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Original Article / Özgün Makale

The impact of coronary artery endarterectomy on mortality and morbidity during coronary artery bypass grafting

Koroner arter baypas greftleme sırasında koroner arter endarterektominin mortalite ve morbidite üzerindeki etkisi

Ali Ümit Yener,[1] Ümit Kervan,[2] Kemal Korkmaz,[3] Hikmet Selçuk Gedik,[3] Ali Baran Budak,[3] Serhat Bahadır Genç,[3] M. Turgut Alper Özkan,[1] İrfan Taşoğlu,[2] Mustafa Paç[2]

Institution where the research was done:
Department of Cardiovascular Surgery, Türkiye Yüksek İhtisas Training and Research Hospital, Ankara, Turkey

Author Affiliations:
[1]Department of Cardiovascular Surgery, Medical Faculty of Çanakkale Onsekiz Mart University, Çanakkale, Turkey
[2]Department of Cardiovascular Surgery, Türkiye Yüksek İhtisas Training and Research Hospital, Ankara, Turkey
[3]Department of Cardiovascular Surgery, Ankara Numune Training and Research Hospital, Ankara, Turkey

Background: This study aims to investigate the effect of coronary endarterectomy (CE) on morbidity and mortality in patients undergoing concomitant coronary artery bypass grafting (CABG).

Methods: We retrospectively reviewed 587 patients who underwent CABG surgery with concomitant CE (CABG+CE group) and patch plasty between March 2000 and April 2010. We compared these patients with randomly selected 600 patients who had undergone CABG surgery without CE (CABG only group) in the same period. A comprehensive evaluation of the groups was achieved by subgroup analysis with large series of parameters from patient files.

Results: The patients in the CABG+CE group were older than the patients in the CABG only group (59.6±10.3 vs. 61.3±7.3; p<0.001). The incidence of atherosclerotic risk factors, triple-vessel disease, and complaints of unstable angina pectoris were slightly higher in CABG+CE group (p<0.05). Concomitant CE prolonged cross-clamp and cardiopulmonary bypass time. Also, postoperative total entubation time (12±10.3 vs. 12±7.4 hours; p<0.05) was significantly longer (p<0.05). The rates of myocardial infarction (p=0.006) and intra-aortic balloon pump requirement (p<0.001) were significantly higher in the CABG+CE group. The mortality rate did not differ between the two groups.

Conclusion: Indication for CE must still be handled restrictively. Endarterectomy should be performed only on occluded, nearly occluded, and/or severely calcified vessels with long-range stenosis if regular anastomoses to these vessels seem to be technically impossible. Endarterectomy should not be considered as a substitute for CABG, and should be performed by an experienced surgical team. However, CE might not be associated with additional mortality compared to conventional coronary bypass surgery.

Keywords: Coronary vessels; endarterectomy; follow-up studies; morbidity; mortality.

Amaç: Bu çalışmada, koroner endarterektominin (KE) eşzamanlı koroner arter baypas greftleme (KABG) geçiren hastalarda morbidite ve mortalite üzerindeki etkisi araştırıldı.

Çalışma planı: Mart 2000 ve Nisan 2010 tarihleri arasında KABG cerrahisi ile beraber eşzamanlı KE ve yama plasti geçiren 587 hasta (KABG+KE grup) retrospektif olarak inceledi. Hastalar randomize bir şekilde seçilmiş ve aynı dönemde KE olmadan KABG cerrahisi geçirmiş 600 hasta (KABG grup) ile karşılaştırıldı. Hasta dosyalarından edinilen büyük parametre serileri ve alt grup analizi ile grupların kapsamlı bir değerlendirmesi yapıldı.

Bulgular: KABG+KE grubundaki hastalar, KABG grubundakilerden daha yaşlıydı (59.6±10.3'e kıyasla 61.3±7.3; p<0.001). Aterosklerotik risk faktörleri insidansı, üç damar hastalığı ve kararsız angina pektoris şikayetleri KABG+KE grubunda biraz daha yüksekti (p<0.05). Eşzamanlı KE, kros klemp ve kardiyopulmoner baypas süresini uzattı. Ayrıca, ameliyat sonrası toplam entübasyon süresi (12±10.3'e kıyasla 12±7.4 saat; p<0.05) anlamlı şekilde daha uzundu (p<0.05). Miyokard enfarktüsü (p=0.006) ve intraaortik balon pompası gerekliliği (p<0.001) oranları KABG+KE grubunda anlamlı olarak daha yüksekti. Mortalite oranı iki grup arasında farklı değildi.

