Long-term survival from 801 adjunctive coronary endarterectomies in diffuse coronary artery disease†

Priyadharshanan Ariyaratnam*a, Kalyana Javangula, Sotiris Papaspyrosb, Evie McCrum-Gardnerc and Ramanpillai Unnikrishanan Nairb

a Department of Cardiothoracic Surgery, Castle Hill Hospital, Cottingham, UK
b Department of Cardiac Surgery, Leeds General Infirmary, Leeds, UK
c University of Ulster, Newtownabbey, UK

* Corresponding author. Department of Cardiothoracic Surgery, Castle Hill Hospital, Cottingham HU16 5JQ, UK. Tel: +44-7814-118367; fax: +44-1482-461619; e-mail: priyadariyaratnam@yahoo.co.uk (P. Ariyaratnam).

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Abstract

OBJECTIVES: The role of coronary endarterectomy (CE) in modern cardiac surgery has been an extant debate as coronary artery bypass grafting (CABG) has advanced. However, as cardiac surgeons are being referred ever more complex coronary disease for surgical correction, adjunctive strategies may need re-evaluation. The long-term results of CE are largely unknown. We present the longest cohort follow-up in a single institution looking at our 20-year experience of CEs employed as an adjunct to CABG in diffuse coronary artery disease.

METHODS: We performed 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. We looked at patient demographics, characteristics of the vessels subjected to endarterectomy and predictors of long-term survival within this surgical group using Cox’s regression analysis.

RESULTS: The mean age was 63.2 (±9.6) years. The mean number of coronary arteries undergoing endarterectomy was 1.16 (±0.4) per patient. Of these, 63.7% were performed on the right coronary artery (n = 558) and 32.3% on the left anterior descending artery (n = 283). The operative mortality was 2.62% (n = 21). The median survival time was 16.67 years (95% confidence interval 15.14–18.19 years). The significant predictors of survival (P < 0.05) were a lower age at surgery, a lower EuroSCORE I, the absence of peripheral vascular disease and shorter bypass times.

CONCLUSION: This significant long-term survival demonstrates that CE can be an attractive adjunct to CABG in otherwise inoperable coronary artery disease.

Keywords: Coronary artery bypass grafting surgery • Endarterectomy

INTRODUCTION

Diffuse coronary artery disease (DCAD) presents a challenge to the cardiac surgeon as more complex artery cases, not amenable to percutaneous stenting or angioplasty, are filtered through regional cardiology multidisciplinary conferences [1].

Coronary artery bypass grafting (CABG) becomes difficult or even impossible in such cases [2, 3]. The mortality associated with inoperable DCAD is >30% at 1 year from cardiac-related causes [4]. Thus, cardiac surgeons are finding recourse to exciting new methods to avoid incomplete revascularization including trans-myocardial laser revascularization with limited results [5, 6].

Coronary endarterectomy (CE) has often been viewed as a step back in coronary surgery with high morbidity and mortality rates. This can, in part, be attributed to the historical context of the operation. However, recently, it is steadily resurfacing as an adjunct to CABG in DCAD revascularization by removing obstructing coronary debris, comprising atheroma and creating safe and feasible anastomotic sites for conduits. Our study focused on establishing the long-term survival benefit for CE as an adjunct to CABG, obtaining data from the largest recent database of patients undergoing this procedure at our institution. In addition, we sought to evaluate the predictors of survival that may influence patient selection for this technique in future.

MATERIALS AND METHODS

Patients and methods

in the UK. This investigation was approved by our Audit Review Board.

Data collection

We prospectively collected the data on patient demographics, co-morbidities and risk factors derived from the EuroSCORE I.

Operative technique for coronary endarterectomy

The criteria for performing CE consisted of identifying diseased vessels supplying the viable myocardium such that these vessels exhibited multiple, discrete obstructing lesions or diffuse atherosclerosis significantly compromising the internal lumen (<1 mm). The viable myocardium was evaluated using a combination of preoperative echocardiography, cardiovascular MRI and intraoperative echocardiography. We employed a standardized hydrodissection method that we have described in the literature and is briefly reiterated below [7].

