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Review Article

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REVIEW ON CORONARY ENDARTERECTOMY- PAST, PRESENT, AND FUTURE!

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Abstract

Coronary endarterectomy is first presented by Baily *et al.* as a surgical revascularization procedure against diffuse coronary artery disease on 29th October 1956. Coronary endarterectomy provides a way of complete surgical revascularization of the myocardium in diffuse and calcified coronary arteries with adequate blood flow to distal part of vessels, thus improving myocardial function. However, the initial outcomes of coronary endarterectomy were not satisfactory but now-a-days several articles have shown that coronary artery bypass grafting with coronary endarterectomy can be done safely with acceptable morbidity, mortality and also patent graft on angiographic evaluation. So that, it's time to reevaluate this old equation, reanalysis the current outcomes of coronary endarterectomy and readdress its indication.

Key Words: Coronary endarterectomy, coronary artery disease.

INTRODUCTION

Endarterectomy is the expulsion of the atheromatous plaque, dismembering and isolating the outer media and adventitia layers of artery and reestablishing the blood flow to the distal part of to the coronary artery. Total revascularization of coronary artery is the basic principle for postoperative outcomes following coronary artery bypass graft surgery (CABG). Patients who are referred for coronary artery bypass graft surgery due to ischemic heart disease, are progressively getting more complex with different comorbidities, like DM, renal impairment, hypertension, and also peripheral vascular disease. However, a large portion of this patients have experienced previous Coronary angioplasty[1,2]. Now-a-days, referred patients for CABG frequently have diffuse and calcified coronary artery disease, which has made complete surgical revascularization of myocardium more difficult and more complicated postoperative recovery[7,9]. However, up to 25% of patients with diffuse coronary artery disease can't be treated viably and safely by conventional CABG and bringing it as incomplete myocardial revascularisation[1,5]. Inadequate revascularization does not influence the quick death rate, but rather increase the occurrence of reoperations with noteworthy obstruction in vessels, which influences the long term cardiac function. These patients have more prominent repeated attach of angina, more awful performance in stress tests and a more noteworthy work absence rate and require a higher number of re-interventions, perhaps the better survival rate of complete CABG patients[6]. In this way, a couple of strategies including coronary endarterectomy, which incorporates extraction of the atherosclerotic plaque through an incision (arteriotomy) from coronary arteries have been proposed to increase postoperative outcome following CABG[3].

Coronary endarterectomy was first described by Baily *et al.* in 1957 as a treatment strategy for CAD without doing CABG[1,3].

The endarterectomy procedure is as yet a matter of controversy[15,18,19]. In particular, LAD endarterectomy was considered as highly troublesome and initial perioperative mortality and myocardial ischemia rate was very high[8,13,28]. Complete revascularization of the LAD is considered as a crucial determinant of the post-operative patient's recovery[20]. There are very few article revealing concurrent coronary endarterectomy (CE) with OPCABG surgery. Off-pump CABG surgery for multi vessel myocardial revascularization in high risk patients has been appeared to decrease the frequency of perioperative morbidity and mortality and the duration of hospital stay[10,12]. Nevertheless, its adverse outcome with mortality and morbidity overshadowed its results in relief of angina[1]. Hence, indications of coronary endarterectomy were limited to patients with diffuse coronary artery disease[23].

Since then, several study have shown that the complete revascularization of coronary artery disease by CABG with coronary endarterectomy can be done safely and it enhanced the post-operative outcomes by improving myocardial function[14,16,22].

Surgical technique

A conclusive decision to endarterectomize a vessel is made per-operatively and depends on technical contemplations. Coronary endarterectomy was considered when no sufficient segment of a vessel, providing blood supply to viable muscle with reversible ischemia, was appropriate for grafting. Endarterectomy of the unhealthy vessel was just performed when the artery was totally or almost impeded with severely calcified plaques and long segment stenosis that extends distally. There are two various approaches to perform coronary endarterectomy: Open method and Close method. But till now, it is unclear which is the perfect procedure[21]. But there is a common practice between these two strategies to remove atherosclerotic plaque that is an arteriotomy is the basic principle in both methods[23].

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In open methods, a longitudinal incision for coronary arteriotomy is performed distal to the atheromatous plaque and extracted the atheroma from vessel[21], followed by reconstruction of endarterectomized site with on lay patch either with Internal thoracic artery or a saphenous venous patch[27,34]. However, a longitudinally opened saphenous vein can be used to repair the arteriotomy and thereafter the left internal mammary artery can be anastomosed with the vein patch[5]. Note that, this open method is time consuming but the atheromatous plaque is extracted under direct vision, so the openings of the distal end of the LAD and side branches can be checked directly. Furthermore, it can be settled to secure the distal portion of artery following an intimal dissection of the coronary artery happens[2].

