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Comparative Outcomes of Closed RCA Endarterectomy and Open LAD Endarterectomy with LIMA Patch Plasty

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ABSTRACT

Introduction: Coronary endarterectomy (CE) is an adjunctive technique used to achieve complete revascularization in patients with diffuse coronary artery disease when conventional bypass grafting is not feasible. To compare early outcomes and graft patency between closed right coronary artery (RCA) endarterectomy and open left anterior descending (LAD) endarterectomy with left internal mammary artery (LIMA) patch plasty.

Methods: This retrospective study included 31 patients undergoing closed traction RCA endarterectomy and 36 patients undergoing open LAD endarterectomy with LIMA patch plasty during CABG. Perioperative outcomes, postoperative arrhythmias, and follow-up coronary angiographic findings were analyzed.

Results: Early mortality occurred only in the closed RCA group but was not statistically significant. Atrial fibrillation rates were similar. The closed RCA group demonstrated significantly higher postoperative bleeding, greater inotropic and intra-aortic balloon pump requirements, longer ICU stay, and more frequent ventricular arrhythmias. Follow-up angiography at a mean of 6.08 ± 2.01 years (open LAD) and 4.21 ± 1.12 years (closed RCA) showed significantly higher anastomotic patency in the open LAD group (94.1% vs. 50.0%, p = 0.008).

Conclusion: Open LAD endarterectomy with LIMA patch plasty provides a more stable early postoperative course and superior mid-term graft patency compared with closed RCA endarterectomy.

Keywords: Coronary endarterectomy; Right coronary artery; Left anterior descending artery; LIMA patch plasty; Coronary artery bypass grafting

Introduction

The population of patients referred for coronary artery bypass grafting (CABG) has evolved considerably over time. In patients with ischemic heart disease and diffuse coronary artery disease, percutaneous coronary interventions such as angioplasty and stent implantation are often not feasible, making CABG the preferred treatment option. In this subset of patients, conventional surgical revascularization techniques may be inadequate or even impossible because of the absence of a suitable coronary lumen. As a consequence of advances in nonsurgical coronary revascularization, the coronary anatomy of patients presenting for CABG has become increasingly complex over time [1–3].

In patients with diffuse coronary artery disease identified on coronary angiography, suitable coronary targets for standard graft anastomosis may not be available, thereby precluding complete revascularization using conventional techniques. In such cases, the available options are either to consider the patient inoperable or to achieve complete revascularization through coronary endarterectomy [3,4]. Since the principal goal of CABG

is complete myocardial revascularization, coronary endarterectomy remains an important adjunctive strategy in selected patients with diffuse coronary artery disease.

Direct head-to-head comparisons between open left anterior descending (LAD) artery endarterectomy with patch reconstruction and closed right coronary artery (RCA) endarterectomy are scarce. Most available studies have evaluated open versus closed techniques in mixed-vessel cohorts or have reported single-vessel series focused on LAD reconstruction or closed traction endarterectomy outcomes [5–7].

The present study aimed to compare the outcomes of patients undergoing closed traction RCA endarterectomy with those undergoing open LAD endarterectomy with left internal mammary artery (LIMA) patch plasty.

Methods

This retrospective observational study included 31 patients who underwent coronary artery bypass grafting (CABG) with right coronary artery (RCA) endarterectomy between January 2005 and January 2024 (Group A) and 36 patients who underwent open left anterior descending (LAD) artery endarterectomy with left internal mammary artery (LIMA) patch plasty between 2005 and 2024 (Group B).

All procedures in Group B were performed using a standardized open technique under cardiopulmonary bypass at four tertiary cardiac surgery centers in Turkey.

The study aimed to compare closed traction RCA endarterectomy and open LAD endarterectomy with LIMA patch plasty with respect to baseline clinical characteristics, operative variables, early postoperative outcomes, arrhythmias, mortality, and longitudinal changes in New York Heart Association (NYHA) functional class. By providing a comprehensive comparison of these two techniques, the study sought to inform clinical decision-making in patients with diffuse coronary artery disease requiring complex revascularization strategies.

Surgical Technique

All operations were performed through a standard median sternotomy. The left internal mammary artery (LIMA) was harvested in a semipedicled fashion in all patients. Following systemic heparinization, the LIMA was divided distally beyond its bifurcation to obtain adequate conduit length. Satisfactory free flow was confirmed, after which the distal end was clipped and the graft was stored in a warm saline–papaverine-soaked sponge to minimize vasospasm.

