Medium-term results of systematic off-pump coronary surgery performed by trainee surgeons

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Abstract

Objective: Our unit has used off-pump coronary artery bypass (OPCAB) surgery since 1998, and has consequently developed teaching methods for surgical trainees. This study aimed to compare the medium-term results of OPCAB performed by experts or supervised trainees.

Methods: We retrospectively analysed the data relating to 1333 OPCAB operations performed between January 1998 and January 2006 (mean patient age: 65.3 ± 13; M/F ratio: 2.9), and compared the medium-term outcomes of the 977 (73.3%) carried out by three expert surgeons (group A) with the remaining 356 (26.7%) carried out by four supervised trainees (group B).

Results: There were no preoperative differences in patient age, gender, angina class, operative priority, extent of coronary artery disease, the presence of a recent myocardial infarction or left main stenosis or European System for Cardiac Operative Risk Evaluation (EuroSCORE) between the two groups. Thirty-day mortality was 1% in group A and 0.6% in group B (p = 0.43), and 4-year actuarial survival, respectively, 97.4 ± 1.1% and 94.3 ± 4.1% (p = 0.41); the freedom from new re-vascularisation rates in the two groups were, respectively, 96 ± 0.7% and 95.3 ± 1.4% (p = 0.3).

Conclusions: The results of this study reflect our unit’s long experience of OPCAB surgery and that its successful re-engineering towards the systematic use of OPCAB was feasible. They also show that, in this context, teaching OPCAB surgery is safe in a non-selected cohort of patients, and that the medium-term outcomes of the patients operated on by trainee or expert surgeons are similar.

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1. Introduction

Off-pump coronary artery bypass (OPCAB) surgery has become increasingly more widespread, over the last 20 years, and is now used by many surgeons [1].

However, despite the considerable evidence that it leads to similar graft patency, reduces the risk of postoperative morbidity, shortens intensive care unit and hospital stays and uses fewer resources than coronary surgery with a cardiopulmonary bypass (CPB) [2–7], <25% of all coronary artery bypass grafting (CABG) operations are carried out using the OPCAB technique [8–10].

OPCAB is undoubtedly technically demanding as surgeons are faced with a beating heart rather than a still and bloodless surgical field. A lack of experience may not only put off even the most experienced conventional CABG surgeon, but also dissuade experienced OPCAB surgeons from teaching the technique.

It is always difficult to teach new operative techniques, not least because a trainee’s learning curve should not disadvantage any patient; furthermore, only an institution’s commitment to OPCAB can lead to its systematic use and allow the development of the standardised surgical, anaesthesiology and nursing procedures necessary to improve trainee tutoring without compromising outcomes [11–13]. Systematic use means considering all of the patients scheduled for isolated coronary bypass surgery, except for those with ST-elevation myocardial infarction (MI) and cardiomegaly with ventricular dysfunction, as candidates for OPCAB.

A few studies have shown that teaching the OPCAB technique to young surgeons is possible and safe, but there is still a lack of longer-term outcome data [14–18].

This study aimed to compare the hospital and medium-term outcomes of OPCAB surgery performed by senior surgeons and trainees.
2. Materials and methods

2.1. Patient population

As OPCAB surgery has been used in our unit since 1998 and it now accounts for up to 95% of all operations for isolated coronary artery disease, we retrospectively analysed the 1333 consecutive patients who underwent isolated OPCAB through a midline sternotomy between January 1998 and January 2006; those who underwent limited access operations were excluded.

Nine hundred and seventy-seven of the procedures (73.3%) were carried out by three expert surgeons (group A) and 356 (26.7%) by four supervised trainees (group B).

All of the data had been prospectively entered in our unit’s off-pump database and an audit has shown that there are <2% missing data points.

Fig. 1 shows the percentage of OPCAB operations in relation to all of the coronary artery surgical procedures performed during the study period.

2.2. Anaesthetic and surgical technique

Anaesthesia was induced by means of a 2-min bolus of remifentanil 1.5 μg kg⁻¹ min⁻¹ and one bolus of midazolam 0.2 mg kg⁻¹ and neuromuscular blockade by means of a 0.15-mg kg⁻¹ bolus of cisatracurium. Maintenance was obtained by infusing propofol 3 mg kg⁻¹ h⁻¹, remifentanil 0.05–0.5 μg kg⁻¹ min⁻¹ and cisatracurium 1.5 μg kg⁻¹ min⁻¹.

Anticoagulation was achieved by administering heparin 300 IU kg⁻¹ before sectioning the internal mammary arteries (IMAs), and additional doses to maintain an activated clotting time of >300 s.

