

Off pump coronary bypass grafting: evidence and long-term results

Abstract

Surgical coronary artery bypass grafting (CABG) is the standard of care for revascularization of left main or three-vessel coronary artery disease. The off-pump coronary artery bypass graft (OPCAB) procedure avoids the use of cardiopulmonary bypass, may improve long-term outcomes by reducing the rates of perioperative myocardial injury, stroke, neurocognitive impairment, and cardiac-related mortality. At this time, several clinical trials have been conducted since OPCAB became popular in the 90s and have demonstrated no benefit of OPCAB over traditional CABG with respect to these outcomes despite favorable short-term reductions in transfusion requirements and other postoperative complications. Ultimately, OPCAB is associated with less effective myocardial revascularization and does not entirely prevent complications traditionally associated with cardiopulmonary bypass. This article reviews actual evidence of OPCAB versus traditional CABG with respect to both short- and long-term clinical outcomes.

Keywords: coronary artery bypass surgery, off pump, myocardial revascularization, cardiac surgical procedures, beating heart coronary artery bypass

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Introduction

Coronary artery bypass grafting (CABG) was first performed by Goetz in 1960 without the use of cardiopulmonary bypass (CPB) as a treatment for coronary heart disease.^{1,2} Kolesov³ was the first who showed excellent results in the late 1970s.⁴ Soon over, with advances in CPB, conventional CABG (ONCABG) with cardiac arrest became the gold standard with the downside of^{5,6} aortic cross-clamping and reperfusion injury leading to systemic inflammation (SIRS), and some other side effects that produce end-organ injury including non-pulsatile flow, micro-emboli, hypoperfusion and a prolonged CPB time,⁷ thus developing consequences that include coagulation dysfunction, complement activation and multiple organ dysfunction compromising end-stage organs.⁸

At the beginning of the new OPCAB era, the most important limitation was the initial surgeon learning curve due to limited exposing of the circumflex artery territory and the most benefited patients were those with heavily calcified aorta where the risk of stroke would be extremely high from atheromatous or calcific emboli,¹⁴ cerebrovascular disease (CVD),^{9,10} high risk patients with advanced age, peripheral vascular disease,^{10,13} low ejection fraction (< 30%), recent myocardial infarction (MI), renal failure current congestive cardiac failure or chronic pulmonary disease and some cases subjected to redo surgery.¹⁵

As a consequence of further improvements in surgical and anesthetic developments during the late 90's the proportion of OPCAB increased up to 30%.⁹⁻¹² Regarding mid- and long-term results, OPCAB would not be inferior to the standard technique expecting less morbidity and mortality with the most benefit for non-developed countries, being more economically viable for the growth of CABG.⁹ Nowadays, a large number of clinical studies have been carried on to answer these queries, and it is the role of cardiothoracic surgeons to evaluate this strong evidence to determine when and in what kind of patients perform OPCAB in clinical practice.

Coronary vessels targets

Most clinical studies show no difference in the number of grafts

performed between OPCAB and ONCABG,^{16,17} but others show a lower number of grafts for the OPCAB patients ($P < 0.01$).^{18,19} These studies showed that it was due to the greater difficulty of performing surgery on a beating heart and hemodynamic instability for coronary artery exposure,²⁰ showing that it may produce worse outcomes if patient selection is not the right.^{21,22} Besides, other authors showed a significantly less mean number of grafts for OPCAB patients. Interestingly, the study introduced the index of complete revascularization (ICRV), defined as the ratio of bypass grafts divided by the number of angiographically significant lesions to compare the completeness of revascularization between the 2 groups. The ICRV was similar between both methods, but was demonstrated that surgeons who perform less than 25% OPCAB patients had a significantly lower ICRV in this group, concluding that patients that required fewer grafts were selected for OPCAB and it was not the incomplete revascularization (IR) that explained this issue.²⁰ With this regard there are studies showing a variable rate of IR in OPCAB patients.²³⁻²⁵ Surprisingly, the right coronary artery (RCA) is less grafted than the circumflex artery, while there was no difference in the rate of left anterior descending (LAD) artery grafting.¹⁷

