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ORIGINAL ARTICLE

Early and mid-term results of coronary endarterectomy: Influence of cardiopulmonary bypass and surgical techniques

Jae Hang Lee[1], Cheong Lim[2], Jun Sung Kim[2], Kay-Hyun Park[2]

[1]Department of Thoracic and Cardiovascular Surgery, Dongguk University Ilsan Hospital, Goyang, Korea
[2]Department of Thoracic and Cardiovascular Surgery, Seoul National University Bundang Hospital, Seongnam, Korea

Abstract

Background: *Coronary endarterectomy (CE) may be a good option for complete revascularization of diffuse coronary artery diseases, but it has not been widely used because the outcomes have not been definitively identified. This study aims to evaluate the mid-term clinical results of CE and compare the outcomes according to the use of cardiopulmonary bypass (CPB) and the surgical technique used.*

Methods: *Between 2004 and 2014, 69 cases of CE were performed in 64 patients. We divided the patients into two groups: 1) on-pump coronary artery bypass with coronary endarterectomy (ONCAB-CE) versus off-pump coronary artery bypass with coronary endarterectomy (OPCAB-CE), and 2) "open" versus "closed" surgical techniques. Operative mortality and major morbidity, were investigated including perioperative myocardial infarction (PMI), and overall survival.*

Results: *Operative mortality was 4.7% (3/64), and no PMI was observed in the study. No statistical differences in operative mortality rate between the ONCAB-CE and OPCAB-CE groups were found (3.1% vs. 6.2%, p = 1.0) or between open versus closed techniques (6.7% vs. 2.9%, p = 0.6). The incidence of major morbidity including cerebrovascular accident, atrial fibrillation, acute renal failure, mediastinitis, respiratory complications, and bleeding was comparable between all groups. There were seven late mortalities, and no differences were found in overall survival rate between all groups.*

Conclusions: *Coronary endarterectomy appears to be a safe option for patients with diffuse coronary artery disease, regardless of whether CPB or a specified selection of surgical techniques are used.* (Cardiol J 2017; 24, 3: 242–249)

Key words: coronary artery disease, endarterectomy, coronary artery bypass grafting, cardiopulmonary bypass

Introduction

With advances in percutaneous coronary interventions (PCI), there has been a change in the spectrum of patients who are referred for coronary artery bypass graft (CABG) surgery. The lesions of coronary arteries have become more complex, and patients with comorbidities such as diabetes mellitus, dyslipidemia, and old age are being referred for surgical revascularization [1, 2]. In cases of diffuse coronary artery disease (CAD), it is not simple to achieve complete revascularization using routine CABG and incomplete myocardial revascularization would lead to poor short- and long-term outcomes after bypass surgery.

First described by Baily et al. [3] in 1957, coronary endarterectomy (CE) is a method for treating patients with severe atherosclerotic CAD.

Address for correspondence: Cheong Lim, MD, PhD, Department of Thoracic and Cardiovascular Surgery, Seoul National University Bundang Hospital, 300 Gumi-dong, Bundang-gu, Seongnam-si, Gyeonggi-do, 463-707, Korea, tel: 82 31 787 7139, fax: 82 31 787 4050, e-mail: mluemoon@snubh.org

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However, there is division of opinion among many surgeons about the safety and effectiveness of the technique; although proponents claim that it is the last option for patients with end-stage CAD [4, 5], opponents assert that it is associated with higher mortality and morbidity [6, 7].

There have been many studies on CE, and most have focused on its safety and efficacy. There is, however, a paucity of data regarding the influence of technique variations and the use of cardiopulmonary bypass (CPB). In the present investigation mid-term clinical outcomes of CE were compared 1) on-pump CABG with CE (ONCAB-CE) and off--pump CABG with CE (OPCAB-CE) and 2) "open" and "closed" endarterectomy.