The proximal right coronary and left anterior descending (LAD) arteries were directly accessed using very little heart manipulation. In order to gain access to the posterior descending and obtuse marginal arteries (PDA and OM), the heart was positioned vertically by applying two or three traction stitches to the posterior pericardium, between the left inferior pulmonary vein and the inferior vena cava.

A long wet strip of gauze was secured to the deepest traction stitch by means of a tourniquet, and the lateral and posterior vessels were exposed by handling the two ends of the gauze, tilting the table head-down and turning it towards the surgeon.

The coronary vessels were stabilised by means of a reusable stainless steel compressive stabiliser developed at our institution, which can be fitted to the supports of the Cosgrove self-retaining mitral retractor (Kapp Surgical Inc., Cleveland, OH, USA).

A filtered blower/mister was used to perform the anastomosis under perfect vision, avoiding any trauma to the arterial walls (ClearView, Medtronic Inc. Minneapolis, MN, USA), and a soft and flexible intracoronary shunt (Anastaflow, Edwards Lifesciences LLC, Irvine, CA, USA) was used to avoid transient ischaemia and reduce bleeding from the anastomotic site [19].

In the case of redo surgery, adhesiolysis and revascularisation were carried out progressively, starting from the anterior branches; similar sequential re-vascularisation was used for patients with critical left main-stem stenosis or depressed left ventricular function, in whom careful manipulation of the heart is required to reach the posterior vessels.

In cases of unstable angina unresponsive to maximal intravenous therapy, or in the presence of severe left ventricular dysfunction, the off-pump operation was performed after the prophylactic insertion of an intra-aortic balloon pump (IABP).

We routinely constructed an arterial conduit using the right skeletonised IMA as a free graft anastomosed terminolaterally to the left skeletonised IMA (Y-graft) in order to re-vascularise the left coronary system. The right coronary system was re-vascularised by means of a saphenous vein graft (usually) or radial artery (rarely) anastomosed to the proximal aorta.

In a few cases, in order to avoid aortic manipulation, the proximal stump of the right IMA was used as an intrathoracic arterial source of flow for the saphenous vein graft [20].

2.3. Definitions

A trainee case was defined as a procedure performed from ‘skin to skin’ by a trainee, with an expert surgeon acting as the first assistant or supervising while another person directly assisted the resident.

Pre-existing renal dysfunction was defined as a preoperative creatinine level >1.5 mg dl⁻¹.

Carotid artery disease was defined as the presence of a >50% stenosis as assessed by means of vascular ultrasonography.

Thirty-day mortality was defined as any death occurring within 30 days of the operation (inside or outside the hospital), or any in-hospital death at any time if the patient had remained in hospital until his or her death.

Perioperative cerebrovascular accident (CVA) was defined as a global or focal neurological deficit lasting less (transient ischaemic attack) or more (stroke) than 24 h, that was apparent after the patient emerged from anaesthesia, diagnosed by a neurologist and confirmed by a brain computed tomography (CT) scan [21,22].

2.4. Training method

All of the three expert surgeons performed >90% of their re-vascularisation surgical procedures using OPCAB. All of the trainees were introduced to OPCAB irrespective of their surgical coronary re-vascularisation background, although
complete competence in establishing and managing a CPB was required.

The trainees performed all of the technical aspects of the operation, such as the exposure and stabilisation of vessels, graft construction and anastomoses. They were also involved in constant intra-operative dialogue with the anaesthetist in order to determine the progress of the operation and assess haemodynamic status, changes in heart rate, variations in myocardial kinesis during heart handling and coronary shunting and anastomoses.

2.5. Follow-up

The cross-sectional follow-up was carried out between December 2008 and March 2009 by reviewing the hospital records, making contact with the patients or their physicians and assessing cardiac events: that is, recurrent angina, MI, cardiac catheterisation, percutaneous transluminal coronary angioplasty (PTCA) and repeated CABG.

The primary clinical end points were survival and freedom from new re-vascularisation (PTCA or repeated CABG).

The additive European System for Cardiac Operative Risk Evaluation (EuroSCORE) was used to stratify the patients on the basis of the predicted risk of operative mortality [23].

3. Results

Table 1 shows the demographic and preoperative characteristics of the two cohorts. The two groups were homogeneous in terms of patient age (65.3 vs 65.2 years), gender, chronic obstructive pulmonary disease, chronic renal failure and diabetes mellitus, but differed in terms of epi-aortic vessel disease ($p = 0.04$) and redo surgery ($p = 0.03$).

