OUTCOMES OF "OFF-PUMP" CORONARY ARTERY BYPASS GRAFTING IN A DEVELOPING COUNTRY: ADVANTAGES OVER CORONARY ARTERY BYPASS GRAFTING ON CARDIOPULMONARY BYPASS.

By

Dr Chima K.P. Ofoegbu
Student number: OFGCHI001

Submitted to the University of Cape Town

In fulfilment of the requirements for the degree

Master of Medicine

In Cardiothoracic Surgery

Faculty of Health Sciences

UNIVERSITY OF CAPE TOWN

Date of submission: 13/12/2010

Supervisor: Prof. Johan G Brink.
Chris Barnard Division of Cardiothoracic surgery
University of Cape Town

DECLARATION

It is hereby declare that this dissertation is original. Parts of this dissertation were presented at the South African Heart Association (SAHA) Congress 2009 held in Sun City, South Africa from October 22-25, 2009; at the Department of Surgery Research Day held in Groote Schuur Hospital, Cape Town on November 28,2009 and at West African College of Surgeons Conference held in Calabar. Nigeria in February 2010.

This dissertation has not been presented to any college for a fellowship, to this or any other university for another degree, nor has it been submitted elsewhere for publication.

I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signature: ……..

Date: …….

ACKNOWLEDGEMENT

This dissertation is dedicated to my wife Olubukola, my parents; Dr and Mrs Ofoegbu, my parents-in –law; Dr and Dr (Mrs) Ayo-Bello for their love and constant encouragement never to give up. It is also for my brothers and sisters, Ogechi, Uche, Kelechi, Nkechi, Gozie and Amaka for their understanding, patience and love.

I wish to acknowledge my supervisor, Professor Johan Brink for his immense contribution to the conception, execution and completion of this thesis.

I also wish acknowledge all the members of the Chris Barnard Division of Cardiothoracic Surgery, University of Cape Town who contributed in no small measure to this thesis in different ways including encouragement, assistance with data collection and analysis and writing of the thesis.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF ABBREVIATIONS

IHD: Ischaemic Heart Disease

YLL: Years of Life Lost

CAD: Coronary Artery Disease

CABG: Coronary Artery Bypass Grafting

PCI: Percutaneous Coronary Intervention

CPB: Cardiopulmonary Bypass

OPCAB: Off-Pump Coronary Artery Bypass grafting

CA: Coronary Arteries

RCA: Right Coronary Artery

LCA: Left Coronary Artery

LAD: Left Anterior Descending artery

Cx: Circumflex Artery

PDA: Posterior Descending Artery

AV: Atrio-Ventricular

LMS: Left Main Stem

AVR: Aortic Valve Replacement

IV: Inter-Ventricular

RV: Right Ventricle

LV: Left Ventricle

OM: Obtuse Marginal

LA: Left Atrium

NYHA: New York Heart Association

EF: Ejection Fraction

ECG: Electrocardiogram

LIMA: Left Internal Mammary Artery

RIMA: Right Internal Mammary Artery

ACT: Activated Clotting Time

IABP: Intra-Aortic Balloon Pump

DM: Diabetes Mellitus

COPD: Chronic Obstructive Pulmonary Disease

CVA: Cerebro-Vascular Accident

PVD: Peripheral Vascular Disease

CCS: Canadian Cardiovascular Society

LVEF: Left Ventricular Ejection Fraction

ICU: Intensive Care Unit

SIRS: Systemic Inflammatory Response Syndrome

HIV: Human Immunodeficiency Virus

RBC: Red Blood Cell

FFP: Fresh Frozen Plasma

PMI: Peri-operative Myocardial Infarction

CK-MB: Creatine Kinase Myocardial Band

ND: Neurologic Dysfunction

AF: Atrial Fibrillation

MACE: Major Adverse Cardiac Event

EUROSCORE:

MI: Myocardial Infarction

SVG: Saphenous Vein Graft

TAR: Total Arterial Revascularisation

RA: Radial Artery

LIST OF DEFINITIONS

Post operative stroke: defined as a new and sudden onset of neurologic deficits lasting more than 24 hours with no apparent nonvascular causes.
Perioperative myocardial infarction: defined as appearance of a new Q wave on the electrocardiogram, or newly developed regional wall motion abnormalities on the postoperative echocardiogram.
Operative mortality: defined as death rate within 30 days of operation or during the same hospital stay.
Deep Sternal Wound infection (Mediastinitis): defined as a sternal wound infection requiring a second surgical procedure for closure.
Duration of Mechanical Ventilation:defined as the duration of mechanical ventilation from the time of admission to the intensive care unit.
Elective case: was defined as a patient waiting at home prior to the procedure
Urgent cases: were defined as cases where surgery was deemed necessary within 24 h to prevent further clinical deterioration.
Emergent cases: were those patients who required an immediate operation

EXECUTIVE SUMMARY

INTRODUCTION: Off-pump coronary artery bypass grafting (OPCAB) was developed to avoid the deleterious effects of CPB. Current literature reveals some peri-operative advantages of OPCAB, with few studies detailing these in Africa. We review our institutional experience with both approaches in higher risk patients to determine pre-operative characteristics, short and mid-term outcomes in a developing country.

PATIENTS AND METHODS: A retrospective review of high risk patients undergoing coronary bypass surgery by 2 surgeons in the department between January 2001 and December 2007. Fields determined include: pre-operative patient characteristics, intra-operative data and post-operative variables (intensive care unit (ICU) stay, blood loss, use of blood products, complications, death and follow-up).

RESULTS: Records of 342 patients were reviewed. Of these, 199 had OPCAB and 143 had CABG-CPB. There were no significant differences between the 2 groups for age and CAD risk factors, with CAD family history commoner in OPCAB patients ($p = 0.009$). There were no significant differences in incidence of co-morbidities, NYHA class, left ventricular ejection fraction (LVEF) and proportion of urgent/emergency surgery. The mean number of vessels grafted was 3.31 and 3.45 in OPCAB and CABG-CPB groups respectively ($p= 0.145$).The intra-operative conversion rate from OPCAB to CABG-CPB was 2.5%. The mean ICU duration for OPCAB and CABG-CPB patients was 80.7 hours and 104.1 hours respectively ($p= 0.181$). The mean mechanical ventilation duration in OPCAB and CABG-CPB patients was 22.3 hours and 38.3 hours respectively ($p= 0.091$). The mean ICU blood loss in OPCAB and CABG-CPB patients was 808.5 mls and 988.2 mls respectively ($p=0.0029$).Mean red cell (RBC) transfusion was 1.72 units and 2.66 units in OPCAB and CABG-CPB patients respectively ($p=0.03$). The CABG-CPB patients had longer post-operative ward stay than OPCAB patients (7.4 versus 5.5 days, $p= 0.01$). The peri-operative mortality rate was 3% and 9% in OPCAB and CABG-CPB patients respectively ($p= 0.016$). There was no significant difference in major adverse cardiac events (MACE) during the follow –up period up to 8 years.

CONCLUSION: The pre-operative characteristics in both groups were similar. There was less ICU blood loss, less usage of blood and shorter hospital stay in the OPCAB group. Peri-operative mortality was worse in the CABG-CPB group, and no difference in MACE during follow up.

I. LITERATURE REVIEW

1. INTRODUCTION

BACKGROUND

Ischaemic heart disease (IHD) is the world's leading cause of mortality accounting for 6.3 million deaths in 1990[1]. Ischaemic heart disease (IHD) is the 2nd commonest cause of mortality and the 11th commonest cause of years of life lost (YLL) amongst South Africans[2]. Although the exact number of myocardial infarction(s) amongst South Africans daily is largely unknown, some unpublished data suggests 33 people die daily because of a heart attack and 37 people die daily from heart failure in South Africa.

Premature deaths caused by heart and blood vessel diseases in the productive age group (35-64 years) are expected to increase by 41% between 2000 and 2030. This effect on the workforce of the country has an enormous negative impact on the economy[3].

Coronary artery disease syndromes include; chronic stable angina, unstable angina, myocardial infarction, cardiogenic shock and ischaemic cardiomyopathy

Coronary artery disease (CAD) can be managed with medical therapy or myocardial revascularization: coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI). The decision to treat a patient with either one or both may depend on past experience or information obtained from databases. Several studies have shown a better 5 year survival for CABG over medical therapy[4].

Myocardial revascularization as we know it today started in the early 20th century with Alexis Carrel playing a pioneering role by attempting the first CABG in 1910; he anastomosed the innominate artery of one dog to the distal coronary artery of another dog. Other surgeons who made valuable contributions to the field of CABG include; Claude Beck, Robertson, Gross, Kolesov, Favaloro, Green, Flemma, Kay and Acar[5]. Others like Sabiston have the distinction of being the first to use a human autogenous saphenous vein for CABG in 1962.

The invention of selective coronary angiography by Sones and Shirley in 1959 enabled lesions to be targeted and vessels suitable for grafting to be identified.

The first effective use of the heart/lung machine (cardio-pulmonary bypass, CPB) for correction of a cardiac defect was performed in the Mayo Clinic in 1954, although routine use of CPB for IHD did not start until the late 1960s.

The use of CPB is associated with many systemic insults (systemic inflammatory response) and deleterious effects including complement activation, multiple organ dysfunction, neurocognitive dysfunction and coagulation abnormalities[6]. The use of cardioplegic arrest of the heart to perform

CABG also has negative effects on myocardial contractility despite the major advances in cardioplegic solutions and myocardial protection.

To avoid the deleterious effects of CPB[7] a resurgence of CABG on a beating heart (also known as "off-pump" CABG or OPCAB) took place in the mid 1990s (though it was first introduced in 1967 by Kolesov).

Initially, off-pump surgery was restricted to patients with isolated single vessel or double vessel CAD and to patients with significant co-morbidities, such as renal failure, calcified aortas or significant peripheral and cerebrovascular disease; patients who could derive maximum benefit from avoiding CPB[6]. The practice of OPCAB at the outset was also bedeviled by crude instrumentation and limited exposure of the lateral, posterior and inferior target coronary vessels.

As anaesthetic and surgical techniques improved, with associated improvements in techniques of retraction and exposure, the proportion of coronary artery surgery done by OPCAB has increased with figures of between 20-30% being quoted[6-11] and has expanded to include more complex coronary anatomy than single or double vessel disease.

2. SURGICAL ANATOMY

The anatomic arrangement of the coronary arteries is important to the cardiac surgeon because he surgically treats the consequences of IHD and also avoids trauma to these vessels when gaining access to the heart chambers.

The coronary arteries are the first branches of the aorta. In the usual distribution, 2 of the 3 aortic sinuses give origin to the coronary arteries (CA), in particular, the right coronary artery (RCA) and the mainstem of the left coronary artery (LCA) which divides into the left anterior descending (LAD) artery and the circumflex artery (Cx). This allows designation of the aortic sinuses as right coronary, left coronary and non-coronary sinuses.

Variations in the origin of the coronary arteries are numerous and include; high take-off (origin above the sino-tubular junction), both arteries arising from one sinus or a solitary CA. All the above have been associated with sudden death episodes. Other variations include; RCA and its infundibular branch arising from separate orifices in the right coronary sinus and the LAD and Cx arteries arising separately from the left coronary sinus.

The major branches of RCA and LCA run within the interventricular (LAD and posterior descending artery-PDA) and atrio-ventricular grooves (Cx and RCA). The interventricular arteries supply the ventricular walls and septa with oblique and perpendicular branches while the RCA and Cx give upward branches to the atrial myocardium and downward branches to the ventricular myocardium.

The RCA runs in the atrio-ventricular groove and gives off the following branches; infundibular, anterior (forms the artery to the sino-atrial node in 60% of people), posterior and middle atrial arteries. Other RCA branches include; right anterior ventricular artery, infundibular artery, acute marginal artery, artery to the atrio-ventricular (AV) node and the PDA. In most cases (90%) the RCA is dominant or codominant and gives rise to the AV node artery and the PDA. In the majority, the RCA continues beyond the crux and supplies the inferior surface of the left ventricle as the posterolateral branch.

The left main stem (LMS) artery originates from the left coronary sinus between the pulmonary trunk and the left atrial appendage. It is seldom longer than 1cm and branches into the Cx and LAD. The LMS may be much shorter than 1 cm with negative consequences in coronary angiography, coronary perfusion during aortic valve replacement (AVR) and may be associated with a higher incidence of proximal CAD.

The LAD runs in the interventricular (IV) groove and gives oblique branches to the right (RV) and left ventricles (LV). The 1st oblique branch is to the RV infundibulum, its importance seen in LAD occlusion when it links up with the RCA counterpart to form the ring of *Veiussens*. The LV branches

are called diagonal arteries and may be multiple (D1, D2, D3), D1 being the most proximal. The LAD also gives septal perforating arteries (sometimes up to 6) which run perpendicularly into the muscular septum. The most significant septal artery is the 1st which supplies the septum through the groove between the subpulmonary infundibulum and the aortic root; it can be damaged during harvesting of the pulmonary valve for autograft AVR (Ross Procedure). Beyond D1, the LAD occasionally has an intramyocardial course before resurfacing just before the apex. It then crosses the apex to run in the posterior IV groove to link up with the PDA.

The Cx arises from the LMS behind the origin of the pulmonary trunk and passes beneath the left atrial appendage to enter the left AV groove. From there, it has a variable course; it may be insignificant only supplying the obtuse margin of the LV, especially when the intermediate artery (3rd LMS branch) is present. In 10% of people, the Cx runs in the left AV groove and gives branches to the left atrium (LA) and obtuse marginal branches to the LV. The Cx marginal branches are numbered according to the take-off from the Cx with the first being obtuse marginal artery 1 (OM1). The Cx continues to the crux where it gives rise to the PDA and the artery to the AV node. In left coronary arterial dominance, it supplies part of the diaphragmatic surface of the RV. In mitral valve surgery, the Cx is at risk of damage in the AV groove. The Cx gives the artery to the sinus node in 40% of people usually form one of the superior atrial branches; sometimes this sinus node artery arises distally from the Cx making it prone to surgical injury.

The PDA is a branch of the RCA in 90% and of the LCA in 10% of individuals. The PDA may arise more proximally from the RCA in a minority of people making it more accessible for in-situ right internal thoracic artery grafts. It gives perforating arteries to the muscular septum and often forms collaterals with perforating branches of the LAD. It usually terminates at the apex where it forms connections with the terminal branches of the LAD.

There can be multiple connections (collaterals) between these arteries especially in the setting of CAD of gradual onset and worsening severity. These connections are formed by the following;

- perforating arteries in the septum
- terminal branches of LAD and PDA
- atrial arteries.

