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Review Article

Surgery Section

Coronary Endarterectomy: Recent Trends

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ABSTRACT

Coronary Endarterectomy (CE) assures complete revascularization of the myocardium in case of diffusely diseased vessels and prevents residual ischemia. Recently cardiac surgeons are performing increasing number of coronary endarterectomy and it has evolved as an important adjuvant procedure in Coronary Artery Bypass Grafting (CABG). There are controversies regarding the efficiency of CE. CE is criticised for its higher rates of morbidity and mortality. At present the available evidence supports CE in Off Pump Coronary Artery Bypass surgery (OPCAB) and along with valvular procedures. Graft patency is better with open technique. Postoperative anticoagulation regimen though not uniform, the overall outcome remains the same. Therefore, it is important to focus on the current results to accept CE as a routine procedure like CABG.

Keywords: Anticoagulation regimen, Conduit patency, Coronary artery bypass grafting, Coronary revascularization

INTRODUCTION

Recently cardiac surgeons are facing increasingly complex CABG due to increased comorbid conditions including diabetes mellitus, renal insufficiency, peripheral vascular disease and previous interventions for coronary disease [1] which often requires endarterectomy.

CE is being performed in all the centres with acceptable results. CE has shown to benefit patients with advanced coronary atheroma by providing complete revascularization as shown by Bailey in late 1950's [2]. The safety and long-term efficacy of the procedure, although controversial, has been demonstrated in both past and recent studies [3-5]. CE has become a routine procedure for single and multiple vessels OPCAB and for combined procedures in the recent era.

The main indication for CE is the presence of discursively diseased coronary arteries that are not suited for distal grafting [6]. Although CE has been performed on all coronary arteries safely, there is some evidence which suggests that endarterectomy of the Left Anterior Descending (LAD) coronary artery may be particularly hazardous [7]. Most surgeons, therefore, perform LAD endarterectomy in a highly selective manner when no other alternatives exist [3]. The LAD atherosclerotic plaque is hard and frail as compared to Right Coronary Artery (RCA), thereby increasing the risk of disruption. The diagonal and septal branches that arise from LAD in two different planes have the risk of shearing-off of branches when plaque is pulled in either direction [8]. Open CE is done when plaque extraction is incomplete through a limited arteriotomy or when the plaque is fractured. The open technique is preferred in such circumstances which provide an adequate exposure to excerpt the atherosclerotic core. The basic principle of coronary endarterectomy is to extract the plaque completely.

Anticoagulation therapy that plays a crucial role in preventing postoperative myocardial infraction (MI) in a case of CE, though not uniform, has been less aggressive.

Unlike the coronary endarterectomy performed in 50's, the paradigm under which cardiac surgery is performed has changed in terms of use of cardiopulmonary bypass, availability of superior drugs and techniques along with the growing experience of the surgeon. This has led to a point in which feared procedures like CE could be performed more safely under different circumstances. Today's conditions are much better than starter time and CE can not be abandoned considering the frequent points of criticism. Therefore, focus on current results is needed.

Literature search strategy: An extensive literature search was performed using PubMed by typing 'diffuse coronary artery disease', 'endarterectomy' and 'outcome.' A total of 43 recently published (year 2000-2015) articles were found and selected for review, whereas the older articles were referred for writing the introductory part. Few large scale studies from the review are mentioned in [Table/Fig-1] as below [9-14].

Off versus on pump CABG: CE is a technically challenging procedure even when Cardio Pulmonary Bypass (CPB) is used. Inexperienced surgeons avoid performing CE because of the unavoidable CPB related inflammation, global ischemia and incomplete revascularization [15,16]. Off-pump coronary artery endarterectomy is considered by many surgeons as the technique of choice, especially in high-risk patients [17,18].

Open vs closed CE: Coronary endarterectomy can be performed by either closed or an open technique. The closed technique involves a small arteriotomy with gentle steady traction on the atheromatous plaque until it comes out from the native artery proximally and distally. It is not possible to prevent intimal flaps and possible residual obstruction with this technique [19]. Open technique CE is performed by opening native artery longitudinally beyond the limits of the endarterectomy which allows the plaque to be carefully lifted off under direct vision and the edges to be fixed. Later, patch closure of the LAD is done followed by bypass grafting [20]. With this technique, complete relief of obstruction is assured and intimal flaps are prevented.