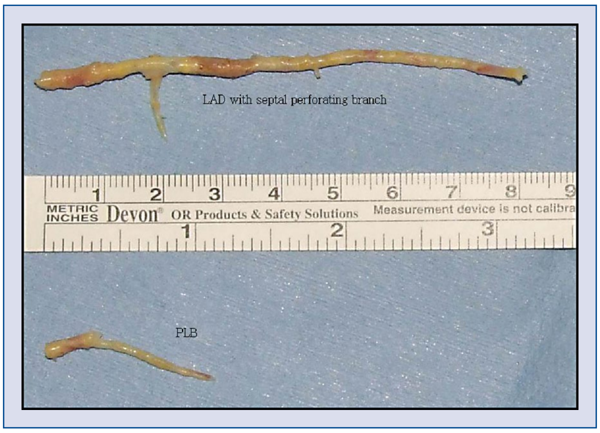

Figure 1. Atheroma excised from the left anterior descending artery (LAD) and posterolateral branch (PLB) in a patient.

Methods

Study population and clinical outcome

Between October 2004 and August 2014, 1,215 patients underwent CABG and 64 patients received CE at Seoul National University Bundang Hospital. A total of 69 cases of CE were performed, and 5 patients had the CE performed in two areas. First, the 64 patients were divided into two groups: ONCAB-CE (n = 32) and OPCAB-CE (n = 32). Second, the same patients were divided into the two groups open (n = 30) versus closed (n = 34) technique. The following outcomes were observed : 1) operative mortality; 2) perioperative myocardial infarction (PMI) and major morbidity; and 3) overall survival.

Surgical indication and technique

Indication of CE was made intraoperatively either after arteriotomy revealed an occluded lumen with no graftable vessel or if a 1-mm coronary probe could not be passed down the target coronary vessel. The surgical techniques depended on the surgeon's preference and the coronary lesion, but all commonly checked that the entire plaque including branches had been removed (Fig. 1) The closed technique was traction of the endarterectomized intima through a small arteriotomy, whereas for the open technique, the arteriotomy was extended proximally and distally towards a lesser diseased arterial wall. In these cases, we often used an additional patch, such as from the saphenous vein or the right internal thoracic artery (RITA) segment, and we routinely anastomosed with 8-0 continuous polypropylene suture. Concerning the use of CPB, we used OPCAB routinely, with the exceptions being urgent, emergency operations or when left ventricular (LV) dysfunction was present, when ONCAB was used selectively. Patients were administered antiplatelet agents with aspirin, 43 patients received clopidogrel in combination; 1 patient with valve replacement surgery received warfarin in combination with aspirin. Four surgeons performed the operations.

Definitions

Operative mortality was defined as death within 30 days of the surgery or death before discharge; LV dysfunction as LV ejection fraction < 40%; and respiratory complications as prolonged mechanical ventilation longer than 7 days or pneumonia confirmed pathologic organism.

We diagnosed the patients with PMI if they had at least two of the following four criteria:

- prolonged (> 20 min) chest pain not relieved by rest or nitrates;
- an elevated cardiac enzyme: either 1) creatine kinase (CK) isoform > 5% of total creatine phosphokinase; 2) CK greater than 2× normal; 3) lactate dehydrogenase (LDH) subtype 1 > LDH subtype 2; or 4) troponin > 0.2 μg/mL;
- newly developed wall motion abnormalities;
- serial electrocardiogram showing changes from baseline or serially in ST-T and/or Q waves that were 0.03 s in width and/or one-third of the total QRS complex in two or more contiguous leads.

Postoperative acute renal insufficiency was defined by the following presented criteria:

- elevated serum creatinine level > 2.0;
- 50% or greater increase in creatinine over baseline preoperative value;
- new requirement for hemodialysis.

Review of clinical data and images

This study was conducted using a retrospective single-center design. Statistical analysis was performed with the SPSS software package (version 19.0; SPSS Inc., Chicago, IL, USA); continuous variables are described as mean ± standard deviation. Continuous variables were compared using Student's t-test and the discrete variables with the χ^2-test or Fischer's exact test; differences were considered significant at $p < 0.05$. In the propensity-matched cohort, all comparisons were tested between the groups using a paired t-test for the continuous variables and McNemar's test for the categorical variables. To determine the independent risk factors for mortality, Cox's proportional hazards models were used. Results are expressed as odds ratios with 95% confidence intervals.

