

Modified Del Nido Versus Custodiol® Cardioplegia for Myocardial Protection in Adult Patients Undergoing Cardiac Surgery; A Prospective Randomized Double-Blinded Clinical Trial

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ABSTRACT

Background: Cardioplegia is essential for myocardial protection. Modified Del Nido and Custodiol® cardioplegia have been successfully used; however, a limited number of clinical trials compared both solutions. Our objective was to evaluate the effectiveness of Modified Del Nido cardioplegia against Custodiol® in protecting the myocardium in adult patients having open heart surgery.

Methods: In this prospective randomized double-blinded clinical trial, fifty-eight adult patients registered for elective open heart surgery at Fayoum University hospitals, Fayoum, Egypt, between February 2022 and November 2023, have enrolled. Patients were randomized to receive either a Modified Del Nido cardioplegia solution (MDN group) ($n = 29$) or Custodiol® cardioplegia (C group) ($n = 29$). The primary outcome was Troponin I ($\mu\text{g/L}$) measured 24 h after surgery.

Results: Both groups had comparable demographics. Troponin I was much lower in the MDN group (median = 2.9, IQR = 2.7-3.2) than in the C group (median = 3.6, IQR = 3.1-4.1) 24 h after surgery. Similarly, there were substantial differences in CK-MB between the two groups 24 h postoperatively. The MDN group had better results in terms of time taken for cardiac arrest, the incidence of ventricular fibrillation upon cross-removal, and the percentage of patients requiring inotropes. The MDN group shows notably reduced hospital length of stay (LOS), intensive care unit length of stay (ICU LOS), and weaning from mechanical ventilation times.

Conclusions: Adult cardiac surgery may be performed safely and successfully using Modified Del Nido cardioplegia in comparison to Custodiol® cardioplegia.

Keywords: Cardiac surgery, Custodiol®, mechanical ventilation, modified del nido, myocardial

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INTRODUCTION

Cardioplegia solutions limit the metabolic activity of the myocardium. It increases the myocardium's ability to withstand prolonged ischemia time. These directly affect surgical outcomes. Cardioplegia has been regarded as a cornerstone for myocardial protection during cardiac

surgery with cardiopulmonary bypass and cardiac arrest.^[1,2] Single-dose strategies for long-acting cardioplegic solutions are advantageous because they minimize cross-clamp duration, enable uninterrupted operation, and enhance cardiac protection.^[3] Bretschneider^[4] first detailed the use

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of Custodiol® (histidine-tryptophan-ketoglutarate) solution in the 1970s. It is used as an alternative to hyperkalemic crystalloid solutions, particularly in difficult cardiac procedures, and it is also employed to preserve organs during organ transplant surgery.^[5,6] Pedro Del Nido^[7] and associates developed a novel cardioplegic remedy (Del Nido cardioplegia) for juvenile cardiac procedures in the 1990s. However, a lot of research has lately suggested using it for adults.^[8] Plasma-Lyte A, an electrolyte solution with a calcium-free composition akin to extracellular fluid, serves as the foundation solution for conventional Del Nido cardioplegia.^[7] Nevertheless, the unavailability of Plasma-Lyte A in several nations hinders its use. When making Del Nido cardioplegia, often referred to as Modified Del Nido cardioplegia, some publications have recommended using lactated Ringer's as a base solution rather than Plasma-Lyte A.^[9] Custodiol® and Modified Del Nido cardioplegia may be administered as a single dose with minimum surgical interruptions and appropriate myocardial protection. However, the research also lacks the idea that one is better than another.^[1] Also, a limited number of clinical studies have compared both cardioplegic solutions directly; to our knowledge, no prospective clinical trial has compared both cardioplegic solutions in adult patients until the conduction of the present research. Therefore, the purpose of this research was to evaluate the effects of Modified Del Nido cardioplegia and Custodiol® on myocardial protection and clinical outcomes in adult patients having heart surgery.

METHODS

The principles of the Declaration of Helsinki were adhered to in this double-blinded, randomized trial. The Fayoum University Hospital Ethical Review Board (R193) accepted the research design, and each subject provided written informed consent. Following registration on ClinicalTrials.gov (NCT05221294; primary investigator: Mahdy Ahmed Abdelhady; registration date: (02/02/2022); (<https://classic.clinicaltrials.gov/ct2/show/NCT05221294>). The trial was carried out at Fayoum University Hospitals; fifty-eight adult patients who were scheduled for elective open heart surgery between February 2022 and November 2023 were enrolled.