The atrial collateral connection is called the Kugel's artery and connects the Cx with anterior or posterior portions of the RCA and also gives branches to the bases of the aortic and mitral valves. The collateral circulation is more evident and significant in the presence of CAD.

3. PATHOLOGY

The major cause of CAD is atherosclerosis which is defined as a degenerative disease of large and medium sized arteries characterized by lipid deposition and fibrosis. It is a process that develops as a response of the vessel wall to chronic multi-factorial injury and leads to the formation of atherosclerotic plaques (also known as fibrous plaques or atheromas) [12, 13]. The plaques are regions of thickened intima composed of various mixtures of fibrous tissue, foam cells and lipids[14].

The risk factors associated with atherosclerosis include reversible factors (smoking, hypercholesterolaemia, diabetes, obesity and hypertension) and irreversible factors (age and family history)

There are 3 stages of atheroma formation;

1) Fatty streaks; these are early lesions that are seen in the coronaries of teenagers. These lesions do not breach the endothelial lining and have no clinical effects in themselves. These are linear lesions on the arterial lumen which are composed of lipid –filled macrophages and lesser number of lipid bearing smooth muscle cells.
2) Fibrolipid plaques; these contain a mixture of macrophages and smooth muscles which migrate into the plaque and are capped by a layer of fibrous tissue. These are seen by 20 years, especially in males. In these lesions, the intima is still intact, but raised and the majority have a lipid rich, hypocellular or acellular core region. There is evidence that most fibrous plaques are derived from pre-existing fatty streaks[15].
3) Complex lesions

Atherosclerotic plaques tend to form near branch points in areas of turbulent flow involving high and low shear stress and also in areas of vessel bifurcation, post-stenotic areas and areas denuded of endothelium. The flow patterns in these areas promote endothelial dysfunction and encourage increased endothelial contact with platelets and monocytes[16].

The regions most prone to atherosclerosis in the coronary artery system include;

- proximal LAD
- proximal and distal RCA

Established atherosclerosis involves all 3 layers of the arterial wall with intimal thickening and fibrosis, medial degeneration and lymphocytic infiltration of the adventitia.

Atherosclerosis leads to remodeling of the vessel wall as the fibrous plaque enlarges. Initially, the vessel wall dilates in a way that the luminal diameter is maintained, probably because of physiological regulation of lumen diameter in response to blood velocity and shear rate[4]. However, once the limit of

this adaptive mechanism is reached, luminal narrowing occurs; when the collagen filled lesion has extended circumferentially round the artery leaving very little normal wall to respond to blood flow. About 50% decrease in luminal diameter, that is 75% luminal area, must occur before blood flow is affected.

An acute ischaemic event is caused by acute changes in the atherosclerotic plaques. Those plaques most prone to these changes are the atheromatous types with thin fibrous capsules and large cores of lipid rich debris. These changes which may appear as erosions, fissures, ulcers or frank rupture often contribute to thrombus formation. Disruption of the plaque surface by mechanisms which include haemodynamic trauma and activation of attached platelets and blood cells predisposes to the formation of intraluminal and intramural thrombi. The pathogenetic sequence of plaque rupture starts with endothelial injury followed by an influx of blood and an increase in intra-plaque pressure leading to subsequent fibrous capsule rupture outwards[6]. Plaque rupture leads to vessel wall damage which stimulates initiation of 2 pathways toward coagulation; the first, intrinsic pathway of the clotting cascade results in thrombin production, while the second pathway involves platelet activation via collagen and von Willebrand factor. These platelets subsequently release vasoactive substances and platelet aggregation factors like thromboxane and adenosine diphosphate which activate more platelets. Fibrinogen in the bloodstream cross-links with platelets via the GP IIB/IIIA receptors and ultimately a clot is formed. The degree of myocardial damage depends on the distribution of myocardium supplied by the artery affected; the degree of obstruction by the clot, amount of small vessel inflammation, thrombotic emboli, vasoconstriction and the extent of collateral flow.

4. INDICATIONS FOR CABG[17]

Coronary artery bypass grafting (CABG) is indicated if PCI is not feasible (tight left main stem disease, diffuse multivessel disease, or calcified coronaries) or is unsuccessful (inability to cross the lesion, in-stent stenosis).
The following are the indications for surgery (CABG);

1) Patient has refractory angina or large amount of myocardium in ischaemic jeopardy

   - NYHA Class III-IV chronic stable angina refractory to medical treatment
   - Unstable angina refractory to medical treatment
   - Acute ischaemia or haemodynamic instability following attempted coronary stenting or angioplasty
   - Acute evolving infarction within 6 hours of onset of chest pain or later if there is evidence of ongoing ischaemia (early post-infarction ischaemia).
   - Markedly posistive stress test prior to major intra-abdominal or vascular surgery.
   - Ischaemic pulmonary oedema.

2) Patients without disabling angina or refractory ischaemia in whom the extent of coronary disease, the status of ventricular function, and the degree of inducible ischaemia on stress test are such that surgery may improve long-term survival.

   - Left main stem stenosis > 50%
   - Three-vessel disease with ejection fraction (EF) < 50%
   - Three-vessel disease with EF > 50% and significant inducible ischaemia
   - Two-vessel disease with involvement of proximal LAD
   - One- and two-vessel disease with extensive myocardium in jeopardy, but lesions not amenable to PCI.

3) Patients who have indications for other open heart procedures and have coronary artery disease.

   - Valvular operations, septal myectomy.
   - Concomitant surgery for post-infarction mechanical defects (left ventricular aneurysm, ventricular septal rupture, acute mitral regurgitation).
   - Coronary artery anomalies with risk of sudden death e.g vessel passing between the aorta and pulmonary artery.
   -

5. INDICATIONS FOR OPCAB

The reason behind the resurgence of OPCAB was and is to avoid the negative effects of CPB which are multi-systemic and include;

- Coagulation disorders[18]; These are because of haemodilution from the pump priming solution, platelet degranulation, hyperfibrinolysis and consumption of the coagulation factors.
- Systemic inflammatory response[18]; This is from induction of complement activation, endotoxin release, leucocyte activation, expression of adhesion molecules and the release of inflammatory mediators like oxygen free radicals, arachidonic acid metabolites, cytokines, platelet activating factor, nitric oxide and endothelins.

These disorders may increase post-operative complications which include respiratory failure, renal failure, multi-systemic organ failure, neurologic dysfunction and bleeding problems[18].

This technique is indicated[6, 7, 18-21] in patients who will derive the maximum benefit from avoidance of CPB. These include those with;

1) Porcelain aorta and severe atherosclerotic and partially calcified aorta, in whom ascending aorta canulation, aortic cross-clamping and application of the side-biting clamp would be extremely difficult or dangerous with consequent strokes and neurologic dysfunction from atheromatous and calcific emboli.
2) Poor left ventricular function(left ventricular ejection fraction $\leq$ 35 %); OPCAB in this situation avoids the myocardial ischaemia and depression from CPB and studies have shown lower morbidity and mortality in this group when compare to those who had CABG-CPB.
3) High risk subgroups; this include those with advanced age, renal dysfunction, pulmonary dysfunction (chronic obstructive pulmonary disease), diabetes mellitus and obesity. They all benefit from avoidance of CPB and its deleterious effects.

It must however be stated that as surgical skills, confidence and techniques of OPCAB have improved with time, the indications and patient subgroups in whom OPCAB is performed have increased.

6. CONTRA-INDICATIONS FOR OPCAB

The group of patients in which OPCAB would be inappropriate[6, 18, 20] and is contra-indicated include; the absolute contra-indications:

1) Cardiogenic shock
2) Ischaemic arrhythmias
3) Thoracic anatomy precluding adequate rotation of the heart, for example; severe pectus excavatum, previous left pneumonectomy

The relative contra-indications include;

1) Intramyocardial coronary arteries
2) Unusually small or calcified coronary arteries
3) If endarterectomy is required
4) If concomitant cardiac surgery is required, for example, mitral valve repair or aortic valve replacement.

7. OPERATIVE MANAGEMENT OF OPCAB PATIENTS[19]

The introduction of OPCAB technique in the operating room raises some patient care issues for all concerned; surgeon, nursing staff and anaesthetists and requires adequate communication between them to ensure patient safety.

This is because an OPCAB case may encounter expected or unexpected changes in haemodynamics, sequence of grafting of the coronary arteries and operative plan and all have to be ready to adjust to these changes to ensure patient safety and operative success.

Anaesthetic Management

All patients for OPCAB are done under general anaesthesia with induction (opiods, benzodiazepines), muscle relaxants (nondepolarizing agents) and maintenance of anaesthesia (isoflurane, propofol) [6, 11, 20-24].

Non–invasive monitoring of electrocardiogram (ECG) and pulse oximetry is mandatory[11, 21, 23, 24]

All patients require invasive monitoring[11, 21, 23-25] which include;

- Arterial line
- Central venous line
- ± Swan Ganz catheter; Usually for those with significant left ventricular depression and for monitoring of the pulmonary artery pressure which elevation is usually the first sign of haemodynamic compromise prior to arrhythmias and cardiovascular collapse.

Heparin is given intravenously (1-1.5mg/kg) to achieve a target activated clotting time (ACT) of > 300-350 seconds[6,10,11,21,22] and this re-dosed as needed to maintain this level during the operation.

The maintenance of normothermia[21, 25, 26] during OPCAB is important because the rewarming seen in CABG-CPB from CPB is absent. This avoids the negative consequences of hypothermia which include bleeding post-operatively, arrhythmias and post-operative complications. The patient is kept warm pre-operatively by warming the induction room, warm blankets and warmed intravenous fluids. Intra-operatively, a convective forced air warming system (Bair Hugger) is also used.

Maintenance of haemodynamic stability[11, 24] is also important especially during lifting and retraction of the heart for exposure of the target coronary vessels. These positional changes may be accompanied by reductions in preload and left ventricular filling due to kinking of the vena cave, the pulmonary veins and the right ventricular outflow tract leading to poor cardiac output. The first line treatment for haemodynamic instability is administration of IV fluids. Other manouevres involve changing the patient's position to alter the patient's preload status to cater for different haemodynamic states. For example, during rightward heart displacement, the Trendelenburg position improves preload while

during the application of the partial occlusion aortic clamps, the reverse Trendelenbug position decreases preload. Another measure to maintain haemodynamic stability includes the use of inotropes (adrenaline, dobutamine, dopamine) and vasopressors [10, 26, 27] (phenylephrine, ephedrine, noradrenaline). Use of inotropes and vasopressors limits the use of intravenous fluids and positions the patient for a more favourable post-operative period in terms of rate of complications.

8. INTRA-OPERATIVE MANAGEMENT

The operation starts with routine draping for median sternotomy[6, 9-11, 24]. Access to the chest is through a median sternotomy, but can also be through a thoracotomy. The left and/or right internal mammary arteries (LIMA/RIMA) [10, 21] are then harvested if planned for use and with simultaneous harvesting of the saphenous vein or radial artery if needed by open or endoscopic means[6, 11, 21]. It is important the divide the diaphragmatic muscle slips under the xiphoid process to allow elevation of the sternal border. The pleural space on the side of the ITA being harvested may or may not be opened[23].

Heparin is given intravenously (1-1.5mg/kg) to achieve a target activated clotting time (ACT) of > 300-350 seconds[6,10,11 ,21, 22]and this re-dosed as needed to maintain this level during the operation.

After heparinization, the IMA is divided and papaverine ± lidocaine is injected extraluminally or intraluminally.

A sternal retractor designed to act as a platform for the stabilizers and positioners for OPCAB are placed in the chest.

A wide inverted T shaped pericardiotomy [19, 24] is done, dividing the pericardium along the diaphragm towards the right and left phrenic nerves. This facilitates cardiac displacement during the operation.

Pericardial traction sutures[9, 10] are then inserted on the left, right and oblique sinus (two-thirds of the way between the inferior vena cava and left pulmonary vein); so called 'Lima' stitches. Alternatively, some cotton slings[6, 24] (e.g. vaginal swab) are applied at the base of the deep posterior pericardial suture. All these sutures and cotton slings are for rotation and elevation of the heart for adequate coronary target vessel exposure.

The ascending aorta is now assessed for atherosclerosis[21] to enable optimal application of the partial occlusion clamps for graft anastomosis. This is done using the epi-aortic ultrasound (most sensitive method), trans-oesophageal echocardiography or digitally. In the absence of diffuse atherosclerosis, the anastomosis proceeds in the normal fashion, but in its presence, other options would include using an anastomotic device[6] or different proximal sources of blood flow; for example, the brachiocephalic artery, LIMA, RIMA or subclavian artery.

The heart is now positioned to commence graft anastomosis using the pericardial sutures and the cardiac stabilizing ± positioning devices[6, 9, 10, 21, 23, 24, 28, 29], the position of these devices can be changed depending on the target vessel. At the OPCAB advent, compression devices were used, but more recently suction type devices such as the Octopus are now used; stabilization is achieved at the mechanical median of the cardiac cycle and is maintained while mechanical interference with ventricular function is minimized. The suction positioning device attaches to the epicardial surface and

elevates and displaces the heart to provide exposure of the target vessels. A suction coronary stabilization device is also used to facilitate exposure and may be applied anywhere on the epicardial surface.

The sequence of grafting of the target vessels is important to avoid myocardial ischaemia and ensure haemodynamic stability. The graft sequence should also be individualized depending on the anatomic patterns of coronary disease, collateralization, myocardial contractility, ascending aortic atherosclerosis, conduit availability and graft geometry. The principles include; grafting the collateralized vessel first and reperfusion with proximal anastomoses or IMA anastomoses; grafting the collateralizing vessel last to avoid interruption of blood flow from the collateralizing to the collateralized vessel until after the collateralized vessel has been grafted; the proximal anastomoses may be performed first[6] to aid in early reperfusion of a critical collateralized vessel (a drawback is difficulty in estimation of graft length after proximal anastomosis); the LIMA- LAD anastomosis is done first if there is tight left main stenosis of if the LAD is collateralized[6,10,21].

After optimal exposure, the target vessel is occluded proximally with silastic vessel loops or soft vascular clamps[6]; this may be accompanied by test occlusion of the target vessel if it is poorly collateralized to determine the effect of regional myocardial ischaemia when anastomosis commences. The target vessel is opened with a coronary knife and the arteriotomy is extended with coronary (Potts) scissors. At this juncture, a coronary shunt may be used. A bloodless field is achieved by dispersal of retrograde bleeding from the target vessel with a humidified CO_2 blower[6]; excellent visualization is necessary for a precise anastomosis. Distal anastomosis is done with 7/0 or 8/0 continuous polypropylene. The proximal anastomosis is done with application of a partial occlusion clamp after the systolic blood pressure has been reduced to < 95mmHg; proximal aortotomies are made with a 4mm aortic punch and vein grafts and arterial graft anastomoses are then made with 6/0 and 7/0 continuously polypropylene sutures respectively. The aortic root is de-aired through the most anterior anastomosis after the partial occlusion clamp is removed before tying the suture. The vein grafts are de-aired with a 25 gauge needle.