Sonuç: Endarterektomi endikasyonu sınırlayıcı bir şekilde ele alınmaya devam edilmelidir. Endarterektomi, anastomozun teknik olarak mümkün görünmediği, sadece tıkanmış, yarı tıkanmış veya ciddi bir şekilde kalsifiye olmuş damarlarda uzun süreli stenoz ile uygulanmalıdır. Endarterektomi, KABG'nin yerine kullanılmamalı ve deneyimli bir cerrahi ekibi tarafından uygulanmalıdır. Öte yandan, konvansiyonel koroner baypas cerrahisine kıyasla KE ek mortalite ile ilişkilendirilemeyebilir.

Anahtar sözcükler: Koroner damarlar; endarterektomi; takip çalışmaları; morbidite; mortalite.

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Correspondence: Ali Ümit Yener, M.D. Çanakkale Onsekiz Mart Üniversitesi Tıp Fakültesi, Kalp ve Damar Cerrahisi Anabilim Dalı, 17100 Çanakkale, Turkey.
Tel: +90 543 - 478 17 17 e-mail: dryener@hotmail.com

The spectrum of surgically treated coronary artery disease (CAD) has changed in recent years. As a result of demographic development, improvements in cardiology diagnostics, medications, and invasive interventions, patients referred for coronary artery bypass grafting (CABG) often have advanced, diffuse, severely calcified CAD with several comorbidities. The shift in the CAD profile has renewed interest in adjunct techniques to facilitate more complete revascularization, such as coronary endarterectomies (CEs) and transmyocardial revascularization.[1]

In 1957, Bailey was the first to describe the use of CE in humans without a cardiopulmonary bypass (CPB) or an associated procedure.[2] Despite its success in relieving angina, there was also substantial morbidity and mortality.[3] Perhaps this is why surgeons are still performing this technique on a highly selective basis when no other alternatives are present. It is difficult to precisely define the ideal patient to undergo CE, and this results in variable indications and the occasional indiscriminate use of this surgical procedure. Thus, CE has been characterized as a risk factor for mortality and morbidity associated with myocardial revascularization. In other words, the use of CE is still controversial, and its results are highly variable due to a lack of uniformity.[4] The purpose of our study was to investigate the impact of comorbidity factors and CE on morbidity and mortality in patients who underwent concomitant CABG and CE and retrospectively compare the results with those for whom only CABG was performed.

PATIENTS AND METHODS

We retrospectively assessed 587 patients who underwent CABG in conjunction with CE (CABG + CE group) between March 2000 and April 2010 at Türkiye Yüksek İhtisas Training and Research Hospital in Ankara, Turkey. This number amounted to 4.56% of the 12,863 surgeries for myocardial revascularization. We compared these patients with 600 randomly selected patients who had CABG surgery without CE (CABG alone group) during the same time frame who were operated on by the same surgical team. Those with diseases other than coronary artery lesions that required surgical intervention, for example valvular pathologies, ascending aortic aneurysms, or carotid artery diseases, were excluded from the study. The average age in the CABG + CE group was 61.3±7.3 (range 40-82) while it was 59.6±10.3 (range 38-84) for the CABG alone group. The demographic characteristics of the study participants are shown in Table 1. A comprehensive evaluation of the two groups was achieved via a subgroup analysis, and we also compared a large series of parameters from the recorded pre-, peri- and postoperative parameters, such as the presence of postoperative myocardial infarction (MI), cardiac rhythm disturbances, chest tube drainage volume, and length of intensive care unit (ICU) and hospital stays. Most of the cases were performed electively, and the relatively small number of emergency cases were proportionally similar in both of the groups. These cases were not deemed to be statistically significant; hence, they were not excluded from the study.

Surgical indications and procedure

Although a preoperative prediction for CE can be obtained from the coronary angiogram, the final decision is made intraoperatively on the basis of technical considerations. We did not consider complete occlusion on the angiogram as a definite indication for CE. Furthermore, we occasionally were confronted with coronary arteries that could not be revascularized with a plain CABG procedure after performing an arteriotomy, even when a preoperative angiography showed a graftable vessel.

Coronary endarterectomies were considered when the vessel supplying a viable myocardium was suitable for grafting and when multiple, discrete obstructing lesions or diffuse atherosclerosis that was significantly compromising the internal lumen was exhibited (<1 mm).

