

## Surgical outcome after isolated on-pump and off-pump anterior descending coronary revascularisation

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### Summary

**PRINCIPLES:** Anterior descending coronary revascularisation can be performed with or without cardiopulmonary bypass. We compared surgical outcomes and postoperative results of two groups of patients operated on for isolated anterior descending coronary revascularisation with the left internal mammary artery, in order to determine the ideal target patient of each technique.

**METHODS:** From July 1997 to December 2012, 243 consecutive patients underwent off-pump (119) or on-pump (124) surgery for isolated revascularisation of the anterior descending coronary artery. We retrospectively collected, analysed and compared preoperative, intraoperative and postoperative variables.

**RESULTS:** In the on-pump group, aortic cross-clamp and bypass times were 22 and 35 minutes, respectively. Mean surgical time was 126 minutes for the off-pump group and 160 minutes for the on-pump group. Off-pump patients were more often men (82% vs 66%,  $p = 0.006$ ), older (median age 67 vs 64 years,  $p = 0.013$ ), with renal failure (11% vs 2.4%,  $p = 0.009$ ) and respiratory failure (20% vs 7.3%,  $p = 0.003$ ), with peripheral vascular disease (17% vs 8%,  $p = 0.038$ ) and affected by a higher degree of angina ( $p < 0.001$ ). Surgical time was shorter off-pump ( $p < 0.001$ ), but a greater number of urgent procedures were performed on-pump (11% vs 3.4%,  $p = 0.042$ ). No difference in postoperative characteristics and complications except for the intensive care unit stay, which was shorter off-pump (median 1 vs 2 days,  $p = 0.046$ ). Hospital mortality was 0.8% off-pump and 1.6% on-pump ( $p = 0.5$ ).

**CONCLUSION:** Both on-pump and off-pump surgery for isolated anterior descending coronary revascularization are safe with equal surgical risk. Off-pump procedures seem to be more appropriate in nonurgent patients with higher surgical risk profiles.

**Key words:** on-pump coronary surgery; off-pump coronary surgery; surgical myocardial revascularisation

### Introduction

During the last 50 years, surgical myocardial revascularisation has proved to have an excellent outcome and long-

term results. Thus it became the gold standard therapy for multivessel coronary disease, left main disease and complex cases not suitable for percutaneous angioplasty. In particular, surgical revascularisation of the left anterior descending coronary artery (LAD) is strictly related to a great impact on patients' quality of life and life expectancy and, since the eighties of the last century, the left internal mammary artery (LIMA) represents the graft of choice for this target vessel, with proved high degree of long-term patency in several clinical trials [1, 2].

With regard to surgical strategies, in the last 20 years off-pump coronary artery bypass surgery (OPCAB) has emerged as a valid alternative to on-pump surgery in selected cases: this technique does not require aortic cannulation, aortic cross clamping and cardioplegic cardiac arrest, but should be performed when the coronary arteries are easily reachable and the quality of the surgical anastomosis is guaranteed. The LAD represents an "easy" target for the off-pump technique and an isolated LAD revascularisation can also be performed through minimally invasive access at the fourth intercostal space [3–7].

Nevertheless, the optimal strategy is still under debate and both techniques appear to be feasible and safe, as described in several published papers [8–16].

With the present study, we have retrospectively compared and analysed patients operated on at our institution for isolated LAD revascularisation with the LIMA, using the on-pump and the off-pump technique. The aim of the study was to define the ideal target patient of each technique.

### Material and methods

The study protocol was designed, and submitted to and accepted by the local Ethics Committee.

Patients operated upon during a period of time of 15 years (July 1997 to December 2012) for isolated surgical myocardial revascularisation with LIMA on the LAD were retrospectively identified using the institutional database and included in the study: 243 records and surgical protocols were located, collected and analysed. One hundred and nineteen patients underwent off-pump coronary surgery and 124 patients were operated on-pump. Preoper-

ative, intraoperative and postoperative selected variables were collected and compared.