After completion and reperfusion of all the grafts, protamine is given to partially correct the ACT[22]. Haemostasis is maintained and chest tubes are inserted into the mediastinal, pericardial and open pleural spaces. Temporary epicardial pacing wires are inserted. The chest is closed in the standard fashion with sternal wires, continuous absorbable stitches for the subcutaneous tissue and absorbable suture or nonabsorbable suture/staples for the skin

MYOCARDIAL PROTECTION DURING OPCAB

Myocardial protection during OPCAB is necessary because occlusion of the target vessels during anastomosis has several negative consequences including; regional ischaemia, myocardial injury, target vessel endothelial injury and apoptosis that contributes to post-operative pathology.

In the initial experiences with OPCAB, intermittent pharmacologic arrest and bradycardia were induced with adenosine and short acting beta-blockers. The mechanism of action was reduction of myocardial motion and myocardial oxygen demand. This method has largely being superceded by the use of the current suction stabilizers.

Ischaemic pre-conditioning has also being used for myocardial protection. This involves a brief occlusion and reperfusion of the target vessel (2-5 minutes) before the long occlusion period necessary to construct a coronary anastomosis and this is thought to improve myocardial protection in the area served by the occluded target vessel. More recent studies on ischaemic preconditioning suggest that any ischaemia is protective.

Maintenance of an adequate systemic blood pressure by optimization of preload and vasopressors is important for perfusion of the coronary arteries and its collaterals. This is especially important during target vessel occlusion.

The optimization of the pericardial sutures, cardiac positioning and stabilization devices may also protect the myocardium by achieving adequate exposure without compression of the cardiac chambers and with unwanted haemodynamic compromise or arrhythmias.

Optimization of the sequence of grafting to reduce myocardial ischemia is also another strategy.

An intracoronary shunt[6, 10,21,24,29] may be inserted selectively or electively. It is useful if significant haemodynamic compromise occurs after target vessel occlusion. It is also useful electively with large right coronary arteries, brady-arrhythmias and intramyocardial vessels where occlusion of the vessel will be dangerous. The shunt when appropriately sized (range between 1-3 mm), is easily placed and provides significant blood flow and a bloodless field. The shunt is removed and the coronary artery is de-aired prior to tying the suture on the distal anastomosis and flow is re-established.

The use of intra-aortic balloon pump (IABP) [10] improves haemodynamic stability especially during exposure and occlusion of the target vessels. Generally, the indication for IABP is similar to the indication for any patient having CABG.

9. POST-OPERATIVE MANAGEMENT

The post-operative management of OPCAB patients does not differ significantly from that of CPB-CABG patients; cardiac, respiratory, renal function and chest tube drainage monitoring procedures are very similar. However, there are some differences in the post-operative management of CABG-CPB and OPCAB patients.

Patients who have had OPCAB have a reduced need for inotropes post-operatively because of reduced myocardial stunning and ischaemia.

Patients also have a reduced need for IV fluids because they are most likely euvolaemic intra-operatively and have avoided the systemic inflammatory response and capillary leak associated with CPB. Instead, low dose vasopressors and careful IV fluid usage is advocated.

They also have a reduced haemorrhage and blood transfusion requirements because of avoidance of CPB. Therefore persistent post-operative haemorrhage is more likely from a surgical cause than coagulation factor deficiency or platelet dysfunction.

Post OPCAB patients are also in a hypercoagulable state making them prone to graft thrombosis. This can be counteracted by commencing aspirin on the day of operation and some authorities also commence clopidogrel.

They also have a reduced need for mechanical ventilation and are sometimes extubated in the operating room or in a high care unit, easily after surgery (‘fast tracking’).

10. OUTCOME MEASURES: OFF PUMP CORONARY BYPASS GRAFTING VERSUS CORONARY ARTERY BYPASS GRAFTING WITH CARDIOPULMONARY BYPASS

PRE-OPERATIVE FACTORS

The literature is replete with studies that have compared the presence of pre-operative CAD risk factors in both OPCAB and CABG-CPB patients.

Most studies showed no significant difference in the ages (range, median, mean) at which both groups were operated on, with most of the patients in both groups being in the 7th decade of life [8,20,29-31] while some studies showed some differences[7,22]

Most studies showed a male preponderance (51-95%) [8, 21, 22, 25, 27, 29, 30, 32] in both groups without any significant intergroup differences, while some showed a female preponderance in the OPCAB group[6,7]. The female gender has been known to be associated with increased resource utilization (prolonged intubation times and hospital stay) in OPCAB patients[11, 33].

There is no significant difference in the incidence of obesity in both OPCAB and CABG-CPB patients with figures of 6.3- 18.9% and 2.3- 20.4% in OPCAB and CABG-CPB patients respectively, though some studies revealed significantly more obesity among male patients who had OPCAB[11, 33].

The incidence of hypertension in both groups ranges between 68-87.5%and 47-69% in OPCAB and CABG-CPB patients respectively without any significant inter group difference[18, 30, 34-36].

Many studies showed no intergroup difference in the incidence of prior pre-operative myocardial infarction with figures of 27.5-50% and 25-43.3% being quoted for OPCAB and CABG-CPB patients' respectively[6, 9, 10, 29].

A review of the incidence of diabetes mellitus (DM) among OPCAB patients showed rates ranging between 10-64.4% and in CABG-CPB patients rates of 20-61.6%, but there was no significant intergroup differences[8, 21, 32, 34].

There are conflicting figures of the incidence of chronic obstructive pulmonary disease (COPD) among OPCAB and CABG-CPB patients with some quoting significantly higher rates in either the OPCAB or CABG-CPB group. Figures quoted have been between 5.7-14% and 0.9-30% for the OPCAB and CABG-CPB groups' respectively [6, 7, 9, 28, 32, 35].

Renal dysfunction is a major predictor of in-hospital and late mortality post CABG. The incidence of renal dysfunction in OPCAB and CABG-CPB 3.06%[40] 4.9%[57]patients ranges between 4.1-4.5% and 3-4.9% respectively[7, 18, 25]. The causes of renal failure in CABG patients include; DM, hypertension, atherosclerosis and glomerulonephritis[30].

Preoperative cerebro-vascular accident (CVA) incidence in both groups of patients ranges between 2.7-15.3% and 2.7-15% in OPCAB and CABG-CPB patients respectively, but with most studies showing no significant intergroup differences and some showing a significantly higher incidence in CABG-CPB patients [6,7,9,32,34,35].

The history of past or current smoking is present in 27-66% of OPCAB patients and 27-59% of CABG-CPB patients with no intergroup differences[7, 9,10,27,29].

The incidence of hypercholesterolaemia in OPCAB and CABG-CPB patients ranges between 31.8-73% and 24-77.5% respectively and without significant differences between them [7,9,21,23,27,34,36].

Peripheral vascular disease (PVD) is seen in 5.7-22.7% of OPCAB patients and 4.1-19% of CABG-CPB patients, but there is no significant difference between the 2 groups[7, 9, 23,25,28,30].

Carotid artery stenosis associated with CAD is seen in 45.5% of OPCAB and 57.1% of CABG-CPB patients[23].

Family history of CAD as a CAD risk factor is reported in 25-60% of OPCAB patients and 14.6-57.2% of CABG-CPB patients [7,27,29,30] with some showing a significantly higher rate in CABG-CPB patients[7].

One study showed a significantly higher rate of pre-operative aspirin usage in OPCAB patients (71%) compared to CABG-CPB patients (64%). There was also a significantly higher rate of clopidogrel use in OPCAB patients (11.8%) when compared to CABG-CPB patients (4.6%) [18]. Another study showed no difference in pre-operative aspirin use for OPCAB (56.8%) and CABG-CPB (53.7%) patients[10].

The incidence of pre-operative arrhythmia was found in one study to be 9% and 11% in OPCAB and CABG-CPB patients respectively[34] while another study showed the incidence of atrial fibrillation among CABG-CPB to be 3.4%[30].

The distribution of the patients into Canadian Cardiovascular Society (CCS) classes for angina severity for OPCAB and CABG-CPB patients respectively are for CCS I; 15-25% and 7-18% , CCS II; 12-50% and 16.7-58%, CCS III; 22.5-54.6% and 17.5-69.2% and finally CCS IV; 2.5-74.3% and 2.5-38.6% respectively[8-10,28,34] .Mean CCS class for OPCAB and CABG-CPB is 3.5±0.7 and 3.25±0.63 respectively[29]. There were no significant intergroup differences.

The distribution of the patients into New York Heart Association (NYHA) classes for degree of cardiac decompensation and dyspnoea for OPCAB and CABG-CPB patients respectively are NYHA I; 4% and 9%, NYHA II; 26% and 37%, NYHA III; 13.6-53% and 8-43% and finally NYHA IV; 17% and 10 % respectively[10,34]. The mean NYHA class for OPCAB and CABG-CPB patients is 3.00 ± 0.27 and 2.94 ± 0.13 respectively[10]. Another study by Reeve and Ascione et al showed the OPCAB and CABG-CPB patients in NYHA class > 2 to be 27.3% and 33.4% respectively[35]. There were no significant intergroup

differences.

The mean left ventricular ejection fraction (LVEF) quoted for OPCAB (47.1 ± 2.34[10] 47.2 ± 9.69[25], 46.9 ± 14.9[32]) and CABG-CPB (48.7 ± 0.58[10,] 46.8 ± 12.7[32]) patients are similar and without significant intergroup differences. Severe LV dysfunction (LVEF < 25%) was present in 2.6-7% of OPCAB patients and 3.7% of CABG-CPB patients[27, 35].

Pre-operative intra-aortic balloon pump (IABP) use in OPCAB and CABG-CPB patients ranges from 2-25.7% and 1-14.8% respectively[6, 7, 9, 10, 34] with most not showing any significant differences and one study showing a higher rate of pre-operative IABP use in CABG-CPB patients[7]. The indications for pre-operative IABP use include; left main stenosis (> 75%), intractable resting pain, left ventricular dysfunction (EF < 35%), recent acute MI and unstable angina[26]. Pre-operative IABP could lead to pre-operative reduction in myocardial ischaemia, avoidance of progressive cardiac dysfunction, minimization of low flow episodes and therefore allow for safer induction of general anaesthesia and improve surgical risk in high-risk patients[26].

The incidence of previous pre-operative cardiological intervention (stents/angioplasty) in OPCAB and CABG-CPB patients is between 7-25.6% and 10-35.5% respectively and no intergroup differences seen [9,10,34].

Many studies showed a previous cardiac operation (CABG) being done in 2.3-6.8% of OPCAB and 3.7-8.0% of CABG-CPB patients and without any significant intergroup differences present[7, 10, 17, 32 34, 35].

The proportion of the operations done as emergency, urgent or elective procedures for OPCAB patients are between 4-37.1%, 58.7-65.4% and 20-72.5% respectively while that for CABG-CPB patients range between 6.9-7.7%, 55-71.4% and 25.8-62.7% respectively[9,18,27,30,34,35,37].Some studies showed a significantly higher proportion of emergency cases in CABG-CPB patients[37].

Unstable angina as an indication for surgery in both groups was seen in 18-74.3% and 13.7-55.7% of OPCAB and CABG-CPB patients respectively with no significant intergroup difference between the 2 groups[9, 27, 30, 32, 38].

INTRA-OPERATIVE FACTORS

Conversion from OPCAB to CABG-CPB intra-operatively occurs occasionally for several reasons which include; anatomic (failure of adequate exposure of target vessel, deep intra-myocardial course of target vessel, small vessels, adhesions or an enlarged heart), haemodynamic instability upon manipulation of the heart(hypotension, mitral and/or aortic regurgitation, bleeding, acute ischaemia as detected by ST segment or wall motion changes, left ventricular dysfunction) and electrical disturbances during the procedure (ventricular fibrillation, ventricular tachycardia, heart block or severe bradycardia)[39]. A significant proportion of patients are converted during grafting of the obtuse marginal vessels or the ramus intermedius[25]. The consequence of intra-operative conversion is increased peri-operative mortality which may be up to 6-12 fold more than in the unconverted group[39, 40]. The conversion rate quoted in literature ranges between 0-8.8 % [21, 25, 26, 35, 38-41].

The cell saver which salvages mediastinal blood for autologous transfusion is used in both OPCAB and CABG-CPB patients, but the quantity of salvaged blood is significantly higher in CABG-CPB patients. It also leads to less homologous blood transfusion in both groups, but significantly less so in OPCAB patients[8].

The mean duration of cardiopulmonary bypass and aortic cross-clamp (ischaemic) time among CABG-CPB patients range between 56-108 minutes and 35.8-97 minutes respectively[6,21-23,30,41].

The mean number of grafts at the advent of OPCAB was significantly less than that for CABG-CPB, but with the passage of time and increased experience with the technique, more recent studies report very similar numbers. Some studies have quoted figures between 2.1-3.5 and 2.9-3.9 grafts for OPCAB and CABG-CPB patients respectively with most being significantly less in OPCAB patients[6,10,25,27,28,30,32,34,38,41] and some not showing any significant difference between the 2 groups[41]. Reasons given for these include the greater technical challenge of doing OPCAB on a beating heart as compared to a still heart as obtained in CABG-CPB and greater associated haemodynamic instability from cardiac manipulation.

The left IMA is used in 34-100% and 31-98.2% of OPCAB and CABG-CPB patients with most studies showing no significant difference between the groups[9, 10, 38, 41], some showing significantly more use in OPCAB patients[6, 21] and others showing more usage in CABG-CPB patients[28]. The rate of right IMA use varies between 11-31.4% and 16-37.7% of OPCAB and CABG-CPB patients[25, 38, 41]. The use of bilateral IMA is avoided in diabetes patients due to the increased risk of post-operative sternal wound infection. The rate of radial artery use varies between 17.4-71.4% and 42-58.7% of OPCAB and CABG-CPB patients respectively in published series[6, 9, 25, 41] with no significant intergroup differences.

The rate of greater saphenous vein graft use in both groups is between 8-77% in both groups[9, 25, 38, 41]. Gastro-epiploic artery graft is used in 8-26.6% and 3-28.9% of OPCAB and CABG-CPB patients respectively[38, 41].

Total arterial revascularization is advocated because of superiority of arterial grafts over venous conduits (long term patency and patients survival) and figures of 34%[21],49.3%[30] have been quoted.