All of the operations were performed using CPB and mild-to-moderate systemic hypothermia (28-32 °C) via a standard median sternotomy. In addition, full heparinization was performed to achieve an activated clotting time (ACT) goal of >400 seconds. Furthermore, myocardial protection was achieved using the combination of antegrade and retrograde cardioplegia, and topical myocardial cooling was used in all cases. According to the preoperative planning regarding the number of vessels to be bypassed, the grafts were prepared by considering the age of the patient and the location of the lesion. The grafts used for CABG in order of frequency were the left internal mammary artery (LIMA), the saphenous vein (SVG), the right internal mammary artery (RIMA), and the radial artery (RA). The gastroepiploic artery was also used in one patient in the CABG + CE group. The CEs were performed on the left anterior descending artery (LADA) and the right coronary artery (RCA) as well as the diagonal (D), posterolateral (PL), posterior descending (PD), obtuse marginal (OM), circumflex (Cx), and right marginal branch of right coronary artery.

The operative technique used for the CE was identical for all of the vessels. Each endarterectomy were performed manually, and the arteriotomy was one and a half times the diameter of the target vessel. However, in a few cases, the incision was extended by up to 35 mm. Moreover, the incision in the conduit was extended to match the arteriotomy, and the conduit was anastomosed to the endarterectomized artery in an end-to-side fashion. We refrained from repairing the arteriotomy with a vein patch. The CE was performed by opening the diseased vessel directly over the plaque and then carefully dissecting the plaque from the arterial wall using a fine dissector to develop a plane between the adventitia and the plaque. The atheroma was then held with a pair of blunt forceps from the middle, and gentle-sustained traction was applied cranially.[5,6] Only 1-2 cm of the proximal core was dissected, and the atheroma was divided at this level in order to not compromise the blood flow through the graft because of the competitive flow between the graft and the native vessel. Adequate distal clearance was ensured by a tapered, thinned-out distal segment of the intima at the end of the atheroma. However, when this was not possible, the arteriotomy was extended distally until a satisfactory result was obtained. After extraction, retrograde cardioplegia was used to flush out any debris that might have embolized distally. A visible flow of retrograde cardioplegia indicated a successful endarterectomy. In addition, we did not introduce a probe distally to avoid dissection at the site where the endarterectomy was terminated.

Definitions, postoperative care, and follow-up

We compared the two groups in terms of postoperative MI, total intubation time, length of ICU and hospital stays, and complications (e.g., bleeding, reoperation, and the necessity for cardiopulmonary resuscitation).

We used the term "arrhythmia" to refer to postoperative atrial fibrillation or flutter, heart blockage that required a pacemaker, and ventricular arrhythmias. "Renal failure" was defined as postoperative renal insufficiency that was managed medically. The term was also used for patients with no prior history of renal disease that required dialysis or for those with renal disease that worsened after the surgery. Neurological complications that were encountered included cerebrovascular hemorrhage, transient ischemic attacks, and permanent strokes, whereas sternal/leg wound infections requiring antibiotics and/or surgical intervention, mediastinitis, and sepsis were classified as infective complications. We also saw respiratory complications such as pneumonia, acute respiratory distress syndrome (ARDS), tracheostomy insertions, pleural effusion requiring drainage, and reintubation as well as gastrointestinal system complications like mesenteric ischemia and gastrointestinal bleeding in the study participants. In addition, we defined "in-hospital mortality" as all mortalities within the same postoperative admission period regardless of the length of hospital stay.

Our anticoagulation protocol was to reverse the heparin completely at the end of the operation, and all patients were given low-molecular-weight heparin (LMWH) subcutaneously six hours later in the ICU if the amount of chest tube drainage was less than 100mL/hr prior to discharge. Postoperatively, all of the patients received acetylsalicylic acid (300 mg daily), and for those who had an endarterectomy, clopidogrel was also administered (75 mg daily) on the first postoperative day to prevent the early initiation of coagulation cascade that often occurs with CEs.[7]

Statistical analysis

The data was analyzed via the SPSS for Windows version 11.5 software program (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test was used to assess the normality of the continuous variables, and the statistics for these variables were given as mean ± standard deviation (SD) or median (minimum-maximum). The categorical variables were shown as the number of cases and percentages. In addition, Student's t-test was used to evaluate the significance of the differences in normal distribution between the two groups, and the Mann-Whitney U test was used to analyze the statistical differences of the changing variables between the groups since these were not normally distributed. Furthermore, the categorical variants were evaluated using Pearson's chi-square or Fisher's absolute value chi-square test, and the results were considered to be statistically significant with a p value of <0.05.

