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Early postoperative results of on-pump coronary endarterectomy: is it still a controversy?

Cüneyt Eriş, Umut Serhat Sanrı, Mesut Engin, Şenol Yavuz

Department of Cardiovascular Surgery, University of Health Sciences, Bursa Yüksek İhtisas Training and Research Hospital, Bursa, Turkey

ABSTRACT

Objectives: The coronary endarterectomy combined with coronary artery bypass grafting (CABG) is an useful but still controversial surgical technique in diffuse coronary artery disease. The aim of this study was to analyze the operative and early postoperative outcomes of the patients who underwent CABG with and without coronary endarterectomy.

Methods: This retrospective study included a total of 312 consequtive patients undergoing on-pump CABG from December 2018 to December 2020 in the Department of Cardiovascular Surgery, Bursa Yüksek İhtisas Training and Research Hospital. Patients were divided into 2 groups as those who underwent coronary endarterectomy combined with on-pump CABG (Group 1, n = 48) and those who underwent isolated on-pump CABG (Group 2, n = 264). Peroperative variables were obtained from our hospital's computerized database and retrospectively analyzed.

Results: Previous percutaneus coronary intervention rate and the number of patients with diabetes mellitus was significantly higher in the endarterectomy group. The demographics and characteristics of the patients were similar between the two groups. The median number of distal anastomoses was 4 (2-5) in Group 1 and 2 (1-5) in Group 2. Median cross-clamp duration and perfusion times in Group 1 were longer than Group 2 (82 min vs. 63 min; $p < 0.001$ and 120 min vs. 95 min; $p = 0.003$, respectively). A total of 54 coronary endarterectomy practices were performed on 48 patients, and the LAD artery (73%) was the most endarterectomized vessel. In Group 1, postoperative 24 hours high-sensitive troponin I levels were significantly higher than in Group 2 ($p < 0.001$). There was no significant difference between the groups in terms of operative mortality, low cardiac output rates and perioperative myocardial infarction rates. Postoperative atrial fibrillation was significantly higher in Group 1 ($p = 0.023$).

Conclusions: Although coronary endarterectomy is a complex procedure, in patients with diffuse coronary artery disease, it is an essential and sometimes mandotary method in order to achieve complete revacularization and can be performed safely with acceptable operative and early postoperative outcomes.

Keywords: Coronary artery disease, complete myocardial revascularization, coronary endarterectomy, postoperative period

Recently, with its less invasive nature and good results, percutaneous coronary interventions have become the treatment of option for coronary artery disease (CAD) even in patients affected by diffuse dis-

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Address for correspondence: *Umut Serhat Sanrı, MD., University of Health Sciences, Bursa Yüksek İhtisas Training and Research Hospital, Department of Cardiovascular Surgery, Mimarsinan Mah., Emniyet Cd., No: 35, 16310 Yıldırım, Bursa, Turkey. E-mail: ussanri@gmail.com, Mobile phone: +90 533 5478543, Fax: +90 224 2756767*

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ease in the presence of a low Syntax Score [1]. As a result, more complex patients with high comorbidity are now referred to coronary artery bypass grafting (CABG) surgery.

Principal aim of CABG is to provide complete revascularization of diseased coronary arteries because complete revascularization [2]. In addition, previous studies have shown that complete revascularization reduces the risk of perioperative myocardial infarction, in-hospital mortality, and relapse of late symptoms [3, 4].

Patients with diffuse calcific disease, long segment or sequential coronary lesions constitute a controversial and challenging group for surgical revascularization. It is essential for surgeons to have an effective for patients with diffuse severe calcific obstructive CAD [5, 6]. Despite initial negative results in the past decades [7], several recent publications have demonstreated that coronary endarterectomy combined with CABG is a useful and sometimes a mandatory surgical option [8].

The aim of this study was to compare the operative and early postoperative clinical results of patients who underwent CABG together with coronary endarterectomy or without coronary endarterectomy.

