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ORIGINAL ARTICLE / ÖZGÜN MAKALE

The off-pump coronary artery bypass grafting has favorable effect on neurological causes of mortality

Çalışan kalpte koroner arter baypas cerrahisinin nörolojik mortaliteye olumlu etkileri

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ABSTRACT

Background: This study aims to evaluate the effect of off-pump coronary artery bypass grafting on neurological causes of mortality.

Methods: Between November 1st, 2014 and December 31st, 2022, a total of 1,154 off-pump coronary artery bypass grafting patients (963 males, 191 females; mean age: 64±10.9 years; range, 13 to 95 years) were retrospectively analyzed. Demographic characteristics, preexisting comorbidities, perioperative status, and postoperative clinical outcomes of the patients were recorded. Survival analysis was carried out.

Results: No-touch aorta coronary artery bypass grafting was performed 958 (83%) patients and single side-biting clamp was used in 196 (17%) patients. Two-hundred seventy-one (23.5%) patients were in an emergent condition, and 63 (5.5%) patients had a history of stroke and/or transient ischemic attack preoperatively. Concomitant carotid endarterectomy was performed in 50 (4.3%) patients. Postoperatively, 139 (12%) patients had atrial fibrillation and five (0.4%) patients had stroke. Seven patients (0.6%) died in the hospital and one (0.08%) patient died in the postoperative 30-day period. One-year, three-year, and five-year survival rates were 98.7%, 97.4%, and 96.5%, respectively.

Conclusion: Off-pump coronary artery bypass grafting is associated with a low incidence of perioperative stroke. Avoidance of aortic manipulation in off-pump coronary artery bypass grafting may reduce the risk of adverse neurological effects of cardiopulmonary bypass. We attribute the long-term survival to shorter lengths of stay in the intensive care unit and hospital and less need for blood products after surgery.

Keywords: Internal mammary artery, off-pump coronary artery bypass grafting, radial artery, stroke.

ÖZ

Amaç: Bu çalışmada çalışan kalpte koroner arter baypas greftlemenin mortalitenin nörolojik nedenleri üzerine etkisi değerlendirildi.

Çalışma planı: 01 Kasım 2014 - 31 Aralık 2022 tarihleri arasında çalışan kalpte koroner arter baypas greftleme yapılan toplam 1154 hasta (963 erkek, 191 kadın; ort. yaş: 64±10.9 yıl; dağılım, 13-95 yıl) retrospektif olarak incelendi. Hastaların demografik özellikleri, mevcut eşlik eden hastalıkları, perioperatif durum ve ameliyat sonrası klinik sonuçlar kaydedildi. Sağkalım analizi yapıldı.

Bulgular: Aortaya dokunulmadan koroner arter baypas greftleme 958 (%83) hastada ve aorta üzerine tek taraflı ısırma klempi 196 (%17) hastada uygulandı. Ameliyat öncesi dönemde 271 (%23.5) hasta acil koşullarda ve 63 (%5.5) hastada ise inme ve/veya geçici iskemik atak öyküsü vardı. Elli (%4.3) hastada eş zamanlı karotis endarterktomi yapıldı. Ameliyat sonrası dönemde 139 (%12) hastada atriyal fibrilasyon ve beş (%0.4) hastada inme tespit edildi. Yedi (%0.6) hasta hastanede ve bir (%0.08) hasta ameliyat sonrası 30 günlük dönemde kaybedildi. Bir yıllık, üç yıllık ve beş yıllık sağkalım oranları sırasıyla %98.7, %97.4 ve %96.5 idi.

Sonuç: Koroner arter baypas greftleme düşük perioperatif inme insidansı ile ilişkilidir. Çalışan kalpte koroner arter baypas greftlemede aort manipülasyonundan kaçınılması, kardiyopulmoner baypasın olumsuz nörolojik etkilerinin riskini azaltabilir. Uzun dönem sağkalım oranlarımız, yoğun bakım ve hastanede kısa kalış sürelerinin daha kısa oluşu ve cerrahi sonrası kan ve kan ürünleri kullanımımızın daha az olması ile ilişkilendirilmiştir.