This study was approved by the institutional review board of the documented medical institution. Informed consent was waived due to the retrospective nature of the study.

Results

There were more male patients in the group that received the open technique (p = 0.01). More patients were observed with LV dysfunction in the ONCAB-CE group (p = 0.003) and more patients with ascending aorta calcification in the OPCAB-CE group (p = 0.02). In the other preoperative characteristics such as age, hypertension, diabetes, dyslipidemia, smoking, comorbidities including chronic renal failure, chronic obstructive pulmonary disease, peripheral arterial occlusive disease, and acute myocardial infarction, there were no significant differences between any of the groups. In all groups, a majority of patients had undergone elective surgery and had been diagnosed with triple vessel disease (Table 1).

In most cases, CE was conducted in the left anterior descending artery (67%, 43/64), and the bilateral internal thoracic artery (87.5%, 56/64) was the most frequently used. In seven patients, valve surgery was conducted together with CE, and in 3 patients, the Dor procedure was conducted; in operative data, there were no significant differences between the groups (Table 2). The postoperative courses were favorable; most patients could be extubated on the day of the surgery and discharged by postoperative day 8 or 9. Regarding the hospital course, such as mechanical ventilation time, intensive care unit stay, and hospital days, there were no differences between the groups (Table 3).

Operative mortality was 4.7% (3/64); 2 patients died due to bowel ischemia, and the other patient committed suicide before discharge, no PMI was observed in this study. There were no significant differences between the two groups in postoperative complications such as cerebral vascular accident, new-onset atrial fibrillation, acute renal insufficiency, mediastinitis, respiratory complications, and bleeding (Table 4). We performed propensity score matching to minimize the effects on the five factors in Tables 1 and 2: male sex (p = 0.01), ascending aortic calcification (p = 0.02), elective operation (p = 0.06), triple vessel disease (p = 0.10), and associated procedure (valve or Dor); a total of 28 patients were matched. Even in the matched cohort, no significant differences were found between the two groups in postoperative course (Table 5) or early postoperative complications (Table 6). On multivariable analysis, diabetes and triple vessel disease emerged as significant and independent risk factors for mortality (Table 7).

The average patient follow-up was 60.2 ± 33.3 months (range: 17–134 months). There were 7 late mortalities in this study — 1 patient died from sudden cardiac arrest, 5 died of unknown causes, and the other died of pneumonia; the 5 unknown deaths included patients who had been dead on arrival at the emergency room and patients whose deaths had been confirmed by telephone survey. In overall survival rates, there were no significant differences between the groups (Fig. 2).

Discussion

The primary goal of CABG is to achieve complete revascularization of diseased coronary arteries. It has been shown that incomplete revascularization is one of the most important risk factors associated with poor ventricular function, high reoperation rate, perioperative morbidity, and mortality [8, 9]. However, with advances in PCI, the lesions of coronary arteries treated surgically have become more calcified and complex; as such, it would be difficult to achieve complete revascularization using the conventional CABG in numerous cases with diffuse CAD.

In 1957, Baily et al. [3] first introduced the CE technique. However, even after half a century, the current opinions about the safety and effectiveness of CE are varied, and the technique remains controversial. Although it is the only surgical technique that can resolve severe diffuse calcified coronary lesions, it can also lead to increased perioperative morbidity and mortality, and there are reports

Table 1. Preoperative characteristics.

