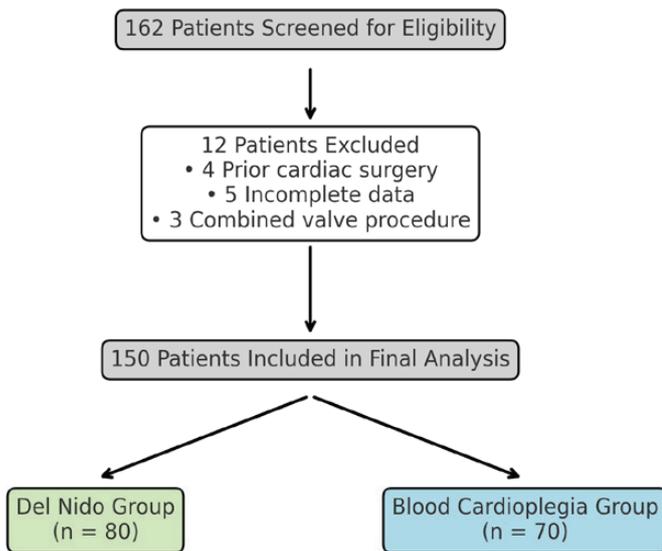


Figure 1. Flow diagram of patient selection and group allocation

Patients in the DN group demonstrated higher postoperative LVEF at discharge (41.0±4.8% vs. 37.8±5.1%; p=0.012). The incidence of postoperative AF was significantly lower with DN (18% vs. 29%; p=0.046). Rates of stroke and perioperative myocardial infarction were low and did not differ significantly between the groups. Thirty-day mortality was 3.8% in the DN group and 5.7% in the BC group (p=0.38). ICU stay was shorter in the DN group (3.1±1.8 vs. 3.9±2.1 days; p=0.048), while total hospital stay showed a non-significant trend toward reduction (6.8±2.7 vs. 7.4±3.1 days; p=0.09) (Table 3, Figure 2). Improvement in ventricular function was greater in the Del Nido group, with ΔEF calculated as +5.8±2.1% compared with

+3.2±2.4% in the blood cardioplegia group. Postoperative atrial fibrillation occurred less frequently in the Del Nido cohort (18% vs. 29%).

Table 3. Postoperative outcomes of patients undergoing isolated CABG receiving Del Nido versus blood cardioplegia

Outcome	Del Nido (n=80)	Blood Cardioplegia (n=70)	p-value
ΔEF (%)	+5.8 ± 2.1	+3.2 ± 2.4	0.009
Atrial fibrillation (%)	14 (18%)	20 (29%)	0.04
Stroke (%)	1 (1.3%)	2 (2.8%)	0.52
Perioperative MI (%)	1 (1.3%)	2 (2.8%)	0.52
ICU stay (days)	3.1 ± 1.8	3.9 ± 2.1	0.03
Hospital stay (days)	7.8 ± 3.2	8.4 ± 3.6	0.18
30-day mortality (%)	3 (3.8%)	4 (5.7%)	0.61

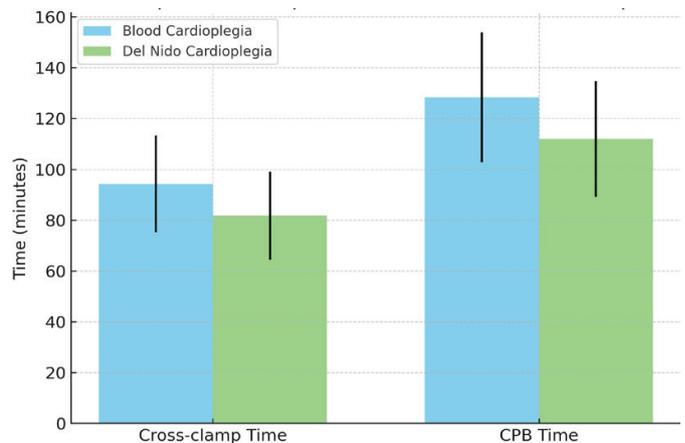


Figure 2: Comparison of Aortic Cross-Clamp and Cardiopulmonary Bypass Durations Between Cardioplegia Strategies