POST-OPERATIVE FACTORS

Studies show that the mean intensive care unit (ICU) duration which is a proxy for the post-operative condition of the patient was between 22-64.8 hours and 31.2-124.8 hours for OPCAB and CABG-CPB patients respectively, with most studies showing no significant intergroup differences[8,11,23,25,28,32,36] and some showing significantly less ICU stay in OPCAB patients [6,30,38]. The longer ICU duration in CABG-CPB patients is attributed to post-operative complications due to systemic inflammatory response syndrome (SIRS). Approximately 42% of OPCAB patients will spend < 24 hours in ICU[35].

It is known that a longer duration of endotracheal intubation and mechanical ventilation suggests a poorer post-operative state and also predisposes the patient to complications such as ventilator associated pneumonia. Risk factors for longer ventilation times include; increased age, female gender, unstable angina, post-operative IABP use, need for blood transfusion, longer CPB duration, haemodynamic instability and renal insufficiency[42]. The mean duration of mechanical ventilation in both groups varies between 2.5-17 hours and 9.5-19.5 hours for OPCAB and CABG-CPB patients respectively with most studies indicating nil difference between the groups[11, 23 25, 32, 36] and some showing significantly longer duration of mechanical ventilation in CABG-CPB patients[6, 38]. Most (80%) OPCAB patients are intubated for < 24 hours[9]. Approximately 35% of both OPCAB and CABG-CPB patients are ventilated for > 12 hours[35]. Early extubation has been shown to be safe and to decrease hospital costs and resource utilization[11]. A subset of patients that have a significantly longer ICU stay and mechanical ventilation duration are those who are acutely converted from OPCAB to CABG-CPB and this portends a worse prognosis for this group[25].

Excessive bleeding plays a key role in the cause of morbidity and mortality after CABG. The aetiology of bleeding post CABG-CPB is multi-factorial and includes exposure of the blood to a synthetic, non-endothelialised surface with subsequent alterations in the coagulation and fibrinolytic systems. A study by Casati showed that CABG-CPB patients experienced transient platelet consumption, higher plasminogen activation and D-dimer formation than OPCAB patients[43].The mean volume of post-operative blood loss among OPCAB patients was 400-950mls and in CABG-CPB patients, 400-818 mls[22, 25, 34] with some studies showing less blood loss in OPCAB patients[18]. A significantly higher proportion of CABG-CPB patients (31%) had > 500mls of post-operative blood loss versus 16% in OPCAB patients[29]. The use of pre-operative anti-platelet agents has been identified as an independent risk factor for increased bleeding post CABG[18]. Techniques to reduce intra-operative and post-operative bleeding in both CABG-CPB and OPCAB patients include the use of aprotinin, epsilon-amino caproic acid, tranexamic acid and arginine vasopressin. Other techniques include; use of

corticosteroids and intra-operative ultra-filtration both of which serve to reduce the systemic inflammatory response associated with CABG-CPB.

The avoidance of CPB is thought to reduce peri-operative bleeding and consequently decrease the use of blood products[22]. Transfusion of allogeneic blood products exposes the patient to extra risks of transfusion reactions, immunosuppresion, viral transmission (hepatitis B, C, HIV) and increased mortality. Multiple post-operative blood transfusions have also been associated with increased morbidity and mortality [44]. The independent risk factors for both single and multiple unit blood transfusion requirements in literature include; advanced age, female gender, increased weight, African ancestry, chronic renal failure, left main stenosis, peripheral vascular disease (PVD) and re-operative CABG[45]. There have been recommendations that OPCAB should be used in those with these risk factors[18]. The proportion of OPCAB and CABG-CPB patients that have red blood cells (RBCs) transfused range between 10-55% and 26-86.6% respectively, with most studies showing significantly less RBC usage in OPCAB patients[7,25,32,35,46] and some showing no significant difference between the 2 groups. The mean number of RBC units transfused is 2-4 units in OPCAB patients and 2-6.1 units in CABG-CPB patients. The median volume of blood received both intra-operatively and post-operatively was significantly greater in CABG-CPB patients compared to the OPCAB patient group with a median of 874mls (range100-10,500mls) and 656mls (range 200-8500mls), respectively ($p < 0.001$)[18]. The proportion of patients that require platelet transfusion is between 11-13% and 17-18% of OPCAB and CABG-CPB patients respectively[22, 34], with less platelets transfused in OPCAB patients[35] and the mean volume transfused in both groups being 1 unit. Clotting factor transfusion is seen in 6.9-13% and 12.7-19% of OPCAB and CABG-CPB patients respectively[34] with significantly less transfused in OPCAB patients[22,35]; mean volume of fresh frozen plasma (FFP) transfused in OPCAB and CABG-CPB patients is 2 and 4 units respectively.

The incidence of major post-operative complications that comprise; peri-operative myocardial infarction (PMI), renal failure, sepsis, deep sternal wound infection (mediastinitis), neurological dysfunction (cognitive dysfunction, stroke),re-operation/re-exploration for bleeding, atrial fibrillation, low cardiac output syndrome varies among the different studies available. The incidence of PMI varies between 0.35-4% and 0.4-3% in OPCAB and CABG-CPB patients respectively [9, 25,29,34,35,40,41,47] with some showing significantly less rates in OPCAB patients[7]. The maximal post-operative creatinine kinase-myocardial band (CK-MB) levels in some studies were significantly lower in the OPCAB group[41, 48]. Meta-analyses of the effect of OPCAB surgery have shown a significantly less PMI rate in OPCAB patients[49, 50].

Post-operative renal failure increases early mortality (7-38%) [52, 53, 54] with a further increase in mortality if dialysis (1-5%) is required (60%) [55]. Cardio-pulmonary bypass was shown to be the main cause of glomerular and tubular dysfunction; the markers of glomerular function (creatinine clearance) and damage (microalbuminuria) as well as of tubular function (fractional excretion of sodium) and damage (urinary N-acetyl-β-glucosaminidase) were found to be significantly higher in CABG-CPB patients[56,57]. The causes of deleterious effects of CPB on the kidney are inflammatory response, non-pulsatile flow, haemodilution, hypoperfusion, low output syndrome, atheroembolism, increased levels of circulating catecholamines and free haemoglobin[58, 59]. Post-operative renal failure is seen in 0-5% and 0-7.9% of OPCAB and CABG-CPB patients respectively, with dialysis rates of 1.2-5% and 0-5% in OPCAB and CABG-CPB patients respectively. The rates are significantly worse in CABG-CPB patients [7,9,29,34,35,38,41,47,51] in most of the studies and in converted [25, 40] and aged (> 80 years) patients[60]. Meta-analysis showed significantly lower post-operative RF rates in OPCAB patients[50].

The incidence of deep sternal infection (mediastinitis) among the 2 groups was between 0-2% and 1-8.1% in OPCAB and CABG-CPB patients respectively[9, 26, 32-35, 47] with one study showing a significantly lower rate in OPCAB patients[61]. Meta-analysis showed a significantly lower infection rate in OPCAB patients[50]. Deep sternal wound infection is also more common in diabetics where bilateral IMA has been used.

Neurological dysfunction is one of the most studied post-operative complications of CABG. There are 2 types of neurological dysfunction described; type 1 neurological dysfunction is overt and consists of cerebro-vascular accident (CVA) which could be transient or permanent (stroke,coma). type 2(subtle,cognitive dysfunction-verbal memory,attention,mental flexibility,finger/hand dexterity,visual attention and word fluency) is seen in 48-79% of CABG-CPB patients long term and is connected to cerebral perfusion[62] ,is usually transient with 2/3 of patients recovering within 6 months, but 1/3 do not and some show late decline[63]. The incidence of stroke in OPCAB and CABG-CPB patients varies between 0-3.4% and 1.8-3% respectively, with stroke incidence worse in converted patients[9, 25, 28, 29, 32, 33, 40]. Many studies have not shown any significant difference in the incidence of early cognitive dysfunction between OPCAB and CABG-CPB patients, but meta-analyses have shown significantly less stroke rates in OPCAB patients[49, 50, 64]. These indicate that apart from CPB, a major part of the immediate post-operative neurological deficit may be related to general and haemodynamic aspects of surgery ranging from the microembolic load to cerebral hypoperfusion[36]. The causes of neurological dysfunction in CABG include; cerebral embolization of atherosclerotic plaque debris from the ascending aorta release during canulation (arterial inflow, cardioplegia) and occlusion (cross-clamping

and tangential clamping for proximal graft anastomosis) [20, 21]. Studies with transcranial Doppler ultrasonography have shown a substantial number of emboli production with aortic canulation and application, re-adjustment and removal of aortic cross and side clamps. Macroemboli and microemboli are most notably detected during application and release of the aortic crossclamp with significant neurologic sequelae, making extensive aortic atherosclerosis one of the most significant risk factors for post-CABG stroke[20]. The tangential clamp application is an independent predictor of post-operative CVA when CPB is not used, while some other studies have refuted this[65, 66]. Others causes of ND on CPB include; haemodynamic fluctuations, loss of pulsatile flow, cerebral hypoperfusion and coagulation/inflammatory cascade derangement[67]. There are significantly less intra-operative micro-emboli (solid and gaseous) in OPCAB patients[64]. The risk factors for neurological dysfunction which include hypertension, advanced age and carotid artery disease are also risk factors for atherosclerosis[68]. The presence of neurologic dysfunction increases chances of mortality significantly.

Surgical re-exploration of the mediastinum for haemorrhage following OPCAB and CABG-CPB varies between 0-6% and 2-5% respectively[18, 22, 25, 32] with some studies showing significantly less rates in OPCAB patients[7]. Coagulopathy during cardiac surgery with CPB results in impairment of haemostasis. The risk factors for re-operation identified include; advanced age, pre-operative clopidogrel, left main stenosis, peripheral vascular disease, cardiogenic shock and re-operative CABG [17, 69].

Post-operative atrial fibrillation (AF) in 10-36.8% and 9.8-36% of OPCAB and CABG-CPB patients respectively[9,25,28,32,34,70],with some showing significantly less rates in OPCAB patients[29] .The risk factors for AF include age which is related to structural changes in the atrium (dilatation, focal fibrosis and muscle atrophy). These factors create changes in local atrial refractory period, called 'dispersion of refractoriness' resulting in lack of uniformity and in the presence of triggering factors may lead to AF[70]. Another theory for development of post-operative AF is atrial denervation response to removal of fat tissue from the anterior surface of the ascending aorta for aortic crossclamping and proximal anastomotic construction. Atrial ischaemia may also serve as a substrate for development of AF[28].The presence of AF may rarely have a fatal outcome and increases hospital stay, risk of stroke, gastro-intestinal complications, patient discomfort and costs[28, 70]. The peak incidence is usually between the 2nd and 4th post-operative day[28, 70].

Peri-operative mortality rates for OPCAB and CABG-CPB patients vary between 0-2.8% and 2-17.2% respectively[24, 25, 27, 29,34,35,70] with some studies showing significantly less rates in OPCAB patients[7, 32]. The independent risk factors for mortality identified from these studies[7,60,70,71] include; female gender,

age (> 80 years), pre-operative IABP use, CPB use, cardiogenic shock, renal failure requiring dialysis, left main stem disease, previous CABG and acute intra-operative conversion from OPCAB to CABG-CPB. Other studies have refuted the claim that the female gender is an independent predictor of peri-operative mortality, showing no gender differences in mortality[33, 60]. Acutely converted patients have a 4 fold increase in peri-operative mortality than in unconverted OPCAB and CABG-CPB patients[35]. The causes of death are usually neurologic, pulmonary, renal or multiple organ dysfunction[7, 70]. Meta-analyses show favourable results of peri-operative mortality with one showing a statistically significant reduction in OPCAB versus CABG-CPB patients[49], which result was not seen in another[49].

The mean post-operative hospital stay (days) for OPCAB and CABG-CPB patients ranges between 4-9.3 days and 6.4-16.8 days respectively, with most studies showing significantly longer stays in CABG-CPB patients [6,8,11,25,27-29,32-34]. A meta-analysis showed significantly less hospital stay in OPCAB patients[50].The hospital stay sometimes serves as a surrogate for costs of hospitalization and a study showed that OPCAB has a 15-35% reduction in hospital costs[29].

FOLLOW-UP FACTORS

The mean duration of post-operative follow up was between 16.8-38.4 months and 30-40.8 months for OPCAB and CABG-CPB patients respectively [30,32,34,35].

Major adverse cardiac event (MACE) comprises the following: angina, congestive heart failure, percutaneous coronary intervention, arrhythmia, sudden death. The repeat revascularisation rates have been found to be more in OPCAB patients 6-25 months post-operatively, but not significantly so as found in one meta-analysis[50]. The MACE rate in CABG-CPB patients was 13.6% in one study[30], while 1 year event free rates for OPCAB and CABG-CPB patients are 95.7% and 96.8% respectively. Another study did not show any difference in symptoms, quality of life, event-free survival and freedom form repeat revascularisation between the 2 groups of patients[29]. The 1 year survival rates between the 2 groups are similar with figures of 95.7-98% and 96.1-98% for OPCAB and CABG-CPB patients respectively[29, 30, 72]. There is increased late mortality with converted patients, who may have poorer anastomoses (an effect of conversion), or some characteristics that predispose them to require acute conversion and subsequently to die earlier than unconverted patients for example, an underdeveloped or absent collateral circulation[35].

II. AIMS AND OBJECTIVES

1) To determine the morbidity, mortality and short-term outcomes of off-pump coronary bypass surgery performed by a single surgeon in the unit.
2) To compare (1) with the morbidity, mortality and short-term outcomes of on-pump CABG in high risk patients performed by senior surgeons in the unit.

III. PATIENTS AND METHODS

1. DESIGN

This was a retrospective study of selected 'off-pump' CABG patients and CABG-CPB patients operated on by the Department of Cardiothoracic surgery, University of Cape Town/Groote Schuur Hospital. It studied patients operated on between January 2001 and December 2007.

2. LOCATION/ POPULATION

The Chris Barnard Division of Cardiothoracic Surgery at Groote Schuur Hospital, one of other referral centres is a tertiary hospital serving a population of the Western Province of about 4 million with a sizeable number from other provinces (Northern and Eastern Cape).

The division has a clinical ward with a 25 bed capacity exclusively dedicated to the management of cardiothoracic surgery patients and also a 6 bed intensive care unit for peri-operative care.

3. PATIENT SELECTION

The inclusion criteria included:

- All patients who had isolated 'Off-pump' coronary artery bypass grafting (OPCAB) during this period and operated by a single surgeon (Professor Johan Brink)
- All patients who had isolated coronary artery bypass grafting on cardiopulmonary bypass (CABG/CPB) during this period and operated by 2 senior surgeons in the unit (Professor Peter Zilla, Professor Johan Brink)
- Above 2 criteria were chosen to eliminate the learning curve associated with surgical procedures as the 2 senior surgeons have advanced beyond the learning curve stages.