	ONCAB-CE (n = 32)	OPCAB-CE (n = 32)	P	Open (n = 30)	Closed (n = 34)	P
Age [years]	68.9 ± 7.5	68.8 ± 8.1	0.96	68.7 ± 9.1	68.9 ± 6.47	0.93
Male sex	21	22	0.79	25	18	0.01
Cardiac risk factor:						
Hypertension	23	21	0.59	23	21	0.20
DM	21	26	0.16	20	27	0.25
Dyslipidemia	10	18	0.44	15	13	0.34
Smoker	12	19	0.08	15	16	0.81
LV dysfunction	15	4	0.003	11	8	0.25
Comorbidities:						
CRF	7	4	0.32	3	8	0.15
COPD	3	1	0.61	2	2	1.00
PAOD	7	6	0.76	4	9	0.19
AA calcification	0	5	0.02	2	3	1.00
AMI	10	10	1.00	12	8	0.16
s/p PTCA	6	10	0.25	10	6	0.15
Operative priority:						
Elective	18	25	0.06	20	23	0.93
Urgent	12	6	0.10	9	9	0.75
Emergent	2	1	1.00	1	2	1.00
Diseased vessels:						
1 VD	0	2	0.49	0	2	0.49
2 VD	1	4	0.36	4	1	0.18
3 VD	31	26	0.10	26	31	0.70

ONCAB-CE — on–pump coronary artery bypass coronary endarectomy; OPCAB-CE — off–pump coronary artery bypass coronary endarectomy; DM — diabetes mellitus; LV — left ventricle; CRF — chronic renal failure; COPD — chronic obstructive pulmonary disease; PAOD — peripheral arterial occlusive disease; AA — ascending aorta; AMI — acute myocardial infarction; PTCA — percutaneous transluminal coronary angioplasty; VD — vessel disease

Table 2. Operative data.

	ONCAB-CE (n = 32)	OPCAB-CE (n = 32)	P	Open (n = 30)	Closed (n = 34)	P
Target vessel [total 69 sites]:						
LAD (D)	19	24	0.44	22	21	0.69
LCx (OM)	5	4	0.73	5	4	0.73
RCA (PDA/PLb)	9	8	0.63	7	10	0.44
Used graft [total 69 sites]:						
LITA	15	20	0.40	17	18	0.91
RITA	9	12	0.59	13	8	0.17
RA	1	0	0.48	0	1	1.00
SVG	8	4	0.15	4	8	0.22
Total number of distal anastomosis	3.7 ± 1.0	3.2 ± 1.1	0.13	3.6 ± 1.1	3.3 ± 1.0	0.31
Associated procedure:						
MVP or MAP	6	0		4	2	0.41
AVR	1	0		1	0	0.47
Dor procedure	3	0		1	2	1.00

ONCAB-CE — on–pump coronary artery bypass coronary endarectomy; OPCAB-CE — off–pump coronary artery bypass coronary endarectomy; LAD — left anterior descending artery; D — diagonal artery; LCx — left circumflex artery; OM — obtuse marginal artery; RCA — right coronary artery; PDA — posterior descending artery, PLb — posterolateral branch; LITA — left internal thoracic artery; RITA — right internal thoracic artery; RA — radial artery; SVG — saphenous vein graft; MVP — mitral valve plasty; MAP — mitral annuloplasty; AVR — aortic valve replacement

Table 3. Postoperative course.

		ONCAB-CE (n = 32)	OPCAB-CE (n = 32)	P	Open (n = 30)	Closed (n = 34)	P
Ventilator time [h]	Mean ± SD	18.8 ± 30.3	12.7 ± 14.2	0.31	14.0 ± 13.6	17.3 ± 30.0	0.58
	Median (range)	13.8 (1.0–174)	4.8 (1.5–33)		12.0 (1.0–68.5)	7.3 (1.5–174)	
ICU stay [h]	Mean ± SD	84.6 ± 208.4	37.6 ± 29.8	0.21	43.3 ± 33.1	76.9 ± 202.9	0.37
	Median (range)	38.8 (9–1183)	23.4 (14–312)		28.0 (15–164)	24.3 (9–1183)	
Hospital stay [day]	Mean ± SD	26.3 ± 59.8	12.1 ± 11.8	0.20	15.0 ± 17.4	22.9 ± 57.3	0.47
	Median (range)	8.5 (6–337)	8 (4–25)		8.5 (5–99)	8 (4–337)	

ONCAB-CE — on-pump coronary artery bypass coronary endarectomy; OPCAB-CE — off-pump coronary artery bypass coronary endarectomy; ICU — intensive care unit; SD — standard deviation

Table 4. Early postoperative complications.