RESULTS

The demographic variables are shown in Table 1. The patients in the CABG + CE group were older than those in the CABG alone group (59.6±10.3 vs. 61.3±7.3, respectively; $p<0.001$). We also determined that atherosclerotic risk factors such as hypertension (HT), diabetes mellitus (DM), and dyslipidemia occurred less in the patients who only underwent CABG. Moreover, the patients in the CABG + CE group suffered more from unstable angina pectoris than those in the CABG alone group ($p<0.001$) (Table 1).

Table 1. Demographic characteristics

Variables	CABG alone group (n=600)				CABG + CE group (n=587)				
	n	%	Mean±SD	Range	n	%	Mean±SD	Range	*p*
Age			59.6±10.3	38-84			61.3±7.3	40-82	<0.001
Sex									<0.001
Male	463	77.2			510	86.9			
Female	137	22.8			77	13.1			
Risk factors									
Hypertension	133	22.1			180	30.7			<0.001
Diabetes mellitus	124	20.6			223	38			<0.001
Obesity	34	5.6			26	4.4			0.155
Dyslipidemia	130	21.6			167	28.4			<0.001
Smoking	211	35.1			249	42.4			0.002
Complaints									
Stable angina	369	61.5			328	55.9			0.015
Unstable angina	72	12.0			123	21.0			<0.001
Systemic disorders									
Neurological	9	1.5			7	1.2			0.537
Urogenital	11	1.8			15	2.6			0.187
Gastrointestinal	29	4.8			23	3.9			0.377
Endocrine system	43	7.1			49	8.3			0.002

Regarding the coronary angiographic distribution of the lesions among the coronary arteries, no differences were detected between the two groups (p>0.05) However, the incidence of three-vessel disease was markedly higher in the CABG alone group (p<0.05), whereas the number of totally (100%) occluded LADAs and RCAs were higher in the CABG + CE group. In addition, a preoperative echocardiographic evaluation showed that there were no statistically significant differences in the left ventricular ejection fraction (LVEF) rates between the two groups (p=0.093) (Table 2).

The most common artery to undergo CE was the RCA (n=309; 52%) followed by the LADA (n=185; 31.5%) (Table 3).

We also found that the postoperative total intubation times were longer in the CABG alone group than the CABG + CE group (12±10.3 vs. 12±7.4 hours, respectively; p<0.05), but the cross-clamp and CPB times were significantly longer in the patients who underwent both procedures (p<0.05). Furthermore, more patients in the CABG alone group underwent emergency CABG, but the difference between the two groups was not statistically significant (p>0.05). We also found that the duration of ICU and hospital stays were longer in CABG alone group (Table 4).

The postoperative complications are listed in Table 5. The MI rate (p=0.006) and the number of patients who needed an intra-aortic balloon pump (IABP) (p<0.001) were significantly higher in the

Table 2. Number of diseased vessels as seen on preoperative coronary angiography

Variables	CABG alone group				CABG + CE group				
	n	%	Mean±SD	Range	n	%	Mean±SD	Range	*p*
Coronary angiography									
LMCA	2	0.3			0	0			0.578
LMCA + 1 CAD	3	0.5			4	0.7			0.479
LMCA + 2 CAD	10	1.6			8	1.4			0.564
LMCA + 3 CAD	13	2.2			21	3.6			0.066
3 CAD	277	46.2			403	68.7			<0.001
2 CAD	174	29.0			134	22.8			0.004
1 CAD	121	20.2			17	2.9			<0.001
LVEF (%)			50.4±10.9	25-65			50.6±9.5	30-65	0.993

LMCA: Left main coronary artery; CAD: Coronary artery disease; LVEF: Left ventricular ejection fraction.

Table 3. Arteries which received coronary artery endarterectomies

Artery distribution	Coronary artery endarterectomy (n=587)	
	n	%
Left anterior descending artery	185	31.5
Right coronary artery	309	52.6
Obtuse marginalis 1	17	2.89
Obtuse marginalis 2	11	1.87
Diagonal artery 1	9	1.53
Right posterior descending artery	33	5.62
Circumflex posterior lateral artery	9	1.53
Optional diagonal	4	0.68
Right posterior lateral	3	0.51
Diagonal 2	3	0.51
Right acut marginal	3	0.51
Circumflex	1	0.17

CABG alone group. Six patients (1%) in this group also experienced cardiac arrest due to low cardiac output in the ICU. Unfortunately, they did not respond to cardiopulmonary resuscitation and they did not survive. In addition, eight (1.3%) patients in the CABG + CE group died following multi-organ failure (MOF) in the postoperative period. However, the mortality rate did not differ between the two groups.