Patients were randomly assigned to two groups in a 1:1 ratio using computer-generated random numbers. The opaque envelopes containing the numbers were opened by research investigators in the operating room (OR). MDN group (got Modified Del Nido cardioplegia solution) and C group (received Custodiol® cardioplegia). The cardioplegia solution was prepared and infused via the anesthesiology

intern who was not included in the study, so until the conclusion of the trial, all participants, researchers, and data collectors were blinded to the group assignment.

Inclusion criteria: patients ≥ 18 years old, scheduled for elective single valve replacement surgery or coronary artery bypass grafting surgery.

Exclusion criteria

- Emergency surgery.
- Chronic kidney disease.
- Hepatic impairment.
- Redo surgery.
- Severe psychiatric illness.

Preoperative testing included a full blood count, coagulation profile, assessment of liver and renal functions, and electrolytes for every patient. Echocardiography, chest radiography, and electrocardiography (ECG) were routinely performed. On-demand requests were made for carotid artery duplex and coronary angiography.

On the morning of the procedure, patients received an intramuscular injection of 10 mg of morphine as premedication. A five-lead ECG device was used to monitor heart rate, rhythm, and ST segments (leads II and V5) before the administration of anesthesia. A peripheral venous cannula was inserted, and a pulse oximeter probe was fastened. Under local anesthetic, a 20 G cannula was placed into the right or left radial artery to monitor arterial pressure and take a blood sample. Following pre-oxygenation, midazolam (2–5 mg), fentanyl (10 µg/kg), Propofol (3–4 mg/kg), and Atracurium (0.5 mg/kg) were used to produce general anesthesia.

To achieve normocarbia, patients' tracheas were intubated and they underwent mechanical ventilation with oxygen in the air. A capnogram and radial arterial blood gas study verified this. Additionally, a urine catheter and an esophageal temperature probe were inserted. For medication infusion, a triple-lumen central venous catheter was placed into the right internal jugular vein. To sustain muscular relaxation, an Atracurium infusion at a rate of 0.5 mg/kg/h was administered together with isoflurane at a concentration of 0.4–1%. Patients had Atracurium infusion along with a 50–100 µg/kg/min Propofol infusion during extracorporeal circulation.

A median sternotomy was used for all procedures. To obtain an active clotting time > 480 s, the patients received intravenous heparin (300–500 units/kg body weight) before the start of cardiopulmonary bypass (CPB). An ascending

aortic cannula and a bicaval/two-stage right atrial cannula were used to implement CPB. Before, during, and after CPB, the mean arterial pressure was adjusted to be higher than 60 mmHg (pump blood flow: 2.4 l/min/m²).

Myocardial protection

The antegrade approach was used to give cardioplegic solution via either the coronary ostia or the aortic root, as needed. Patients were assigned to either Modified Del Nido cardioplegia or Custodiol® cardioplegia.

The ready Custodiol® cardioplegia solution was infused at a pressure of 150–200 mmHg for 6–8 min with a temperature of 4–8°C in a single dosage of 25 ml/kg. Custodiol® is a ready-to-use sterile cardioplegia that contains the following: mannitol (30 mmol/L), sodium chloride (15 mmol/L), potassium chloride (9 mmol/L), magnesium chloride (4 mmol/L), calcium chloride (0.015 mmol/L), histidine (180 mmol/L), tryptophan (2 mmol/L), and ketoglutarate (1 mmol/L) with pH 7.4–7.45 at 4°C and osmolality 310 mosmol/Kg.

Modified Del Nido cardioplegia was prepared at the operating room, and lactated Ringer's solution was used as a crystalloid base with a crystalloid: blood ratio of 4:1. The dosage (20 ml/kg, with a maximum dose of 1000 ml) was administered at 200–300 mmHg administration pressure and a 4°C temperature, with a possible additional dose given 90 min after the first dose. This is the contents of the Modified Del Nido cardioplegia: 13 ml of potassium chloride (2 mEq/L), 13 ml of sodium bicarbonate (1 mEq/ml), 16.3 ml of mannitol 20%, 4 ml of magnesium 50% and 6.5 ml of lidocaine 2%, in 1000 ml of lactated Ringer's solution.