Nishi H et al., compared 68 patients (mean age 64.9±9 years, 30.8% male) undergoing Open CE+CABG with 59 patients (mean age 63±8 and 2% male) undergoing Closed CE+CABG between 1994 and 2003. Mean follow-up was 41.7 months in the Open CE group and 64.6 months in the Closed CE group [21]. Re-exploration for bleeding was 4.4% cases in the Open CE vs 5.1% cases in the Closed CE group. Infection for 2.9% cases in the Open CE vs 6.8% in the Closed CE group. Intra-Aortic Balloon Pump (IABP) for 5.9% in the Open CE vs 11.9% in the Closed CE group (p-value >0.05). Cerebro Vascular Accident (CVA) noted in 2.9% cases in the Open CE vs nil in the Closed CE group (p-value >0.05). Perioperative MI occurred in 2.9% in the Open CE vs 3.4% in the Closed CE group.

Author	Study type	Patient group	Outcome studied	Key results for CABG and CE	Comments
Tiruvoipati R et al., [9]	A retrospective study design	Patients who had CABG between January 1995 and December 2001 were included. They were divided into two groups, 5782 patients in CABG-only group and 461 patients in CABG and CE group.	Perioperative myocardial infarction, postoperative ventricular arrhythmias, cerebrovascular accident, renal impairment, and early mortality.	Myocardial infarction: 7 (1.5%) Ventricular Arrhythmias: 14 (3%) Stroke: 8 (1.7%) Renal impairment: 34 (7.4%) Mortality: 40 (8.6%)	Coronary endarterectomy when combined with CABG seemed to be associated with a higher mortality than isolated CABG in our study groups, but this is related to comorbidities of these patients rather than the CE.
Sirivella S et al., [10]	A prospective study design	Study done during 1985 to July 2002, 8,874 patients who underwent isolated myocardial revascularization procedures, 1,478 patients underwent CE with CABG for diffuse coronary artery disease consecutively. Patients in the CE group were of higher risk with increased rate of co morbidities and triple-vessel coronary disease.	Postoperative comorbidity and mortality, five and 10 year survival, angina and NYHA class	The operative mortality (3.2% versus control 2.2%; p-value=0.03) and the incidence of major postoperative morbidity (not significant) were comparable between the groups. At long-term follow-up, five year and 10 year survivals were 83±5% and 74±3% respectively and alleviate from angina at five and 10 years was 75±5% and 69±4% respectively with 96% of survivors in New York Heart Association class II.	In selected patients with diffuse coronary artery disease, coronary endarterectomy can be used as a tool for myocardial revascularization. The operative mortality and major morbidity were comparable or similar to coronary artery bypass grafting, and short-term and long-term results were favourable.
LaPar DJ et al., [11]	A retrospective study design	Patients undergoing isolated CABG operations from 2003 to 2008 were retrospectively reviewed where 99 patients underwent CE and 3:1 propensity matched them to 297 CABG-alone patients, based upon clinical factors.	Operative mortality, ICU stay, hospital stays, long-term mortality, MI.	Operative mortality was 4.0%, ICU stay was 75.06 hrs and hospital stays were 9.01days.	Patients undergoing CABG with coronary CE required longer ventilator support and ICU stay. Yet have comparable operative mortality, major complication rates, and long-term survival to isolated CABG.
Ariyaratnam P et al., [12]	Retrospective study design	The study involves retrospective analysis of data collected prospectively on 801 patients undergoing CEs between February 1988 and September 2010 by a single surgeon using a standard open hydrodissection technique.	Operative mortality and median survival time.	The operative mortality was 2.62%. The median survival time was 16.67 years.	Significant long-term survival demonstrates that CE can be an attractive adjunct to CABG in otherwise inoperable coronary artery disease.
Schmitto JD et al., [13]	Prospective study Design	Between August 2001 and March 2005, 104 patients underwent coronary artery bypass grafting CABG with adjunctive CE in the Department of Thoracic, Cardiac and Vascular Surgery, University of Goettingen.	Number of vessels endarterectomised, open or closed technique, operative mortality, long term survival, symptom improvement.	CE was performed on RCA (n = 55), on LAD (n = 52) and Circumflex artery (RCX) (n = 7). Closed technique was used in 18%, open technique in 79% and in 3% a combination of both. Only 5% follow-up for 24.5±13.4 months and survival rate 92% NYHA-classification significantly improved after CABG with CE from 2.2±0.9 preoperative to 1.7±0.9 postoperative	Early results of CE are acceptable with respect to mortality, NYHA and CCS. This technique offers a valuable surgical option for patients with end stage coronary artery disease in whom complete revascularization otherwise cannot be obtained.
Vohra HA et al., [14]	A prospective study design	680 patients underwent OPCAB with adjunctive CE in 70 patients.	CE in OPCAB	18 patients (35%) had impaired left ventricular function. There were no conversions to cardiopulmonary bypass. Three patients (4.3%) suffered from postoperative myocardial infarction, and three patients required postoperative IABP counter pulsation.	The study concluded that OPCAB surgery with CE is feasible and in patients with diffuse coronary artery disease the surgical revascularization is achieved successfully.

