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The Outcomes of Concomitant Carotid Endarterectomy and Off-Pump Coronary Artery Bypass Grafting

Eş Zamanlı Karotis Endarterektomi ve Pompasız Koroner Arter Bypass Greftlemesinin Sonuçları

ORIGINAL ARTICLE
KLİNİK ÇALIŞMA

ABSTRACT

Objective: Limited data exist on the concurrent application of carotid endarterectomy (CEA) and off-pump coronary artery bypass grafting (OPCABG).

Method: This retrospective study collected data from 42 patients who underwent simultaneous carotid endarterectomy and off-pump coronary artery bypass grafting between November 2015 and June 2023 at two affiliated institutions. CEA was performed first via eversion endarterectomy, followed by OPCABG using mostly arterial grafts on a beating heart, primarily with a "no-touch" aortic technique. Patient data were obtained from digital hospital records, and follow-up was completed through electronic systems or phone contact.

Results: Among 1,154 OPCABG patients, 42 (3.6%) underwent simultaneous CEA, with a median age of 72 (range: 59-84); 35 patients (83.3%) were male and seven (16.7%) female. All patients were asymptomatic for carotid disease and diagnosed preoperatively via routine Doppler ultrasound. Complete arterial revascularization without aortic manipulation was achieved in 83.3% of cases, with a mean of 3.66 ± 1.22 distal anastomoses. Early mortality occurred in one critically ill patient (2.4%). One patient (2.4%) experienced a postoperative transient ischemic attack and recovered without neurologic sequelae. Seventeen patients (40.4%) were extubated in the operating room. During follow-up, no patients experienced cerebrovascular events; two patients died due to non-cardiac disease. As all events occurred within the first year, the Kaplan–Meier one-, three-, and five-year stroke-free survival rates were identical at 92.6 ± 4.1%.

Conclusion: Concomitant CEA and OPCABG surgery is considered the optimal strategy for patients with extensive carotid and coronary artery stenosis at experienced centers. It is an achievable treatment that minimizes the risk of postoperative cerebrovascular events and cognitive deficits.

Keywords: Carotid endarterectomy, combined surgical procedures, coronary artery bypass, enhanced recovery after surgery (ERAS), off-pump, stroke/prevention & control

ÖZET

Amaç: Karotis endarterektomi (KEA) ve pompasız koroner arter baypas greftlemesinin (OPCABG) birlikte uygulanmasına ilişkin veriler sınırlıdır.

Yöntem: Bu retrospektif çalışmada, Kasım 2015–Haziran 2023 tarihleri arasında iki bağlı merkezde eş zamanlı karotis endarterektomisi (KEA) ve pompasız koroner arter baypas greftleme (OPCABG) uygulanan 42 hastanın verileri incelendi. KEA, önce eversion endarterektomi yöntemiyle yapıldı; ardından çalışan kalpte, çoğunlukla "no-touch" aort tekniğiyle ve çoğunlukla arteriyel greftler kullanılarak OPCABG uygulandı. Hasta verileri dijital hastane kayıtlarından elde edildi ve takip elektronik sistemler veya telefon görüşmesi yoluyla tamamlandı.

Bulgular: Toplam 1.154 OPCABG hastasının 42'sine (%3,6) eş zamanlı KEA uygulandı; medyan yaş 72 (59–84 arası) idi; hastaların 35'i (%83,3) erkek, 7'si (%16,7) kadındı. Tüm hastalar karotis hastalığı açısından asemptomatikti ve preoperatif dönemde rutin Doppler ultrason ile tanı konmuştu. %83,3 olguda aort manipülasyonu olmaksızın tam arteriyel revaskülarizasyon sağlandı; ortalama distal anastomoz sayısı 3,66 ± 1,22 idi. Erken mortalite bir kritik hastada (%2,4) görüldü. Bir hasta (%2,4) postoperatif geçici iskemik atak geçirdi ve nörolojik sekelsiz iyileşti. On yedi (%40,4) hasta ameliyathanede ekstübe edildi. Takip süresince hiçbir hastada serebrovasküler olay görülmedi, iki hasta kardiyak dışı nedenlerle kaybedildi. Tüm olaylar ilk yıl içinde gerçekleştiği için Kaplan–Meier 1., 3. ve 5. yıllık inmesiz sağkalım oranları %92,6 ± 4,1 olarak eşitti.