Cardiopulmonary bypass (CPB) was established via ascending aortic and right atrial cannulation, and the aorta was cross-clamped. Myocardial arrest was achieved using cold blood cardioplegia delivered through the aortic root, while systemic temperature was maintained at 32–34 °C. Myocardial protection was ensured by intermittent antegrade cold blood cardioplegia administered at 15-minute intervals, initially through the aortic root and subsequently through the grafts after completion of the distal anastomoses.

Closed Traction RCA Endarterectomy

For right coronary artery (RCA) endarterectomy, a limited arteriotomy was performed, and the atheromatous core was gently extracted by traction from the distal vessel segment (Figure 1; red arrows indicate the direction of traction). Traction was applied parallel to the longitudinal axis of the RCA, allowing the plaque to be withdrawn proximally. Subsequently, a saphenous vein graft was anastomosed to the distal RCA.

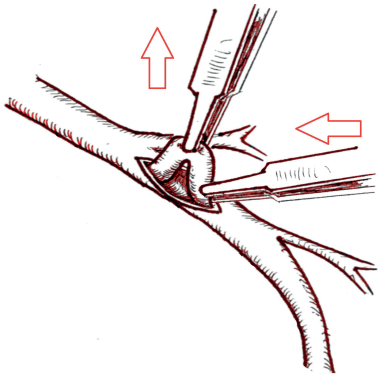

Figure 1 – Illustration depicts the surgical technique of traction RCA endarterectomy

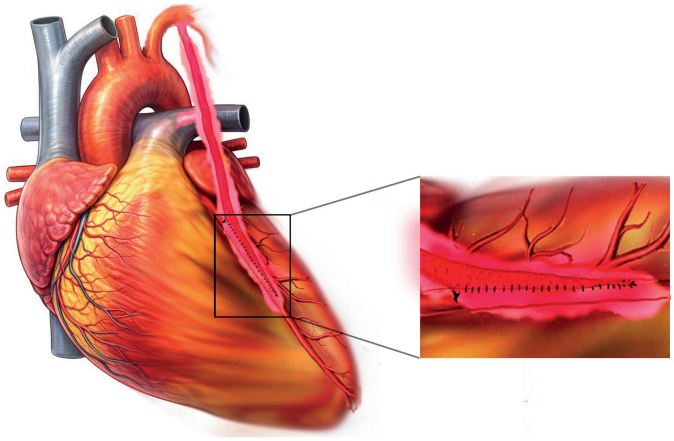

Figure 2 – Illustration depicts the surgical technique of Open LAD endarterectomy and LIMA patch

Open LAD Endarterectomy with LIMA Patch Plasty

After completion of distal anastomoses to all coronary targets other than the LAD, attention was directed to LIMA–LAD reconstruction. The epicardial surface over the LAD was exposed, and the overlying epicardial and connective tissues were meticulously dissected using a No. 15 scalpel blade. The indication for LAD endarterectomy was determined either preoperatively, based on coronary angiography demonstrating diffuse LAD disease, or intraoperatively when an adequate distal lumen for conventional anastomosis could not be identified or when extensive atherosclerosis extended beyond the planned anastomotic site.

Following longitudinal extension of the LAD arteriotomy and meticulous removal of the atherosclerotic plaque, the LIMA was anastomosed as an onlay patch to achieve arterial reconstruction. Figure 2 illustrates the surgical technique.

Statistical Analysis

Statistical analyses were performed using SPSS software (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality using the Shapiro–Wilk test. Normally distributed variables are presented as mean ± standard deviation and were compared using the Student's t-test, whereas non-normally distributed variables are presented as median (interquartile range) and were compared using the Mann–Whitney U test. Categorical variables are expressed as frequencies and percentages and were compared using the chi-square or Fisher's exact test, as appropriate.