The ejection fraction values obtained by means of echocardiography were divided into three classes on the basis of the EuroSCORE definition (poor, moderate and good) in order to highlight any differences: there was no significant difference between the expert and trainee surgeon groups in any of the classes.

### Table 1

<table>
<thead>
<tr>
<th>Variables</th>
<th>Expert surgeons ($n = 977$)</th>
<th>Trainee surgeons ($n = 356$)</th>
<th>$p$-value $^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>65.3 ± 13.2</td>
<td>65.2 ± 15.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Gender (male/female)</td>
<td>769/173</td>
<td>277/63</td>
<td>0.9</td>
</tr>
<tr>
<td>COPD</td>
<td>106</td>
<td>51</td>
<td>0.08</td>
</tr>
<tr>
<td>Pre-existing renal dysfunction</td>
<td>57</td>
<td>19</td>
<td>0.3</td>
</tr>
<tr>
<td>Carotid artery disease</td>
<td>190</td>
<td>53</td>
<td>0.048</td>
</tr>
<tr>
<td>DM</td>
<td>243</td>
<td>97</td>
<td>0.3</td>
</tr>
<tr>
<td>Priority</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elective</td>
<td>740</td>
<td>277</td>
<td>0.6</td>
</tr>
<tr>
<td>Urgent</td>
<td>197</td>
<td>63</td>
<td>0.3</td>
</tr>
<tr>
<td>Emergent</td>
<td>40</td>
<td>16</td>
<td>0.3</td>
</tr>
<tr>
<td>Left main stenosis</td>
<td>309</td>
<td>98</td>
<td>0.1</td>
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<tr>
<td>Extent of coronary artery disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single vessel</td>
<td>72</td>
<td>7.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Double vessel</td>
<td>278</td>
<td>28.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Triple vessel</td>
<td>627</td>
<td>64.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor (&lt;30%)</td>
<td>22</td>
<td>2.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Moderate (30–50%)</td>
<td>297</td>
<td>111</td>
<td>0.3</td>
</tr>
<tr>
<td>Good (&gt;50%)</td>
<td>658</td>
<td>235</td>
<td>0.3</td>
</tr>
<tr>
<td>Redo surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent MI (&lt;90 days)</td>
<td>467</td>
<td>178</td>
<td>0.4</td>
</tr>
<tr>
<td>Unstable angina</td>
<td>194</td>
<td>66</td>
<td>0.6</td>
</tr>
<tr>
<td>Preoperative IABP</td>
<td>22</td>
<td>2.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Median additive EuroSCORE</td>
<td>2 (1–3)</td>
<td>2 (1–2)</td>
<td>0.7</td>
</tr>
</tbody>
</table>

COPD: chronic obstructive pulmonary disease; IABP: Intra-aortic balloon pump; MI: myocardial infarction; DM: diabetes mellitus; and EuroSCORE: European System for Cardiac Operative Risk Evaluation.

$^a$ Values shown as frequencies and percentages, means ± SD or medians (25th and 75th centiles).

$^b$ $\chi^2$ test and Fisher’s exact test or the Mann–Whitney U-test.
The two groups were also similar in terms of surgical priorities (elective, urgent or emergent) and the extent of the coronary artery disease, but the expert surgeon group included more patients with carotid artery disease ($p = 0.048$).

The median EuroSCORE-predicted risk of mortality was 2 in both the groups ($p = 0.7$).

Table 2 shows the intra-operative results. The mean number of grafts per patient was $2.46 \pm 0.82$ in the expert surgeon group and $2.37 \pm 0.85$ in the trainee surgeon group; the difference is not statistically significant ($p = 0.1$).

All of the patients received a graft on the anterior system; grafts on the lateral system were performed in 73.4% of the patients in the expert surgeon group and 68% of those in the trainee surgeon group ($p = 0.06$); grafts on the posterior system were performed in, respectively, 41% and 41.2% of the patients ($p = 0.9$).

The use of a CPB was necessary in 30 patients in the expert surgeon group (3%) and 15 in the trainee surgeon group (4%) ($p = 0.3$).

Table 3 shows that there was no significant between-group difference in terms of perioperative morbidity or mortality. There were ten 30-day deaths in the expert surgeon group (1%) and two in the trainee group (0.6%) ($p = 0.4$), for a total hospital mortality rate of $<1\%$ (12/1333). The incidence of MI (2.4% vs 1%; $p = 0.4$), acute renal failure (1% vs 1%; $p = 0.06$) and neurological complications (0.4% vs 0.3%; $p = 0.4$) was similar in the two groups.