Sonuç: Eş zamanlı KEA ve OPCABG cerrahisi, yaygın karotis ve koroner arter darlığı olan hastalarda deneyimli merkezlerde optimal strateji olarak bilinmektedir ve postoperatif serebrovasküler olaylar ile bilişsel defisit riskini en aza indirirken uygulanabilir bir tedavi seçeneğidir.

Anahtar Kelimeler: Karotis endarterektomi, kombine cerrahi girişimler, pompasız koroner arter baypas, ameliyat sonrası iyileşmenin hızlandırılması (ERAS), inme/önleme ve kontrol

Mehmet Şanser Ateş[1]

Eray Aksoy[2]

Zümrüt Tuba Demirözü[1]

Sami Gürkahraman[2]

[1]Department of Cardiovascular Surgery, Koç University Faculty of Medicine, İstanbul, Türkiye
[2]Department of Cardiovascular Surgery, Vehbi Koç Foundation American Hospital, İstanbul, Türkiye

Corresponding author:
Mehmet Şanser Ateş
✉ msanserates@yahoo.com

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Coronary artery disease remains an important cause of mortality, particularly in the elderly, with in-hospital mortality rates reported as high as 8.6% in patients aged 75 years and older.[1] Since carotid artery disease frequently coexists with coronary artery disease in this population, the overall risk of stroke and mortality is further increased. Carotid endarterectomy (CEA) remains the gold standard for stroke prevention in patients with carotid artery disease.[2] When both coronary artery bypass grafting (CABG) and coronary artery endarterectomy are necessary, concomitant surgery has been shown to reduce the risk of catastrophic events that may occur when two procedures are performed sequentially.[3,4] However, given the lack of established body of evidence on concomitant surgery, concerns have emerged regarding the simultaneous performance of these procedures.[5,6] There are limited data on concomitant CEA and off-pump coronary artery bypass (OPCABG), and the role of aortic manipulation in stroke risk is uncertain, as most CABG-CEA reports are based on conventional on-pump experiences. The potential benefits of concurrent OPCABG–CEA include eliminating the risk of a potential stroke or acute coronary syndrome between staged operations and avoiding the additional stress of a second surgery and anesthesia.[7,8] The present study aims to evaluate the outcomes of simultaneous OPCABG-CEA for the treatment of critical carotid artery stenosis and coronary artery disease.

ABBREVIATIONS

AF	Atrial fibrillation
BIMA	Bilateral internal mammary arteries
CABG	Coronary artery bypass grafting
CEA	Carotid endarterectomy
COVID-19	Coronavirus Disease 2019
CT	Computed tomography
CVA	Cerebrovascular accident
ERAS	Enhanced recovery after surgery
EuroSCORE	European System for Cardiac Operative Risk Evaluation
IABP	Intra-aortic balloon pump
IQR	Interquartile range
LIMA	Left internal mammary artery
LITA	Left internal thoracic artery
LVEF	Left ventricular ejection fraction
MI	Myocardial infarction
MRI	Magnetic resonance imaging
NYHA	New York Heart Association
ONCABG	On-pump coronary artery bypass grafting
OPCABG	Off-pump coronary artery bypass grafting
RIMA	Right internal mammary artery
RITA	Right internal thoracic artery
STS	Society of Thoracic Surgeons