Changes in NYHA functional class over time were analyzed using paired nonparametric tests. Early mortality was

Table 1 Baseline Demographic Characteristics

Variable	Open LAD endarterectomy (n=36)	Closed RCA endarterectomy (n=31)	p-value	Statistical test
Age, years	61.6 ± 8.9	62.3 ± 9.4	0.734	Student t-test
Hypertension	24 (66.7)	16 (51.6)	0.210	Chi-square
Diabetes mellitus	28 (77.8)	6 (19.4)	<0.001	Chi-square
Family history of CAD	6 (16.7)	4 (12.9)	0.742	Fisher's exact
Smoking history	18 (50.0)	16 (51.6)	0.895	Chi-square
Preoperative myocardial infarction	9 (25.0)	5 (16.1)	0.373	Chi-square
Preoperative EF, %	39.5 ± 11.0	52.2 ± 11.8	<0.001	Mann–Whitney U

Values are presented as mean ± SD or n (%). EF, ejection fraction; CAD, coronary artery disease; RCA, right coronary artery; LAD, left anterior descending artery.

defined as death occurring within 30 postoperative days. A two-sided p value < 0.05 was considered statistically significant.

Results

Baseline demographic, clinical, and operative characteristics are summarized in Table 1. Group A consisted of 31 patients who underwent CABG with closed traction RCA endarterectomy, whereas Group B included 36 patients who underwent open LAD endarterectomy with LIMA patch plasty. The groups were compared with respect to age, sex, cardiovascular risk factors, preoperative left ventricular ejection fraction, functional status, and operative variables.

In the closed RCA endarterectomy group, preoperative coronary angiography demonstrated severe but incomplete RCA stenosis (>70%) in 24 patients, whereas 7 patients had complete (100%) RCA occlusion. All patients underwent CABG with closed RCA endarterectomy because of diffuse RCA disease. All patients in the open LAD endarterectomy group received dual antiplatelet therapy consisting of clopidogrel 75 mg and acetylsalicylic acid 100 mg once daily for six months, followed by lifelong clopidogrel therapy. In the closed RCA endarterectomy group, all patients received lifelong clopidogrel 75 mg once daily. In addition, warfarin was administered to three patients who were considered to require additional antithrombotic and anticoagulant therapy, and warfarin treatment was continued for six months.

Early mortality occurred in three patients, two on postoperative day 1 and one on postoperative day 11. All early deaths occurred in patients with severe but incomplete RCA stenosis, whereas no early mortality was observed among patients with complete RCA occlusion. Continuity-corrected 2 × 2 contingency analysis demonstrated a higher risk of early mortality in patients with severe but incomplete stenosis compared with those with complete occlusion (odds ratio, 2.44; 95% confidence interval, 0.11–53.0), although this difference did not reach statistical significance (p > 0.05). These findings suggest a potential inverse relationship between the degree of preoperative RCA stenosis and early mortality following closed RCA endarterectomy.

The mean duration of intra-aortic balloon pump (IABP) support was significantly longer in the closed RCA endarterectomy group than in the open LAD endarterectomy with LIMA patch plasty group (0.74 vs. 0 days; p = 0.013).

Aortic cross-clamp and cardiopulmonary bypass times were comparable between the groups. ICU stay was significantly shorter in the open LAD group (1.17 ± 0.38 days vs. 2.19 ± 2.52 days; p = 0.026). The closed RCA group required significantly longer durations of adrenaline and dopamine support. Postoperative atrial fibrillation rates were similar between the groups, whereas ventricular arrhythmias occurred exclusively in the closed RCA group. Postoperative bleeding volume was significantly higher in the closed RCA group (684.2 cc vs. 527.9 cc; p = 0.002).

Follow-up coronary angiography was performed in 16 symptomatic patients in the open LAD endarterectomy group at a mean follow-up duration of 6.08 ± 2.01 years and in 14 symptomatic patients in the closed RCA endarterectomy group at a mean follow-up duration of 4.21 ± 1.12 years. Despite the limited sample size, follow-up coronary angiography demonstrated a significantly higher anastomotic patency rate in the open LAD endarterectomy with LIMA patch plasty group than in the closed RCA endarterectomy group (94.1% vs. 50.0%, Fisher's exact test, p = 0.008). Correlation analysis demonstrated significant associations between postoperative bleeding, IABP use, inotropic support, arrhythmias, and mortality in the closed RCA group (Table 2). No such correlations were observed in the open LAD group. Figure 3 demonstrates the aorta–right coronary artery anastomosis 48 months after closed endarterectomy.