Conduits for coronary artery grafting

Advantages with the use of the internal mammary artery (IMA) include increased survival, low MI risk, a decrease in repeat revascularization and a low hospitalization rate with improved early outcomes and reduced early post-operative deaths.^{16,18,26,27} though the use of bilateral IMA (BIMA) is a risk factor for increased sternal wound infection rate and is discouraged in diabetes, COPD and grossly obese patients.^{28,29} The radial artery (RA) has a proper length to access coronary arteries and a regular luminal calibre, thus placing as.^{10,30,31} one of the grafts of choice for most patients. On the other hand, due to its muscular layer, the RA is more likely to spasm and has a higher intimal hyperplasia and atherosclerosis than other conduits.³² There is no data showing differences in RA use with both techniques. Finally, the saphenous vein graft (SVG) is used in both groups because it is easy to harvest, handling and its reproducibility permits simplification of the operation.¹⁰

Total arterial revascularization

The concept of total arterial revascularization (TAR) has been widely encouraged because of the advantage of arterial over venous conduits in terms of long-term graft patency in terms of late survival and adverse cardiovascular events.³³ The Radial Artery Patency Study (RAPS) compared RA and SVG patency over 5 years postoperatively and it showed less functional graft occlusion in the RA group. BIMA grafting has shown better survival than a single IMA up to 15 years, which is also true in diabetic patients. Also, TAR is a complex task to perform in OPCAB patients due to a more challenging technique compared to ONCAB surgery.³⁴ Some authors proclaimed TAR without touching the aorta and OPCAB as the optimal strategy for CABG with reduced neurologic postoperative dysfunction.¹⁹ There is a greater long-term survival with the use of BIMA and RA compared to LIMA and SVG with less reoperations decreasing from 7% to 3%.³⁴

OPCAB Conversion

Conversion from OPCAB to ONCAB is due to some situations such as failure of exposure of coronary arteries, small vessels, pericardial adhesions, a dilated heart, or arrhythmias or haemodynamic instability during traction of the heart causing hypotension, left heart valve insufficiency, acute ischaemia or left ventricular dysfunction during the procedure.³⁵ The most frequent coronary territories associated to conversion are the obtuse marginal vessels.²⁹ Several studies state the conversion rate is related to surgical volume.³⁶ being the highest at low volume centres (3.6% high vs. 6.0% intermediate vs. 7.3% low, $p < 0.0001$). The reason for this incremental was due to a combination of increasing proportions of complex disease and severe comorbidities, leading to more intra-operative instability.¹⁷ Additional reasons for this include low surgical team experience with an observed increment in the number of surgeons who do OPCAB not on a regular basis and a low proportion of OPCAB cases.¹⁹ Moreover, mortality from intra-operative conversion is seen to be increased up to 10 times.^{33,37} Similar studies showed that conversions from OPCAB have poor results and a hospital mortality rate up to 10.3% for these patients.^{38,39} This negative effect of conversion persisted at 5-year follow-up.¹⁷

Morbidity, mortality and long-term survival

Early retrospective studies showed that OPCAB reduces hospital morbidity and mortality in CABG.^{40,41} Later on, other randomized controlled trials (RCT) studies included a greater number of low-risk patients, demonstrating that although the in-hospital mortality rate was lower for OPCAB than for CABG, it was not significantly different, with no significant difference of postoperative complications.⁴²

The ROOBY trial (Randomized On/Off Bypass) trial.⁴³ compared a large number of patients randomly assigned to undergo OPCAB or ONCAB, showing no significant difference between in terms of in-hospital mortality, and less postoperative graft patency for OPCAB, concluding that OPCAB is a difficult surgical technique with low reproducibility that requires an strong expertise and it is reserved for trained surgeons. The CORONARY study (CABG Off or On-Pump Revascularization Study), into which our center contributed with a significant number of patients, concluded that hospital mortality is similar between surgery for both groups, and OPCAB significantly reduced transfusion requirements, acute renal failure and respiratory complications and reoperation for bleeding was lower. Like other studies, 30-day hospital mortality between groups was similar, however, morbidity was lower in the OPCAB group.⁴⁴⁻⁴⁸ Short-term mortality were similar in several studies.^{46,49} Moreover, a large meta-analysis.¹⁸ concluded that benefits of OPCAB including CVA, MI and