Materials and Methods

The retrospective study protocol was approved by the Ethics Committee of Koç University (Approval Number: 2023.350. IRB1.124, Date: 02.10.2023). This study included all patients who underwent off-pump CABG and CEA between November 1, 2014 and June 30, 2023, at two affiliated hospitals. Of 1,154 patients who underwent off-pump CABG during this period, 42 also underwent CEA performed concurrently with OPCABG. According to our institutional practice, concomitant CEA–OPCABG was routinely performed when critical carotid artery stenosis was diagnosed in patients scheduled for CABG. The staged procedure for CEA and off-pump CABG was not performed. Patients with a history of preoperative ischemic stroke or severe cerebrovascular accident were censored. Electronic medical records were analyzed. We reviewed the health records of 1,154 off-pump CABG patients and collected data on demographic characteristics and preexisting comorbid conditions, such as hypertension, hyperlipidemia, smoking history, and 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).[9] 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 procedures. We collected the following data for postoperative outcomes: re-exploration for bleeding, postoperative atrial fibrillation ([AF], defined as AF occurring after surgery that required treatment during hospitalization), postoperative renal failure (defined as a new requirement for hemodialysis at discharge), prolonged artificial ventilation (defined as > 24 hours of postoperative mechanical support), deep sternal wound infection, postoperative stroke (defined as any confirmed neurologic deficit of abrupt onset caused by a disturbance of cerebral blood supply that did not resolve within 24 hours), transient ischemic attack (TIA, defined as abrupt loss of neurologic function with complete return of function within 24 hours), 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 mortality (during the hospital stay) and 30-day mortality, and long-term follow-up (more than 24 months postoperatively). All patients underwent 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, with the diagnosis clinically confirmed. No patients had missing data at follow-up. Follow-up data were obtained via electronic medical records or phone communication.

Statistical Analysis

All statistical analyses were conducted using SPSS Statistics for Windows, version 19.0 (IBM Corp., Armonk, NY, USA). Continuous data were expressed as mean (standard deviation, SD) or median (interquartile range, IQR), and categorical variables were expressed as count (percentage) in complete-case analyses. 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 endpoint. Operative mortality included deaths occurring within 30 days of surgery or during hospitalization. The cut-off value for statistical significance was set as 0.05.

Surgical Procedure and In-Hospital Progress

All surgeries were performed with the patient supine, the neck extended, and rotated 45 degrees to the opposite side. After placement of sterile drapes, the common, internal, and external carotid arteries were dissected free and encircled with vessel loops via a longitudinal incision along the anterior border of the sternocleidomastoid muscle. Intravenous heparin was administered. The common carotid artery was clamped proximally, and the external carotid artery was clamped distally. The internal carotid artery was not clamped but gently elevated with a vessel loop for control. In this way, the entire occlusive plague could be removed, debris embolization prevented, and backflow of blood from the contralateral side evaluated. The common carotid artery was then transected just proximal to the bifurcation. Using eversion endarterectomy, plaque in the internal and external carotid arteries was first removed from the carotid artery lumen, followed by plaque in the common carotid artery. The common carotid artery was anastomosed end-to-end with 6.0 polypropylene after ensuring adequate backflow. None of the patients received a patch closure, and no drain was placed. After controlling bleeding, the OPCABG procedure was initiated.

Midline sternotomy was used for all primary OPCABG procedures, while left anterolateral thoracotomy was performed in one patient who underwent redo off-pump CABG. Patients underwent full revascularization with bilateral internal mammary arteries (BIMA), the right internal mammary artery (RIMA), or the left internal mammary artery (LIMA), as needed. The radial artery was used to complete revascularization. In addition to arterial grafts, we used saphenous vein grafts for patients who might undergo kidney transplantation to spare the radial artery. Composite T grafts and Y grafts were used for total arterial revascularization. The technique involved inserting 1.0 silk epicardial stay sutures into the four corners of the target coronary artery without the use of a stabilizer or epicardial suction device, as previously described.[10] Heparin was administered (150 IU/kg) to achieve an activated clotting time greater than 300 seconds. Protamine 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 100 mg and clopidogrel 75 mg daily and were discharged on the fourth or fifth postoperative day.

Seventeen (40.4%) patients were awakened and extubated on the operating table post-surgery. They were closely monitored in the intensive care unit during the early postoperative period before being transferred to the ward after 24 hours.

Patient Follow-up

The patients were followed up at one week, one month, and three months at scheduled outpatient visits after hospital discharge. At follow-up, all patients underwent physical examination, blood serum analysis, chest radiography, and echocardiography.