Anahtar sözcükler: İnternal torasik arter, çalışan kalpte koroner arter baypas greftleme, radial arter, inme.

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Coronary artery bypass grafting (CABG) is a common treatment for coronary artery revascularization, and off-pump CABG has been used increasingly in the past decade to minimize the risks associated with cardiopulmonary bypass (CPB) and aortic manipulation and to reduce the potential for neurologic, renal, and myocardial injuries. The elderly patients, 70 years of age or older patients with a history of carotid disease, cerebrovascular disease, as well as those with type 2 diabetes, and renal failure may have benefit from off-pump CABG depending on our experiences since early 2000s.[9]

Stroke remains one of the most catastrophic complications of cardiac surgery for patients and their families.[1] Atherosclerosis of ascending aorta is the single most significant risk factor for stroke after cardiac surgery. Ascending aorta cannulation, manipulation of the aorta, clamping-related injuries lead to postoperative stroke.[2,3]

High-risk patients have more increased risk of perioperative neurological complications, and stroke remains the drawback from conventional CABG. The data from the observational registries report that the incidence of perioperative stroke after cardiac surgery ranges from 0.8 to 5.2%.[4-6] In the present study, we aimed to evaluate neurological outcomes of CABG and to determine whether off-pump CABG was safe and effective in decreasing the neurological causes of mortality.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Vehbi Koç Foundation American Hospital, Department of Cardiovascular Surgery and Koç University School of Medicine, Department of Cardiovascular Surgery between November 1st, 2014 and December 31st, 2022. Using no exclusion criteria, we reviewed the health records of 1,154 off-pump CABG patients (963 males, 191 females; mean age: 64±10.9 years; range, 13 to 95 years) and collected data for demographic characteristics, preexisting comorbid conditions, such as hypertension, hyperlipidemia, smoking history, type 2 diabetes, perioperative status; left ventricular ejection fraction (LVEF); recent myocardial infarction (MI); prior carotid stent, coronary artery stent or CABG; preoperative inotropic support or intra-aortic balloon pump (IABP); New York Heart Association (NYHA) classification; and European System for Cardiac Operative Risk Evaluation (EuroSCORE).[7] We collected the following data for operative characteristics: territory of anastomoses, number of anastomoses, composite grafts, types of grafts, no-touch aorta technique, and concomitant carotid artery endarterectomy (CEA) procedures. We collected the following data for postoperative outcomes: reexploration for bleeding, postoperative atrial fibrillation (AF) occurring after surgery which required treatment during the patient's hospitalization, postoperative renal failure defined as a new requirement for hemodialysis at the time of discharge, prolonged artificial ventilation defined as greater than 24 h of postoperative mechanical support, deep sternal wound infection, postoperative stroke defined as any confirmed neurological deficit of abrupt onset caused by a disturbance of cerebral blood supply that did not resolve within 24 h, transient ischemic attack (TIA) defined as loss of neurological function that was abrupt in onset but with complete return of function within 24 h, length of cardiovascular intensive care unit (ICU) stay, length of hospital stay, postoperative total drainage from the chest and mediastinal tubes, required blood products (e.g., erythrocyte suspension and fresh frozen plasma), in-hospital and 30-day mortality, and long-term follow-up (more than 24 months postoperatively). All patients had preoperative carotid-subclavian Duplex ultrasound screening. Patients suspected of having postoperative neurological events were evaluated by a neurologist and underwent brain imaging with computed tomography (CT), magnetic resonance imaging (MRI), or both, and the diagnosis was clinically confirmed. No patients had missing data during follow-up. Written informed consent was obtained from each patient. The study protocol was approved by the Koç University Ethics Review Board for Clinical Studies (Date: 12.10.2023, No: 2023.346.IRB1.120). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical methods

All patients had off-pump CABG with facile stabilization and exposure techniques. We used a ribcage lifing technique described by Karagoz et al.[8] Stabilization of the target territory was achieved through four radial traction 2-0 silk sutures placed 5 mm lateral to the target artery and fixed at both sides of the sternum. The lateral wall of the left ventricle was exposed without hemodynamic compromise, the right pleural cavity was opened, the diaphragmatic edge of the right pleura was incised completely toward the inferior vena cava, and the heart was rotated toward the right hemithorax.[9,10]

The patients underwent complete revascularization with bilateral internal mammary

arteries (BIMAs), the right internal mammary artery (RIMA), or the left internal mammary artery (LIMA), as needed. The radial artery (RA) was used to complete revascularization. In addition to arterial grafts, we used saphenous vein grafts for patients possibly undergoing kidney transplants to spare the RA. Composite T grafts and Y grafts were used for total arterial revascularization.