Table 3 Correlation Matrix of Postoperative Adverse Outcomes in RCA Close Endarterectomy Group

Parameter	Bleeding	IABP requirement (days)	Inotropic support	Arrhythmia	Mortality
Bleeding	1.00	+ (p < 0.05)	+ (p < 0.05)	NS	NS
IABP requirement (days)	+ (p < 0.05)	1.00	+ (p < 0.05)	+ (p ≈ 0.05)	+ (p < 0.05)
Inotropic support	+ (p < 0.05)	+ (p < 0.05)	1.00	+ (p < 0.05)	+ (p < 0.05)
Arrhythmia	NS	+ (p ≈ 0.05)	+ (p < 0.05)	1.00	NS
Mortality	NS	+ (p < 0.05)	+ (p < 0.05)	NS	1.00

Abbreviations: IABP, intra-aortic balloon pump; NS, not significant. Statistical method: Spearman's rank correlation test. Significant positive correlations were observed between postoperative bleeding, IABP requirement, and inotropic support. IABP use and inotropic support were also significantly associated with mortality, indicating that advanced hemodynamic support clustered with worse early postoperative outcomes.

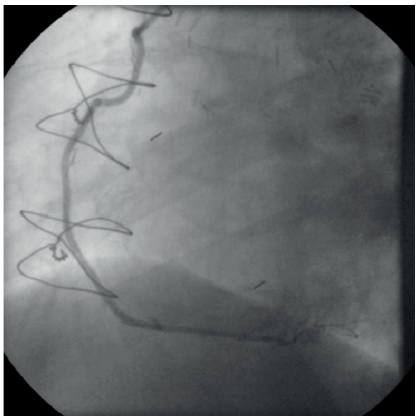

Figure 3 – Right coronary artery after a 5-cm closed endarterectomy

Angiographic patency of the Ao–RCA anastomosis at 48-month follow-up is demonstrated.

In the functional capacity analysis, normality of distribution was assessed using the Shapiro–Wilk test, which demonstrated a nonnormal distribution in both the closed RCA group ($p < 0.001$) and the open LAD group ($p < 0.001$). Therefore, nonparametric tests were applied. At the last follow-up, there was no statistically significant difference in NYHA functional class between the closed RCA endarterectomy group and the open LAD endarterectomy with LIMA patch plasty group (Mann–Whitney U test, $p = 0.695$). Within-group comparisons revealed no significant improvement in functional capacity in the closed RCA group (Wilcoxon signed-rank test, $p = 0.217$). In contrast, the open LAD group demonstrated a statistically significant improvement in NYHA functional class from the preoperative period to the last follow-up (Wilcoxon signed-rank test, $p < 0.001$).

Discussion

The present study compared closed traction RCA endarterectomy with open LAD endarterectomy using LIMA patch plasty in patients undergoing CABG for diffuse coronary artery disease. Several important observations emerged.

All early deaths occurred in patients with severe but incomplete RCA stenosis. The absence of early mortality among patients with complete RCA occlusion may reflect chronic myocardial adaptation and well-developed collateral circulation. In patients with severe but incomplete stenosis, residual antegrade flow and an irregular intimal surface following closed traction endarterectomy may predispose to early thrombotic occlusion, acute right ventricular ischemia, malignant ventricular arrhythmias, and low cardiac output syndrome. It is known that myocardial ischaemia and infarction leads to severe metabolic and electrophysiological changes that induce silent or symptomatic life-threatening arrhythmias [8]. Right ventricular infarction complicates 50% of cases of acute inferior ST-segment elevation myocardial infarction, and is associated with high in-hospital morbidity and mortality [9]. The ischemic dilated Right Ventricle is also prone to malignant ventricular arrhythmias [9]. The higher mortality observed in the closed RCA endarterectomy group may partly be attributed to the fact that all deaths occurred in patients with severe but incomplete RCA occlusion. This finding may reflect mechanisms similar to those described in the literature for acute RCA occlusion, and may help explain the observed mortality following closed endarterectomy.

Open LAD endarterectomy with LIMA patch plasty was associated with a shorter ICU stay and reduced inotropic requirements, suggesting improved early myocardial perfusion and hemodynamic stability. Despite its more extensive reconstructive nature, operative times were not prolonged. The absence of ventricular arrhythmias in the open LAD group may indicate superior early postoperative resistance to acute occlusion, potentially related to the well-established antithrombotic and vasoprotective properties of the LIMA, as described in detail in previous studies [10-13].