The exclusion criteria included:

- All patients who had CABG/CPB or OPCAB during the period under study and **NOT** operated by any of these 2 surgeons.
- Combined procedures involving CABG.

4. CONSENT AND ETHICS

Institutional consent was obtained from the University of Cape Town's Faculty of Health Sciences Ethical and Research Committee. No consent was obtained from the patients as this was a retrospective study and no patient confidentiality was breached.

5. DATA COLLECTION

The data collected for each patient was enumerated in the data collection sheet (attached).

The data was accessed from the following sources;

1) The 'Filemaker' cardiac surgery database belonging to the Chris Barnard Division of Cardiothoracic Surgery.
2) Patients' Groote Schuur Hospital folders and hospital records.
3) Patients' records in the Cardiac Clinic, Groote Schuur Hospital.

6. DATA ANALYSIS

The data generated from this study was analyzed using STATA 10 and Microsoft Excel software.

Categorical variables were analysed with the Pearson's chi squared test and Fisher's exact test when outcome variables were less than 5. The continuous variables between the 2 groups were analysed with the Student t test. Continuous variables were depicted as ranges, mean and standard deviation. A value of $p < 0.05$ was set as statistical significance.

7. LIMITATIONS OF THE STUDY

These may include:

1) Some loss of pertinent information associated with retrospective studies. However, all peri-operative data elements were prospectively entered into a cardiac surgery research database according to pre-specified definitions.
2) There was no measurement of graft patency.
3) The patients enrolled in the study were not randomized to either group and only those suitable, according to the surgeon, were selected as candidates for OPCAB surgery. There was no way of ascertaining reasons why one technique was preferred over another for particular patients.
4) Our study was performed in a single institution with a single surgical group, which may bias the operative data.
5) There was no risk stratification for the patients possible. The objective EUROSCORE assessment and relevant data captured was only included in the departmental database from 2007 onwards. Generally, however, lower risk coronary patients had their surgery done by less senior surgeons and the high risk patients almost exclusively by the 2 senior surgeons.

IV. RESULTS

TOTAL POPULATION

Three hundred and forty two (342) patients that fulfilled the criteria had records available for review from the data sources and were operated between January 2001 and December, 2007. There were 199 OPCAB patients and 143 CABG-CPB patients.

PRE-OPERATIVE FACTORS

There was no significant difference in age at operation between the 2 groups, with the mean ± standard deviation (SD) for OPCAB and CABG-CPB patients being 59.2 ± 10.5 years and 60.1 ± 9.6 years respectively. The age range was 23.4-84.3 years and 33.9-84.8 years for OPCAB and CABG-CPB patients respectively. Most of the patients were between 50-70 years; 63.2% and 68.3% of OPCAB and CABG-CPB patients respectively. **Tables 1** and **2** show the pre-operative characteristics between the 2 groups.

The distribution of gender did not reveal any significant differences between the 2 groups. The female gender comprised 25.1% (male, 74.9%) and 26.6% (male, 73.6%) of OPCAB and CABG-CPB patients respectively.

There was no significant difference in the incidence of obesity in both groups.

The proportion of the patients that had previous MI was 55.3% and 58.3% of OPCAB and CABG-CPB patients respectively, without any significant difference between them.

The incidence of hypertension in both groups was not significantly different with 65.1% and 69% of OPCAB and CABG-CPB being hypertensive respectively.

Diabetes mellitus (DM) was seen in 30.4% and 35.9% of OPCAB and CABG-CPB patients respectively, without any significant intergroup differences.

The incidence of COPD was 13.8% and 7.1% in OPCAB and CABG-CPB patients respectively, a difference which did not quite reach statistical significance (p= 0.053).

The incidence of pre-operative renal failure was 3% and 2.1% in OPCAB and CABG-CPB patients respectively without a significant intergroup difference. The mean pre-operative creatinine value was 96.5 and 90 for OPCAB and CABG-CPB patients respectively, with no statistical significance between the 2 groups of patients.

Previous CVA was present in 3.1% and 2.8 % of OPCAB and CABG-CPB patients, and without significant difference between them.

The proportion of patients who were smokers was 75.5% and 71.8% in OPCAB and CABG-CPB

patients respectively and this was not significantly different.

Hypercholesterolaemia was present in 58.3% and 58.8% of OPCAB and CABG-CPB patients and without any significant difference in distribution between the 2 groups.

The incidence of PVD was 9.2% and 9.9% in OPCAB and CABG-CPB patients respectively with no significant difference between the 2 groups.

Positive family history of CAD was significantly more present in OPCAB patients with a figure of 69% versus 55.1% for CABG-CPB patients (p=0.009).

Most of the patients in both groups were on aspirin pre-operatively, 85.1% and 85.4% of OPCAB and CABG-CPB patients respectively and there was nil difference between the 2 groups. The mean duration of aspirin stoppage pre-operatively was 3.51 days and 3 days for OPCAB and CABG-CPB patients respectively, also without any intergroup difference.

Pre-operative AF was present in 9.2% and 8% of OPCAB and CABG-CPB patients respectively and this too, did not show any significant intergroup difference.

About 50.8% of OPCAB patients were pre-operatively in NYHA classes III/IV versus 50.7% in CABG-CPB patients and there was no significant difference between the 2 groups, while there tended to be more CABG-CPB patients in CCS classes III/IV (81.4%) versus 74.6% in OPCAB patients, but this superiority did not meet statistical significance p=0.154).

A larger proportion of CABG-CPB patients had an IABP pre-operatively (12.8%) compared to 9.5% of OPCAB patients, but this did not meet statistical significance.

The mean left ventricular ejection fraction (LVEF) was 56.9 and 56.7 for OPCAB and CABG-CPB patients respectively with most patients in both groups having a good LVEF (> 50); OPCAB (74.3%) and CABG-CPB (72.1%). However, there was no significant difference in these 2 values for these 2 groups.

Some of the patients in both groups had 1undergone prior percutaneous coronary intervention (PCI) with figures of 13.6% and 7.7% in OPCAB and CABG-CPB patients respectively and the larger OPCAB proportion tended to, but did not translate into statistical significance (p=0.088).

A small percentage of patients in both groups had a previous cardiac operation, 5.6% and 2.9% in OPCAB and CABG-CPB patients respectively, without any intergroup difference.

There was a larger proportion of CABG-CPB patients who had urgent/emergency surgery (44.9%) versus 34.2% of OPCAB patients and this tended to, but was not statistically significant (p=0.169).

The indication for surgery was unstable angina/acute MI in 70% and 70.5% of OPCAB and CABG-CPB patients respectively and there was no intergroup difference.

INTRA-OPERATIVE FACTORS

The proportion of patients who were acutely converted from OPCAB to CABG-CPB was 2.5% (n=5). The reasons for conversion were haemodynamic instability in all the cases. Conversion was not a risk factor for death in this study. **Tables 3** and **4** show the intra-operative characteristics of both groups.

The mean CPB duration for CABG-CPB was 123 minutes, while the mean aortic crossclamp (ischaemic) time was 76.7 minutes.

The use of the cell saver was significantly more in OPCAB patients (26%) versus 6.4% in CABG-CPB and this was not unexpected.

There was no significant difference in the mean number of distal anastomoses done and this was 3.31 grafts and 3.45 grafts in OPCAB and CABG-CPB patients respectively. The proportion of patients in both groups who had a LIMA-LAD graft was 93.4% and 90 % in OPCAB and CABG-CPB patients respectively and without any intergroup difference. **Table 5** shows the different distribution of target vessels and conduits between the 2 groups. Significantly more right IMA and radial arteries were used in OPCAB patients, while significantly more saphenous vein grafts (SVG) were used in CABG-CPB. Significantly more OPCAB patients (26%) had total arterial revascularization (TAR), compared to 4.3% in CABG-CPB patients.

POST-OPERATIVE FACTORS

The mean duration of ICU stay was less in OPCAB patients (80.7 hours) versus 104 hours in CABG-CPB patients, but there was no statistical significance. Significantly more OPCAB patients had < 24 hours ICU stay (8.4%) than CABG-CPB patients (3.4%). **Tables 6 and 7** show the different post-operative characteristic between the 2 groups.

The mean duration of mechanical ventilation was 22.3 hours and 38.3 hours in OPCAB and CABG-CPB patients respectively and this tended towards but was not statistically significant (p=0.09). A larger proportion of CABG-CPB patients (24.6%) versus OPCAB patients (14%) were ventilated for > 24 hours.

The mean ICU blood loss was significantly less with OPCAB patients (808 mls) than CABG-CPB patients (988 mls).

A larger proportion of CABG-CPB patients needed ICU red blood cell transfusion (48.3%) versus 20.1% in OPCAB patients and there were significantly more mean number of RBC units transfused in CABG-CPB patients (2.66) versus 1.72 units in OPCAB patients.

Though post-operative MI was seen in a larger proportion of OPCAB patients (2.5%) than CABG-CPB patients (0.7%), the difference was not statistically significant.

There was no significant difference in the rate of post-operative renal failure between OPCAB (4%) and CABG-CPB (7%) patients.

Post-operative ICU septicaemia was significantly more common in CABG-CPB (5.6%) than in OPCAB (1.5%) patients.

The incidence of post-operative pneumonia was 8.5% and 7% in OPCAB and CABG-CPB patients respectively, without a significant intergroup difference.

There was a significantly higher incidence of deep sternal wound infection (mediastinitis) in CABG-CPB (4.2%) versus 0.5% in OPCAB patients.

Post-operative CVA was seen in 1% and 5.6% of OPCAB and CABG-CPB patients respectively and the difference was statistically significant.

Though there was a higher incidence of post-operative AF in CABG-CPB patients (4.2%) compared to 2% of OPCAB patients, this was not statistically significant.

There was no difference in the incidence of re-exploration for haemorrhage between OPCAB (1%) and CABG-CPB (2.8%) patients.

Death rates were 3% and 9% in OPCAB and CABG-CPB patients respectively and the higher CABG-CPB rate was statistically significant. However, a limitation of this study was the inabilities to risk stratify the patients retrospectively.

The mean post-operative stay in the ward was significantly less in OPCAB patients at 5.5 days compared to 7.4 days by CABG-CPB patients.

FOLLOW UP FACTORS

The follow-up data was available for 49.2% (n= 104) and 68.5% (n=92) of OPCAB and CABG-CPB patients respectively, and the mean follow-up duration was 17.8 months and 15.2 months respectively without any statistically significant difference between the groups.

Tables 8 and 9 show the follow-up variables between the 2 groups.

Of these patients the angina recurrence rate during the follow up period was not significantly different between the groups, being 18.3% (18 of 98) and 20.4% (20/98) in OPCAB and CABG-CPB patients respectively. The recurrence of angina on average was significantly sooner in OPCAB patients at 8.3 months compared to 23.4 months in CABG-CPB patients.

The MACE rate was also similar between the 2 groups being 20.4% and 23.4% in OPCAB and

CABG-CPB patients respectively.

V. DISCUSSION

Off-pump coronary artery bypass grafting (OPCAB) has been in existence since the 1960s and was initially a technique for CABG, but which went out of favour with the advent of CPB and cardioplegic arrest.

As time passed and with increased CPB use, the deleterious effects of CPB became more obvious and efforts were then directed at prevention or reduction of these negative effects. This led to the resurgence of OPCAB surgery in the early 1990s. The thinking was, elimination of CPB would lead to a more physiological milieu that would optimize organ function and reduce organ specific complications especially in high risk patients.

South Africa is a unique country in the sense that it has both traditionally 'western' diseases (CAD) and cardiac diseases associated with low socio-economic situations (rheumatic heart disease) and is economically classified as a developing country.

This classification positions it to reap the perceived advantages of OPCAB over CABG-CPB which early studies showed.

This study was done to explore the presence of any advantage off OPCAB over CABG-CPB peri-operatively and also in the short/mid term.

PRE-OPERATIVE CHARACTERISTICS

The demographics among the 2 groups did not show any significant difference except for family history of CAD which was significantly more common in OPCAB patients.

When this study's figures were compared to figures found in the literature, there were no significant differences found. **Table 10** shows the figures found in the literature. The variables compared include; age, female gender, previous MI, hypertension, DM, renal failure, previous CVA, smoking and hypercholesterolaemia. Other variables compared include; PVD, COPD, family history of CAD, use of pre-operative aspirin, presence of pre-operative AF, NYHA and CCS classes, use of pre-operative IABP, previous cardiac operation and previous PCI.

The mean LVEF of 56.9% and 56.7% for OPCAB and CABG-CPB patients respectively was similar to 50-65% and 45-63% seen in other studies[49,73,88,99-101], with one being significantly more in OPCAB patients[99]. The proportion of patients in the 2 groups with low LVEF(< 30%) was 5.9% and 5.3% for OPCAB and CABG-CPB patients respectively and was also similar to figures of 1.9-8.6% and 2.3-8.2% found in other studies [72,75,76,98,99,].

Though this was a retrospective study, indications for pre-op IABP use gleaned from other studies

included; cardiac index < 1.8, haemodynamic instability, severe left ventricular dysfunction and high grade left main stenosis[83]. The use of IABP has also being found to be an independent risk factor for 30 day mortality[90, 94]. The figures of 9.5% and 12.8% for OPCAB and CABG-CPB patients respectively, are similar to those found in the literature of 1-10% and 4-11.6% for OPCAB and CABG-CPB patients respectively[46, 74, 79-81, 85, 89, 94]. Though there was a higher rate of usage in CABG-CPB patients and no intergroup difference in this study, many studies showed significantly less IABP rates pre-operatively in OPCAB patients[79-81]. This may suggest a higher percentage of high risk patients in CABG-CPB group.

INTRA-OPERATIVE CHARACTERISTICS

The priority of the patients' operation as urgent/emergent was 34.1% and 43.9% in OPCAB and CABG-CPB patients respectively and there was no difference between the groups, though a larger proportion had urgent/emergent surgery in CABG-CPB. These figures compare with 21-70.9% and 25-74.3% for OPCAB and CABG-CPB patients respectively from other studies [37,73,79,81,89,90,94,102]. Most of the studies had a significantly higher proportion of CABG-CPB patients having urgent/emergent surgery [37, 79-81,102]. This larger proportion may be a surrogate for the worse clinical condition of the CABG-CPB patients which may also explain the higher mortality rate in CABG-CPB patients. There was a significant difference in mortality rates between elective and urgent/emergent cases being worse in the latter.