### Surgical techniques

#### *On-pump surgery*

Through a median sternotomy, the left internal thoracic artery was harvested and prepared following standard techniques based on the surgeon's preferences. After full heparinisation (300 IU/kg), patients were cannulated in the standard fashion and crystalloid or blood cardioplegia was employed according to the surgeon's preference.

#### *Off-pump surgery*

During the study period, off-pump surgery for isolated LAD revascularisation was achieved through a median sternotomy (66 cases [56%]) or a left anterolateral mini-thoracotomy (MIDCAB) at fourth intercostal space (53 cases [44%]), according to the surgeon's preference. Intracoronary shunts and different models of coronary stabilisers were routinely employed.

### Statistical analysis

The statistical analysis was performed using Stata for Windows, version 13.1. Variables were retrospectively collected and compared according to the surgical method (off-pump or on-pump surgery). Continuous variables are presented as mean  $\pm$  standard deviation (SD) if the distribution is nearly normal and as median / interquartile range (IQR) if not normally distributed. Mean values were compared using the t-test whereas differences in medians were evaluated using the Mann-Whitney test. Categorical data are expressed as frequency (percentages) and were compared using the  $\chi^2$  test or Fisher's exact test where appropriate. All hypotheses were two-sided and a p-value less than 0.05 was deemed statistically significant.

## Results

Patients who underwent off-pump coronary surgery were significantly older (mean age of 67 and 64 years for the off-pump and the on-pump group, respectively,  $p = 0.013$ ). In addition, we found significantly more males in the off-pump group compared with the on-pump group (81% vs 66%,  $p = 0.006$ ) and more former smokers in the off-pump group (29% vs 18%,  $p = 0.047$ ). Furthermore, off-pump patients suffered more often from chronic renal failure (11% vs 2.4%,  $p = 0.009$ ), respiratory failure (20% vs 7.3%,  $p = 0.003$ ) and peripheral vascular disease (17% vs 8.1%,  $p = 0.038$ ). On the other hand, on-pump patients were significantly more affected by dyslipidaemia (73% vs 53%,  $p = 0.002$ ). Preoperative characteristics are listed in table 1. Concerning the intraoperative surgical variables (table 2), no patient initially planned for an off-pump procedure was converted to on-pump coronary artery bypass graft surgery (CABG) and *vice versa*.

The surgical time was significantly shorter in the off-pump group, with a median procedural time of 126 min (110–155 min) off-pump and 160 min (135–180 min) on-pump ( $p < 0.001$ ), but there were significantly more urgent procedures in the on-pump group (10% vs 3.4%,  $p = 0.042$ ).

Postoperative data are listed in table 3. Postoperative follow-up includes in-hospital data and the only significant difference between the two groups was the intensive care unit (ICU) length of stay: patients who underwent off-pump CABG had a shorter ICU stay compared to patients who underwent on-pump surgery (the median was 1 day (IQR: 1–2) for the off-pump group and 2 days (IQR: 1–3) for the on-pump group ( $p = 0.046$ )). There were three postoperative myocardial infarctions among the off-pump group (2.5%) and only one in the on-pump group (0.8%), but the difference is not statistically significant ( $p = 0.362$ ), and in both groups, we noticed three patients with heart failure after surgery (2.5% off-pump and 2.4% on-pump) not treated with a temporary assist device (an aortic balloon pump in one case). Seven off-pump patients (5.9%) and three (2.4%) on-pump patients ( $p = 0.209$ ) developed transitory postoperative renal failure without need for haemodialysis. We identified four cases (3.4%) of respiratory failure in the off-pump group and two (1.6%) in the on-pump group ( $p = 0.439$ ). A cerebrovascular event occurred once after off-pump surgery (0.8%) and twice after on-pump CABG (1.6%) ( $p = 1.000$ ). There were ten cases of pneumonia (8.4%) after off-pump CABG and nine (7.3%) infections (eight pneumonia and one mediastinitis) after on-pump CABG ( $p = 0.629$ ). Two patients (1.7%) of each group needed a blood transfusion ( $p = 1.000$ ), whereas the mean hospital stay was 10 days in both groups.