The follow-up was 99.8% complete, and had a median duration of 4 years (interquartile range: 3–4 years; Table 4).
Death during follow-up occurred in 3.5% of the patients in the expert surgeon group and 4.2% of those in the trainee surgeon group ($p = 0.6$); there were more deaths due to stroke in the expert surgeon group ($p = 0.04$).

Almost all of the patients in both the groups resumed their working or daily activities ($p = 0.6$). The recurrence of angina was $<4%$ in both groups ($p = 0.7$). A new angiographic examination was performed in 7.3% of the patients in the expert surgeon group and 6.2% of those in the trainee group ($p = 0.4$); 25 (2.6%) and 12 patients (3.4%) underwent new revascularisation.

Fig. 2 shows that Kaplan–Meier 1-, 2- and 4-year event-free survival was similar in the expert and trainee surgeon groups: $98.5\% \pm 0.4\%$ versus $99.7\% \pm 0.2\%$, $97.6\% \pm 0.5\%$ versus $98.8\% \pm 0.6\%$ and $97.4\% \pm 1.1\%$ versus $94.3\% \pm 4.1\%$ ($p = 0.4$); the same was true of new re-vascularisation-free survival: $99.2\% \pm 0.2\%$ versus $98% \pm 0.7\%$, $98.6\% \pm 0.3\%$ versus $97.1\% \pm 0.8\%$ and $96.6\% \pm 0.7\%$ versus $95.3\% \pm 1.4\%$ ($p = 0.3$; Fig. 3).

4. Discussion

The widespread acceptance of a new surgical technique depends on its reproducibility and the feasibility of teaching it to the next generation of surgeons. Conventional CABG using CPB and cardioplegic arrest has been the gold standard treatment of ischaemic heart disease for several decades, and provides surgeons with a still and bloodless operating field. However, in order to avoid the potentially negative effects of extracorporeal circulation, the performance of coronary bypass surgery has evolved over the last few years with the use of beating-heart techniques. The results show that coronary surgery without CPB is at least as safe as conventional CABG, and it offers the additional benefits of less myocardial and cerebral damage, fewer transfusions, lower costs and a shorter hospital stay [7,9].

Although these positive results encourage its wider adoption, OPCAB surgery is not yet performed throughout the world, and junior surgeons are only sporadically taught how to operate on a beating heart. The academic pathway of
coronary surgery is traditionally based on the sequential steps of proximal vein anastomosis, distal vein—coronary anastomosis on an arrested heart, distal left internal mammary artery (LIMA) anastomosis on an arrested heart, the assembly of composite conduits or sequential grafts and anastomosis on a beating heart; however, although OPCAB surgery may require a different approach because some of the typical CABG skills are more relevant than others, only a few surgical schools have changed their training schedule [24].

This resistance to change is mainly due to the sporadic use of OPCAB surgery by the training institute itself. However, if coronary surgery is systematically performed without CPB (as has been the case in our hospital, where up to 95% of surgical re-vascularisations are carried out using OPCAB techniques), it is necessary to modify training as well as surgical, anaesthesiology and nursing procedures and technologies.

In our opinion, systematic use of the technique is the sine qua non for OPCAB surgery, and they often used OPCAB surgery for their very first myocardial re-vascularisation.

In addition to undergoing a long period of assiduously assisting with OPCAB cases, the trainees were taught how to prepare and handle a skeletonised composite arterial graft in order to make them familiar with arterial anastomoses (mainly Y-grafts using IMAS), shunt insertion, LAD anastomoses (mainly using the LIMA), heart positioning and stabilisation for OM and PDA as single anastomoses and then sequential anastomoses.

In general, we believe that coronary shunts are an essential acquisition of modern surgical practice and that coronary snaring has to be abandoned: modern shunts seem to be trulyatraumatic, avoid myocardial ischaemia and act as a mould that guarantees patency (which also helps beginners in coronary surgery). Haste and imprecision are usually the enemies of surgeons. Moreover, suturing a coronary artery in vivo (rather than the empty and collapsed structures of cardioplegic arrest) improves haemostasis, and we have experienced a negligible number of anastomoses requiring additional haemostatic sutures.

The results of this retrospective study show that OPCAB surgery can be taught to surgical trainees with good clinical and angiographic results that are maintained during medium-term follow-up. Unlike those in studies, the patients in this series were not selected for OPCAB or for trainees, but represent a consecutive sample of the ongoing workload of our unit. This explains the homogeneous distribution of the preoperative data in the two groups (there was only few statistically significant differences between them), and suggests that both the expert and trainee surgeons were faced with similar cases and that the corresponding outcome was not influenced by patient selection.