[Table/Fig-1]: Showing recent articles on Coronary endarterectomy [9-14].

Thirty days-mortality was seen in 2.9% in the Open CE vs 6.8% in the Closed CE group (p-value > 0.05). In early angiographic study, 92.1% of grafts in the Open CE vs 88.6% of grafts in the Closed CE group (p-value >0.05) were patent {Saphenous Vein (SV) - 95.0%, Internal Thoracic Artery (ITA) - 90.5% in the Open CE group)}. Late angiography outcome (at mean of 21±16 months) were significantly better for Open CE compared to closed technique (89.1% vs 81.0%) for patency of the grafts. SV-76.9%, ITA - 93.5% in the Open CE group however the difference in the five year survival rate was insignificant between the groups.

Myers PO et al., retrospectively studied 224 patients (mean age 66.2±10.2 years, 84% male) undergoing Open CE+CABG between 1992 and 2010 [22]. Surgical techniques included: arteriotomy + Open CE + {SV patch + Left Internal Thoracic Artery (LITA)} or (LITA only). CE was done to LAD only. Operative mortality was 3.6%. Perioperative MI was 7.1%, of which 4% cases had in the LAD territory. IABP was inserted (Intra/postop) in 4.5% patients. Re-exploration for bleeding needed in 2.2% cases. A total of five and 10 year survival was 83.1±2.7% and 47.5±6.1% respectively. Authors concluded that extensive LAD-CE and reconstruction is a safe and feasible technique in diffuse coronary artery disease. Complete extraction of the plaque along with appropriate myocardial protection and postoperative antithrombotic management were considered to be very essential steps. This study was retrospective observational study design and lacked angiographic follow-up.

Role of arterial versus vein conduits: With increasing experience of total arterial grafting in CABG, surgeons have started using arterial conduits for endarterectomised vessels [23,24]. There is paucity in evidence regarding the role of arterial grafts in endarterectomised vessels in relation to late survival and graft patency.

Schwann TA et al., reviewed their 288 CABG-CE patients (mean age 63±10 years) of which men were 207 [25]. A total of 1,056 grafts {275 ITA (26%); 221 radial (21%), 560 vein (53%)} were used. Total 325 (31%) conduits were placed to CE targets. Perioperative mortality occurred in 18 (6.3%) patients. The one and five-year survival for the 270 discharged patients was 95.2% and 83.0%, respectively. Survival was superior for patients with radial (n=154) versus no-radial (n=134) artery grafting (p-value=0.021). Multivariate Cox regression analysis associated with increased number of arterial grafts {Hazard Ratio (HR)=0.64 (0.44 to 0.92)}; HR (95% confidence interval) to improved survival, whereas RCA endarterectomy (HR=1.8, 1.0, 3.3; p-value=0.054) was associated with worse survival. Repeat

Authors	Anticoagulation Regimen
LaPar DJ et al., [11].	Dual antiplatelet therapy for at least 3 months. Postoperative myocardial infarction - 1%. Operative mortality - 4%.
Schmitto JD et al., [13].	Heparin infusion four hours postoperatively if the bleeding ≤50 ml/hr. 100 mg of aspirin were given daily, starting at the first postoperative day. In hospital mortality - 5%.
Marzban M et al., [28].	Reverse the heparin completely at the end of the operation Start heparin six hours later in the ICU if bleeding ≤100 ml/hr Warfarin: 2-3 months (INR: 2.5-3.5). Hospital mortality - 5%.
Kumar S et al., [29].	300 mg of aspirin per rectally six hours after the procedure. Combination of aspirin and clopidogrel 75 mg each daily from the first postoperative day. Clopidogrel for six months postoperatively and aspirin lifelong. Patients in atrial fibrillation and/or mechanical valves are anticoagulated with warfarin and aspirin. Reported mortality - 9.8%.