Heparin was administered (150 IU/per kg) to achieve an activated clotting time greater than 300 sec. Protamine reversal dose was administered after the anastomoses were completed. All patients received low molecular-weight heparin until hospital discharge. To prevent platelet aggregation, patients received acetylsalicylic acid and clopidogrel.

Table 1. Baseline and preoperative demographic characteristics for off-pump CABG patients (n=1,154)

Characteristic	n	%		Median	Range
Age (year)			64±10.9	65	13-95
Sex					
Female	191	16.5			
Male	963	83.5			
Body mass index (kg/m^2)	28.1	4.2		27.6	16-48.8
Hypertension	864	74.9			
Hyperlipidemia	652	56.5			
Smoking history	322	27.9			
Diabetes	502	43.5			
LVEF (%)					
<30	26	2.3			
30-50	334	28.9			
>50	794	68.8			
Recent MI	246	21.3			
Previous carotid artery stent	4	0.3			
Previous coronary artery stent	220	19.1			
Previous CABG	29	2.5			
Previous stroke/TIA	63	5.5			
Renal failure/dialysis	49	4.2			
Left main stem stenosis	159	13.8			
Peripheral vascular disease	49	4.2			
Preoperative IABP	7	0.6			
Preoperative inotropic support	11	1.0			
COPD	125	10.8			
Emergent	271	23.5			
Preoperative atrial fibrillation	37	3.2			
NYHA Class					
I	13	1.1			
II	380	32.9			
III	654	56.7			
IV	107	9.3			
EuroSCORE					
0-3	459	39.8			
4-6	612	53.0			
≥7	83	7.2			

CABG: Coronary artery bypass grafting; LVEF: Left ventricular ejection fraction; MI: Myocardial infarction; TIA: Transient ischemic attack; IABP: Intra-aortic balloon pump; COPD: Chronic obstructive pulmonary disease; NYHA: New York Heart Association; EuroSCORE: European System for Cardiac Operative Risk Evaluation.

Follow-up

The patients were followed at one week, one month, and three months at scheduled outpatient visits after hospital discharge. During follow-up, all patients had a physical examination, blood serum analysis, a chest radiograph, and an echocardiography study.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 28.0 software (IBM Corp., Armonk, NY, USA). Continuous data were expressed in mean ± standard deviation (SD) or median and interquartile range (IQR), while categorical variables were expressed in number and frequency. Survival was estimated by the Kaplan-Meier method, with the date of surgery as the starting point and the date of death or last follow-up as the end point. The operative mortality rate includes deaths occurring within 30 days of operation or during hospitalization. A p value of <0.05 was considered statistically significant.

RESULTS

Baseline characteristics and preoperative demographic parameters are listed in Table 1. Of the patients, 13 were NYHA Class I, 380 were NYHA Class II, 654 were NYHA Class III, and 107 were NYHA Class IV. Preoperatively, 271 patients were considered to have emergent status, 246 patients had a history of MI, and 159 patients had left main stenosis. Eleven patients had preoperative inotropic support, and seven patients had IABP support before off-pump CABG. For 83 patients, the EuroSCORE was over 7.

All 1,154 patients had off-pump CABG without conversion to CPB. Bypass grafting was to the left anterior descending territory in 1,132 (98.1%) patients, to the circumflex artery territory in 978 (84.7%) patients, and to the right coronary artery territory in 857 (74.3%) patients. The mean number of anastomoses was 3.8±1.1. The CABG procedure was done with the no-touch aorta technique in 958 (83%) patients, and single side-biting clamp was used 196 (17%) patients. Composite grafts were used for multiple arterial revascularizations: 820 (71.1%) patients had T grafts and 31 (2.7%) patients had Y grafts.