METHODS

This retrospective study was conducted between December 2018 and December 2020 at Bursa Yuksek Ihtisas Training and Research Hospital, Bursa, Turkey. A total of 48 patients who underwent coronary endarterectomy combined with on-pump CABG (Group 1) and also 264 patients who underwent isolated on-pump CABG (Group 2) were analyzed. All cases included the study were operated by two surgeons and the same surgical team. The study was conducted in accordance with the Decleration of Helsinki Ethical Principles and Good Clinical Practices and ethics committee approval was obtained (Decision no. 2011-KAEK-25 2020/60-03, date: 24.06.2020).

Patients' variables were obtained from our hospital's computerized database. Data collection was based on hospital clinic records and intensive care data and observational records. Age, sex, body mass index (BMI), diabetes, hypertension, smoking history, hypercholesterolaemia, peripheral artery disease (PAD), preoperative left ventricular ejection fraction (LVEF) between two groups were compared. Cross-clamp times, perfusion times, number of bypass grafts used, left internal thoracic artery (LITA) use, defibrilation needs, intraaortic baloon pump (IABP) requirement, inotrope agent requirement, perioperative electrocardiogram changes, development of new atrial fibrillation, extubation times, intensive care unit (ICU) stay times, hospital discharge times were compared. Blood samples were drawn from each patient 1 day before the operation, 24 hours postoperatively to measure the myocardial biomarker, high sensitive troponin I (hsTnI). The patients with valvular heart diseases, emergency cardiac operations, those who had undergone additional cardiovascular operation were excluded from the study. All patients had continuous electrocardiographic monitoring at the ICU. Twelve-lead electrocardiographic recordings were performed preoperatively, postoperative first hour at ICU, daily for at least the first 3 postoperative days and at discharge day. LVEFs were measured and compared preoperatively and postoperatively by 2D echocardiography before discharge.

Surgical Technique

All the operations were performed under cardiopulmonary bypass (CPB) with mild hypothermia (30-32°C) after aortic cross-clamping and cardioplegic arrest. Cardiac arrest was provided with a single dose cold blood cardioplegia given from the aortic root antegradely. During CPB period, myocardial protection was provided with a half dose antegrade and a half dose retrograde cold blood cardioplegia given at every 20 minutes in all cases. Last dose of isothermal blood cardioplegia was given before removing the cross clamp.

Although the decision to apply coronary endarterectomy was considered as an option during preoperative coronary angiographic examination, the actual decision and choice of technique were based on intraoperative findings of the target coronary artery. If graft placement was not possible due to insufficient lumen diameter or diffuse thread-like appearance could be an indication for endarterectomy. Coronary endarterectomy can be performed by either through an open or closed technique [9]. In the closed technique, the endarterectomized plaque is pulled out from a smaller arteriotomy by gently applied steady traction

proximally and distally (Fig. 1). In all cases, closed technique is our primary option because the closed technique is shorter, simple and it requires a smaller anastomosis. Open coronary endarterectomy is performed when plaque extraction cannot be completed through a limited arteriotomy or when the plaque is broken, which provides sufficient exposure to remove the atherosclerotic core completely.

When we performed open endarterectomy technique in the right coronary and circumflex artery, we used the saphenous vein graft as an on-lay patch, and when we applied the closed technique saphenous vein graft was directly anastomosed to the arteriotomy. In the LAD artery, we have always preferred the open endarterectomy technique and we used the LITA as an on-lay patch graft. We applied LITA graft anastomosis on the saphenous vein patch in arteriotomies longer than 6 cm.

Postoperative Anticoagulation Protocol

Postoperatively, depending on the amount of drainage low-molecular-weight heparin (5,000 U/d) was initiated at the ICU, at 6th hour. After the patients were extubated, aspirin (100 mg/day) and clopidogrel (75 mg/day) were oraly administered together. Low-molecular-weight heparin (5,000 U/day) treatment was continued for one month, clopidogrel (75 mg/day) for one year and aspirin (150 mg/day) was recommended to continue for lifelong.