The initial application of OPCAB in the early 1990s was directed mainly at highly selected and relatively low risk patients. Early evidence suggested potential advantages of OPCAB and many surgical units have experienced an increased percentage of OPCAB usage with time and later high risk patients with risk factors that make them susceptible to the negative effects of CPB have been added to the patient pool[89].The OPCAB advantages elucidated include; eliminating intra-operative global ischaemia, lower mortality,lower morbidity, lower costs and less use of blood products[82].Other advantages include lower rates pulmonary infection, necessity for vaso-active drugs, bleeding, blood transfusion and ICU stay[82]. The disadvantages listed include; more time in operating room, lower number of grafts[81] and regional ischaemia. Conversion to non-selective application of OPCAB did not increase morbidity nor lead to a change of practice[103]. Presently OPCAB can be performed for lesions in virtually any coronary artery with a high degree of patient safety and surgeon comfort[84]. The proportion of CABG cases as OPCAB across many units has steadily increased since the inception. One study quoted increasing percentages from 6% in 1997 to 99% in 2002[99]. The range in literature is between 20 and 99% [46,72,79,87,89,90,99,104].

The mean CPB and aortic cross-clamp times in this study of 123minutes and 76.7 minutes respectively were higher than in other studies which reported ranges of 57-169 minutes and 29-64 minutes respectively [41,46,75,77,79,82,89,96,105]. These longer times can be attributed to the high risk profile of our patients. The deleterious effects of CPB are well known and include evoking an inflammatory response with evidence of complement activation and free radical generation[76]. These effects then lead to renal, pulmonary, neurologic complications, bleeding and multiple organ dysfunction[79]. All these combine to an increase in hospital stay[84, 87].

The mean number of distal anastomoses in this study was 3.31 and 3.45 for OPCAB and CABG-CPB

patients respectively without any significant intergroup difference. These figures are similar to 1.8-3.5 and 1.7-4 grafts reported in other studies [37,41,46,72,73,82-89,97] However, most of these studies show a significantly higher number of grafts in CABG-CPB patients [37,46,73,83,84,86-88]. A recent prospective randomized study; ROOBY showed fewer grafts in the OPCAB patients [106]. These results were identified as one of the earliest disadvantages of OPCAB, but in some centres, with increasing knowledge and experience with the OPCAB technique, minimal differences in mean number of distal anastomoses were noticed between OPCAB and CABG-CPB patients. The similarity in the number of grafts in this study rules out the possibility of incomplete revascularisation in OPCAB patients previously suggested and allows for better comparison between the 2 groups[89]. Furthermore the absence of a significant difference in distribution of the distal anastomoses to the vascular territories decreases the possible bias that could be involved in the selection of the procedure[89]. The LAD was the target vessel in 98% and 98.5% in OPCAB and CABG-CPB patients respectively, figures that are similar to 100% and 95-97.8% seen in other studies[73,86,93]. The diagonal arteries were the target vessels in 54.1% and 54.3% of OPCAB and CABG-CPB patients respectively and without intergroup differences and also similar to 48.4-70% and 54.3-71% respectively seen in other studies[73, 86, 93]. The obtuse marginal arteries were the target vessels in 77.5% and 84.8% in OPCAB and CABG-CPB patients; figures higher than 54.8-69% for OPCAB patients, but similar to 89-100% reported for CABG-CPB patients[73, 86]. One study showed a significantly more OM graft rate in CABG-CPB patients and this may be related to the difficulty of grafting the lateral surfaces of the heart in OPCAB (increased likelihood of haemodynamic instability)[86]. The RCA (excluding PDA) was a target vessel significantly more times in CABG-CPB (13%) than OPCAB (4.6%) patients. These figures are much lower than 22.6-32% seen in OPCAB patients, but similar to 10.9-43% in CABG-CPB patients[73, 86, 93]. This may also be explained by the technical and physiological difficulty of grafting the RCA in OPCAB. The PDA was the target vessel in 62.7% and 54.3% of OPCAB and CABG-CPB patients respectively and these are similar to 27-51.6% and 29-80.4% for OPCAB and CABG-CPB patients respectively seen in other studies[73, 86], with one showing significantly higher rates in CABG-CPB[107]. The LIMA is recognized as the ideal graft for the LAD[41] and was used as conduit in 93.4% and 90.4% of OPCAB and CABG-CPB patients respectively in this study. These figures are similar to 34-100% and 35-95.6% in OPCAB and CABG-CPB patients respectively seen in other studies. The use of the RIMA as a conduit was significantly more at 6.1% in OPCAB patients than 0.7% in CABG-CPB patients. This may reflect surgeon's preference, higher percentage of urgent/emergent cases and also correlates with a higher rate of total arterial revascularization (TAR) seen in OPCAB patients (26%

versus 4.3%). These RIMA figures are similar to 1.7-17.2% and 1-16% seen in OPCAB and CABG-CPB patients respectively[41, 73,79,86,93]. The SVG is the most widely used graft because of its accessibility and ease of use[73] and was used as a conduit in this study in significantly more CABG-CPB patients (95%) than OPCAB patients (73.5%). These figures are similar to 60.7-90.3% and 90.8-97.8% for OPCAB and CABG-CPB patients respectively found in other studies[73, 86, 93] with one study showing a significantly higher SVG use in CABG-CPB patients[101]. This figure reflects ease of harvesting the conduit and a higher urgent/emergent case rate seen in CABG-CPB patients. The RA was the conduit in significantly more OPCAB patients (25%) than CABG-CPB (11.6%); figures that are much higher than 2.9-8.2% in OPCAB patients, but similar to 3.1-13% for CABG-CPB patients seen in other studies[73, 86, 93]. This may also reflect a higher TAR pursued in OPCAB patients in this study.

Conversion intra-operatively from OPCAB to CABG-CPB was necessary in 2.5% of OPCAB patients with the reason being haemodynamic instability in all cases. This figure is similar to 0-13.3% seen in other studies [41, 74,79,83,84,102]. One study attributed its high rate of conversion (13.3%) to variable surgeon experience and high percentage of 3 vessel CAD in their patient cohort. Conversion has been associated with higher morbidity, mortality and increased hospital costs[74]; findings that are absent in this study. The most common reasons for conversion include; ischaemia, inability to visualize a target vessel and haemodynamic instability.

POST-OPERATIVE CHARACTERISTICS

The mean peri-operative blood loss in this study was 808mls and 988 mls in OPCAB and CABG-CPB patients respectively and this was significantly more in the CABG-CPB group. These figures are similar to 503-789mls and 560-1389 mls reported for OPCAB and CABG-CPB patients respectively in other studies[41, 48, 82, 88], most of which show significantly more blood loss in CABG-CPB patients. Though many studies report less peri-operative blood loss with the OPCAB technique, an area of concern is the uncertainty of an existing pro-coagulant or hypercoagulant state in OPCAB operations. This may endanger graft patency peri-operatively. The factors that activate coagulation in CABG-CPB are well defined and include contact of blood with the foreign surfaces of the extra-corporeal circuit, blood air contact in the open venous reservoir as well as use of the cardiotomy suction[96].

Red blood cell transfusion was needed in 20% and 48.3% of OPCAB and CABG-CPB patients respectively; significantly more in CABG-CPB patients. These figures are similar to 10-52% and 26-56.2% for OPCAB and CABG-CPB groups respectively, with one randomised controlled trial showing a significantly more need for RBC transfusion in CABG-CPB patients [41, 46, 82,106]. Different blood transfusion rates may be because of different transfusion guidelines and indications in the units and the use of cell saving devices[41]. The mean RBC units transfused was significantly more for CABG-CPB patients at 1.72 and 2.66 for OPCAB and CABG-CPB patients respectively; figures similar to 1.2-4 units and 2.9-6.1 units for OPCAB and CABG-CPB patients respectively[41,82,88].

The mean duration of ICU stay was higher but not significantly so in CABG-CPB patients at 104.1 hours versus 80.7 hours in OPCAB patients. These correlate with figures of 29.3-93.6 hours and 22-124.8 hours in OPCAB and CABG-CPB patients respectively, with some studies not showing any intergroup difference[41,74,77,82,97,100,105,106,108] and others showing significantly more time spent in ICU by CABG-CPB patients[77,87,89]. The identified risk factors for prolonged stay in ICU include; lung disease, no sinus rhythm, reoperation and no elective operation[108] .It must be conceded though that local ICU bed availability may influence ICU stay duration.

The mean duration of mechanical ventilation among OPCAB patients (22.3 hours) was less than that for CABG-CPB patients (38.3 hours), but not significantly so and was higher than figures of 8.4-17.1 hours and 4-22.2 hours in other studies[41, 74, 82, 97,100,106]. Many studies report significantly longer ventilator hours in CABG-CPB patients[77, 86,109]. This discrepancy cannot be adequately explained by the pre-operative or intra-operative characteristics of patients in this study. The duration of mechanical ventilation is an important surrogate for costs and early endo-tracheal extubation has been shown to decrease costs[87].

The incidence of post-operative renal failure among OPCAB and CABG-CPB patients was 4% and 7% respectively, without any intergroup difference and similar to 0-3.8% and 0-6.2% respectively. Most of the studies show no difference between the groups[41, 47,73,77,79,81,83,89,106,110], while some show a higher rate in CABG-CPB patients. Logistic regression did not show post-operative renal failure to be a risk factor for death in this study unlike in another study[51].

The incidence rate of post-operative stroke (Type 1 neurologic deficit) was significantly more in CABG-CPB at 5.6% versus 1% in OPCAB patients and these figures were within ranges of 0-2% and 0-7% for OPCAB and CABG-CPB patients respectively. There are conflicting reports with some showing no intergroup difference[37,47,73,74,81-84,89,97,102,105,106] and others showing a significantly higher rate in CABG-CPB patients[46,79,110]. A meta-analysis showed a trend towards the reduction of strokes in OPCAB patients, while a recent randomised controlled study showed no difference between the 2 groups in incidence of post-operative stroke[106]. The risk factors identified for strokes from previous studies include; advanced age, history of previous strokes, redo cardiac surgery and history of PVD[46, 91]. The mechanisms for stroke in OPCAB patients include; haemodynamic changes, use of the partial occlusion aortic clamp and a decrease in cerebral perfusion by myocardial dislocation, while for CABG-CPB patients include; cerebral emboli (atheromatous), usually more in CABG-CPB, and cerebral hypoperfusion[41,88].

There was a higher rate of postoperative MI in OPCAB patients (2.5%) compared to 0.7% in CABG-CPB, similar to 0-3.7% and 0-7.5% in OPCAB and CABG-CPB patients respectively in other studies' [41, 47, 73,74,81,82,84,89,94,110]. Most studies showed a higher rate, though insignificant in CABG-CPB patients, with no intergroup differences unlike in this study. Studies have shown that in routine clinical practice, the OPCAB technique is associated with significantly reduced post-operative cardiac enzyme (troponin I, CK-MB) release compared to CABG-CPB suggesting significantly lower levels of perioperative myocardial injury[72, 83, 97,111]. Perioperative CK-MB release has been shown to be a reliable marker for myocardial ischaemia and injury in both OPCAB and CABG-CPB patients[72]. A meta-analysis showed a trend towards reduction in incidence of post-operative MI in OPCAB patients. Some have attributed the different concepts of regional ischaemia in OPCAB and global ischaemia in CABG-CPB caused by aortic crossclamping as the reason for the myocardial protective effect of the OPCAB technique[89].

Deep sternal wound infection (mediastinitis) was found post-operatively in significantly more CABG-CPB patients (4.2%) compared to 1% in OPCAB patients. Most of the studies showed no significant intergroup difference in the incidence rate of mediastinitis, but these figures were within the range of 0-3.5% and 0.3-3.7% for OPCAB and CABG-CPB patients respectively [37, 47, 73, 77, 79, 82-84,105,106,110].

Cardiopulmonary bypass causes leucocyte dysfunction and coupled with increased tissue oedema and cytokine activation may explain the trend towards a decrease in postoperative mediastinitis in OPCAB patient[84].

There was no intergroup difference in the rate of re-exploration for haemorrhage between OPCAB patients (1%) and CABG-CPB patients (2.8%); figures similar to 0-7.1% and 1.4-6.7% of OPCAB and CABG-CPB patients respectively in other studies. Some of the studies show significantly higher rates in CABG-CPB patients[46,79,87,110], while others do not [37,73,77,81-84,87,89,97,102].

The mean duration of postoperative hospital stay was significantly less in OPCAB patients (5.5 days) when compared to CABG-CPB patients (7.4 days) and these figures were similar to 3-10.9 days and 4-12.3 days for OPCAB and CABG-CPB patients respectively. Many studies showed a significantly longer stay by CABG-CPB patients[37,75,79,81,83,87,110], while others showed no difference [46,82,84,89,97,100,106].

The factors associated with increased postoperative hospital stay include; CPB use, RBC transfusion, increasing age, female gender and increased mechanical ventilation duration[87.]Cardiopulmonary bypass use was found to be an independent predictor for increased postoperative stay[84].

The incidence of peri-operative mortality was significantly different between the 2 groups at 3% and 9% for OPCAB and CABG-CPB patients respectively. These figures are similar to 0-3.5% and 0-12% for OPCAB and CABG-CPB patients respectively, though most studies showed no significant difference between them [37,41,46,47,73,74,76,80,82-84,88,97,102,105,106,110] and some showed more deaths with the CABG-CPB technique [79,81,87,89]. Risk factors for mortality include; intra-operative conversion from OPCAB to CABG-CPB[74], age, female gender, carotid artery disease, chronic renal failure, low LVEF, pre-operative IABP and recent MI[80,84]. In our series the higher mortality can be attributed to the fact that during the time period of the study, all the higher risk patients were assigned to the 2 senior surgeons in the study. It was not possible retrospectively to do an objective risk assessment (such as EUROSCORE, PARSONNET or STS risk evaluation), due to data being incomplete in majority of our patients.

FOLLOW UP CHARACTERISTICS

In this study the rate of angina recurrence was similar between the 2 groups, but with an earlier recurrence in OPCAB patients. This is difficult to explain this because there was no significant difference in the number of distal anastomoses between the 2 groups; lower number of grafts in OPCAB patients was the reason proposed for earlier angina recurrence and higher rates of angina recurrence in OPCAB patients in the past. There was significantly less SVG use and significantly higher total arterial revascularisation rate in OPCAB patients in this study, factors that should have ensured lesser angina recurrence rates. The long-term patency of grafts is one of the major factors that determine MACE components like angina. The patency rate of arterial grafts after OPCAB is comparable to arterial grafts done by CABG-CPB[73].It may be that the use of SVG in OPCAB played a more important role in angina recurrence. Saphenous vein grafts after OPCAB in the early post-operative period have been shown to have slightly lower patency rates than arterial grafts and also a significantly lower patency rate 1 year post-operatively, than SVG done with CABG-CPB[48, 73]. The patency of SVG after CABG is affected by 3 processes that cause SVG failure; thrombosis, fibro-intimal hyperplasia and vein graft arteriosclerosis. Among the 3 processes, thrombosis accounts for most graft failures within the first month, but may continue for as long as 1 year post-CABG. Fibro-intimal hyperplasia occurs predominantly after 1 month to 5 years and SVG arteriosclerosis may begin as early as the first year, but is fully developed only after 5 years[73]. Some authors have proposed sub-optimal anastomoses as the reason for poorer graft patency rates in OPCAB patients (a surrogate for angina recurrence) [41]. A recent randomised trial also showed lower graft patency rates in OPCAB patients at 1 year[106].