The median operative risk score (assessed using the additive EuroSCORE) was 2 in both groups (with a 75th percentile of 2 in the trainee and 3 in the expert surgeon group), and there were no differences in the extent of revascularisation. However, because of the complexity of the surgery involved, the expert surgeons performed more re-operations than the trainees.

The main causes of conversion to CPB (necessary in <5% of the cases in both groups) were deep intra-myocardial coronary vessels, new-onset and persistent myocardial ischaemia and the prohibitive exposure of posterior or lateral coronary vessels due to cardiomegaly.

The rates of morbidity and mortality were low, with 30-day mortality being recorded in only 0.6% of the 356 patients who were operated on by a trainee surgeon. The major complications involved four patients who suffered a perioperative MI, nine who required the use of an IABP and one who experienced a perioperative CVA. The overall incidence of perioperative CVA was 5/1333 (0.37%), thus supporting the well-known neuroprotective role of OPCAB, which can reduce or eliminate the need for aortic manipulation during surgery [25].

The incidence of angiographic examinations in both groups was higher than the percentage of patients with angina, probably because they were not always carried out because of the presence of spontaneous symptoms, but also because of those due to scheduled ergometric tests. Four-year new re-vascularisation-free survival was similar in both the groups: 96.6% ± 0.7% in the patients operated on by an expert surgeon, and 95.3% ± 1.4% in those operated on by a trainee.

The results of this study reflect the long experience of our unit in OPCAB surgery, and provides further data concerning medium-term outcomes to supplement those published by other authors who have analysed the feasibility of training in OPCAB surgery [14—18].

The study presents many intrinsic limitations primarily due to its retrospective analyses nature and involvement of only a single institution. A further confounding factor may be the fact that the operations were performed by ‘four hands’ and, particularly in the early training phases, an expert surgeon may have intervened to help the trainee to position the heart, find a deep vessel or perform a more-difficult-than-expected anastomosis. However, the prevalent surgeon labelled the case. Finally, we did not consider the issues relating to the trainees’ background in conventional CABG or their learning curves.

In conclusion, our data show that OPCAB procedures can be safely and effectively performed by cardiothoracic trainees with good results that are maintained over time. In our opinion, systematic use of the technique is the condicio sine qua non for the development of a successful training programme.

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References


Appendix A. Conference and discussion

Dr M. Shrestha (Hannover, Germany): I fully agree with you that only complete commitment of an institution can lead to any full implementation of any new techniques such as OPCAB. Moreover, any new technique, however beneficial or better than the conventional technique, will only be broadly accepted if it is reproducible and can be taught to the next generation of surgeons. This has also been shown very successfully in the case of OPCAB by Dr Sergeant’s team in Leuven over many years. But I do have some questions regarding your presentation.

First of all, although in the patient characteristics you say that they were similar in both groups operated by the senior surgeons and the residents, how were the patients selected? Was it blindly, randomised, or by selection?

Dr Messina: Patients were not selected for OPCAB and also were not selected for trainee. They represent a consecutive sample of the ongoing workload of our unit during 8 years.

Dr Shrestha: In 40% of your patients with triple-vessel disease, the right coronary was revascularised with a venous graft or a radial artery graft as a free graft with a proximal anastomosis to the aorta. As we all know, one of the biggest advantages of OPCAB is the so-called ‘no-touch’ technique of the aorta. Since you are doing the proximal anastomosis on the aorta, do you explain the supposed advantage of this technique against a normal technique with CPB, because if you touch the aorta, then you can as well do it with CPB.

Dr Messina: Well, since ’98 we use both mammarys arranged in a “Y” graft to perform a re-vascularisation of the anterior and lateral coronary system and a saphenous vein graft proximally anastomosed to the aorta for the other anastomoses. Four years ago we analysed our results, and noted that the patients who didn’t receive a proximal anastomosis showed less incidence of cerebrovascular accidents. So recently we developed a new technique to avoid aortic clamping. We performed a proximal anastomosis of the saphenous graft to the right mammary artery stump, termo-terminal anastomosis, to avoid the tangential clamp and to reduce cerebrovascular accidents as discussed this morning in the SYNTAX study.

Dr Shrestha: I have a final short question. Did you look into the patients who were re-vascularised again and did you find out if the reoperations were because of new stenosis or because of problems in the grafts?

Dr Messina: Well, the analysis was conducted on new re-vascularisations overall. Also patients who received a new re-vascularisation in the coronary that were not treated with an off-pump bypass were included in the statistical analysis to overestimate the need of new re-vascularisation.