The primary outcome

Troponin I (µg/L) 24 h post-surgery is the main measure used to compare the two cardioplegia solutions utilized in terms of myocardial protection.

Secondary outcomes included

1. Total volume of cardioplegia solution (in ml).
2. The cross-clamp and CPB times (in min).
3. Time (in seconds) to cardiac arrest following cardioplegia infusion.
4. Ventricular fibrillation after cross-clamp removal.
5. Postoperative left ventricular ejection fraction.
6. The need for inotropes
7. CK-MB (U/L) one day following surgery.
8. The level of serum lactate, 24 h following surgery.
9. New-onset postoperative atrial fibrillation (AF).
10. Rate of myocardial infarction (MI) following surgery (defined as; type 5 myocardial ischemia according to the

joint American College of Cardiology/American Heart Association/European Society of Cardiology/World Health Federation task force of procedure-related myocardial injury 2018).^[10]

11. The time (in h) to wean off of mechanical ventilation.
12. Duration of stay in ICU, duration of stay in hospital (in days), and mortality.

Sample size calculation

Based on prior research by Talwar *et al.*^[11] We estimated the sample size. In their study, the mean $\pm$ SD of 24-h troponin I was 4.19 ± 2.91 in the Del Nido group and 8.15 ± 5.26 ng/mL in the Custodiol group. So, for each group, a minimum of 26 patients was required to achieve power levels of 0.90 and alpha levels of 0.05. To account for dropouts, the computed sample size was raised by 10%–29 in each group.

The necessary sample size was estimated using the G*Power program version 3.1.9.2 from the Institute of Experimental Psychology at Heinrich Heine University in Düsseldorf, Germany.

Statistical analysis

IBM SPSS statistics for Windows version 27 (IBM Corp., Armonk, NY) and GraphPad Software version 6.05; Dotmatics. were used for the statistical analysis of the obtained data. The Shapiro-Wilk test was used as the normality test. Quantitative variables, such as age and Body mass index (BMI), had a normal distribution and were expressed as mean $\pm$ standard deviation (SD). The two groups' means were compared using an unpaired *t*-test. The outcome variables were not distributed normally and were reported as the median and interquartile range (IQR); a significant test, the Mann–Whitney *U* test, was used. The treatment effect was provided as a median difference with its 95% Confidence interval (95% CI). Numbers and percentages were employed to convey the qualitative data, and the Chi-squared test or Fisher's exact test was utilized to assess the statistical significance. The treatment impact was estimated using the 95% confidence interval (CI) and relative risk (RR). A *P* value of less than 0.05 on both sides was deemed statistically significant.

RESULTS

Based on the predetermined inclusion and exclusion criteria, the eligibility of 65 patients was evaluated for this investigation. Seven patients were not included in the analysis: three were scheduled for off-pump Coronary artery bypass grafting (CABG), two had emergency surgery, and two underwent reoperation. A Modified Del

Nido cardioplegia solution (MDN group) and Custodiol® cardioplegia (C group) were randomly given to the remaining 58 patients, as shown in the CONSORT flow diagram [Figure 1].

Regarding the baseline characteristics, there was no discernible difference between the two groups [Table 1]. In addition, the total cardioplegia volume, the cross-clamp (CX) duration, CPB time, and the 24-hour lactate level were not substantially different [Table 2]. Pre and postoperative ejection fractions (EF%) did not significantly vary between the two groups, and neither did the percentage changes in EF for intra-group or inter-group analysis [Table 3]. Between the two groups, the incidence of postoperative MI did not differ significantly [Table 4]. In both groups, no new cases of postoperative AF were noted. Furthermore, no deaths were noted.

When comparing Modified Del Nido cardioplegia to

Custodiol® cardioplegia, the time taken for cardiac arrest was considerably shorter (median, IQR 20, (20–24) vs. 30, (28–34) seconds, respectively; the difference in median (95% CI) was -10.0 (-11.0 , -7.0), with a P value < 0.001) [Table 2].