mortality are significantly related to patient risk profile, suggesting that OPCAB should be strongly considered in high-risk patients. A large meta-analysis.⁵⁰ found that the difference between OPCAB and ONCAB was minimal in RCTs, whereas OPCAB was found to be considerably superior in the observational studies. Furthermore, another study.⁵¹ compared both techniques in STS database cases with high STS scores, and they found that in high risk cases in-hospital morbidity and mortality was lower for OPCAB. In conclusion, many past and recent studies has shown.^{6,14,16,52,53} less hospital mortality in OPCAB patients.^{54,55} with no difference in cardiovascular deaths between the groups at 5 years.^{17,46} However, in the other hand, some authors showed a greater 5-year mortality rates in OPCAB.^{56,57} that maybe could be explained because of the less observed graft patency and incomplete revascularization rates. In this regard, it seems that complete revascularization widely decreases long-term mortality in multivessel disease and diabetes patients.⁵⁸ Risk factors for mortality are conversion from OPCAB to ONCAB, advanced age, female gender, carotid artery disease, chronic renal failure, low LVEF, pre-operative intra-aortic balloon pump (IABP) and recent MI.⁵⁹

In terms of long-term survival and time free from major cardiac adverse events such as MI, recurrent angina and repeated revascularization, and graft patency and quality of life all important studies converge to there are no differences between both groups when is performed by a very skilled surgeon. Similar findings were reported at 1-, 5-, and 10-year survival rates by some authors.⁴⁶⁻⁶⁴

Complete revascularization and graft patency

Factors used to determine the quality of CABG include revascularization of all coronary territories obstructed and postoperative graft patency. Therefore, as stated before, completeness of revascularization is a key factor to obtain good long-term outcomes, thus, has been demonstrated that incomplete revascularization is an independent risk factor for late mortality with a 20-year survival up to 40%, compared with 75% in those in whom the revascularization was complete. Interestingly, in elderly patients has been showed that IR does not affect long-term survival, so may be permitted to perform revascularization only on the anterior descending artery.^{47,65}

Regarding postoperative graft patency, some studies showed that patency is a goal less likely to be reached in OPCAB, thus it is related to a greater proportion of long-term events.^{66,67} An important recent meta-analysis showed OPCAB in hands of skilled experienced surgeons, graft patency is comparable to ONCAB in the long term.⁶⁸⁻⁷⁰ concluding that quality of OPCAB surgery can only be maintained when performed by a skilled expert surgeon at a center with high surgical volume. This study also showed a statistically significant higher proportion (35%) of postoperative graft occlusion in the OPCAB patients,⁵⁸ and this fact was due to SVG occlusion due to thrombosis or technical failure in OPCAB, with no significant differences when LIMA and RA grafts were utilized.⁷¹ In the DOORS study, there were more IR for OPCAB grafts in all coronary artery territories and the graft patency was better in the mid term in ONCAB, also showing that though the patency of LIMA grafts was similar between groups, it was diminished in the right and circumflex territories for OPCAB patients. As a surprise this study concluded that the proportion of patent LIMA was 95% in both groups, with a greater rate of malfunction for SVG and RA or RIMA grafts, thus reinforcing the idea of a technically demanding technique.⁷²

Regarding to repeated revascularization and OPCAB some studies communicated no difference in 5-year revascularization rates between both groups, so much for either PCI or CABG as a new revascularization method.⁴⁶