There was no difference between the MACE rates during the limited follow up period; a finding confirmed by some studies[72] and refuted by others reporting MACE rates in CABG-CPB patients [81,110] . The reported disadvantages of OPCAB; frequent incomplete revascularisation resulting in increase in cardiac events were not evident during the short follow up period[77].

VI. CONCLUSION

The conclusion of this study is as follows;

1) There were similar pre-operative characteristics between the OPCAB and CABG-CPB patients.
2) There was less ICU blood loss and less usage of blood products in OPCAB patients.
3) There was shorter hospital stay in OPCAB patients.
4) There were lower rates of sepsis, deep sternal wound infection and post-operative stroke in OPCAB patients.
5) Peri-operative mortality was lower in OPCAB patients.
6) There was an earlier recurrence of angina in OPCAB patients, but the same overall rate.
7) There was no difference in major adverse cardiac events during the limited follow-up period.
8) An obvious cost savings in OPCAB patients due to
    a) Lower cost of consumables.
    b) Less blood usage.
    c) Shorter hospital stay
    d) Lower rates of sepsis, infection and strokes.

BIBLIOGRAPHY

1) Murray CJ, Lopez AD. Mortality by cause for eight regions of the world: Global Burden of Disease Study. Lancet 1997; 349 (9061):1269-1276.
2) Norman R, Bradshaw D, Schneider M, Pieterse D, Groenewald P. Revised Burden of Disease Estimates for the Comparative Risk Factor Assessment, South Africa 2000. Methodological Note. Cape Town: South African Medical Research Council, 2006.
4) Leeder S, Raymond S, Greenberg H. Race against time: The challenge of cardiovascular disease in developing economies. New York: Columbia University, 2004.
5) Yusuf S, Zucker D, Peduzzi P. Effect of coronary artery bypass graft surgery on survival: Overview of 10 year results from randomized trials by the Coronary Artery Bypass Surgery Trialists Collaboration. Lancet 1994; 344:563-570.
6) Buxton B, Frazier OH, Westaby S. Ischaemic Heart Disease Surgical Management. 1999. Mosby International Ltd.
7) Lee JH, Capdeville M, Marsh D, Abdelhady K, Poostizadeh A, Murrell H. Earlier Recovery With Beating-Heart Surgery: A Comparison of 300 Patients Undergoing Conventional Versus Off-Pump Coronary Artery Bypass Graft Surgery. J Cardiothorac Vasc Anesth 2002; 16(2): 139-143.
8) Magee MJ, Jablonski KA, Stamou SC, Pfister AJ, Dewey TM, Dullum MKC, Edgerton JR, Prince SL, Acuff TE, Corso PJ, Mack MJ. Elimination of Cardiopulmonary Bypass Improves Early Survival for Multivessel Coronary Artery Bypass Patients. Ann Thorac Surg 2002; 73:1196–203.
9) Niranjan G, Asimakopoulos G, Karagounis A, Cockerill G, Thompson M, Chandrasekaran V. Effects of cell saver autologous blood transfusion on blood loss and homologous blood transfusion requirements in patients undergoing cardiac surgery on- and off- cardiopulmonary bypass: a randomised trial. Eur J Cardiothorac 2006; 30: 271-277.
10) Varghese D, Yacoub MH, Trimlett R, Amrani M. Outcome of non-elective coronary artery bypass grafting without cardio-pulmonary bypass. Eur J Cardiothorac 2001; 19: 245-248.
11) Kerendi F, Puskas JD, Craver JM, Cooper WA, Jones EL, Lattouf OM, Vega JD, Guyton RA. Emergency Coronary Artery Bypass Grafting Can Be Performed Safely Without Cardiopulmonary Bypass in Selected Patients. Ann Thorac Surg 2005; 79: 801-6.
12) Scott BH, Seifert FC, Glass PSA. Does Gender Influence Resource Utilization in Patients Undergoing Off-Pump Coronary Artery Bypass Surgery. J Cardiothorac Vasc Anesth

2003;3(June): 346-351.

13) Ross R. The pathogenesis of atherosclerosis- an update. N Engl J Med 1986; 314:488.

14) Munro JM, Cotran RS. The patogenesis of atherosclerosis:atherogenesis and inflammation. Lab Invest 1988; 58:249.

15) Pearson TA, Kramer EC, Solez K, Hepstinstall RH. The human atherosclerotic plaque. Am J Pathol 1977; 86: 657.

16) Guyton JR, Klemp KF: Transitional features in human atherosclerosis:intimal thickening, cholesterol clefts and cell loss in human aortic fatty streaks. Am J Pathol 1993; 143: 1444-1457.

17) Bojar R. Manual of perioperative care in adult cardiac surgery. 4th ed. Blackwell Publishing

18) Glagov S, Weisenberg E, Zarins CK. Compensatory management of human atherosclerotic coronary arteries. N Engl J Med 1987; 316:1371.

19) Frankel TL, Stamou SC, Lowery RC, Kapetanakis EI, Hill PC, Haile E, Corso PJ. Risk factors for hemorrhage-related reexploration and blood transfusion after conventional versus coronary revascularisation without cardiopulmonary bypass. Eur J Cardiothorac 2005; 27: 494-500.

20) Kron, Kaiser Spray. Mastery of Cardiothoracic Surgery.

21) Kapetanakis EI, Stamou SC, Dullum MKC, Hill PC, Haile E, Boyce SW, Bafi AS, Petro KR, Corso PJ. The Impact of Aortic Manipulation on neurologic Outcomes After Coronary Artery Bypass Surgery: A Risk-Adjusted Study. Ann Thorac Surg 2004; 78: 1564-71.

22) Chavanon O, Durand M, Hacini R, Bouvaist H, Noirclerc M, Ayad T, Blin D. Coronary Artery Bypass Grafting With Left Internal Mammary Artery and Right Gastroepiploic Artery, With and Without Bypass. Ann Thorac Surg 2002; 73:499-504.

23) Nuttall GA, Erchul DT, Haight TJ, Ringhofer SN, Miller TL, Oliver WC, Zehr KJ, Schroeder DR. A Comparison of Bleeding and Transfusion in Patients Who Undergo Coronary Artery Bypass Grafting Via Sternotomy With and Without Cardiopulmonary Bypass. J Cardiothorac Vasc Anesth 2003; 17(4): 447-451.

24) Chernov VI, Efimova NY, Efimova IY, Akhmedov SD, Lishmanov YB. Short-term and long-term cognitive function and cerebral perfusion in off-pump and on-pump coronary bypass patients. Eur J Cardiothorac 2006; 29: 74-81.

25) Sergeant P, Worm E, Meyns B, Wouters P. The challenge of departmental quality control in the re-engineering towards off-pump coronary artery bypass grafting. Eur J Cardiothorac Surg 2001; 20:558-543.

26) Vassiliades TA, Nielsen JL, Lonquist JL. Hemodynamic Collapse during Off-Pump Coronary

Artery Bypass Grafting. Ann Thorac Surg 2002; 73: 1874-9.

27) Kim K, Lim C, Ahn H, Yang J. Intraaortic Balloon Pump Therapy Facilitates Posterior Vessel off-Pump Coronary Artery Bypass Grafting in High-Risk Patients. Ann Thorac Surg 2001; 71:1964-8.

28) Do Q, Goyer C, Chavanon O, Couture P, Denault A, Cartier R. Hemodynamic changes during off-pump CABG surgery. Eur J Cardiothorac Surg 2002; 21:385-390.

29) Hakala T, Pitkanen O, Hartikainen J. Cardioplegic arrest does not increase the risk of atrial fibrillation after coronary artery bypass surgery. Eur J Cardiothorac Surg 2004; 25: 415-418.

30) Kastanioti C. Costs, clinical outcomes, and health-related quality of life of off-pump vs on-pump coronary bypass surgery. Eur J Cardiovasc Nurs 2006: 1-6.

31) Hirose H, Amano A, Takahashi A, Nagano N. Coronary artery bypass grafting for patients with non-dialysis-dependent renaldysfunction(serum creatinine ≥ 2.0 mg/dl). Eur J Cardiothorac Surg 2001; 20: 565-572.

32) Zimmermann N, Kurt M, Wenk A, Winter J, Gams E, Hohlfeld T. Is cardiopulmonary bypass a reason for aspirin resistance after coronary artery bypass grafting? Eur J Cardiothorac Surg 2005; 27: 606-610.

33) Dewey TM, Herbert MA, Prince SL, Robbins CL, Worley CM, Magee MJ, Mack MJ. Does Coronary Artery Bypass Graft Surgery Improve Survival Among Patients With End-Stage Renal Disease? Ann Thorac Surg 2006; 81: 591-8.

34) Capdeville M, Chamogeogarkis T, Lee JH. Effect of Gender on Outcomes of Beating Heart Operations. Ann Thorac Surg 2001; 72: S1022-5.

35) Ascione R, Narayan P, Rogers CA, Lim KHH, Capoun R, Angelini GD. Early and Midterm Clinical Outcome in patients With Severe Left ventricular Dysfunction Undergoing Coronary Artery Surgery. Ann Thorac Surg 2003; 76: 793-800.

36) Reeves BC, Ascione R, Caputo M, Angelini GD. Morbidity and mortality following acute conversion from off-pump to on-pump coronary artery surgery. Eur J Cardiothorac Surg 2006; 29: 941-947.

37) Stroobant N, Van Nooten G, Van Belleghem Y, Vingerhoets G. Short-term and long-term neurocognitive outcome in on-pump versus off-pump CABG. Eur J Cardiothorac Surg 2002; 22: 559-564.

38) Hernanadez F, Cohn WE, Baribou YR, Tryzelaar JF, Charlesworth DC, Clough RA, Klemperer JD, Morton JR, Westbrook BM, Olmstead EM, O'Connor GT. In-Hospital Outcomes of off-

Pump Versus On-Pump Coronary Artery Bypass Procedures: A Multicentre Experience. Ann Thorac Surg 2001; 72: 1528-34.

39) Louagie Y, Jamart J, Broka S, Collard E, Scavee V, Gonzalez M. Off-pump coronary artery bypass grafting: a case-matched comparison of hemodynamic outcome. Eur J Cardiothorac Surg 2002; 22: 552-558.

40) Edgerton JR, Dewey TM, Magee MJ, Herbert MA, Prince SL,Jones KK, Mack MJ. Conversion in Off-Pump Coronary Artery Bypass Grafting: An Analysis of Predictors and Outcomes. Ann Thorac Surg 2003; 76: 1138-43.

41) Jones RH. Intraoperative Crossover: The Well-Kept Surgical Secret to Apparent Surgical Success. JACC 2005; 45 (9): 1529-31.

42) Kobayashi J, Tashiro T, Ochi M, Yaku H, watanabe G, Satoh T, Tagusari O, Nakajima H, Kitamura S, Japanes Off-Pump Coronary Revascularisation Investigation (JOCRI)Study Group. Circulation 2005; 112: 338-343.

43) Doering LV, Imperial-Perez F, Monsein S, Esmailain F. Preoperative and postoperative predictors of early and delayed extubation after coronary artery surgery. Am J Crit Care 1998; 7:37-44.

44) Casati V, Gerli C, Franco A, Della Valle P, Benussi S, Alfieri O, Torri G, D'Angelo A. Activation of coagulation and fibrinolysis during coronary surgery: on-pump versus off-pump techniques. Anesthesiology 2001; 95:1103-9.

45) Baud O, Lacaze-Masmonteil T, Monsaingeon-Lion A, Chabernaud JL, Zupan V, Boithias C, Andre P, Gross E, Dehan M. Eur J Pediatr 1998; 157:579-82.

46) Grubitzch H, Wollert HG, Eckel L. Emergency coronary artery bypass grafting: does excessive pre-operative anticoagulation increase bleeding complications and transfusion requirements? Cardiovasc Surg 2001; 9: 510-6.

47) Zangrillo A, Crescenzi G, Landoni G, Leoni A, Marino G, Calabro MG, Corno C, Pappalardo F, Alfieri O. Off-pump Coronary Artery Bypass Grafting Reduces Postoperative Neurologic Complications. J Cardiothorac Vasc Anesth 2005; 19 (2): 193-196.

48) Puskas JD, Williams WH, Mahoney EM, Huber PR, Block PC, Duke PG, Staples JR, Glas KE, Marshall JJ, Leimbach ME, McCall SA, Petersen RJ, Bailey DE, Weintraub WS, Guyton RA. Off-Pump vc Conventional Coronary Artery Bypass Grafting: Early and 1-Year Graft Patency, Cost and Quality of Life Outcomes: A randomized Trial. JAMA 2004; 291(15): 1841-1849.

49) Widimsky P, Straka Z, Stros P, Jirasek K, Dvorak J, Votava J, Lisa L, Budesinsky T, Kolesar M,

Vanek T, Brucek P. One-Year Coronary Bygraft Patency: A Randomised Comparison Between Off-Pump and On-Pump Surgery; Angiographic Results of the PRAGUE-4 Trial. Circulation 2004; 110: 3418-3423.

50) Van der Heijden GJMG, Nathoe HM, Jansen EWL, Grobbee DE. Meta-analysis on the effect of off-pump coronary bypass surgery. Eur J Cardiothorac Surg 2004; 26: 81-84.

51) Reston JT, Tregear SJ, Turkelson CM. Meta-Analysis of Short-Term and Mid-Term Outcomes Following Off-Pump Coronary Artery Bypass Grafting. Ann Thorac Surg 2003; 76: 1510-5.

52) Di Mauro M, Gagliardi M, Iaco AL, Contini M, Bivona A, Bosco P, Gallina S, Calafiore AM. Does Off-Pump Coronary Surgery Reduce Postoperative Acute Renal failure? The Importance of Preoperative Renal Function. Ann Thorac Surg 2007; 84: 1496-503.