	ONCAB-CE (n = 32)	OPCAB-CE (n = 32)	P	Open (n = 30)	Closed (n = 34)	P
Operative mortality	1	2	1.00	2	1	0.60
Perioperative MI	0	0		0	0	
Cerebrovascular accident	1	0	1.00	0	1	1.00
Atrial fibrillation	7	4	0.32	6	5	0.58
Acute renal failure	3	2	1.00	2	3	1.00
Mediastinitis	1	0	1.00	1	0	0.47
Respiratory complication	1	1	1.00	0	2	0.49
Bleeding	2	0	0.49	0	2	0.49

ONCAB-CE — on-pump coronary artery bypass coronary endarectomy; OPCAB-CE — off-pump coronary artery bypass coronary endarectomy; MI — myocardial infarction

Table 5. Postoperative course of propensity score matched patients.

		ONCAB-CE (n = 14)	OPCAB-CE (n = 14)	P	Open (n = 10)	Closed (n = 18)	P
Ventilator time [h]	Mean ± SD	25.5 ± 44.5	9.1 ± 8.4	0.188	8.8 ± 8.6	22 ± 39.6	0.312
	Median (range)	12.5 (1–174)	4.8 (1.5–24.5)		5.5 (1–29.6)	8.5 (1.5–174)	
ICU stay [h]	Mean ± SD	124.4 ± 306.9	51 ± 78.4	0.394	34.6 ± 28.2	117.2 ± 275.6	0.358
	Median (range)	23 (15–1183)	22.8 (15–312)		20.5 (15–94)	24 (15–1183)	
Hospital stay [day]	Mean ± SD	36.2 ± 88.1	11.8 ± 5.7	0.319	9.8 ± 3.6	31.9 ± 77.5	0.380
	Median (range)	8 (6–337)	11 (5–21)		8 (6–16)	9.5 (5–337)	

ONCAB-CE — on-pump coronary artery bypass coronary endarectomy; OPCAB-CE — off-pump coronary artery bypass coronary endarectomy; ICU — intensive care unit; SD — standard deviation

that it is not advantageous to long-term survival [6, 7, 10].

Studies show the mortality after CE to be 0% to 15% [6, 11–13]. These could be seen as high rates compared with the results of conventional CABG only, but it could be said that rather than the technique itself being dangerous, the patients who receive CE already have high comorbidities and risk factors; in fact, the total CABG mortality during the same period in our hospital was 5.1% (62/1215), showing no significant difference statistically. For PMI, which is known to be one of the biggest complications of CE, mortality is also reported as ranging from 0% to 15% [11–14]. However, the incidence of PMI is gradually decreasing because of improvements in surgical techniques

Table 6. Early postoperative complications of propensity score matched patients.

	ONCAB-CE (n = 14)	OPCAB-CE (n = 14)	p	Open (n = 10)	Closed (n = 18)	p
Operative mortality	0	1	1	0	1	1
Perioperative MI	0	0	–	0	0	–
Cerebrovascular accident	1	0	1	0	1	1
Atrial fibrillation	2	2	1	1	3	1
Acute renal failure	1	1	1	0	2	0.524
Mediastinitis	0	0	–	0	0	–
Respiratory complication	1	1	1	0	2	0.524
Bleeding	1	0	1	0	1	1

ONCAB-CE — on–pump coronary artery bypass coronary endarectomy; OPCAB-CE — off–pump coronary artery bypass coronary endarectomy; MI — myocardial infarction

Table 7. Multivariable analysis for risk factors of mortality after coronary endarterectomy.