Following cross-clamp removal, the MDN group saw a much lower incidence of ventricular fibrillation than the C group (13.8% vs. 41.4% with RR (95% CI) 0.333 (0.122, 0.913) and 0.019). Additionally, there was a significant difference in the percentage of patients who needed inotropes between the MDN and C groups (51.7% vs. 79.3% with RR (95% CI) 0.652 (0.438, 0.971) and P value 0.027) [Table 4].

At 24 h after surgery, there was a significant difference in troponin I ($\mu\text{g/L}$) between the two groups; the median, IQR, was 2.9 (2.7–3.2) in the MDN group and 3.6 (3.1–4.1) in the C group, with a median difference (95% CI) of -0.7 (-1.0 , -3.0) and a P value < 0.001 . Similarly, the MDN group had considerably lower CK-MB (U/L) 24 h after surgery [Figure 2]. When comparing the MDN group to the C group, the period for weaning off mechanical ventilation, the ICU LOS, and the hospital LOS were all noticeably shorter [Table 2].

DISCUSSION

Compared to Custodiol® cardioplegia, our research demonstrated that Modified Del Nido cardioplegia might be used safely and successfully for adult cardiac surgery. Modified Del Nido cardioplegia also demonstrated some benefits, including a reduced time to asystole following cardioplegia administration, a greater rate of spontaneous rhythm recovery following cross-clamp

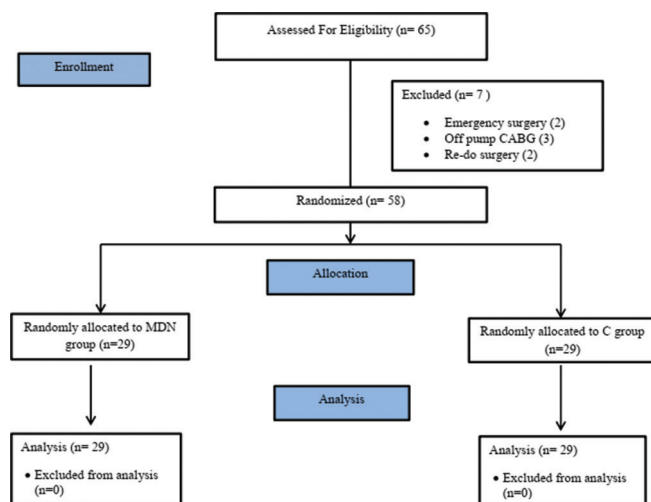


Figure 1: CONSORT flow diagram of the study population

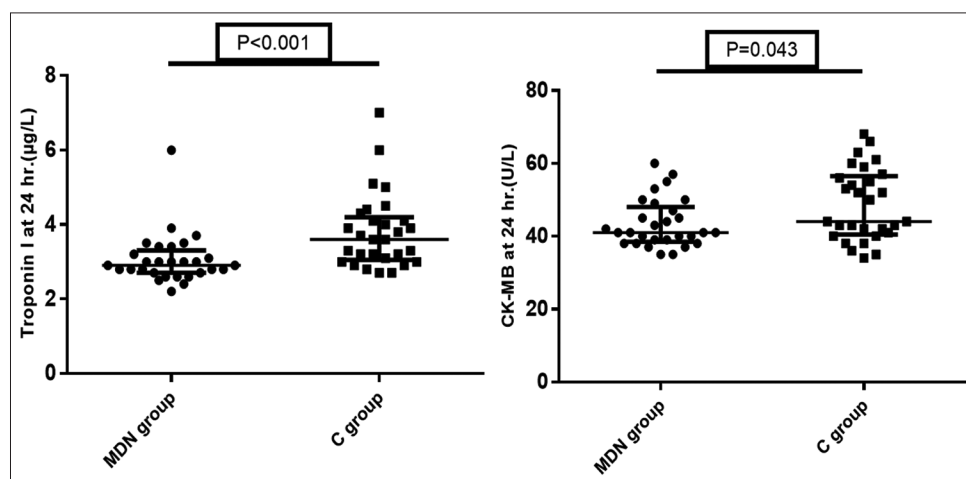


Figure 2: Jitter plot with median and IQR for Troponin I at 24 hr. and CK-MB at 24 hr. levels in both study groups. C group = Custodiol® cardioplegia and MDN = Modified Del Nido cardioplegia

removal, a decreased need for inotropic support, lower cardiac enzyme levels, a shorter duration of mechanical ventilation, and a shorter LOS in the intensive care unit and hospital. However, whether comparing the preoperative and postoperative results within the same group or when comparing the percent change between the two groups, the

EF% did not vary. Also, the incidence of postoperative MI did not vary between the two groups. In both groups, no cases of new-onset postoperative AF were noted.