Statistical Analysis

Statistical analysis was performed with SPSS 21.0 (IBM Statistical Package or the Social Sciences Statistic Inc. version 21.0, Chicago, IL, USA). Normality distribution of data was assessed with Kolmogorov-Smirnov and Shapiro-Wilk tests. Student's t-test was used for normally distributed data (expressed as mean±standard deviation) and Mann Whitney U test was used for non-normally distributed data (expressed as median interquartile range). Nominal variables were expressed in frequency and percentage and Chi-Square test was used for analysis. A p value less than 0.05 was considered as statistically significant.

RESULTS

Data from the 48 (22%) patients who underwent coronary endarterectomy combined with on-pump CABG were evaluated as Group 1 (n = 48; 35 (72.9%) of them were males; median age 62 years (range: 42-81 years). The data from the 264 (78%) patients who underwent isolated consecutive on-pump CABG were evaluated as Group 2 (n = 264; 182 (69%) of them were males; median age 59 (range: 40-84 years). The data for these two groups were compared. Previous PCI and the number of patients with diabetes mellitus was significantly higher in the endarterectomy group. Except those there was no statistically significant difference between two groups in terms of demographic characteristics (Table 1).

Operative and postoperative clinical data are summarized in Table 2. The aortic cross-clamping times and perfusion times were significantly longer in Group

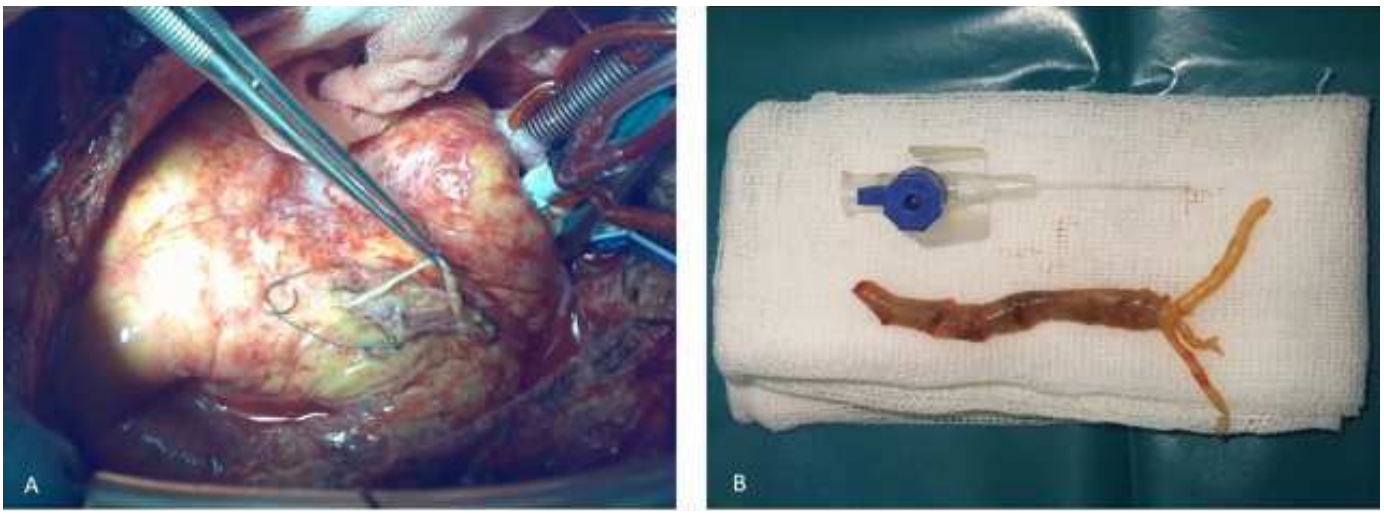

Fig. 1. (A) Intraoperative view of endarterectomy procedure. (B) The removed endarterectomy material.