All the operations were performed using cardiopulmonary bypass and moderate systemic hypothermia (32°C). The myocardial preservation was achieved using intermittent antegrade cold blood cardioplegia through the aortic root and the proximal end of the completed vein graft and, in some cases, via a retrograde approach through the coronary sinus. Topical myocardial cooling was used in all cases.

The operative technique used for the right coronary artery (RCA) and left anterior descending (LAD) artery endarterectomy was identical. In the case of the RCA, an incision approximately 1.5 times the RCA diameter is made above the crux. The atheroma is elevated through this incision using a 20F gauge Abbocath (Abbott Laboratories) attached to a 20-ml syringe containing cold saline is inserted into the plane between the atheroma and the medial wall of the artery including the distal branches. Gradual instillation of saline is used to extend the dissection of the atheroma. When the saline reaches the distal end of the artery, it should be possible to remove the atheroma by traction of its proximal end and by pressure exerted around the distal artery with a set of forceps. Once the atheroma is extracted, the new lumen is thoroughly cleaned of debris before completing the on-lay graft anastomosis.

Similarly, the LAD artery is entered through an incision of 1.5 times the LAD diameter and elevation dissection, and the extraction of the atheroma is completed as in the case of RCA CE. The new lumen is again cleared of debris, and then the conduit anastomosis is completed on-lay directly on to the LAD artery.

In both RCA and LAD artery, the aim is to complete the extraction of distal atheroma and, if any part is broken off during dissection, the distal segment is removed by a limited arteriotomy and patch angioplasty.

The conduit selection was similar to non-CE CABG, where, preferentially, a pedicled left internal mammary artery was used for the LAD artery unless this was contraindicated, and saphenous vein grafts were used for other coronary vessels.

We have refrained from using a full-length LAD arteriotomy with vein patch roofing as to avoid an unnecessary left internal mammary artery anastomosis to the vein roof.

Postoperatively, all the patients received aspirin 300 mg 6 h following surgery (if they were not bleeding) and were commenced on dual antiplatelet agents (aspirin 75 mg and clopidogrel 75 mg) from the first postoperative day. Anticoagulation was carefully selected in a small subset of patients based on factors such as atrial fibrillation, poor left ventricular ejection fraction and peripheral vascular disease, preferring warfarin for 3 months with a target international normalized ratio of 2.5–3.0.

Statistical methods and analysis

Patients were followed up routinely at clinic 8 weeks following their operation. The follow-up was 100% complete during a 6-month closing interval ending April 2011.

The operative mortality was defined as occurring during the operative hospitalization or within 30 days of operation for discharged patients. Long-term survival data was obtained from the national on-line NHS registry. Long-term survival data included death from all causes. Continuous variables were expressed as mean ± 1 standard deviation, and categorical variables were expressed as percentages.

All variables were first analysed with univariate analysis ($\chi^2$, Mann–Whitney, Kruskal–Wallis or analysis of variance depending on the scale of measurement of the variables) to determine whether any single factor influenced mortality. Variables that achieved $P$-value of <0.05 in the univariate analysis were examined with multivariate Cox’s proportional hazard analysis to evaluate independent risk factors for mortality (SPSS version 19.0 software; SPSS Inc., Chicago, IL, USA).

RESULTS

Table 1 shows the characteristics of the patient cohort including their co-morbidities and the operative priority. 2.50% ($n = 20$) were New York Heart Association Functional Class IV, 2% (16 of 801) had a poor left ventricular ejection fraction and 1.37% ($n = 11$) were non-elective operations.

Table 1 also demonstrates the intraoperative characteristics including the proportion of concomitant procedures. An intraoperative intra-aortic balloon pump was indicated in 5.24% of cases ($n = 42$), and the mean cross-clamp time was 47.97 min (standard deviation [SD] ±26.368).

Table 2 demonstrates the postoperative complications. The operative mortality was 2.62% ($n = 21$). Of these, 42.9% (9 of 21) were cardiac-related deaths and these were attributable to cardiac failure and an inability to wean from a high inotropic support. There were no confirmed cases of myocardial infarction following CE. Reopening rates for bleeding was indicated in 2.00% ($n = 16$) and ventricular arrhythmias occurred in 0.62% ($n = 5$) of cases.