Modified Del Nido cardioplegia is an extracellular cardioplegia solution that induces cardiac arrest by supplying a high extracellular potassium concentration, whereas Custodiol® cardioplegia is an intracellular-type cardioplegia that involves the balance of intra- and extracellular Na⁺. Both forms of cardioplegia solutions are used to produce cardiac arrest to preserve the myocardium from damage and to assist surgical operations.^[7,12]

Cardiac troponin level is typically raised after cardiac surgery, and the 24 h postoperative troponin has been assessed to be an independent predictor of short and long-term outcomes.^[13] This study's results regarding CK-MB and 24 h postoperative Troponin I levels showed a significant difference between the MDN and C groups. These findings suggest that Modified Del Nido cardioplegia offers greater myocardial protection than Custodiol® cardioplegia.

Table 1: Baseline characteristics

	MDN group (n=29)		Custodiol® cardioplegia (C group) (n=29)		P
Age (years)	41.6	14.9	41.8	14.3	0.971
BMI	28.4	3.3	27.2	3.9	0.223
Sex					
Male	14	48.3%	12	41.4%	0.597
Female	15	51.7%	17	58.6%	
Preoperative ECG					
AF	4	13.8%	2	6.9%	0.670
NSR	25	86.2%	27	93.1%	
Preoperative EF%	64	(56–67)	58	(55–66)	0.233
Surgery type					
Valvular	15	51.7%	13	44.8%	0.599
CABG	14	48.3%	16	55.2%	

AF=Atrial fibrillation, BMI=Body mass index, CABG=Coronary artery bypass grafting, NSR=Normal sinus rhythm; n=Number. Values are presented as mean±SD or numbers (percentages)

Table 2: Different variables outcomes

	MDN group (n=29)		Custodiol® cardioplegia (C group) (n=29)		Median difference (95% CI)	P
	Median	IQR	Median	IQR		
Troponin I at 24 hr.(µg/L)	2.9	(2.7– 3.2)	3.6	(3.1–4.1)	–0.7 (–1.0, –3.0)	<0.001
Total cardioplegia volume (ml.)	1500	(1000– 1500)	1500	(1375–1700)	0 (–375.0, 0.0)	0.077
Time taken for arrest (seconds)	20	(20–24)	30	(28–34)	–10.0 (–11.0, –7.0)	<0.001
CX time (min)	100	(61– 120)	110	(90– 120)	–10.0 (–30.0, 5.0)	0.160
CPB time (min)	130	(100–150)	135	(120–155)	–5.0 (–30.0, 10.0)	0.341
CK-MB at 24 hr.(U/L)	41	(39–47)	44	(41–56)	–3.0 (–10.0, 0.0)	0.043
lactate at 24 hr.(mmol/L)	2.5	(2–3)	3	(2–3.5)	–0.5 (–1.0, 0.10)	0.081
ICU LOS (in days)	2	(2–2)	3	(2–3)	–1.0 (–1.0, 0.0)	0.015
hospital LOS (in days)	4	(3–4)	4	(4–5)	0.0 (–1.0, 0.0)	0.018
Time for weaning from MV (hrs.)	4	(3–5)	5	(4.5–6)	–1.0 (–1.5, –0.5)	0.004

Values are presented as median (IQR). CPB=cardio-pulmonary bypass, CI=confidence interval, CX time=Cross-clamp time, IQR=Inter-quartile range, ICU=Intensive care unit, LOS=Length of stay, MV=Mechanical ventilation, MDN=Modified Del Nido cardioplegia

Table 3: Comparison of the EF% and percent change between both groups

	MDN group (n=29)		Custodiol® cardioplegia (C group) (n=29)		Median difference (95% CI)	P
	Median	IQR	Median	IQR		
Preoperative EF%	64	(56–67)	58	(55–66)	6.0 (–1.0, 7.0)	0.233
Postoperative EF%	64	(55–67)	60	(55–65)	4 (0.0, 6.0)	0.171
Percentage Change in EF%	0.00	(–1.52–0.00)	0.00	(–3.23–3.45)	0.00 (–2.86, 1.71)	0.822
P		0.681		0.861		