Table 1. Demographic data and preoperative features of the patients

Variables	Group 1 (n = 48)	Group 2 (n = 264)	*p* value
Age(years), mean (range)	62 (42-81)	59 (40-84)	0.119
Male gender, n (%)	35 (72.9)	182 (69)	0.712
BMI (kg/m^2), mean (range)	27.9 (24-35)	28.3 (24-36)	0.196
Hypertension, n (%)	33 (68.7%)	175 (66.2%)	0.833
Previous PCI, n (%)	23 (47.9%)	74 (28%)	0.011
PAD, n (%)	13 (27%)	51 (19%)	0.421
Hiperlipidemia, n (%)	36 (75%)	175 (66.2%)	0.378
Diabetes mellitus, n (%)	18 (37.5%)	53 (20%)	0.014
COPD, n (%)	12 (25%)	44 (16.6%)	0.238
Smoking, n (%)	20 (41.6%)	77 (29.1%)	0.108
History of CVA, n (%)	3 (6%)	13 (4.9%)	0.978
Preoperative EF (%), mean (range)	50 (35-65)	50 (35-65)	0.778

Group 1 = CE combined with on-pump CABG, Group 2 = isolated on-pump CABG, BMI = body mass index, CABG = coronary artery bypass grafting, CE = coronary endarterectomy, CVA = cerebrovascular accident, COPD = chronic obstructive pulmonary disease, EF = ejection fraction, PAD = peripheral arterial disease, PCI = percutaneus coronary intervention

1 than in Group 2 (isolated CABG group) (82 min vs. 63 min; $p < 0.001$); (120 min vs. 95 min; $p = 0.003$) respectively. At the time of cross-clamp release more cases in Group 1 (39%) needed defibrillation compared with Group 2 (30%) but there was no significant difference ($p = 0.180$).

LITA use was similar between the groups. Coronary endarterectomy was applied to a total of 54 target coronary artery in 48 patients. Thirty-five patients had LAD endarterectomy, 15 patients had RCA/RPD endarterectomy, and 6 patients had multiple endarterectomies. The target vessel distribution and procedure types for which we applied CE were shown in Table 3.

Inotropic agent support was needed 25% in Group 1 and 19% in Group 2 at the time of weaning from CPB. Postoperative ejection fractions were not significantly different between the two study groups. We also found that postoperative cerebrovascular accident (CVA) rates (2% versus 1.5%), postoperative IABP need (8.3% versus 3%) was not significantly different. In Group 1, postoperative hsTnI levels were statisti-

Table 2. Operative variables of the patients

Variables	Group 1 (n = 48)	Group 2 (n = 264)	*p* value
Total perfusion time (min), median (range)	120 (85-175)	95 (80-164)	**0.003**
Cross-clamp time (min), median (range)	82 (60-140)	63 (50-110)	**< 0.001**
LITA use, n (%)	46 (95.8%)	255 (96.5%)	0.974
Inotropic support need, n (%)	12 (25%)	50 (19 %)	0.108
Intraaortic balon pump need, n (%)	4 (8.3%)	8 (3%)	0.177
Defibrilation, n (%)	19 (39%)	79 (30%)	0.180
Number of distal anastomoses, median (range)	4 (2-5)	2 (1-5)	0.154

Group 1 = CE combined with on-pump CABG, Group 2 = isolated on-pump CABG, CABG = coronary artery bypass grafting, CE = coronary endarterectomy, LITA = left internal thoracic artery

Table 3. Target vessels undergoing coronary endarterectomy

	n = 48
CE on LAD, n (%)	35 (73%)
CE on diogonal branches, n (%)	2 (4%)
CE on RCA/RPD, n (%)	15 (31%)
CE on OM, n (%)	2 (4%)
Multivessel CE, n (%)	6 (12%)
Open CE, n (%)	40 (74%)
Closed CE, n (%)	14 (26%)

CE = coronary endarterectomy, LAD = left anterior descending, OM = Obtuse marginal, RCA = right coronary artery, RPD: right posterior descending

cally significantly higher at 24 hours (p = < 0.001) postoperatively than in Group 2 (Table 4). Postoperative atrial fibrillation was signigicantly higher in Group 1 (27.1% vs 14) (p = 0.023).