Results

The OPCABG-CEA group included 42 patients (3.63%) out of 1,154 OPCABG patients, with a median age of 72 years (IQR: 59–84 years). Thirty-five patients (83.3%) were male. None of the patients had carotid artery disease symptoms on admission and were diagnosed with severe carotid artery disease during routine carotid Doppler ultrasound examination before OPCABG. Baseline characteristics of the patients are presented in Table 1. The mean number of target coronary anastomoses was 3.66 ± 1.22. Complete revascularization without aortic manipulation was performed in 35 patients (83.3%), and 17 patients (40.4%) were extubated in the operating room and transferred to the intensive care unit spontaneously breathing. Operative and early postoperative outcomes are detailed in Tables 2 and 3.

Table 1. Baseline characteristics (n=42)

Characteristic	No. (%)
Age, years	
Mean (SD)	71.59 (7.05)
Median (range)	72 (59–84)
Gender	
Female	7 (16.7)
Male	35 (83.3)
Body mass index (kg/m^2)	
Mean (SD)	26.47 (4.31)
Median (range)	26.31 (16.05–7.18)
Concomitant disease	
Diabetes	16 (38.1)
Hypertension	32 (76.2)
Dyslipidemia	24 (57.1)
Pulmonary disease	11 (26.2)
Previous stroke	7 (16.7)
Tobacco use	13 (31.0)
Impaired renal function	3 (7.1)
Previous myocardial infarction	12 (28.6)
Previous coronary stent	10 (23.8)
Previous CABG	3 (7.1)
Previous carotid stenting	1 (2.4)
Peripheral artery disease	13 (31.0)
Preoperative IABP	2 (4.8)
Preoperative inotropes	1 (2.4)
Atrial fibrillation	3 (7.1)
Emergent/urgent	13 (31.0)
Ejection fraction	
< 30%	0 (0)
30–50%	16 (38.1)
> 50%	26 (61.9)
NYHA classification	
> Class II	30 (71.4)
Euroscore	
0–3	17 (40.5)
4–6	16 (38.1)
≥ 7	9 (21.4)

SD, standard deviation; CABG, Coronary artery bypass grafting; IABP, Intra-aortic balloon pump; NYHA, New York Heart Association.

Table 2. Operative data (n=42)

Variables	No. (%)
Territory	
Left anterior descending artery	39 (92.9)
Left circumflex artery	37 (88.1)
Right coronary artery	32 (76.2)
Number of distal anastomoses	
1	3 (7.1)
2	2 (4.8)
3	13 (31.0)
4	14 (33.3)
> 4	10 (23.8)
Composite graft	
T	33 (78.6)
Y	2 (4.8)
No-touch aorta	35 (83.3)
Grafts	
Radial artery	28 (66.7)
LITA	39 (92.9)
RITA	12 (28.6)
Saphenous vein	4 (9.5)

LITA, Left internal thoracic artery; RITA, Right internal thoracic artery.

Early mortality occurred in one patient, an 83-year-old woman who was critically ill and underwent surgery following cardiopulmonary arrest and resuscitation. She died on the first postoperative day due to multiple organ failure and sepsis. Postoperative morbidities are presented in Table 3. One patient (2.4%) experienced a postoperative transient ischemic attack and recovered without neurologic sequelae. The mean follow-up time was 35.98 ± 28.46 months (range: 1.23-97.03 months). During follow-up, three patients underwent carotid artery stenting of the contralateral side (two elective and one following a transient ischemic attack), and one patient underwent elective CEA of the contralateral side. Two patients died during follow-up: an 80-year-old man with severe left ventricular dysfunction was re-hospitalized in the intensive care unit for severe Coronavirus Disease 2019 (COVID-19) lung involvement and died 51 days after surgery. Another patient, a 65-year-old man on long-term dialysis, died 4.5 months after surgery from severe pneumonia and sepsis. Throughout the follow-up period, no patients experienced cerebrovascular events. As all events occurred within the first year, the Kaplan–Meier one-, three-, and five-year stroke-free survival rates were equal at 92.6 ± 4.1% (Figure 1).