There was no significant difference ( $p = 0.498$ ) in the 30-day mortality between the two groups: one off-pump patient (0.8%) died from acute pulmonary oedema due to postoperative heart failure and two on-pump patients (1.6%) died from multiple organ failure and irreversible ventricular fibrillation that occurred 30 minutes after weaning from cardiopulmonary bypass.

## Discussion

On-pump surgery induces a higher inflammatory response owing to the extracorporeal circulation which is not a full physiological system. Therefore, several studies have been conducted to demonstrate the benefits of off-pump surgery. For the time being, results are still controversial.

In 2001, Hernandez and colleagues showed that patients who underwent OPCAB surgery were not exposed to improved risk of short-term adverse outcome. The OPCAB patients had lower need for intraoperative or postoperative intra-aortic balloon pump, lower rate of postoperative atrial fibrillation, and shorter hospital stay [3].

In 2003, Sharif showed in a retrospective comparative study that OPCAB for multivessel myocardial revascularisation in high-risk patients reduces the incidence of perioperative myocardial infarction and other major complications, ICU length of stay and surgical mortality [4]. Articles published by Kjaergard and Widimsky showed that there was no major difference in the graft patency between on-pump and off-pump surgery [5, 6]. Moreover, a randomised controlled trial published in 2004 and a retrospective study from 2012 showed that OPCAB achieves similar long-term graft patency to on-pump surgery [7, 8]. Cardiac outcomes and quality of life at 30 days and 1 year postsurgery were

similar in the randomised controlled trial. OPCAB patients were more cost effective [7].

A very important finding comes from an article published in 2005 from Hussanein and coworkers: the authors showed that there is no difference in the quality of the anastomosis performed on the LAD on-pump or off-pump [9]. However, as far as other coronary arteries are concerned the quality of the anastomosis can be worse in OPCAB surgery, mostly because of the surgical accessibility. Vural confirmed that the off-pump LIMA graft is a durable treatment for isolated LAD, with good clinical outcomes and long-term patency [10].

With regards to the patient selection, a prospective clinical trial from Ramadan and colleagues underlined that off-pump surgery should be planned for high-risk profile patients because it provides complete myocardial revascularisation with a mortality rate comparable to lower-risk patients undergoing on-pump arterial revascularisation [11]. However, all these arguments in favour of OPCAB surgery have been questioned by other similar reports supporting the on-pump technique. A review of the literature concluded that OPCAB is as safe as on-pump surgery, and a study published in 2013 supported the fact that the use of cardiopulmonary bypass does not affect survival and free-