OPCAB in high-risk patients

Nowadays, a special issue corresponds to the increasing worldwide proportion of people in advanced stages of life, so it is assumed that an elevated number of patients will be subjected to CABG in further years. This group concentrate a larger number of comorbidities increasing risks and mortality with a higher length of stay and costs. However this findings, a recent meta-analysis of patients ≥ 70 years.⁷³⁻⁷⁵ concluded that OPCAB have less mortality, CVA and AF which may result in a shorter length of hospital stay, obtaining the most benefit from OPCAB surgery. Same findings were achieved by two recent RCTs.^{76,77} in which patients more than 75 years of age operated on with or without CPB were resulting in no significant difference in-hospital mortality and survival at 6 months and 1 year. In terms of operative risk a study included patients.⁷⁵ with a EuroScore of >6 showing that the rate of composite primary end point in the first 30 days of surgery defined as presence of MI, CVA, operative mortality, renal failure, major bleeding requiring surgery was significantly lower in the OPCAB group. Nevertheless, another study in patients with a EuroScore of ≥ 5 showed no difference in these end points, but the rate of CVA is lower for off pump patients.^{78,79} Currently there are no studies including dialysis patients with end-stage renal disease,^{80,81} but some indicated that OPCAB could have a greater benefit in those cases. In non dialysis patients an important meta-analysis reported that OPCAB has more advantages in preventing the development of acute renal failure. When using the STS score as a predictor of mortality OPCAB was associated with significantly reduced in stay morbidity and mortality. A special comment deserves the GOPCABE study in patients 75 years of age or older.⁸² showing that the mean number of distal anastomoses in the OPCAB group was less, and the reasons for conversion were due to calcified vessels, haemodynamic instability and same as many others, inappropriate exposure; with no significant difference in the composite endpoints at 1 year follow up, but the OPCAB group had more need of a new revascularization within 30 days and less transfusion. And, probably because of the high risk older patients, there were no differences in operative time, mechanical ventilation, length of ICU and length of hospital stay. Similar findings were found in other studies.^{35,51}

Coronary surgery is the gold standard strategy in diabetes patients with multivessel disease compared to angioplasty.⁸³ Despite advances in cardiac surgery still operative management in diabetes patients is difficult. A recent study performed in a few patients showed a greater risk of mortality after OPCAB, a smaller number of graft and more IR,^{83,84} concluding that these patients benefit with up to 10% less mortality when complete revascularization is achieved.

Experienced OPCAB team

Several studies have shown that for hospitals with a higher number of OPCAB patients operated, the risk of in-hospital mortality and complications were statistically significant less than for ONCAB patients.^{18,20} which could be interpreted as high volume centers could act as a referral center due to their greater expertise in the field. Another study showed that off pump skill level is crucial for the development of a OPCAB center. Also, suggests that achievement of greater outcomes produces by itself an important decrease in risk of death when done by surgeons with more than 150 off pump surgeries per year. In the other hand, another trial showed that the higher conversion rates occurs when the surgeon perform a reduced number of off pump cases with a lower number of grafts and consequently a higher mortality.¹⁷ Also showed that there was no significant difference in major end points and long term mortality when surgeons

performing more than 60 surgeries/year when compared to ONCAB only surgeons,¹⁷ although OPCAB surgeons had a higher in-hospital mortality rate because they preferred the OPCAB technique for high-risk patients with a low left ejection fraction and high creatinine preoperative levels.¹⁷ Important is to mention that exist a significant diminish of risk of stroke, renal failure and longer hospital stays when OPCAB is performed in hospital with a high surgical volume.⁸⁵⁻¹⁰⁰

Conclusion

Coronary bypass surgery is the gold standard of care for complex multivessel disease patients and the outcomes depends much on the level of skill of the cardiac surgeon, producing that reproducibility is a challenging and difficult task to achieve between surgeons. After more than almost 3 decades of continuing experience with this more technically demanding method of revascularization and the vast amount of information and understanding produced by many authors, off pump coronary surgery can be performed expecting very similar outcomes than the standard on pump technique when is developed by very committed and much experienced surgeons in tertiary referral centers in order to obtain the best long-term results. Moreover, off pump coronary surgery requires thorough strategies of patient selection, an adequate direct training of interested surgeons and gradual incorporation of more complex cases into their skills set. Today, there is a strong evidence pointing out to develop guidelines in coronary surgery in order to help surgeons to choose either techniques as a method of obtain the most greater results for this complex and prevalent group of patients.

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Conflicts of interest

The author declares no conflict of interest.

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