Predictor	Univariate OR (95% CI)	P	Multivariate OR (95% CI)	P
Age	1.04 (0.95–1.15)	0.362	1.08 (0.92–1.20)	0.152
Gender	1.61 (0.45–5.72)	0.466		
Hypertension	1.42 (0.40–5.06)	0.584		
Diabetes mellitus	4.45 (1.25–15.82)	0.021	13.62 (1.55–119.98)	0.019
Dyslipidemia	0.92 (0.27–3.21)	0.901		
Smoker	2.79 (0.72–10.88)	0.139		
Left ventricular dysfunction	1.42 (0.30–6.73)	0.657	1.28 (0.22–7.37)	0.783
Chronic renal failure	1.80 (0.23–14.23)	0.577		
Chronic obstructive pulmonary disease	0.53 (0.07–4.26)	0.552		
Peripheral arterial occlusive disease	2.27 (0.29–18.05)	0.437		
Ascending aortic calcification	0.95 (0.12–7.56)	0.962		
Acute myocardial infarction	37.64 (0.15–9782.31)	0.201		
Percutaneous coronary intervention	3.01 (0.38–23.83)	0.297		
Emergent operation	0.45 (0.06–3.62)	0.454	0.07 (0.01–1.10)	0.058
Triple vessel disease	3.82 (0.99–14.82)	0.053	37.56 (3.30–427.28)	0.003

OR — odds ratio; CI — confidence interval

and added myocardial protection techniques, and no PMI were observed in this study.

The achievement of OPCAB with good results has encouraged surgeons to perform endarterectomy on beating hearts, and recent studies on OPCAB-CE showed favorable outcomes [15–17]. In these studies, OPCAB-CE was feasible and could be performed in patients with LV dysfunction who were expected to benefit from complete revascularization. In addition to, in the current study, the outcomes were examined of patients who underwent CE with either on- or off-pump CABG. Naseri et al. [18] reported that OPCAB-CE can be performed safely with morbidity and mortality comparable with those of ONCAB-CE.

In this study, half the total number or 32 patients received OPCAB-CE. The total operative mortality of CE in this study was 4.7% (3/64), which was comparable with findings of previous studies. We prefer ONCAB in patients with LV dysfunction but OPCAB in patients with ascending aortic calcification, and thus, there were differences in these two preoperative characteristics between the two groups. The 10 ONCAB-CE patients with a valve disease and concomitant LV aneurysm procedure could have affected our results. There was a limitation of small sample size in this study, thus propensity score matching was performed so that similar results could be described.