Contrary to expectations, postoperative bleeding was greater in the closed RCA group, possibly reflecting inter-operator variability, as these procedures were performed by multiple surgeons. These findings indicate that meticulous hemostatic technique can mitigate bleeding risk even in open endarterectomy procedures.

The significantly higher anastomotic patency rate observed in the open LAD endarterectomy with LIMA patch plasty group, despite the longer follow-up duration, suggests a potential durability advantage of this reconstructive strategy. The use of the left internal mammary artery, combined with open endarterectomy and patch reconstruction, may provide more uniform luminal restoration and improved endothelialization, thereby reducing the risk of late thrombosis and restenosis [14]. In parallel, Nishigawa et al. reported that optical coherence tomography (OCT), performed in 8 patients, demonstrated complete endothelialization of the endarterectomized LAD within one year postoperatively, the surface of the reconstructed lumen had become homogeneous [14]. In contrast, closed traction RCA endarterectomy relies on indirect plaque extraction through a limited arteriotomy, which may predispose to residual intimal irregularities or distal dissection, potentially compromising long-term graft patency. Importantly, follow-up coronary angiography was performed at a longer mean interval in the open LAD group than in the closed RCA group, yet patency rates remained significantly higher. This finding strengthens the interpretation that the observed difference is unlikely to be solely attributable to follow-up duration. Nevertheless, given the limited sample size and the non-systematic nature of angiographic follow-up, Larger prospective studies with standardized angiographic surveillance are warranted to confirm the long-term patency advantages suggested by the present findings.

Although the open LAD endarterectomy with LIMA patch plasty group demonstrated a statistically significant improvement in NYHA functional class over time, no significant difference was observed between the two surgical strategies at long-term follow-up. These findings suggest that while open LAD reconstruction may provide a more pronounced early functional recovery, both techniques ultimately achieve comparable long-term symptomatic outcomes. The significant within-group improvement observed in the open LAD cohort may reflect more effective myocardial revascularization of the anterior wall, which is known to have a substantial impact on global left ventricular performance. In contrast, the absence of a statistically significant functional improvement in the closed RCA group might be related to the smaller myocardial territory supplied by the right coronary artery in most patients, potentially limiting the magnitude of measurable symptomatic change. Importantly, despite differences in early functional recovery, long-term NYHA class did not differ between groups, indicating that both revascularization strategies provide sustained clinical benefit. This supports the concept that surgical endarterectomy—whether performed as an open LAD reconstruction with LIMA patch plasty or as a closed RCA technique—can yield acceptable long-term functional outcomes when complete revascularization is achieved. Taken together, these findings suggest that open LAD endarterectomy may confer earlier symptomatic improvement, whereas long-term functional capacity appears to be comparable between techniques.

Conclusion

Both closed RCA endarterectomy and open LAD endarterectomy with LIMA patch plasty are feasible revascularization strategies in patients with diffuse coronary artery disease. Although early mortality and atrial fibrillation rates were comparable, closed RCA endarterectomy was associated with a more complex early postoperative course and clustering of adverse outcomes. In contrast, open LAD endarterectomy with LIMA patch plasty demonstrated a more stable postoperative profile, suggesting that patient selection and the endarterectomy technique may play a more decisive role.

However, the compared groups differed not only in terms

of surgical technique (open vs. closed) and conduit type, but also in terms of myocardial territories. The myocardial mass supplied by the LAD artery is greater than that supplied by the right coronary artery. A larger myocardial mass results in greater runoff through the grafts. Therefore, it should be kept in mind that graft patency rates and the associated early postoperative outcomes may be related not only to the preferred surgical technique and conduit type, but also to the myocardial mass supplied by the RCA or LAD arteries, which provide different runoff characteristics.

Limitations

This study has several limitations. First, its retrospective and non-randomized design inherently introduces selection bias and limits causal inference. Second, follow-up coronary angiography was not performed systematically in all patients and was limited to those who underwent clinical evaluation, introducing potential selection bias in patency assessment. The relatively small sample size limits statistical power, particularly for mortality and subgroup analyses. Finally, the potential influence of surgeon- and center-related variability may have affected perioperative management strategies, operative decision-making, and postoperative outcomes in addition to the surgical techniques themselves.

Larger prospective studies with standardized operative protocols and uniform follow-up strategies are needed for further studies.

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Consent for publication: All data were fully anonymized, and no individual patient-identifiable information was included in this study.

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