DISCUSSION

This study indicates that Del Nido cardioplegia provides effective myocardial protection in patients with low LVEF undergoing emergency CABG. Compared with conventional BC, DN significantly reduced operative times, improved postoperative ventricular function, and decreased atrial fibrillation without increasing mortality or neurological events. These findings align with prior studies supporting DN’s safety and efficacy in adult cardiac surgery (3–9). The trends further demonstrate DN’s advantages in myocardial recovery and rhythm stability. The advantages of DN likely stem from its composition: lidocaine and magnesium stabilize cellular membranes and reduce calcium influx, while mannitol mitigates oxidative injury (2,4,6). The single-dose approach minimizes interruptions, reducing ischemia–reperfusion injury, which is particularly critical in compromised myocardium. Reduced postoperative atrial fibrillation may reflect improved ionic homeostasis. Recent meta-analyses confirm DN as a superior or equivalent myocardial protection method in high-risk cardiac surgery (1,2,10,14). The present study demonstrates that single-dose Del Nido cardioplegia provides safe and effective myocardial protection in adults undergoing emergency coronary artery bypass grafting (CABG) with reduced left ventricular ejection fraction (LVEF). In this high-risk clinical setting, Del Nido was associated with shorter cross-clamp and cardiopulmonary bypass durations, reduced need for intraoperative defibrillation, and su-

perior early ventricular recovery, as reflected by a significantly higher Δ EF compared with conventional blood cardioplegia. These findings align with contemporary evidence supporting the increasing use of Del Nido cardioplegia in adult cardiac surgery (15–17).

Several recent meta-analyses and large cohort studies have shown that Del Nido offers myocardial protection equivalent or superior to blood cardioplegia, particularly by prolonging arrest duration, reducing calcium influx, and enhancing metabolic stability during ischemia–reperfusion events (15,16). Its lower calcium load and lidocaine-enriched composition have been proposed to mitigate intracellular calcium overload and arrhythmogenic potential, contributing to improved early postoperative myocardial function (18,19). The results of our study, demonstrating greater improvement in postoperative ejection fraction, support these mechanistic insights.

In high-complexity adult cardiac operations, especially those involving prolonged ischemic times, Del Nido cardioplegia has been shown to maintain adequate myocardial protection while reducing interruptions for repeated dosing (17). Our findings of shorter cross-clamp and bypass times are consistent with this benefit and may partly explain the improved Δ EF and reduced arrhythmia rates observed in the Del Nido group. Lower incidence in the Del Nido group (AF14 (18%) of postoperative atrial fibrillation in our cohort similarly agrees with recent comparative studies reporting enhanced electrophysiological recovery with Del Nido (18–20).

Importantly, the safety profile of Del Nido cardioplegia observed in our study, evidenced by comparable rates of stroke, perioperative myocardial infarction, and early mortality between groups, is supported by a 2025 narrative review summarizing extensive adult surgical experience (21). This confirms that Del Nido cardioplegia does not increase adverse neurological or ischemic complications, even in patients with significantly compromised ventricular reserve.

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Despite advances in the literature, limited data exist specifically for emergency CABG patients with low LVEF—a particularly vulnerable subgroup with diminished ischemic tolerance. Most previously published studies have evaluated elective or mixed surgical cohorts (11). Our study contributes important evidence supporting the use of Del Nido in this context, demonstrating superior early myocardial recovery without increasing perioperative risk.

This study is limited by its retrospective design and the absence of postoperative biochemical markers (e.g., troponin, CK-MB), which were not routinely available for all emergency CABG patients. Future prospective studies with standardized biomarker evaluation and long-term ventricular function follow-up are warranted. Nevertheless, the consistency of our findings with recent high-quality meta-analyses, cohort studies, and narrative reviews strengthens the clinical relevance of our results.

In conclusion, Del Nido cardioplegia offers a simple, efficient, and reproducible myocardial protection strategy suitable even in high-risk emergency CABG cases.

ACKNOWLEDGEMENT

The authors would like to thank the surgical team, perfusionists, and nursing staff of the Department of Cardiovascular Surgery, Trabzon Ahi Evren Thoracic and Cardiovascular Surgery Training and Research Hospital, for their invaluable support during data collection and patient care.

FUNDING

No specific funding was received for this study.

SPARENCY DECLARATION

Conflicts of interest: None to declare.

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