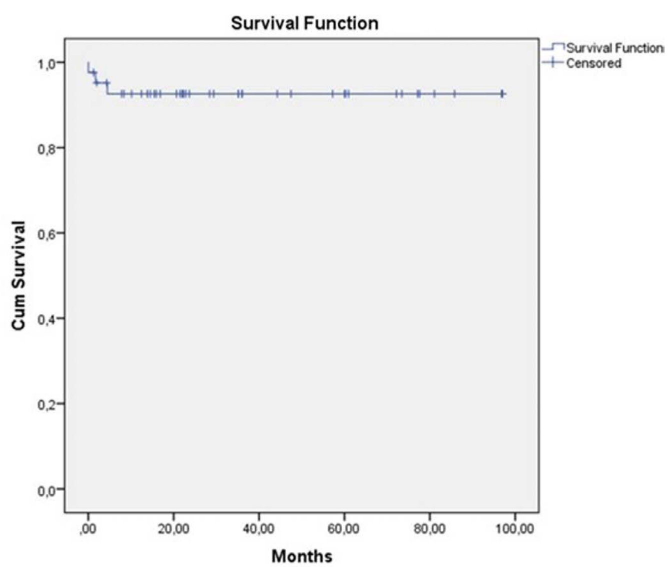
Discussion

In the present study, concurrent OPCABG-CEA produced favorable outcomes in terms of rapid recovery and low morbidity. Complete arterial coronary revascularization was performed in 35 of 42 patients using the no-touch aorta technique. Concomitant CEA with OPCABG facilitated extubation in the operating room for 40% of patients, thereby reducing both intensive care duration and overall hospital stay.

Table 3. Postoperative data

Morbidity*	No. (%)
Re-exploration for bleeding or tamponade	0
Postoperative AF	12 (28.6)
Deep sternal wound infection	1 (2.4)
Inotropic support	3 (7.1)
Renal failure/dialysis	3 (7.1)
Postoperative IABP	0
Transient ischemic attack	1 (2.4)
Postoperative MI	0
In-hospital mortality	1 (2.4)
Outcome parameters**	**Mean (SD) Median (range)**
Artificial ventilation, hours	6.624 (6.73)
	6 (0-25)
Length of ICU stay, hours	32.78 (29.47)
	24.00 (15-190)
Length of hospital stay, days	9.65 (7.25)
	7 (4-44)
Postoperative drainage, mL	672.92 (271.84)
	600.00 (300-1450)
Blood products, unit	
Erythrocyte suspension	0.43 (0.63)
	0 (0-2)
Fresh frozen plasma	0.53 (0.986)
	0 (0-3)

*All patients (n=42); **Among survivors (n=41); AF, Atrial fibrillation; MI, Myocardial infarction; IABP, Intra-aortic balloon pump; ICU, Intensive care unit.



Months	0	12	24	36	48	60	72
Number at risk	42	33	20	16	12	11	8
Cum proportion of overall and CVA-free survival	92.6%	92.6%	92.6%	92.6%	92.6%	92.6%	92.6%

Figure 1. Kaplan-Meier survival curve.

Technical benefits of performing carotid endarterectomy first, followed by CABG without cardiopulmonary bypass, include avoiding the inflammatory and embolic risks associated with cardiopulmonary bypass, reducing the risk of aortic manipulation (no-touch or limited-touch), avoiding the potential side effects of non-pulsatile artificial cerebral perfusion, preventing neck hematoma by using less heparin, reducing the length of the operation, and enabling fast-track extubation to assess neurological status shortly after surgery.

Critical coronary artery disease has been reported in up to one-third of patients before carotid endarterectomy,[11] and the incidence of > 70% carotid stenosis among candidates for CABG ranges from 5.8% to 13.4%. However, routine screening for one condition in the presence of the other has been debated.[12] All patients in our series were asymptomatic for carotid disease, and critical carotid stenosis was diagnosed at a rate of 3.63% during routine carotid duplex scanning.

Contradictory opinions exist regarding staged versus combined surgery for coronary artery disease and critical carotid artery stenosis. Furthermore, if two procedures are to be conducted in stages, there is no definite agreement on which procedure should be performed first, or, more crucially, how much time should be allowed between the two surgeries.[4,13] Due to limited data in the literature, the latest practice guidelines leave this option to institutional practice or patient-specific requirements.[2]

In the series by Kurtoğlu et al.,[8] concurrent CEA–OPCABG in 84 patients yielded an early mortality rate of 3.5%, a stroke rate of 4.8%, and a myocardial infarction rate of 2.3%. In our cohort of 42 patients, early mortality occurred in one patient (2.4%), a transient ischemic attack was observed in one patient (2.4%), and no perioperative myocardial infarction was recorded. Both series employed similar surgical techniques, including complete arterial revascularization when feasible and aortic no-touch techniques. Together, the two studies demonstrate that concurrent CEA–OPCABG can be performed with controllable morbidity and mortality rates.