Perhaps in the close method, coronary endarterectomies were performed manually by slow sustain and continuous traction of atheroma trailed by reproduction with anastomosis with pre-planned graft[2,34]. Two synchronous arteriotomy can be used for coronary endarterectomy to make the framework rapid and reduce ischemic time[17]. The close method is shorter in duration and the graft anastomosis is easier than open method[24]. But the rate of snowplow effect is more in LAD following closed method as inadequate endarterectomy is more possible[37]. Despite delicate balance of traction force, closed endarterectomy may have associated with intimal flap on distal part of endarterectomized vessel. Accordingly, obstacle of the lumen may happen distally as a result of a dissection or thrombus[2,17].

However, regardless of the way that the open endarterectomy takes extra time; the chance of intimal flap formation is less and subsequently preventing residual obstruction. So that, some author used the open technique for coronary endarterectomy, the quality is guaranteed[23]. Nishi *et al*. observe the outcome of both closed and open methods endarterectomy and finds that open method endarterectomy is superior to closed one[27]. Patients who experienced open method endarterectomy had a lower perioperative morbidity and mortality. Perhaps, this group of patients have significant long tern outcome.

The five-year survival rate was 74% in closed endarterectomy group but 90.7% in open method group. Also 85.2% patients of open method group are free from angina in compare to closed method where only 76.6% patients were free from angina on subsequent follow up. So that, though open method is time consuming but the outcome is the better than closed one[27].

All procedures were performed through a standard median sternotomy and a CPB circuit is on standby for all cases. After the conduits (internal mammary artery, radial artery, and the saphenous vein) were collected, heparin was used to maintain an ACT (Activated clotting time) more than 400 seconds. Almost all the operations were performed off pump CABG and a few cases required the assistance of cardiopulmonary bypass (CPB), using a membrane oxygenator, utilizing the surgical procedures to acquire the graft[4]. To ensure complete expulsion of the distal atheroma, the atheromatous plaque carefully inspected for a smooth distal tapper end. In addition, back flow of blood from the distal vessel following extraction of the atheroma is a consoling indication of adequate removal atheromatous plaque and that is special feature in OPCABG endarterectomy[10].

Indication of CE

In spite of the presentation of coronary endarterectomy (CE) 55 years prior[1]as a strategy for treatment of diffuse and calcified coronary artery disease, its application remains controversial as it conveys a higher perioperative hazard and poor long term survival [23,27,33,38]. Coronary endarterectomy (CE) is performed when the coronary vessel is extremely affected by atherosclerotic process, so that conventional CABG is insufficient to provide adequate myocardial revascularization. Trehan and Mishra[9] are accounted the essential indications for coronary endarterectomy:

1. Multiple lesions in a coronary artery.
2. Diffusely disease with calcified plaque.
3. Long segment of lesion
4. Occlusion of the main artery and its branches.
5. Diffusely diseased coronary artery.
6. Division of the plaque amid anastomosis.

In diffuse LAD lesion, conventional CABG itself is not sufficient to supply blood to side branches and persistent of angina is more likely. Also, neither immature atherosclerotic plaques nor extensive calcification are contraindications to procure a delightful anastomosis after coronary endarterectomy[2]. However, CE provides more collateral circulation via side branches (Diagonal and Septal branches) in case of diffuse CAD. Perhaps, if an anastomosis is performed in calcified vessel, embolization of atheromatous plaque may happen. So in presence of diffuse atherosclerosis with calcification of coronary artery, CE is required to provide good distal run off in diseased artery[3,5].

Shapira *et al*. stated that preoperative coronary angiographic findings like irregular thickening with diffuse string like appearance and lumen less than 1mm in diameter can constitute signs for endarterectomy[24]. However, a conclusive decision to perform endarterectomy is made per-operatively when the above criteria are noted[17,23].

Anticoagulation therapy

Following coronary endarterectomy, in absence of endothelium, coagulation cascade become activated because sub-endothelium exposed to circulation[5]. So that, after coronary endarterectomy, routine Heparin infusion is prescribed to prevent thrombosis in graft or native tissue in the early post-operative period followed by oral Warfarin for next 3-6 months[19,34]. Perhaps, combination of antiplatelet and anticoagulation is also required[2]. Till date, there is no standard anticoagulation regimen after coronary endarterectomy exists[21]. Postoperatively, intravenous heparin, 75 mg combination of Ecosprin with Clopidogrel, and warfarin are used. Heparin is continued until desired warfarin effect achieved that is INR (International normalized ratio) is 1.5 to 2.5. After 3-6 months, use of warfarin is suspended for Ecosprin[5,23,27].