**Table 1:** Preoperative patient characteristics.

Variable	Off-pump (n = 119)	On-pump (n = 124)	Total (n = 243)	p-value
Age, years (median, IQR)	67 (59–75)	64 (55–70)	66 (57–73)	0.013
Sex				0.006
Women	22 (18%)	42 (34%)	64 (26%)	
Men	97 (81%)	82 (66%)	179 (74%)	
Smoking	55 (46%)	49 (39%)	104 (43%)	0.291
Former	35 (29%)	23 (18%)	58 (24%)	0.047
Current	20 (17%)	26 (21%)	46 (19%)	0.408
Obesity	27 (23%)	27 (22%)	54 (22%)	0.864
BMI (median, IQR)	26.9 (24–29)	26.1 (24–29)	26.6 (24–29)	0.396
Diabetes	28 (23%)	29 (23%)	57 (23%)	0.979
Type 1	10 (8.4%)	13 (10%)	23 (9.5%)	0.580
Type 2	18 (15%)	16 (13%)	34 (14%)	0.618
Hypertension	81 (68%)	83 (67%)	164 (67%)	0.851
Dyslipidaemia	63 (53%)	90 (73%)	153 (63%)	0.002
Chronic renal failure	13 (11%)	3 (2.4%)	16 (6.6%)	0.009
Chronic respiratory failure	24 (20%)	9 (7.3%)	33 (14%)	0.003
LVEF				0.253
<30%	7 (5.9%)	3 (2.4%)	10 (4.1%)	0.209
30–50%	28 (23%)	37 (30%)	65 (27%)	0.267
>50%	84 (71%)	84 (68%)	168 (69%)	0.631
Previous stroke / TIA	8 (6.7%)	6 (4.8%)	14 (5.8%)	0.529
Previous myocardial infarction	47 (39%)	41 (33%)	88 (36%)	0.297
Previous cardiac arrhythmia	8 (6.7%)	13 (10%)	21 (8.6%)	0.297
Angina	119 (100%)	124 (100%)	243 (100%)	0.003
Class I	30 (25%)	36 (29%)	66 (27%)	0.503
Class II	21 (18%)	37 (30%)	58 (24%)	0.026
Class III	35 (29%)	14 (11%)	49 (20%)	0.000
Class IV	33 (28%)	37 (30%)	70 (29%)	0.717
Vascular disease	20 (17%)	10 (8.1%)	30 (12%)	0.038
Peripheral	4 (3.4%)	3 (2.4%)	7 (2.9%)	0.718
Carotid	16 (13%)	7 (5.7%)	23 (9.5%)	0.038
Family history of coronary disease	22 (18%)	27 (22%)	49 (20%)	0.523

BMI = body mass index; IQR = interquartile range; LVEF = left ventricular ejection fraction; TIA = transient ischaemic attack  
 Displayed numbers represent counts (percentage) unless otherwise specified

**Table 2:** Intraoperative data and surgical technique.

Variable	Off-pump (n = 119)	On-pump (n = 124)	Total (n = 243)	p-value
Clinical conditions at surgery				0.042
Urgent operation	4 (3.4%)	13 (10%)	17 (7%)	
Elective operation	115 (97%)	111 (89%)	226 (93%)	
Type of operation				
OPCAB (full sternotomy)	66 (56%)	0		
MIDCAB	53 (44%)	0		
ONCAB	0	124 (100%)		
Cardiopulmonary bypass time, min (median, IQR)		35.5 (29–43)		
Aortic cross-clamp time, min (median, IQR)		22.5 (20–29)		
Operating time, min (median, IQR)	126 (110–155)	160 (135–180)	145 (120–175)	<0.001

IQR = interquartile range; MIDCAB = minimally invasive direct coronary artery bypass; ONCAB = on-pump coronary artery bypass; OPCAB = off-pump coronary artery bypass  
 Displayed numbers represent counts (percentage) unless otherwise specified

dom from reintervention during a 10-year follow-up [12, 13]. With regard to the graft patency, it has been argued that intraoperative transit time flow measurements are worse in OPCAB patients and that the patency at 3 months is worse off-pump than on-pump [14, 15]. In 2009, a randomised prospective study postulated that patients undergoing off-pump coronary artery surgery had a worse outcome and lower graft patency than patients undergoing on-pump coronary surgery [16].

In our study, patients operated upon under off-pump surgery (n = 119) and on-pump surgery (n = 124) were not randomised and the surgical strategy was mainly based on the clinical evaluation, including the study of patient comorbidities, and on the surgeon's experience with off-pump surgery. Off-pump patients carried more comorbidities and, therefore, showed higher surgical risk profiles than on-pump patients: patients scheduled for off-pump surgery were older, more often with renal failure and respiratory failure and they often had severe peripheral vascular disease with a higher degree of angina. However, we did not objectify these findings by calculating, retrospectively, the logistic EuroSCORE.

Surgical time was shorter in the off-pump group, although during the MIDCAB procedures the LIMA harvesting is more time-consuming. This finding confirms previously published results from other groups.

There were more "urgent" procedures in the on-pump group and this confirms what has been reported by other authors: off-pump surgery seems to be more appropriate in nonurgent, high risk profile patients.