The first-choice graft was arterial: LIMA, 1,111 (96.3%) patients; RIMA, 473 (41%) patients, BIMA; 452 (39.2%) patients; RA, 712 (61.7%) patients, and 50 (4.3%) patients with saphenous vein grafts in addition to arterial grafts. Fifty (4.3%) patients had a concomitant CEA, and 484 (41.9%) patients were extubated in the operating room according to the

Table 2. Intraoperative data (n=1,154)

Variables	n	%	Mean±SD	Median	Range
Territory					
LAD	1,132	98.1			
Circumflex	978	84.7			
RCA	857	74.3			
Distal anastomoses, No.			3.8±1.2	4	1-8
Composite graft					
T	820	71.1			
Y	31	2.7			
No-touch aorta	958	83			
Side biting clamp	196	17			
Grafts					
Radial artery	712	61.7			
LIMA	1,111	96.3			
RIMA	473	41			
Saphenous vein	50	4.3			
Carotid endarterectomy	50	4.3			

SD: Standard deviation; LAD: Left anterior descending artery; RCA: Right coronary artery; LIMA: Left internal mammary artery; RIMA: Right internal mammary artery.

Enhanced Recovery After Surgery (ERAS protocol) (Table 2).[11]

Postoperative outcomes and survival data were analyzed and showed the following: 27 (2.3%) patients had reexploration for bleeding; 139 (12%) patients had postoperative AF; 484 (41.9%) patients were extubated in the operating room after their off-pump CABG procedure and transferred to the cardiovascular ICU with a simple mask oxygen at a flow rate of 2 to 4 L/min FiO_2. The rest of the 670 (58%) patients were extubated in the ICU. The mean time for artificial ventilation was 4.9±18.5 h. Forty-one (3.6%) patients had postoperative inotropic support, which was discontinued during the 24-h postoperative period. Nine (0.8%) patients had postoperative renal replacement therapy (RRT).

The mean length of ICU stay was 33.6±113.9 h, and the mean length of hospital stay was 6.4±5.9 days. The mean amount of postoperative drainage was 664.7±349.5 mL. Erythrocyte suspensions (mean: 0.3±0.9 U) and fresh frozen plasma (mean: 0.5±1.0 U) were the main postoperative blood products given.

Of other postoperative outcomes, no patients required postoperative MI and IABP implantation. Eighteen (1.6%) patients had deep sternal wound infections and required vacuum-assisted wound closure. Five (0.4%) patients had postoperative stroke, of these patients were over 65 years (69, 70, 74, 76, and 78 years) with four of five stroke patients were operated no-touch aorta, three of five stroke patients primary comorbid conditions: one patient had redo CABG, one patient had a history of previous stroke, and the other one had concomitant CEA procedure.

The patient with a history of CABG, end-stage renal failure had died due to subarachnoid hemorrhage and multiorgan failure and the other four patients had single episode of ischemic stroke, diagnosed with cranial CT and diffusion MRI during early postoperative period. A 76-year old patient who had no-touch aorta off-pump CABG ×5, had left internal carotid artery bulbar stent implantation during early postoperative 8-h period. All four patients were closely followed by the Neurology and Physical Medicine and Rehabilitation Departments, and all patients recovered uneventfully. Their medication regimen was acetylsalicylic acid, clopidogrel and enoxaparin sodium.

According to the Kaplan-Meier plots, one-year, three-year, and five-year survival rates were 98.7%, 97.4%, and 96.5%, respectively (Figure 1a). No patients had repeat coronary revascularization. The in-hospital mortality rate was 0.6% (n=7), and 30-day mortality rate was 0.08% (n=1) (Table 3).

According to the Kaplan-Meier analysis, one-year, three-year, and five-year stroke-free survival rates were 98.4%, 97.1%, and 96.4%, respectively (Figure 1b). The oldest stroke patient, who was 78 years old, died from hemorrhagic stroke and multiorgan failure, and the remaining four patients who had single event of ischemic stroke were discharged from the hospital.