Table 3 demonstrates the characteristics of the coronary arteries undergoing CE. The mean number of coronary arteries undergoing CE was 1.16 (±0.4) per patient. The most common artery to undergo CE was the RCA ($n = 558$) with 63.7%, while 32.3% were performed on the LAD artery ($n = 283$).

Figure 1 shows the Kaplan–Meier plot for actuarial survival. The median survival time is 16.67 years postoperatively (95% confidence interval [CI] 15.14–18.19 years). The proportion surviving (with 95% CIs) was 86 (84–89), 70 (66–74), 56 (49–63) and 46% (34–57%) at 5, 10, 15 and 18 years, respectively.

Seven (0.87%) patients were readmitted to our surgical unit after our operation for suspected postoperative complications.
Only 1 patient was reoperated on and this was 5 years following his CE to the LAD artery as his LAD graft had become stenosed.

Univariate analysis of the characteristics and factors outlined in Tables 1–3 identified six factors adversely associated with mortality (age, EuroSCORE I, peripheral vascular disease, CE to the LAD artery, CE to the RCA and cardiopulmonary bypass times) from which multivariate analysis by Cox’s regression identified four significant (P < 0.05) factors to be independent predictors of mortality: a higher age at surgery, a higher EuroSCORE I, the presence of peripheral vascular disease and longer cardiopulmonary bypass times. The hazard ratios for these significant factors common to both the univariate and multivariate analyses are given in Table 4.
Figure 2a and b and 3a show the stratified Kaplan–Meier survival plots for these predictors (higher age, presence of peripheral vascular disease and EuroSCORE I).

Figure 3b shows CE performed over the last 20 years as a proportion of the total CABG operations undertaken at our unit.

**DISCUSSION**

CE was introduced in 1957 by Bailey et al. [8] and was performed without cardiopulmonary bypass or associated CABG. With the advent of modern CPB techniques, venous and arterial autograft modalities rapidly evolved, translating into reduced mortality figures for myocardial revascularization and as such, CE became an outdated modality [9].

Achieving complete revascularization has, however, become more difficult and this is detrimental to the patient as completeness of revascularization has been shown to correlate with improved early and late outcomes [10, 11].

Recent early results employing CE revascularization in DCAD have been promising in that they are comparable with standard CABG morbidity and perioperative mortality rates in complex patients [12–14]. Short-term follow-up studies in patients undergoing CE have shown a 5-year actuarial survival ranging from 71 to 90% [15–17]. The differences in outcomes between various reports can be accounted for by the subtle differences in patient selection, the technique employed, frequency of CE, conduit selection for the endarterectomized target and the mode of reconstruction.

With regard to patient selection, our criteria for performing CE were strict in its adherence to the factors outlined in the methodology of this study so as to appropriate a realistic degree of success in improving patient survival. From Table 1, although certain characteristics such as a higher male population in our cohort are evident, we did not consciously select patients depending on such characteristics.

With regard to the varying technique, our CE technique did not vary profoundly over time as it was performed by a single surgeon who had mastered his technique over many decades using the standard hydrodissection method that we have described in the literature [7]. Our cohort of patients mainly underwent single-vessel CE and most were done on the RCA (Table 3). We did not sacrifice any side branches of the coronary arteries as during the hydrodissection of the LAD artery, almost all the distal diagonals and septal branches are cleared if the procedure is done correctly. We used this method over other CE techniques as the pressure exerted by fluid is uniform and the fluid progression is gradual. The use of gas differs from fluid in that firstly it can cause uneven pressure and also the force can vary. Secondly, unlike gas, fluid does not cause embolism and also allows deeper dissection into the septal branches quite easily. Thirdly, the use of fluid also helps to wash out any debris that arises during the dissection. On the other hand, using blunt dissection with probes not only lacks any of the benefits described above with hydrodissection but is also more likely to cause rupture of the atheroma.

Studies have questioned that the safety of CE as an increased risk of perioperative mortality and morbidity accompanies this
technique when performed on the LAD artery [18]. Our results did not show CE to the LAD artery to have a significant adverse effect on survival.