[Table/Fig-2]: Showing different anticoagulation regimens for endarterectomy.

angiography was done in 68 patients comprising 78 CE (38 vein, 24 ITA, and 16 radial) and 162 non-CE (84 veins, 40 ITA, and 38 radial) grafts. For CE targets, graft failure was worse for vein (55% vs 35%; p-value=0.05) and unchanged for arterial (13% vs 15%; p-value=0.88) grafts. Authors concluded that combined CABG/CE is associated with acceptable long-term outcomes. Increased arterial grafting achieved by radial artery utilization offers a survival benefit in high-risk population.

Single vs double vessel endarterectomy: Results of single vessel LAD endarterectomy are better than multiple vessel endarterectomies [26]. The reason being good visualization of LAD along the majority of its course, minimum hemodynamic disturbance in off-pump procedures. The option of onlay patch grafting using mammary artery is almost limited to LAD.

In a retrospective study on single vessel CE by Takahashi M et al., constituting 12 patients (Age: 72±4 years) the mean numbers of diseased coronaries were 3±0.4, and the mean numbers of grafts performed were 4±0.8 [27]. One patient was converted from off-pump to on-pump. The mean intensive care unit stay and the mean hospital length of stay was 3±2.8 and 15±13 days respectively. Postoperative follow-up (mean 24±19 months) was complete, and no ischaemic events were seen in early and mid-term follow-up. The study concluded that off-pump endarterectomy of the LAD is a viable option for patients with diffuse LAD disease.

Marzban M et al., in their four year long retrospective study, analysed 310 patients (3.28%) who underwent concomitant coronary artery endarterectomy, 39 of whom (12.6%) required double vessel endarterectomy (Group 2) and the rest of whom required single endarterectomy (Group 1) [28]. Variables of these groups were compared by means of univariate analysis. Group 1 consisted of 76.3% men and mean age of the patients was 58.73±9.36 year. Perioperative MI reported in 13% and 15.4% patients in Group 1and 2 respectively. In Group 1, the early mortality rate was 3.3% compared to 10.3% in Group 2 (p-value <0.05). In multivariate analysis of endarterectomised arteries, the combinations of vessels most strongly associated with mortality were LAD or Diagonal along with RCA. There was no association between endarterectomy of particular vessels and perioperative myocardial infarction. The study concluded that addition of second endarterectomy worsens the prognosis dramatically.

Endarterectomy in combined coronary and valvular surgery: Literature analysing effects of CE in combined procedures is lacking although available report supports it. Kumar S et al., in their 14 year retrospective study on 237 patients who underwent CABG with valve surgery, 41 patients needed CE. The intensive therapy unit stay was less than 48 hours after surgery in 32 patients. Six mortalities occurred during the 14 year follow up with ten year survival of 57.2% (95% CL, 37.8%–86.6%). None required further percutaneous or surgical intervention. Authors inferred that CE does not add to the overall mortality incidence in combined procedures [29].

Postoperative anticoagulation regimen: At present there is no unified guideline available regarding the use of antiplatelet or anticoagulation therapy in patients undergoing CE. Though most of the authors have followed different anticoagulation regimen as per their institute protocols, the overall reported difference in bleeding and mortality remains clinically insignificant. Anticoagulation regimens used by different authors are shown in [Table/Fig-2].

Use of an antifibrinolytic agent: Early graft occlusion is the concern with perioperative antifibrinolytic therapy. Ruel MA et al., studied 221 patients who underwent CABG with CE of the RCA alone in 149, the LAD in 35, or both right and left anterior descending in 27 [30]. Tranexamic Acid (TA) was given intraoperatively in 87 patients (TA group: average total dose 62±4.4 mg/kg), and was not used in 134 patients (No TA group). The patient risk distribution was similar in both the groups. The perioperative MI rate was 2% and 5% in the TA and No TA groups, respectively (p-value=0.49). Patients in the TA group had a significant reduction in postoperative chest tube drainage and in the use of fresh-frozen plasma (p-value=0.03).

Authors concluded that the use of tranexamic acid in patients undergoing coronary endarterectomy is not associated with a higher incidence of MI-related complications.

CONCLUSION

At present the available evidence supports CE in off-pump CABG. Long term patency of the graft is better with open technique however the 5-year survival remains the same for both open and closed methods. Multi-vessel CE increases the overall morbidity and mortality. Use of arterial conduits especially radial grafts is associated with better long term outcome in high risk patients. Adjuvant CE in valvular procedures does not affect the overall outcome. Postoperative anticoagulation regimen is not uniform at present and initial report supports use of antifibrinolytic therapy in postoperative period.

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