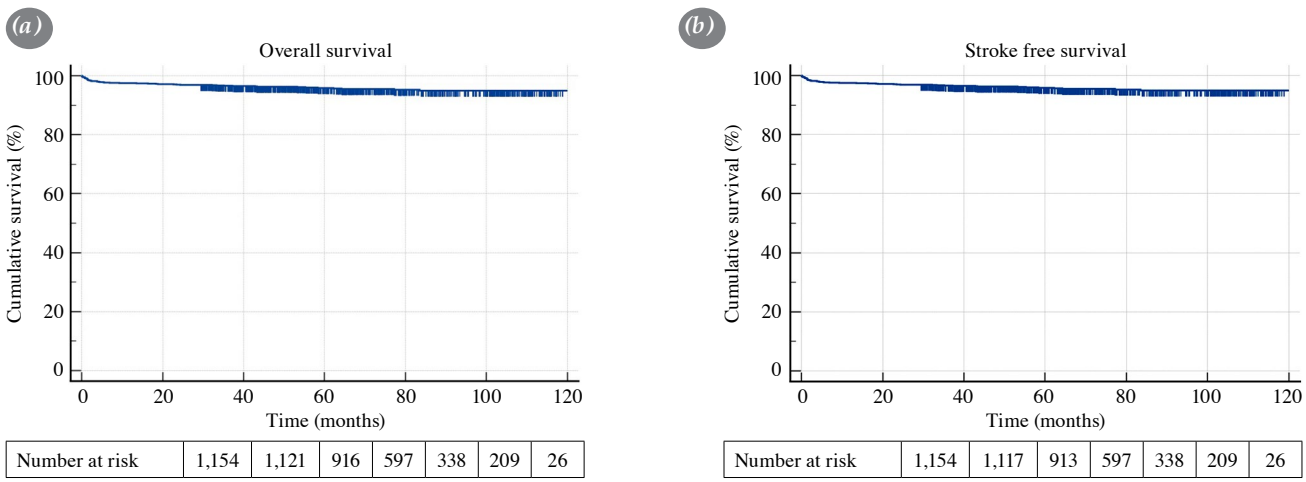


Figure 1. (a) Kaplan-Meier overall survival of 1,154 off- pump CABG patients. **(b)** Kaplan-Meier stroke-free survival of 1,154 off- pump CABG patients.

CABG: Coronary artery bypass grafting.

Table 3. Postoperative outcomes (n=1,154)

Outcomes	n	%	Mean±SD	Median	Range
Reexploration for bleeding	27	2.3			
Postoperative AF	139	12.0			
Deep sternal wound infection	18	1.6			
Inotropic support	41	3.6			
Renal failure/dialysis	9	0.8			
Postoperative IABP	0	0			
Stroke/TIA	5	0.4			
Postoperative MI	0	0			
Mortality	7	0.6			
In-hospital	1	0.08			
30-day					
Artificial ventilation (h)			4.9±18.5	4	0-504
Length of ICU stay (h)			33.6±113.9	24	4-3600
Length of hospital stay (Day)			6.4±5.9	5	1-150
Postoperative drainage (mL)			664.7±349.5	600	0-4350
Blood products (unit)					
Erythrocyte suspension			0.3±0.9	0	0-16
Fresh frozen plasma			0.5±1.0	0	0-14

SD: Standard deviation; AF: Atrial fibrillation; IABP: Intra-aortic balloon pump; TIA: Transient ischemic attack; MI: Myocardial infarction; ICU: Intensive care unit.

DISCUSSION

The potential benefits of off-pump CABG depend on the avoidance of CBP, and reduction of aortic manipulation in comparison to on-pump CABG.[12] In our study, the ages of our patients ranged broadly, ranging from 13 to 95 years. Our results showed that off-pump CABG had low rates of major adverse events and mortality. The Kaplan-Meier overall one-year, three-year, and five-year survival rates were 97.4%, 97.4%, and 96.5%. Of the patients, only five patients had single episode of stroke. Although a risk factor in cardiac surgery older age, chronic renal failure, reoperation, peripheric arterial disease has been shown in some studies.[13,14]