DISCUSSION

Principal goal of CABG is to achieve complete revascularization because incomplete revascularization of the coronary arteries may lead to poor outcomes and high mortality rates after CABG [10]. Up to 25% of patients with extensive CAD cannot be safely and successfully treated with standard CABG. Therefore, the technique of coronary endarterectomy, which involves removal of the atherosclerotic core from the coronary artery lumen, can sometimes become risky but mandotary [11].

Coronary endarterectomy has been a controversial since its first application in 1957 by Bailey *et al*. [12]. In the 1990s, this method was not recommended in routine practice due to its high mortality and morbidity rates [13]. However, in recent years, the coronary endarterectomy procedure can be performed more successfully. This is the result of improved surgical techniques and surgical experience, improvements in cardiopulmonary bypass management, and better myocardial protection methods.

Shapira *et al*. [13] stated that, mortality and morbidity rates after CABG operations were similar in patients with coronary endarterectomy or without coronary endarterectomy. And also coronary endarterectomy was not an independent predictor of postoperative MI. Tiruvoipathy *et al*. [10] considered that the higher mortality rate of the CABG procedure with coronary endarterectomy compared to isolated

Table 4. Postoperative features and complications of the patients

Variables	Group 1 (n = 48)	Group 2 (n = 264)	*p* value
Chest tube drenaige (ml), median (range)	800 (400-1600)	750 (350-1400)	0.114
hsTnI (ng/L, 24th hours), median (range)	480 (400-1100)	250 (150-900)	**< 0.001**
Total ICU stay (days), median (range)	2 (2-18)	2 (2-10)	0.321
Total hospital stay (days), median (range)	9 (7-25)	7 (6-30)	0.228
Mortality, n (%)	2 (4.1%)	5 (1.8%)	0.328
LCOS, n (%)	3 (6,2%)	11 (4.1%)	0.214
Perioperative myocardial infarction, n (%)	2 (4.1%)	4 (1.5%)	0.124
Cerebrovascular accident, n (%)	1 (2%)	4 (1.5%)	1.000
Infection, n (%)	1 (2%)	4 (1.5%)	1.000
Reoperation due to bleeding, n (%)	2 (4.1%)	10 (3.7%)	0.432
Atrial fibrillation, n (%)	13 (27.1%)	37 (14%)	**0.023**
Respiratory failure, n (%)	2 (4.1%)	5 (1.8%)	0.124
Postoperative EF (%),median (range)	45(25-60)	45 (30-60)	0.694

Group 1 = CE combined with on-pump CABG, Group 2 = isolated on-pump CABG, CABG = coronary artery bypass grafting, CE = coronary endarterectomy, EF = ejection fraction, hsTnI = high-sensitive troponin I, ICU = Intensive care unit, LCOS = low cardiac output syndrome,

CABG was more associated with the patient's comorbidities such as age, renal failure and diabetes mellitus. Perioperative MI is another important point in patients who underwent CABG with coronary endarterectomy. The perioperative myocardial infarction rate ranges from 3% to 25% in the literature [14]. In a meta-analyses conducted by Wang *et al*. [15], they stated that CABG with coronary endarterectomy was significantly associated with 30-day mortality and higher rates of early term postoperative complications. However log-term survival was similar in CABG + coronary endarterectomy and isolated CABG patients. The authors stated that early poor results were due to the high risk profile of patients undergoing coronary endarterectomy [15].

In an another meta-analyses conducted by Soylu *et al*. [16], they reported that adjunctive CE was associated with increasing 30-day mortality, perioperative and postoperative myocardial infarction when compared with isolated CABG. The relatively high rate of postoperative MI (9.0%) in their study could have resulted from the inclusion of patients with an enzymatic definition of postoperative MI. In our study the operative mortality of patients undergoing coronary endarterectomy was 4.1%, which is superior to other clinical reports and 1.8% for the patients with isolated CABG. There was no significant difference in terms of mortality between two groups. The percentage of perioperative MI in our study was slightly higher in group 1, but it was not statistically significant (4.1% vs 1.5%; p = 0.124).