DISCUSSION

Due to improvements in cardiology diagnostics, medications, and invasive interventions, CABG has changed substantially with surgeons often facing more advanced atherosclerotic burdens. In our study, the patient's age and incidence of atherosclerotic risk factors like HT, DM, and dyslipidemia were higher in the CABG + CE group, which reflected the increased preoperative risk. Furthermore, the high-risk patients suffered more frequently from unstable angina pectoris. Additionally, achieving a complete revascularization of diffuse, calcified, or multi-segmentary lesions via standard bypass techniques is more challenging and generally requires an additional complimentary method.

Since the first application of CE by Bailey et al.[2] in 1957, the interest in this procedure has dramatically increased in spite of the unsatisfactory initial results, and the concomitant application of CABG and CE has proven to be beneficial for certain types of patients.[8,9] Traditionally, CE is the preferred method for the extraction of occluding atheromatous material and is defined as the removal of the intima and most of the media from the coronary artery surface to restore an intact lumen for the continuity of the blood flow.[10-12] However, there has been an ongoing controversy regarding the applicability and indications for CE as an adjunct to CABG. While CE is theoretically simple, the higher rates of morbidity and mortality have provoked frequent criticism, leading to a secondary role of importance for this procedure.[13,14] Despite technological developments in alternative techniques such as transmyocardial laser revascularization and angiogenic growth factor therapies, CE is still the preferred method for treating diffusely diseased vessels as an adjunct to conventional CABG.

The frequency of patients undergoing CABG together with CE varies in the literature between 3.7%

Table 4. Operative and postoperative variables

Variables	CABG alone group (n=600)				CABG + CE group (n=587)				
	n	%	Mean±SD	Range	n	%	Mean±SD	Range	*p*
Temperature			30.6±1.7				30.0±1.9		<0.001
Operation type									
Elective	582	97			563	96			>0.05
Emergency	18	3			24	4			>0.05
Mean cross-clamp time (minutes)			52.6±31.3				98.9±32.6		<0.05
Mean CPB time (minutes)			87.7±41.4				162±56.5		<0.05
Positive inotropic support	117	19.5			110	18.7			0.701
Intensive care unit complications	5	0.8			17	2.9			<0.001
Hospital complications	5	0.8			19	3.2			<0.001
Total intubation time (hours)			12±10.3	4-2341			12±7.4	5-840	<0.001
Drainage (ml)			700±6.5	250-4350			650±8.2	450-5100	0.151
Intensive care unit stay (days)			2.0±3.2	1-30			2.6±2.8	1-24	<0.001
Hospital stay (days)			10.6±5.4	5-30			14.3±6.3	6-30	<0.001

CPM: Cardiopulmonary bypass.

Table 5. Postoperative complications

Complications	CABG alone group (n=600)		CABG + CE group (n=587)		
	n	%	n	%	*p*
Neurological complications	–	–	5	0.85	0.023
Congestive heart failure	2	0.3	7	1.1	0.087
Peripheral embolism	–	–	1	0.17	0.311
Respiratory complications	17	2.83	23	3.91	0.300
Renal failure	–	–	1	0.17	0.311
Reoperation	9	1.5	7	1.1	0.646
Intra-aortic balloon pump insertion	19	3.1	43	7.3	<0.001
Myocardial infarction	41	6.8	61	10.4	0.006
Bleeding	1	0.16	5	0.85	0.096
Infective complications	1	0.16	1	0.17	0.987
Arrhythmias	51	8.5	53	9.02	0.547
Gastointestinal system complications	–	–	1	0.17	0.311
In-hospital mortality	6	1	8	1.3	0.562

and 42%[4,15] This wide range is mainly due to the absence of certain indications for the CE procedure. In our department, the combination of CE and CABG was performed in 587 patients over approximately a 10-year period, meaning that 4.56% of all patients underwent this type of surgery. The indication for CE was handled restrictively as we agree with LaPar et al.[16] that CE should be considered when the vessel supplying a viable myocardium is suitable for grafting with a minimum diameter of 2 mm or when multiple, discrete obstructing lesions or diffuse atherosclerosis significantly compromise the internal lumen (<1 mm).