Haywood et al.[7] reported in a recent study that the combined CEA-CABG group did not differ from the staged cohort in terms of 30-day stroke, mortality, or composite events; however, the myocardial infarction rate was lower. In contrast, Wang et al.[3] reported that outcomes of combined CABG–CEA were primarily determined by the severity of coronary artery disease. Furthermore, in the presence of stable angina, the risk of stroke or death was comparable between the two approaches. The risk of composite events (stroke, death, MI) was higher in patients who underwent combined CEA-CABG, whereas the risk of myocardial infarction was higher in patients with unstable angina who underwent isolated CEA. These findings demonstrate that urgent patients requiring combined CEA-CABG are a subgroup with a unique risk profile and that proficiency in the routine technique should be maintained to reduce the operative risk of CABG. Penton et al.[4] demonstrated, in the largest study to date, that simultaneous CEA-ONCABG yielded a stroke prevalence comparable to CABG five years after CEA.

Off-pump coronary artery bypass grafting not only eliminates the risk of adverse effects associated with cardiopulmonary bypass but also provides stroke prevention, particularly when the aorta is not manipulated and arterial grafts are used.[14] Ramponi et al.[15] recently reported a prospective series of 39 patients undergoing synchronous CEA and anaortic OPCABG, with a 30-day stroke rate of 2.6% and no perioperative myocardial infarction. Their conclusion that synchronous CEA-anaortic OPCABG is both safe and effective is consistent with our outcomes, supporting the role of anaortic OPCABG techniques in minimizing neurologic complications. However, because most previous combined CABG-CEA studies used the ONCABG procedure for coronary revascularization, data on both technical details and specific outcomes for OPCABG-CEA are limited.[16] According to a recent study, 32.5% of 222 patients undergoing combined CABG-CEA received the off-pump technique. The overall postoperative stroke and mortality rates ranged from 1.4% to 9% and 2.2% to 8%, respectively, showing a decline compared with previous decades. Although this study found no difference in neurological outcomes between on-pump coronary artery bypass grafting (ONCABG) and OPCABG patients, technical details about OPCABG, such as the number of revascularized target vessels and use of the aortic no-touch technique, were insufficient to make a strong definitive conclusion.[17]

Limitations

The main limitation of this study is the retrospective nature of the data. It is also difficult to design a study to compare outcomes with on-pump CABG patients. Our group has practiced off-pump CABG with a facile stabilization technique since the late 1990s. No-touch aorta versus single side-biting techniques were not compared, as 83.3% of the patients underwent no-touch aorta procedures. Male versus female patients were not compared, as women comprised only 20% of the study population. The study population consisted of CABG candidates with asymptomatic carotid artery disease diagnosed during preoperative duplex screening. The data available for analysis were primarily obtained from electronic medical records. Additionally, our cardiac surgery outcomes were affected by the COVID-19 pandemic.

Conclusion

Our study showed that concomitant off-pump CABG and CEA, mainly using a no-touch aorta technique and complete arterial revascularization, was safe and effective for patients with coronary artery disease and severe carotid artery disease. Neurological events were a leading cause of mortality after CABG. Neither off-pump nor aortic no-touch techniques can eliminate neurological complications. Therefore, we suggest that concomitant off-pump CABG and CEA with no-touch aorta be considered the preferred revascularization technique at hospitals with skilled cardiovascular surgery and anesthesiology teams. We also suggest that larger randomized studies be conducted to further validate these outcomes while minimizing the risk of postoperative cerebrovascular events and cognitive deficits.

Ethics Committee Approval: Ethics committee approval was obtained from Ethics Committee of Koç University (Approval Number: 2023.350. IRB1.124, Date: 02.10.2023).

Informed Consent: The Institutional Review Board approved this study protocol and waived informed consent, which was obtained for all patients who agreed to the use of their data for research, as all evaluations were made from existing institutional data.

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