In our retrospective study, 63 patients had a history of preoperative stroke or TIA, 49 patients had perioperative renal failure or dialysis history, 271 patients were in emergent status, seven patients had IABP implantation, and 11 patients had inotropic support during preoperative period. Dominici et al.[12] reported that the avoidance of CPB reduced the CPB-related inflammation and end-organ injury. Other studies documented the reduced aortic manipulation in the off-pump group may have reduced incidence of neurological complications.[13-16]

Ramponi et al.[15] reported anaortic off-pump CABG of 1,041 patients with a 30-day stroke rate of 0.4%, and 39 patients underwent synchronous CEA and anaortic off-pump CABG. The authors observed one stroke, two deaths, and two TIAs. In our study, five patients had postoperative stroke, one patient was operated with single side biting clamp, and the remaining four were no-touch aorta off-pump CABG patients. The oldest patient was 78 years of age, redo CABG, chronic renal failure, type 2 diabetes, peripheral artery disease. He was operated no-touch aorta off-pump CABG ×2, the patient died on postoperative Day 4 due to multiple organ failure and subarachnoid hemorrhage. The remaining of the four patients had ischemic stroke. One of the four patients who had no-touch off-pump CABG ×5 had left internal carotid artery bulbar stent implantation on postoperative Day 1, and the other patient who had concomitant no-touch aorta off-pump CABG and right CEA, was diagnosed as ischemic infarct. All our patients had comorbidities as older age, type 2 diabetes, peripheral arterial disease, and

one patient had a history of stroke at perioperative period.

Approximately 6 to 14% of patients referred for coronary surgery have significant (>80%) carotid artery stenosis, and the presence of carotid artery stenosis >70% is associated with a more than five-fold increased risk of aortic arch artherosclerosis.[17,18] In our study, 1,154 patients had preoperative carotid-subclavian Duplex ultrasound screening, and 50 patients were identified with significant concomitant carotid disease who underwent synchronous CEA, and off-pump CABG. Four patients had a history of previous carotid artery stent implantation in the preoperative period. Twenty-seven patients had reexploration for surgical bleeding, and 139 patients had newly onset of AF postoperatively and were treated with an antiarrhythmic regimen, and they were discharged at sinus rhythm. There was no postoperative MI in the postoperative period.

Lorusso et al.[19] compared the off-pump and on-pump CABG patients, and reported the reoperation for surgical bleeding was lower in the off-pump group (172 *vs*. 680 patients, 2.1% *vs*. 3.9% with off-pump CABG versus on-pump CABG, respectively; p<0.001), and they showed that the incidence of postoperative AF was lower in the off-pump group (1,452 *vs*. 3,247 patients, 17.5% *vs*. 18.8% with off-pump CABG versus on-pump CABG, respectively; p<0.001).

In the current study, nine of 1,154 patients had temporary RRT as continuous veno-venous hemofiltration (CVVHD) in the postoperative period. Lorusso et al.[19] reported 452 off-pump CABG patients had postoperative renal failure, and 53 patients had postoperative stroke. Valley et al.[1] documented their surgical bleeding rate as 4.7%, and their infection rate was 4.3% with no-touch aorta off-pump CABG patients. Our data showed that 18 patients had deep sternal wound infection and were treated with vacuum-assisted wound closure. Shintomi et al.[20] reported the data of 269 total arterial off-pump CABG patients with no mediastinitis and no reexploration for bleeding. In the aforementioned off-pump CABG series, seven patients had major adverse cardiac and cerebrovascular events, and one patient had cerebral infarction.

In the present study, there was no postoperative MI. Forty-one of our patients needed inotropic support during postoperative 24-h period. The mean duration of artificial ventilation was 4.9±18.5 h, the mean length of ICU stay was 33.6±113.9 h, and 484 of our patients were extubated in the operating room. Nine-hundred fifty-eight of our patients were operated with no-touch aorta technique. Composite grafts were used for total arterial revascularization: 820 patients had T-graft and 31 patients had Y-graft. Choi et al.[21] reported the outcomes of 834 no-touch aorta off-pump CABG with five permanent stroke patients, 24 postoperative renal failure, one deep sternal infection, and 125 prolonged ventilation time.

