

Heart, Lung and Circulation (2016) xx, 1–8  
1443-9506/04/\$36.00  
<http://dx.doi.org/10.1016/j.hlc.2016.02.012>

# The Influence of On-pump versus Off-pump Surgery on Short- and Medium-term Postoperative Coronary Flow Reserve after Coronary Artery Bypass Grafting

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Received 14 December 2015; received in revised form 16 February 2016; accepted 18 February 2016; online published-ahead-of-print xxx

## Background

Although several clinical trials have compared surgical outcomes between off-pump and on-pump coronary artery bypass grafting (CABG), whether there is a difference in the early- and medium-term postoperative coronary microvascular functions is not fully understood. We compared short- and medium-term coronary microvascular function after off-pump and on-pump CABG.

## Methods

A prospective study of patients undergoing off-pump and on-pump CABG. Eighty-two patients scheduled for CABG were recruited: 38 underwent off-pump surgery and 44 on-pump surgery. Each participant's coronary flow reserve (CFR) and diastolic function were measured with transthoracic Doppler echocardiography six and 12 months after surgery.

## Results

Baseline and hyperaemic diastolic peak flow velocity in the left anterior descending artery were similar in both groups, as was CFR ( $2.22 \pm 0.66$ ) in the off-pump group compared with ( $2.13 \pm 0.61$ ) in the on-pump group, ( $P = 0.54$ ). Coronary flow reserve was significantly and inversely correlated with high sensitivity C-reactive protein concentration ( $r = -0.416$ ;  $P < 0.001$ ) and positively correlated with mitral E/A-wave velocity ratio ( $r = 0.247$ ;  $P = 0.02$ ). Stepwise linear regression analysis revealed that only high sensitivity C-reactive protein concentration was independently correlated with CFR ( $\beta = -0.272$ ,  $P = 0.02$ ).

## Conclusions

Heart-lung bypass technique had no medium-term influence on the coronary microcirculation, despite a possible initial unfavourable effect. Serum hs-CRP concentration was an independent predictor of medium-term coronary microvascular dysfunction.

## Keywords

Off-pump surgery • Coronary flow reserve • hsCRP • Diastolic function

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## Introduction

Coronary artery surgery can be performed with or without cardiopulmonary bypass (CPB): the latter is known as the beating heart or off-pump technique. Previous clinical studies have shown that off-pump coronary bypass surgery (off-pump CABG) is associated with outcomes equal or superior to those of standard surgery using cardiopulmonary bypass (CPB) [1]. Concerns regarding anastomosis quality and the extent of revascularisation with off-pump surgery appear not to have been justified, as surgeons have gained technical ability and experience so that similar outcomes can be achieved in terms of vessel patency assessed by coronary angiography [2]. Thanks to techniques and devices that create a partially immobile region of cardiac tissue by stabilising the area of interest, or clamp and rotate the heart to expose the vessel or vessels of interest, coronary bypass surgery can now be successfully performed for almost every coronary vessel when the heart is beating.

Measurement of coronary flow reserve (CFR) is used to assess the epicardial coronary arteries and the integrity of coronary microvascular circulation. Impairment of CFR, which reflects coronary microvascular dysfunction, is reportedly an early manifestation of coronary artery disease [3]. Recent advances in transthoracic Doppler echocardiography (TTDE) have allowed direct imaging of coronary blood flow. The accuracy and reliability of TTDE-measured CFR have been tested in comparative studies with other invasive and non-invasive techniques, and favourable results have been achieved [4,5]. The technique has also been used to assess coronary flow after percutaneous interventions or bypass surgery [6], and the patency of internal mammary artery or saphenous veins before and after bypass [7–9].

We undertook a prospective study to examine the influence of off-pump and on-pump CABG on CFR 6–12 months after surgery.

## Materials and Methods

### Study design and subjects

In this prospective study, we measured postoperative CFR in patients who had undergone CABG and been discharged having made a full recovery after an uneventful hospital stay. We included patients aged between 50 and 70 years with angiographically documented proximal multivessel coronary stenosis of >70% by visual assessment, stable angina and preserved ventricular function who had been referred for isolated CABG for the first time. All patients had stenosis either of the left main coronary artery or the proximal left anterior descending artery (LAD). Patients with acute or chronic renal failure, chronic obstructive lung disease, pre- or postoperative atrial fibrillation, additional cardiac valve disease or diabetes mellitus were excluded from the study. Patients using drugs other than aspirin, calcium channel blockers, beta-adrenoreceptor blockers or cholesterol lowering drugs were also excluded. Owing to the potential for

haemodynamic instability to diminish the accuracy of TTDE in the immediate postoperative period, all echocardiographic assessments of the coronary microvascular bed were made six months to one year after surgery.

### Surgical techniques

Surgical access was via median sternotomy in all patients. All severely stenosed vessels larger than 1 mm were bypassed. A left internal mammary artery graft was used only for LAD anastomosis; the radial artery was primarily used to graft the circumflex artery system, and saphenous veins were used to graft other vessels. In off-pump surgery, a standard tissue stabiliser and an intracoronary shunt were used, and 7/0 propylene suture material was used for the distal anastomosis. In on-pump surgery, after cardiac arrest with crystalloid cardioplegia solution, distal anastomoses were fashioned with 7/0 propylene and the heart was restarted, followed by the formation of proximal anastomoses above the aorta with a 6/0 propylene underside clamp. All patients were commenced on postoperative aspirin therapy. Patients who underwent CABG using the radial artery were commenced on intravenous diltiazem therapy for the first 24 hours post-operatively, followed by oral therapy for six months.

### Laboratory measurements

Blood samples were obtained from patients on the morning of surgery after 12 hours of fasting for measurement of the concentrations of fasting plasma glucose (FPG), total serum cholesterol, triglyceride, high- and low-density lipoprotein cholesterol and uric acid. The concentration of serum C-reactive protein was measured by the use of a highly sensitive sandwich enzyme-linked immunosorbent assay (ELISA) technique (hs-CRP).

### Echocardiographic examination

All patients were recalled six months to one year after surgery to undergo TTDE performed by two cardiologists blinded to the study groups. Each subject was examined using an Acuson Sequoia C256® Echocardiography System equipped with a 3V2c broadband transducer with second harmonic capability (Acuson, Mountain View, CA). Two-dimensional, M-mode and subsequent standard and pulsed tissue Doppler echocardiographic examinations were performed on each subject in the lateral decubitus position. Images were recorded on VHS videotapes. Diastolic and systolic interventricular septal (IVS) thickness, posterior wall (PW) thickness, and left ventricular end-diastolic (LVDD) and left ventricular end-systolic (LVSD) diameters were measured on the parasternal long-axis views. All measurements were performed in M-mode imaging.

The assessment of left ventricular diastolic function has been described in detail [10]. Briefly, from an apical four-chamber view, transmitral flow was sampled by pulsed wave Doppler at the level of the mitral valve leaflet tips. Peak velocities of the early phase (E) and late phase (A) of the mitral inflow were measured, and their ratio (E/A) was calculated. Left ventricular myocardial velocities were

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