Safety of coronary endarterectomy

Inadequate myocardial revascularization has been appeared to be a standout amongst the most critical components that influences perioperative outcome, ventricular function, early and late mortality[20]. However, LAD endarterectomy is thought to be higher hazardous than other territory, and in this way, it might be stayed away from by a few surgeons. Perhaps complete revascularization of the LAD is considered as a crucial determinant of the post-operative patient's

recovery[17,20]. Coronary endarterectomy, particularly of the LAD, can adequately be performed with diffuse CAD, as it can achieve adequate myocardial revascularization and provide better post-operative outcome[17]. Myocardial contraction in the LAD territory is more vigorous than the RCA region. That aides in the extraction of the distal atheromatous plaque by traction technique easily from LAD artery as compared to expulsion in the RCA[14]. Previously, the internal mammary artery (IMA) has been utilized cautiously as a conduit to an endarterectomized vessel as a result of concerns in regards to the mismatch of luminal diameter. Perhaps, many authors have now detailed satisfactory early and late clinical results and luminal patency of IMA to an endarterectomized vessel compared to great saphenous vein conduit[15,19]. It has been contended that the utilization of the IMA for reproduction of the LAD graft prompts early patency, decreased perioperative myocardial dead tissue, and enhanced 5-year survival rate[26].

In a study, Takahashi *et al*. observed mortality rate zero percent in a small study of CE with OPCABG and conversion of procedure to on-pump CABG rate is 8.33%. Post-operative morbidity was very minimum with no perioperative stroke or MI. Reoperation rate was 16.66% due to excessive bleeding and post-operative new onset atrial fibrillation rate also 16.66%. one patient developed respiratory complications who requires tracheostomy. Postoperative mean follow-up period was 24 ± 19 months; revealed neither early nor mid-term myocardial ischemia[34]. Naseri *et al*. likewise demonstrated that the intubation time, ICU stay, and the length of hospitalization was not exactly same between on pump CABG with coronary endarterectomy (CE) and after OPCABG with CE[22]. Besides, in spite of the fact that the duration of ventilation was comparative in our review and that of Eryilmaz *et al*. the length of hospitalization was higher in the last arrangement[16]. In a review of CE group of patients by Naseri *et al.* who revealed no neurologic deficit[22]. Post-operative acute myocardial infarction (MI) due to acute graft occlusion is a noteworthy complication following CE with an incidence rate of 1.5% to19%[19]. The occurrence of post-operative MI was higher (6.8%) after OPCABG with CE in completely blocked or more than >50% stenosis in a study by Naseri *et al.* But in another study, Vohra *et al*. observed that postoperative MI rate following OPCABG with coronary endarterectomy is 4.3%and 10% recurrence rate of angina following OPCABG with coronary endarterectomy[14]. In another study, Djalilian *et al*. shows only 9% of their patients got angina at 46±19 months follow up, though Gill *et al*. observed intermittent angina in 15% of their patients at a mean follow-up of 36±16 months[15,19]. However, Christakis *et al*. observed 35% recurrence rate of angina at 5 years follow up in their study, which is significantly higher than our study[31]. This distinction in recurrence of side effects might be because of the especially extreme nature of the coronary disease or to inadequate revascularization accomplished.

Although multi-vessel endarterectomy has been described but single vessel especially LAD endarterectomy is preferred as adequate stabilization of LAD is easier, can be easily visible throughout its full length and less mobilization of heart is required to achieve CE during OPCABG[35]. However, Erdil *et al*. shows that clinical and angiographic findings is excellent following right coronary endarterectomy and no additional mortality or morbidity is associated with CABG following RCA endarterectomy in relation to non-endarterectomized RCA during CABG[30]. However, early mortality rate is accounted to be higher after LAD endarterectomy and in patients experiencing endarterectomy of more than one coronary artery[18]. The frequency of early mortality after CE with OPCABG of 2-15%[31]. Regardless, the mortality after CABG with endarterectomy is more than conventional CABG because of the associated risk factors and other comorbidities rather than the CE itself[2]. However, long term graft patency rate following CE is 40%- 81.5% and single CE carries better result than multiple endarterectomy[19,27,36]. By the way, postoperative MI rate also high following multiple CE, no matter which artery is incorporated[36]. Here, this article will familiarize you in detail with the outcomes of a couple surveys including patients who experienced coronary endarterectomy due to diffuse CAD. (Table- 1).