Instead, we found that a higher age, the presence of peripheral vascular disease, longer cardiopulmonary bypass times and a higher EuroSCORE were significant predictors of mortality and these are common to most cardiac operations and previous literature on CABG alone.

With regard to postoperative complications, our reopening rates for bleeding (2%), postoperative ventricular (0.62%) and supraventricular (14.36%) tachyarrhythmias, cerebrovascular accidents and renal complications are comparable with most CABG and valvular procedures across the developed world.

Myocardial infarction immediately following CE is a recognized phenomenon. Our 5% use of IABP during the operation may, in part, reflect this although other factors such as moderate or poor LV function preoperatively may also account for this. We did not customarily analyse serum cardiac enzyme levels in the postoperative period as their elevation is not uncommon following cardiac surgery and in those cases where we have utilized them for a high clinical index of suspicion of myocardial infarction, we could not confirm such infarctions.

Our permanent pacemaker insertion rate is low despite a high employment of CE on the RCA, which may suggest that our method of entering the RCA at the crux may safely avoid conduction complications.

Although complete revascularization ‘at the time of surgery’ is beneficial to survival, paradoxically, the few studies in the literature where the ‘long-term patency’ of the grafts were reported, observed little correlation between symptoms and patency of the endarterectomized vessel [19]. However, this does not shy away from the evidence that concentric and uniform myofibrointimal proliferation is systematically observed at the endarterectomy site 5 years post-surgery [20].

However, there are emerging surgical options incorporating endarterectomy techniques that may antagonize these morphological changes. One such technique is coronary artery re-construction using the internal mammary artery. Autologus arterial patching of an open-endarterectomized artery in animal models of carotid and vascular surgery seems to enhance re-endothelialization of the endarterectomized area, and when applied to coronary arteries, may thus prevent or at least greatly reduce the concentric myofibrointimal proliferation typically found on medium-term follow-up in CE [21, 22].

In relation to this, angiography was not routinely employed in the follow-up of our patients to confirm long-term patency, given its invasive nature, unless patients re-presented clinically with ischaemia. The handful of recorded angiograms we do have demonstrate patency of the endarterectomized vessel as can be seen in the example 14 years following CE (Fig. 4).

We made no attempt to compare the outcomes between ‘CABG with CE’ and ‘CABG without CE’ in a propensity-matched analysis, because these groups are inherently different by virtue of the very nature of their coronary disease. The clinical issue we tried to address was the outcome in the decision to perform CE in the management of an otherwise ungraftable vessel, and thus a patient who may otherwise be deemed unable to undergo surgical revascularization. However, out of curiosity, if one were to compare our 20-year survival with CABG without CE over a similar survival timeframe from other studies, we would observe that our results are profitable. For example a study from Atlanta, Georgia in 2003 showed their survival to be 35.6% at 20 years, which compares with our survival of 46% at 18 years [23]. However, the stratification of their data revealed that whilst age as a significant predictor of survival following CABG alone concurs with our stratification, their other predictors of adverse survival were not found to be significant in our analysis of CABG with CE.

This study suffers from the weakness inherent in any retrospective study, including potential inconsistency of the data acquired over time (for example our low deep sternal wound infection rates may be due to varying definition of the condition as data were entered over time in our database), acquisition of late events and the absence of a control group.

Despite this, however, our study emphasizes the hard endpoint of death both in the early and late postoperative periods. Livesey et al. [24] had produced the largest data on CE >25 years ago, but here we have presented the longest follow-up survival for adjunctive CE in recent years.

In conclusion, in contrast to the high mortality associated with non-revascularization in DCAD [4] and as CE techniques and coronary artery reconstruction continue to be refined in future, we argue, given the appreciable long-term survival and low peri-operative complications, that there is a place for adjunctive CE in
coronary revascularization in otherwise inoperable coronary artery disease.

Conflict of interest: none declared.

REFERENCES


Figure 4: (a) Coronary angiogram demonstrating patency of the LIMA-LAD artery following endarterectomy to the LAD artery (proximal LIMA) 14 years following operation. (b) Coronary angiogram demonstrating patency of the LIMA-LAD artery following endarterectomy to the LAD artery (distal LIMA-LAD artery) 14 years following operation.