As far as the postoperative course was concerned, we came to the same conclusions as Sharif and coworkers: patients

who underwent off-pump CABG had a significantly shorter ICU stay compared with those who underwent on-pump CABG, but the final hospital stay was similar in the two groups [4]. For the index procedure complications such as myocardial infarction, heart failure, neuropsychological dysfunction, stroke, cardiac arrhythmia, blood transfusion, and rethoracotomy for bleeding, there was no statistically significant difference.

The present study has some important limitations: it includes a relatively small number of patients and it is a retrospective analysis without long-term follow-up and postoperative angiographic checks.

In conclusion, as previously pointed out by other authors, our series confirms that both techniques have good hospital outcomes with low rates of postoperative complications and acceptable hospital mortality [3, 7, 12]. Off-pump and on-pump surgery for isolated LAD revascularisation are safe and reliable techniques, and the choice of surgical method is mainly based on the patient's clinical presentation and surgeon's experience. Nevertheless, OPCAB surgery on the isolated LAD seems to be more appropriate for nonurgent patients with a higher degree of surgical risk.

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**Table 3:** Surgical outcome and postoperative complications.

Variable	Off-pump (n = 119)	On-pump (n = 124)	Total (n = 243)	p-value
Myocardial infarction	3 (2.5%)	1 (0.8%)	4 (1.6%)	0.362
Cardiac failure	3 (2.5%)	3 (2.4%)	6 (2.5%)	1.000
Acute renal failure	7 (5.9%)	3 (2.4%)	10 (4.1%)	0.209
Respiratory failure	4 (3.4%)	2 (1.6%)	6 (2.5%)	0.439
Neuropsychological dysfunction	8 (6.7%)	6 (4.8%)	14 (5.8%)	0.529
Stroke / TIA	1 (0.8%)	2 (1.6%)	3 (1.2%)	1.000
Cardiac arrhythmia	23 (19%)	32 (26%)	55 (23%)	0.217
AF/flutter	22 (18%)	32 (26%)	54 (22%)	
Ventricular tachycardia	1 (0.8%)	0	1 (0.4%)	
Conduction abnormality	3 (2.5%)	3 (2.4%)	6 (2.5%)	0.853
AVB	2 (1.7%)	1 (0.8%)	3 (1.2%)	
Branch block	1 (0.8%)	2 (1.6%)	3 (1.2%)	
Gastrointestinal disorders	4 (3.4%)	1 (0.8%)	5 (2%)	0.206
Haematological disorders	1 (0.8%)	5 (4%)	6 (2.5%)	0.214
Anaemia	0	4 (3.2%)	4 (1.6%)	
Thrombocytopenia	1 (0.8%)	1 (0.8%)	2 (0.8%)	
Pulmonary atelectasis	20 (17%)	27 (22%)	47 (19%)	0.327
Infections	10 (8.4%)	9 (7.3%)	19 (7.8%)	0.629
Pneumonia	10 (8.4%)	8 (6.5%)	18 (7.4%)	
Mediastinitis	0	1 (0.8%)	1 (0.4%)	
IABP	1 (0.8%)	0	1 (0.4%)	0.490
Transfusions	2 (1.7%)	2 (1.6%)	4 (1.6%)	1.000
Rethoracotomy for bleeding	4 (3.4%)	3 (2.4%)	7 (2.9%)	0.718
ICU stay, days (median, IQR)	1 (1–2)	2 (1–3)	1 (1–3)	0.046
Hospital stay, days (median, IQR)	10 (8–15)	10 (9–12)	10 (9–13)	0.870
Mortality (30 days)	1 (0.8%)	2 (1.6%)	2 (0.8%)	0.498

AF = atrial fibrillation; AVB = atrioventricular block; IABP = intra-aortic balloon pump; ICU = intensive care unit; IQR = interquartile range; TIA = transient ischaemic attack  
Displayed numbers represent counts (percentage) unless otherwise specified

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