Values are presented as median (IQR). CI=Confidence interval, EF=Ejection fraction, IQR=Inter-quartile range

Table 4: Incidence of VF, MI, and inotropic requirements

Items	Category	MDN group (n=29)		Custodiol® cardioplegia (C group) (n=29)		RR (95% CI)	P
VF after CX removal	Yes	4	13.8%	12	41.4%	0.333 (0.122, 0.913)	0.019
	No	25	86.2%	17	58.6%		
Need for Inotropes	Yes	15	51.7%	23	79.3%	0.652 (0.438, 0.971)	0.027
	No	14	48.3%	6	20.7%		
Postoperative MI	Yes	1	3.4%	2	6.9%	0.5 (0.048, 5.218)	1.000
	No	28	96.6%	27	93.1%		

Values are presented as numbers and percent. CX=Cross-clamp, MDN=Modified Del Nido cardioplegia, MI=Myocardial infarction, N=Number; VF=Ventricular fibrillation

Additionally, Talwar *et al.*^[11] found that, in children, Del Nido cardioplegia resulted in a lower 24-hour Troponin I level than histidine-tryptophan-ketoglutarate (HTK) (Custodiol®) cardioplegia. Furthermore, Bojan *et al.*^[14] found that newborns who received HTK (Custodiol®) cardioplegia had greater postoperative troponin I levels than those with warm blood cardioplegia. Additionally, Lee *et al.*^[15] discovered that among patients who had minimally invasive cardiac surgery, postoperative peak levels of troponin I and CK-MB were considerably lower after Del Nido cardioplegia as compared to HTK (Custodiol®). However, in their retrospective analysis, Duan *et al.*^[16] did not discover a statistically significant difference in postoperative peak troponin levels between the groups with del nido (DN) and HTK (Custodiol®) cardioplegia.

In this investigation, MDN was much quicker than Custodiol® cardioplegia to produce cardiac arrest, with a greater rate of spontaneous restoration to sinus rhythm following CX removal and fewer requirements for inotropic assistance. Numerous studies have shown comparable results.^[11,14,16] These results show that MDN is linked to a lower risk of myocardial ischemia-reperfusion damage; calcium influx is the primary cause of ischemic-reperfusion injury. Magnesium sulfate, a calcium blocker, is included in both cardioplegia solutions to prevent calcium influx. In addition, MDN includes lidocaine; lidocaine provides membrane stability by blocking the rapid sodium channels in the heart, protecting against sodium currents, which can produce spikes of depolarization and thus arrhythmias. Because lidocaine and magnesium work together to inhibit calcium as well, MDN is better able to prevent reperfusion damage and provide improved membrane stability.^[11,16,17] Additionally, the faster the heart arrests following CX, the greater the preservation of intracellular adenosine triphosphate (ATP) reserves.^[18] In our investigation, individuals who had Custodiol® cardioplegia required far more inotropic assistance. A comparable result was also reported by Talwar *et al.*^[11] Other research^[15,16,18,19] did not identify a statistically significant difference between Del Nido cardioplegia and HTK (Custodiol®) regarding inotropic support. However, some studies indicated a decreased requirement for inotropic support after Del Nido cardioplegia as compared to other forms of cardioplegia solutions other than HTK (Custodiol®).^[20-25] Inotropic support medications are commonly used after cardiac surgery to enhance hemodynamic function, prevent hypotension and to prevent low cardiac output syndrome (LCOS). Numerous definitions have been proposed to characterize LCOS of these; two definitions are based on the usage of inotropic support, while two more are based on the

time length of inotropic support.^[26] Numerous additional definitions of LCOS have also included a cardiac index of less than 2.0 L/min/M².^[27,28] Talwar *et al.*'s research^[11] revealed that the DN group's CI values were considerably greater than the HTK (Custodiol®) group's after 6 and 24 h following the discontinuation of CPB. These results may indicate that MDN cardioplegia, as opposed to Custodiol® cardioplegia, can protect against LCOS following cardiac surgery.