The aortic cross-clamp and CPB times were longer in the CABG + CE group in our study, which can be explained by several factors, such as the severity of atherosclerosis, localization, and high rate of calcification. As shown in Table 2, the majority of the patients for whom both CABG and CE were performed suffered from three-vessel disease, which resulted in almost four bypass grafts per patient. Furthermore, as seen in Table 3, a right coronary endarterectomy was performed in 52.6% of the patients in the CABG + CE group, which is usually considered to be the most technically challenging and time-consuming localization. As previously mentioned, CE was only performed when standard anastomosis was impossible. In other words, it was the last resort for revascularizing the ischemic myocard. Furthermore, the need for CE also pointed out the presence of end-stage CAD in the CABG + CE group.

Many different techniques can be used to perform CE, including the injection of cardioplegia into the endarterectomy region, the application of carbon dioxide (CO_2) to elevate the endarterectomy plaque,[17] and open or closed endarterectomies. Our study supports the previous literature[3] which showed no significant differences in postoperative morbidity and mortality for the various surgical techniques, but others have indicated that an open endarterectomy is a safer technique.[14,18] Following an endarterectomy of the LADA or other vessels, there are many ways of reconstructing the arteriotomy, for example saphenous vein patch plasty. It may seem like a simple and easy technique, but when the LIMA is not used, it is a disadvantage. Another common technique involves the direct partial closure of the arteriotomy and coronary endarterectomy segment with the LIMA anastomosis site remaining open. However, the disadvantage of this procedure is the high degree of thrombogenicity produced by the primarily closed arteriotomy.[18,19] A third surgical option is closing the arteriotomy with patch plasty via the saphenous vein followed by the anastomosis of the LIMA to the saphenous patch. However, this technique is also highly thrombogenic.[16,20]

The need for emergency CABG was higher in the CABG + CE group, but this did not reach a level of statistical significance. However, this finding offers another clue regarding the progressive severity of CAD.

In addition, there were longer ICU and hospital stays in the patients who underwent both CABG and CE because the rates of postoperative MI and IABP were significantly higher in this group. However, considering the presence of severe end-stage atherosclerosis as well as these patients' increased preoperative risk, the prolonged stays were not surprising.

Walley et al.[7] determined that vessels which undergo CE manifest important changes that lead to the predisposed formation of thrombosis in the first postoperative week. Afterwards, the fibrous mural thrombi and thrombocytes become organized in the region of the CE, resulting in the advancement of the vascularization process. By the 50th postoperative day, the concentric and uniform reformation of the luminal layer and accumulation of collagen rich deposits can be seen. Medical treatment is the best way to avoid this sequence of events. Livesay et al.[21] and Chesebro et al.[22] recommended the use of acetylsalicylic acid and dipyridamol postoperatively, whereas Ferraris et al.[14] prescribed the use of warfarin for three months after the surgery. Gill et al.[23] recommended another treatment option in which intravenous heparin was infused for the first 48 hours postoperatively, which was then followed by the use of thienopyridine derivatives (ticlopidine and clopidogrel). At our facility, we prefer to administer LMWH at the postoperative sixth hour followed by acetylsalicylic acid and clopidogrel on the first postoperative day.

In addition to LIMA patch plasty, which is our preferred surgical approach for CE, the three factors described by Loop et al.[4] represent the mainstay of our strategy. The first factor is that careful dissection is crucial in order to free up the plaque entirely and protect the integrity of the coronary artery. The second factor is that entire extraction of the atherosclerotic plaque is mandatory for better postoperative myocardial perfusion, and the third is that appropriate postoperative medical treatment is necessary to inhibit the formation of postoperative thrombosis.

In support of our findings, the results of Okur et al.[24] were similar to our study in that angiographic studies performed on the patients demonstrated beneficial late results. Furthermore, they found low mortality and high graft patency after concomitant CABG and CE bypass surgery.

Conclusion

In this study, our findings demonstrate that the results of CE performed by an experienced surgical team are acceptable with respect to mortality. This procedure can also have an impact on morbidity; therefore, the higher preoperative risk as well as the more advanced, diffuse, and severe calcification of the coronary artery vessels should be taken into account. In spite of this, we believe that CE is a valuable surgical option for diffuse and end-stage CAD, but it should not be considered as a substitute for CABG. Careful attention should be paid when evaluating the indications for CE, and it should be performed by an experienced surgical team to enhance the chances of success.

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