The combination of coronary endarterectomy with CABG prolongs aortic cross-clamping and CPB times compared to isolated CABG. As a result, this situation increases the risk of ischemia reperfusion injury and end-organ damage with worse outcomes in the early postoperative period [16]. In order to minimize myocardial ischemic damage, we used the retrograde cardioplegia method in addition to antegrade cardioplegia in all patients that we applied coronary endarterectomy. We think that retrograde cardioplegia method both provides more widespread cardioplegia distribution through the significantly developed collaterals and increases the success rate of the procedure by clearing debris in the distal coronary bed.

In the literature, LAD is the most common endarterectomized vessel (40%-83%) that feeds a significant part of the left heart and also is the most important target artery for complete revascularization [17]. Endarterectomy of the right coronary artery is performed more courageously due to the technical simplicity and a lower risk. In our study, 73% of the patients underwent LAD endarterectomy. We observed that RCA was the second common endarterectomied vessel with 31% in our study. In the literature, this ratio varies between 21.1% and 83% [14]. In our study, we determined that multiple coronary endarterectomies were performed simultaneously in 12.5% of the patients.

It is also controversial whether the open or closed coronary endarterectomy method is the optimal technique. The basic principle of coronary endarterectomy is the complete removal of the atherosclerotic core without leaving an obstructing plaque. In the closed technique, a shorter arteriotomy and thus a shorter anastomosis is performed, but it requires more experience. Distal and proximal embolism risk is higher since most of the procedure is performed under a closed area [18]. On the other hand, the open method is safer in terms of distal embolism since the complete cleaning of the atherosclerotic core is performed under direct vision [9]. The disadvantage of the open method is that the arteriotomy is longer, requiring a longer anastomosis and therefore a longer ischemic time.

In the study of Nishi *et al*. [19] comparing the open method with the closed method, the perioperative mortality rate (2.9% vs 6.8%) was found to be lower in patients who underwent open endarterectomy, although it was not significant. In addition, long-term results in terms of morbidity (85% vs 77%) were significantly better in the open endarterectomy group. At a mid-term follow up (16-22 months) graft patency rates were 89.1% vs 81% in favor of open endarterectomy [19]. In our study, the open endarterectomy method was mostly used (74% vs 26%), and the onlay patch LITA was used for vascular reconstruction, especially in the LAD region.

Poor outcomes of coronary endarterectomy especially the high incidence of myocardial infarction may be attributed to endothelium damage which can lead platelet aggregation and finally acute thrombosis of the endartherectomised vessel [20]. Therefore we started acetylsalicyclic acid (100 mg) and clopidogrel (75 mg) treatment for all patients immediately after surgery.

Limitations

Our study had several limitations: first of all, it was a single center, retrospective and non randomized study. The number of patients was relatively small. Also, our study focused on clinical follow-up, and graft patency rates were not examined with imaging techniques (i.e., conventional or CT angiography). Follow-up angiography was performed for only a minorty of patients. Therefore, further studies with a larger number of patients are needed.

CONCLUSION

Coronary endarterectomy appears as a satisfactory and sometimes mandatory surgical option in the presence of diffuse CAD. It can be performed safely with acceptable mortality and morbidity rates, as a result of the increased surgical experience and advances in myocardial protection techniques, especially the use of retrograde cardioplegia. In addition, we think that postoperative aggressive anticoagulation especially dual antiplatelet therapy increases the success of the technique.

Authors' Contribution

Study Conception: CE, USS; Study Design: CE, ME; Supervision: ŞY; Funding ŞY; Materials: CE, USS; Data Collection and/or Processing: USS, ME; Statistical Analysis and/or Data Interpretation: CE; Literature Review: USS; Manuscript Preparation: CE, ME and Critical Review: ŞY.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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