Numerous factors determine times of MV, ICU LOS, and hospital LOS following cardiac surgery; we observed that MDN cardioplegia outperformed Custodiol® cardioplegia in these parameters. This is in line with the findings of Talwar *et al.*,^[11] who compared Del Nido and HTK (Custodiol®) cardioplegia and reported similar outcomes. Nonetheless, Duan *et al.*^[16] reported a much shorter ICU LOS, with no difference between Del Nido and HTK (Custodiol®) cardioplegia in terms of MV or hospital LOS duration. Additionally, Kantathut N, *et al.*^[9] described that the MDN group had shorter hospital and ICU lengths of stay as compared to the blood cardioplegia group, with no change in MV duration. Moreover, Li *et al.*^[29] in their meta-analysis have demonstrated a shorter MV time and lower ICU LOS with Del Nido when compared with traditional cardioplegia. Better myocardial protection and lesser demand for inotropic support linked with MDN might explain our results. However, as many of these studies, including the present one, evaluated both variables as continuous ones, the cut-off criteria for ICU and hospital LOS in the majority of reporting studies are not consistent or standardized.^[30]

When comparing each group's postoperative left ventricular ejection fraction (LVEF) to its preoperative value, as well as the postoperative values and the % change between the two groups, we could not find any differences. An analysis of the same result was provided by Kantathut N, *et al.*^[31] Furthermore, no change in LVEF or % change was seen between MDN and blood cardioplegia by Kantathut N *et al.*^[9]

Regarding postoperative mortality and serum lactate 24 h after surgery, we did not find any differences between the two groups. Kantathut N. *et al.*,^[31] Misra S *et al.*^[32] and Talwar *et al.*^[11] reported the same results. Furthermore, Chan J *et al.*^[33] did not find any differences regarding the mortality rate, new onset of AF or cerebrovascular stroke when comparing blood, Del Nido and Custodiol® cardioplegia for minimally invasive cardiac surgery.

Finally, an important item to be discussed is the cost-effectiveness. In developing countries, the low-cost medications are usually preferred if they have the same effectiveness and safety. In their study, Talwar *et al.*^[11] highlighted the cost-effectiveness of Del Nido when compared with HTK (Custodiol®) cardioplegia.

Study limitations

The present research has some limitations. Firstly, all the individuals were singled out and had either CABG or valvular surgery performed, although it was not statistically significant. The fact that all of our patients are adults and native Egyptians may restrict how broadly applicable our findings may be, in addition to the Lack of preoperative scoring assessment e.g. EURO score. Inadequate outcome comparisons were also caused by the dearth of clinical studies comparing MDN to Custodiol® cardioplegia in adult patients. Furthermore, we did not assess the individuals' cardiac output, cardiac index, or vasoactive inotropic score, as inotropic support was assessed as a yes/no variable. Finally, a single measurement of cardiac enzymes and a brief period of follow-up in addition to measuring the LOS in days not h, represents another limitation.

CONCLUSION

Adult cardiac surgery may be performed safely and successfully using Modified Del Nido cardioplegia. Compared to Custodiol® cardioplegia, it is linked to a quicker onset, lesser myocardial injury, less release of cardiac enzymes, a shorter MV period, and a shorter ICU LOS. We recommend further studies on a wider range of populations to validate these findings.

List of abbreviations

MDN: Modified Del Nido.
ICU: Intensive care unit.
LOS: Length of stay.
MV: Mechanical ventilation.
OR: Operative room.
ECG: Electrocardiography.
CPB: Cardiopulmonary bypass.
VF: Ventricular fibrillation.
AF: Atrial fibrillation.
MI: Myocardial infarction.

Authors' contributions

Data collection: MAH, MAA, MSG, ASG, AAH
Data analysis: MAA, MAH, ASG
Writing: MAH, ASG, MAA, MSG
Revising: MAH, MAA, MSG, ASG, AAH
Study design: MAA, MAH, MSG, ASG, AAH

Patient recruitment: MAA

All authors contributed equally to this work.

Corresponding author and the guarantor: MAA.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

The ethical review board of Fayoum University Hospital approved the study design before the start of the study (R193) according to the relevant guidelines and regulations. Written informed consent was obtained from all patients.

Consent for publication

Not Applicable.

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Conflicts of interest

The authors declare no conflicts of interest.

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