In another study at the Shin-Tokyo Specialist's office and the Sakakibara Heart Association included 148 patients who experienced CE of the LAD between April 2001 and March 2008[2]. 81.8% Off-pump CABG was performed and mortality rate was 2.7%. 6.1% patients were suffered from LOS (low cardiac output syndrome), 25.7% developed new onset AF, 12.2% were postoperative MI. Other co morbidity was insignificant like 6.8% respiratory complications, 3.4% reoperation due to bleeding, 2.7% stroke, 3.4% required renal replacement therapy and 3.4% patents developed mediastinitis. Early postoperative angiography revealed 94% graft patency rate for both left internal mammary artery and LAD. Only one patient suffered from graft failure due to thrombosis and have had post-operative MI, however the mortality was zero. Fundarò *et al*. analyzed 13 patients who encountered an open LAD endarterectomy and 5 patients who encountered an open RCA endarterectomy and observed no early or late postoperative mortality. No unpleasant postoperative events were noted either, beside a perioperative MI, however not in the domain of the endarterectomized vessel. Angiographic evaluation between the ninth and the fifteenth postoperative day in 16 patients demonstrated one close graft after LAD endarterectomy[3]. In another survey by Shapira *et al*. observed 37 patients who experienced LAD endarterectomy shows, only 2.7% intra-operative mortality rate and one case of perioperative MI were viewed[17]. Shapira *et al*. observed 3.3% intraoperative mortality in another study including 61 patients who experienced RCA endarterectomy, and a 4.9% perioperative MI. During follow up (14–55 months) revealed one patient's death whose preoperative LVEF was 27%. The cause of death after five months of operation was due to of congestive cardiomyopathy[24].

However, Nishi *et al*. studied 127 patients with diffuse CAD who experienced CE with CABG in the year of January 1994 to April 2003 at Osaka City General Specialist's office[27]. This audit endorsed that coronary endarterectomy is related to an acceptable operator risk as mortality rate was 4.7%, however only 3% patients experienced perioperative MI. Infection was found in six cases, six patients required re-operation for excess bleeding, and only two patients have had TIA. Furthermore, intra-aortic balloon pump was required 17% patients and late mortality rate was 15.75%[27]. Finally, Livesay *et al*. observed long term benefits following CE in their study over a period of 14 years includes a large study

group about 27095 patients. Of whom 12.4% patients experienced CE and they observed that 10 year's survival rate was 68% which is very close to only CABG group 74%[13]. Here, this article will familiarize you in detail with the outcomes of a couple surveys including patients who experienced coronary endarterectomy due to diffuse CAD (Table- 1).

Table1 Experience of Coronary endarterectomy (CE) by different surgeons

Author, Year	CE%	LCA%	RCA%	Perioperative MI	Early Mortality
Trehan et al. 1993	12.4%		62.9%	?	?
Shapira et al. 1988	100%	100% (LAD)	27.0%	2.7%	2.7%
Tyszka et al. 2003	11.5%	?	21.0%	3.12%	3.12%
Livesay et al. 1986	12.4%	?	83%	5.4%	4.4%
Gill et al. 1998	21.9%	?	?	21.6%	4%
Vohra et al. 2006	10.2%	17% (LAD), 1.43% (OM)	81%	4.3%	2.85%
Cooley et al. 1971	38%	?	?	?	7.7%
Qureshi et al. 1985	42%	?	72%	12%	4%
Fundaro et al. 1987	100%	72.2% (LAD)	27.2%	5.6%	0%
Brenowitz et al. 1988	50%	?	51.7%	10%	8.3%
Salerno et al. 1994	3.9%	?	61.8%	9%	4.5%
Asimakopolous et al. 1999	4.1%	?	51.5%	5.4%	3.6%
Nishi et al. 2005	100%	55.9% (LAD), 13.7% (LCX), 5.5%(D)	41.7%	?	4.7%
Takanashi et al. 2008	100%	100% (LAD)	?	12.2%	2.7%
Schmitto et al. 2009	100%	50% (LAD),	52.8%	2.9%	4.8%
Takahashi et al. 2013	100%	100% (LAD)	?	0%	0%
Alreshidan et al. 2014	20.0%	52.6% (LAD), 18.4% (OM), 3%(D)	31.5% (RCA, PDA)	2.6%	7.9%

Note: CE-Coronary endarterectomy, LCA-Left coronary artery, LAD- Left anterior descending artery, OM-Obtuse marginal artery, D- Diagonal artery, RCA-Right coronary artery, PDA-Posterior descending artery.

CONCLUSION

Despite the higher risk group, diffuse coronary artery disease requiring endarterectomy should not be considered as a contraindication to OPCABG. However, coronary endarterectomy is not an alternative to CABG, but instead, CE is an adjunctive to CABG in treating diffuse calcified CAD.

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