In the current study, the mean amount of postoperative drainage was 664.7 (349.5) mL, the mean requirement for erythrocyte suspension was 0.3±0.9 U, and for fresh frozen plasma 0.5±1.0 U. Due to our data, 1,111 patients had a LIMA, 473 patients had a RIMA, and 712 patients had a RA graft. For 50 patients, saphenous veins were used in addition to arterial grafts. In our series, 1,104 patients had complete multiarterial revascularization, with a mean number of anastomoses of 3.8±1.2.

In a meta-analysis, Zhao et al.[13] identified that elimination of aortic manipulation ultimately resulted in superior neurological outcome, and decreased risk of postoperative stroke and also elimination of CPB could reduce the risk of short-term mortality, renal failure, surgical bleeding, AF, and shorter length of ICU stay. Several studies have reported that one of the most frequently used arguments against off-pump CABG is technical issues and difficulty of the procedure. The intrinsic features of anaortic off-pump CABG including volume loading to stabilize the vital signs during posterior vessel revascularization may affect the outcomes, and most of the surgeries were performed by a highly experienced surgeon for no-touch aorta off-pump CABG.[16,17]

Total arterial no-touch aorta off-pump CABG represents the apex of the advanced techniques based on the evidence of conduit selection and reducing perioperative neurological injury. The use of single or BIMA flows, combined with the RA to compose multiarterial grafts to complete sequential grafting off-pump CABG techniques without manipulating the aorta.[13,22]

In our study, the in-hospital mortality was observed in seven patients, and 30-day mortality was observed in one patient. Others have also reported the advantages of LIMA-RA composite graft and demonstrated the excellent long-term outcomes with this approach.[23] Puskas et al.[24]

reported that an average of 7.5 years of follow-up of 100 patients undergoing off-pump CABG performed better than those 100 patients with CPB in many neuropsychological domains and concluded that these outcomes might be due to nature of off-pump CABG which provide reductions in major adverse cardiac events such as death, stroke and MI.

Emmert et al.[25] reported in their series that occurrence of stroke and neurological events between off-pump CABG and on-pump CABG (1.1% *vs*. 2.4%; odds ratio [OR]=0.45; 95% confidence interval [CI]: 0.27-0.74; p=0.002) remained significantly lower in off-pump CABG patients when combined with all arterial grafting offers to reduce stroke by eliminating the need of aortic cannulation and aortic cross-clamping. In our retrospective study, Kaplan-Meier one-year, three-year, and five-year stroke-free survival rates were 98.4%, 97.1%, and 96.4%, respectively.

The main limitation to this study is the retrospective nature of the data. It is also diffucult to design a study, to compare the outcomes with on-pump CABG patients since our group were undergoing off-pump CABG from early 2000s. Our group practice off-pump CABG with a facile stabilization technique since late 1990s. No-touch aorta versus single side-biting techniques were not compared, since 83% of the patients were operated as no-touch aorta. The male versus female patients were not compared, since female patients consisted the one-third of the patient population. In addition, the data available for analysis were commonly recorded in electronic medical records. Also, our cardiac surgery outcomes were affected by the novel coronavirus disease 2019 (COVID-19) pandemic.

In conclusion, our study results suggest that off-pump coronary artery bypass grafting, using a no-touch aorta technique and multiarterial grafting, is successful and safe for coronary artery disease patients. Neurological events seem to be leading causes of mortality after coronary artery bypass grafting. Neither off-pump, nor aortic no-touch techniques can completely eliminate the neurological complications. Based on these findings, we conclude that off-pump coronary artery bypass grafting with no-touch aorta can be performed as the preferred revascularization technique at hospitals with skilled cardiovascular surgery and anesthesiology teams. Further multi-center, large-scale, prospective randomized studies are needed to confirm these findings.

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

Author Contributions: Idea/concept, design, critical review: Z.T.D., M.S.A., E.A., S.G.; Control/supervision: Z.T.D., M.S.A.; Data collection and/or processing, analysis and/or interpretation: Z.T.D., E.A.; Literature review, writing the article: Z.T.D.

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