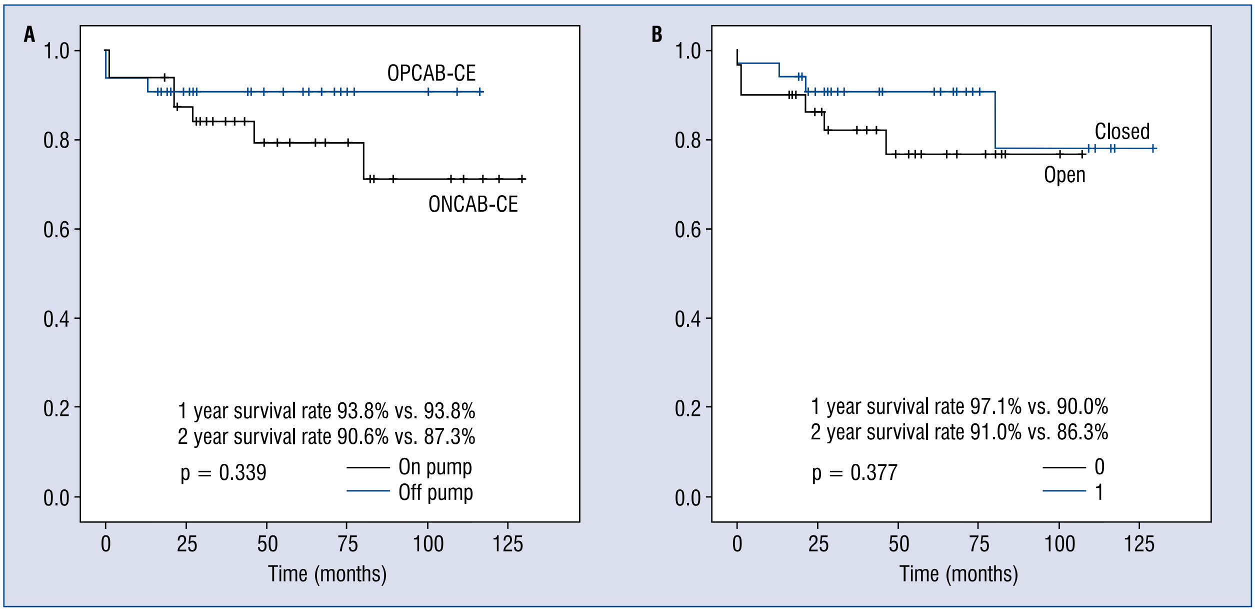

Figure 2. A, B. Kaplan-Meier curves for overall survival comparing (1) on-pump coronary artery bypass grafting with closed endarterectomy (CE) (ONCAB-CE) and off-pump coronary artery bypass grafting with CE (OPCAB-CE), and (2) open and CE.

As already noted, CE can be conducted in two ways, either open or closed. The open technique is with arteriotomy extended proximally and distally towards a lesser diseased arterial wall. In contrast, the closed technique entails traction of the endarterectomized intima through a small arteriotomy. The open technique sometimes uses the saphenous vein or remnant RITA segment to perform an on-lay patch angioplasty; this has the advantage that the obstruction or flap inside the native coronary artery can be checked, but this surgery takes a long time and the bleeding risk is increased. The closed technique is also called the traction technique, and it has the advantage that operation time is short and concise, but there is the possibility of an obstruction and intimal flap that cannot be completely ruled out with this operation. Nishi et al. [14] compared the closed and on-lay patch bypass techniques and showed that there was no difference between the two groups in terms of perioperative mortality and morbidity, but they did note that the on-lay patch bypass group had better mid-term angiographic results. However, that study was different from this one as all patients received conventional CABG using CPB and cardioplegia.

Many studies have evaluated graft patency after CE, and the patency rate has been reported as occurring in 80–98.6% of cases [14, 19, 20]; these studies report on the mid-term or long-term patency from coronary angiography (CAG). In this study there was an attempt to evaluate the mid-term patency of CE, but postoperative computed tomographic angiography (CTA) was performed in only 58% of the patients. In most of the cases in which CTA was not conducted, there were limitations in using contrast due to accompanying chronic kidney disease, and in the remaining cases, patients refused to participate in the postoperative study; in this limited study, the interval was 5.5 ± ± 2.4 months. Thirty-eight sites were patent among the 41 (92.7%) vessels, and there was no difference in the mid-term patency between the open and closed technique groups (22/23, 95.7% vs. 16/18, 88.9%; $p = 0.41$) or between the ONCAB-CE and OPCAB-CE groups (21/24, 87.5% vs. 17/17, 100%; $p = 0.25$).

Unlike previous studies, our study used CTA to measure the patency of CE. In the presented hospital, postoperative coronary CTA was routinely conducted rather than CAG because it is less invasive. In addition, graft patency can be accurately estimated using CTA because the graft is less influenced by cardiac motion, the graft diameter is large, and there is very little calcification. CTA is also relatively widely used in South Korea because of national health insurance policy.

There are a number of limitations in this study. First, the study was conducted retrospectively, and second, we lacked a control group. Finally, a relatively small number of patients were enrolled, and results are based on a mid-term follow-up. Thus, a large number of patients and long-term follow-up periods are needed for more complete results.

Conclusions

This study revealed that CE can be a good option for achieving complete myocardial revascularization in selected patients with diffuse CAD. Also, CE may be performed securely with acceptable outcomes, regardless of whether CPB is used or selection of the surgical techniques.

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Conflict of interest: None declared

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