53) Andersson LG, Ekroth R, Bratteby LE, Hallhagen S, Wesslen O. Acute renal failure after coronary surgery: a study of incidence and risk factors in 2009 consecutive patients. J Thorac Cardiovasc Surg 1993; 41:237-41.

54) Chertow GM, Lazarus JM, Christiasen, Cook EF, Hammermeister KE, Grover F, Daley J. Preoperative renal risk stratification. Circulation 1997; 95:878-84.

55) Stallwood MI, Grayson AD, Mills K, Scawn ND. Acute renal failure in coronary in coronary artery bypass surgery. Independent effect of cardiopulmonary bypass. Ann Thorac Surg 2004; 77: 968-72.

56) Zanardo G, Michielon P, Paccagnella A. Acute renal failure in the patient undergoing cardiac operation. Prevalence, mortality rate and main risk factors. J Thorac Cardiovasc Surg 1994; 107: 1489-95.

57) Ascione R, Lloyd CT, Underwood MJ, Gomes WJ, Angelini GD. On-pump versus off-pump coronary revascularisation: evaluation of renal function. Ann Thorac Surg 1999; 68: 493-8.

58) Loef BG, Epema AH, Navis G, Ebels T, van Overen W, Henning RH. Off-pump coronary revascularisation attenuates transient renal damage compared with on-pump revascularisation. Chest 2002; 121: 1190-4.

59) Zhou W, Farrar CA, Abe K. Prominent role for C5b-9 in renal ischemia/reperfusion injury. J Clin Invest 2000; 105: 1363-71.

60) Karkouti K, Beattie WS, Wijeysundera DN. Hemodilution during cardiopulmonary bypass is an independent risk factor for acute renal failure in adult cardiac surgery. J Thorac Cardiovasc Surg 2005; 129: 391-400.

61) Bharathi HS, Seifert FC, Grimson R, Glass PSA. Octogenarians Undergoing Coronary Artery

Bypass Graft Surgery: Resource Utilization, Postoperative Mortality and Morbidity. J Cardiothorac Vasc Anesth 2005; 19(5): 583-588.

62) Hirose H, Amano A, Takahashi A. Off-Pump Coronary Artery Bypass Grafting for Elderly Patients. Ann Thorac Surg 2001; 72: 2013-9.

63) Murkin JM, Marizke JS, Buchan AM, Bentley C, Wong CJ. A randomised study of the influence of perfusion technique and pH management strategy in 316 patients undergoing coronary bypass surgery. J Thorac Cardiovasc Surg 1995; 110:349-62.

64) Newman MF, Kirchner JL, Phillips-Bute B, Gaver V, Grocott H, Jones RH, Mark DB, Reves JG, Blumenthal JA. Longitudinal assessment of neurocognitive function after coronary artery bypass surgery. N Engl J Med 2001; 344: 395-402.

65) Abu-Omar Yasir, Cifelli A, Matthews PM, Taggart DP. The role of microembolisation in cerebral injury as defined by functional magnetic resonance imaging. Eur J Cardiothorac Surg 2004; 26: 586-591.

66) Patel NC, Deodhar AP, Grayson AD. Neurological outcomes in coronary surgery: independent effects of avoiding cardiopulmonary. Ann Thorac Surg 2002; 74:400-6.

67) Hirose H, Amano A. Stroke rate of off-pump coronary artery bypass: aortocoronary bypass versus in-situ bypass. Angiology 2003; 54: 647-53.

68) Taggart DP, Westaby S. Neurological and cognitive disorders after coronary artery bypass grafting. Curr Opin Cardiol 2001; 16: 271-6.

69) Puskas JD, Winston AD, Wright CE. Stroke after coronary artery operations, incidence, correlates, outcomes and costs. Ann Thorac Surg 2000; 69: 1053-6.

70) Sirivella S, Gielchinsky I, Parsonnet V. Results of Coronary Artery Endarterectomy and Coronary Artery Bypass Grafting for Diffuse Coronary Artery Disease. Ann Thorac Surg 2005; 80:1738-45.

71) Siebert J, Anisimowicz L, Lango R, Rogowski J, Pawlaczyk R, Brzezinski M, Beta S, Narkiewicz M. Atrial fibrillation after coronary artery bypass grafting: does the type of procedure influence the early postoperative incidence? Eur J Cardiothorac Surg 2001; 19:455-459.

72) Choi J, Cho KR, Kim K. Does Diabetes Affect the Postoperative Outcomes After Total Arterial Off-Pump Coronary Bypass Surgery in Multivessel Disease? Ann Thorac Surg 2005; 80:1353-61.

73) Kuduvalli M, Newall N, Stott A, Grayson AD, Fabri BM. Impact of avoiding cardiopulmonary

bypass for coronary surgery on perioperative cardiac enzyme release and survival. Eur J Cardiothorac Surg 2006; 29:727-735.

74) Kim K, MD, Lim C, Lee C, Chae I, Oh B, Lee M, MD, Park Y. Off-Pump Coronary Artery Bypass May Decrease the Patency of Saphenous Vein Grafts. Ann Thorac Surg 2001; 72: S1033-7.

75) Le´gare J, Buth KJ, Hirsch GM. Conversion to on pump from OPCAB is associated with increased mortality: results from a randomized controlled trial. Eur J Cardiothorac Surg 2005; 27: 296–301.

76) Musleh GS, Patel NC, Grayson AD, Pullan DM, Keenan DJM, Fabri BM, Hasan R. Off-pump coronary artery bypass surgery does not reduce gastrointestinal complications. Eur J Cardiothorac Surg 2003; 23: 170–174.

77) Reddy SLC , Grayson AD, Oo AY, Pullan MD,Poonacha T, Fabri BM. Does off-pump surgery offer benefit in high respiratory risk patients? A respiratory risk stratified analysis in a propensity-matched cohort. Eur J Cardiothorac Surg 2006; 30: 126—131.

78) Hirose H, Amano A, Takahashi A. Off-Pump Coronary Artery Bypass Grafting for Elderly Patients. Ann Thorac Surg 2001; 72:2013–9.

79) Jensen BØ, Hughes P, Rasmussen LS, Pedersen PU, Steinbru¨chel DA. Health-related quality of life following off-pump versus on-pump coronary artery bypass grafting in elderly moderate to high-risk patients: a randomized trial. Eur J Cardiothorac Surg 2006; 30: 294—299.

80) Cleveland JC, Shroyer ALW, Chen AY, Peterson E, Grover FL. Off-Pump Coronary Artery Bypass Grafting Decreases Risk-Adjusted Mortality and Morbidity. Ann Thorac Surg 2001; 72: 1282–9.

81) Stamou SC, Jablonski KA, Garcia JM, Boyce SW, Bafi AS, Corso PJ. Operative mortality after conventional versus coronary revascularization without cardiopulmonary bypass. Eur J Cardiothorac Surg 2004; 26: 549–553.

82) Stamou SC, Jablonski KA, Hill PC, Bafi AS, Boyce SW, Corso PJ. Coronary Revascularization Without Cardiopulmonary Bypass Versus the Conventional Approach in High-Risk Patients. Ann Thorac Surg 2005;79: 552–7.

83) Gerola LR, Buffolo E, Jasbik W, Botelho B, Bosco J, Brasil LA, Branco JNR. Off-Pump Versus On- Pump Myocardial Revascularization in Low-Risk Patients With One or Two Vessel Disease: Perioperative Results in a Multicenter Randomized Controlled Trial. Ann Thorac Surg 2004;77: 569–73.

84) Brown JM, Poston RS, Gammie JS, Cardarelli MG, Schwartz Ki, Sikora JAH, Yi S, Pierson III RN, Griffith BP. Off-Pump Versus On-Pump Coronary Artery Bypass Grafting in Consecutive Patients: Decision-Making Algorithm and Outcomes. Ann Thorac Surg 2006;81: 555–61.

85) Puskas JD, Thourani VH, Marshall JJ, Dempsey SJ, Steiner MA, Sammons BH, Brown III WM, Gott J P, Weintraub WS, Guyton RA. Clinical Outcomes, Angiographic Patency, and Resource Utilization in 200 Consecutive Off-Pump Coronary Bypass Patients. Ann Thorac Surg 2001;71: 1477–84.

86) Mack MJ, Brown PP, Kugelmass AD, Battaglia SL, Tarkington LG, Simon AW, Culler SD, Becker ER. Current Status and Outcomes of Coronary Revascularization 1999 to 2002: 148,396 Surgical and Percutaneous Procedures. Ann Thorac Surg 2004; 77:761–8.

87) Shennib H, Endo M, Benhamed O, Morin JF. Surgical Revascularization in Patients With Poor Left Ventricular Function: On- or Off-Pump?Ann Thorac Surg 2002;74:S1344–7.

88) Scott,BH, Seifert FC, Grimson R, Glass PSA. Resource Utilization in On- and Off-Pump Coronary Artery Surgery: Factors Influencing Postoperative Length of Stay—An Experience of 1,746 Consecutive Patients Undergoing Fast-Track Cardiac Anesthesia. J Cardiothorac Vasc Anesth 2005; 19(1):26-31.

89) Lee JD, Lee SJ, Tsushima WT, Yamauchi H, Lau WT, Popper J, Stein A, Johnson D, Lee D, Petrovitch H, Dang CR. Benefits of Off-Pump Bypass on Neurologic and Clinical Morbidity: A Prospective Randomized Trial. Ann Thorac Surg 2003; 76:18–26.

90) Al-Ruzzeh S, Nakamura K, Athanasiou T, Modine T, George S, Yacoub M, Ilsley C, Amrani M. Does off-pump coronary artery bypass (OPCAB) surgery improve the outcome in high-risk patients? a comparative study of 1398 high-risk patients. Eur J Cardiothorac Surg 2003; 23: 50–55.

91) Stamou SC, Jablonski KA, Garcia JM,Boyce SW, Bafi AS, Corso PJ. Operative mortality after conventional versus coronary revascularization without cardiopulmonary bypass. Eur J Cardiothorac Surg 2004; 26: 549–553.

92) Aboyans V, Labrousse L, Lacroix P, Guilloux J, Sekkal S, Le Guyader A, Cornu E, Laskar M. Predictive factors of stroke in patients undergoing coronary bypass grafting: statins are protective§. Eur J Cardiothorac Surg 2006; 30:300—304.

93) Gobran SR, Goldman S, Ferdinand F, Wertan MA, Trace C, Grunkemeier GL, Wu YX, Sutter FP. Outcomes After Usage of a Quality Initiative Program for Off-Pump Coronary Artery

Bypass Surgery: A Comparison With On-Pump Surgery. Ann Thorac Surg 2004; 78:2015–21.

94) Eryilmaz S, Corapcioglu T, Eren NT, Yaziciog˘lu L, Kaya K, Akalin H. Off-pump coronary artery bypass surgery in the left ventricular dysfunction. Eur J Cardiothorac Surg 2002; 21: 36–40.

95) Al-Ruzzeh SF, George S, Yacoub M, Amrani M. The clinical outcome of off-pump coronary artery bypass surgery in the elderly patients. Eur J Cardiothorac Surg 2001; 20: 1152–1156.

96) Swart MJ, Coetzer S, Korb A.,Schoeman C, Joubert G. The prevalence of risk factors for coronary artery disease in patients who had had CABG. Cardiovasc J SA 2005; 16(4): 227-8.

97) Englberger L, Immer FF, Eckstein FS, Berdat PA, Haeberli A,Carrel TP. Off-Pump Coronary Artery Bypass Operation Does Not Increase Procoagulant and Fibrinolytic Activity: Preliminary Results. Ann Thorac Surg 2004; 77:1560–6.

98) Brown PP, Mack MJ, Simon AW, Battaglia S, Tarkington L, Horner S, Culler SD, Becker ER. Outcomes Experience With Off-Pump Coronary Artery Bypass Surgery in Women. Ann Thorac Surg 2002; 74:2113–20.

99) Onorati F, De Feo M, Mastroroberto P, di Virgilio A, Esposito A, Polistena M, Renzulli A, Cotrufo M. Unstable angina and non-ST segment elevation: surgical revascularization with different strategies. Euro J Cardiothorac Surg 2005; 27: 1043–1050.

100) Sergeant P, Wouters P, Meyns B, Bert C, Van Hemelrijck J, Bogaerts C, Sergeant G, Slabbaert K. OPCAB versus early mortality and morbidity: an issue between clinical relevance and statistical significance. Eur J Cardiothorac Surg 2004; 25: 779–785.

101) Montes FR, Maldonado JD,PaezS, Ariza,F. Off-Pump Versus On-Pump Coronary Artery Bypass Surgery and Postoperative Pulmonary Dysfunction. J Cardiothorac Vasc Anesth 2004;18 (6):698-703.

102) Bergsland J, Kabil E, Mujanovic E, Terzic I, Røislien J, Svennevig JL, Fosse E. Training of Cardiac Surgeons for Bosnia and Herzegovina: Outcomes in Coronary Bypass Grafting Surgery. Ann Thorac Surg 2007; 83:462–7.

103) Hernandez F, Brown JR, Likosky DS, Clough R A, Hess AL, Roth RM, Ross CS, Whited CM, O'Connor GT, Klemperer JD. Neurocognitive Outcomes of Off-Pump Versus On-Pump Coronary Artery Bypass: A Prospective Randomized Controlled Trial. Ann Thorac Surg 2007; 84:1897–903.

104) D'Ancona G, Karamanoukian H, Soltoski P, Salerno T, Bergsland J. Changing referral pattern in off-pump coronary artery bypass surgery:a strategy for improving surgical results. Heart Surg

Forum 1999;2 (3):246–249.

105) Fuster RG, Montero JA, Gil Ó, Hornero F, Cánovas S, Bueno M, Buendía J, Rodríguez I. Trends in Coronary Artery Bypass Surgery: Changing Type of surgical Patient. Rev Esp Cardiol. 2005; 58 (5):512-22.

106) Mizutani S, Matsuura A, Miyahara K, Eda T, Kawamura A, Yoshioka T, and Yoshida K. On-Pump Beating-Heart Coronary Artery Bypass: A Propensity Matched Analysis. Ann Thorac Surg 2007; 83:1368–73.

107) Shennib H, Endo M, Benhamed O, Morin JF. Surgical Revascularization in Patients With Poor Left Ventricular Function: On- or Off-Pump. Ann Thorac Surg 2002; 74: S1344-7.

108) Shroyer A.L, Grover FL, Hattler B, Collins JF, McDonald GO, Kozora E, Lucke JC, Baltz JH,Novitzky D for the Veterans Affairs Randomized On/Off Bypass (ROOBY) Study Group. On-Pump versus Off-Pump Coronary-Artery Bypass Surgery. N Engl J Med 2009; 361:1827-37.

109) Janssen DPB, Noyez L, Wouters C, Brouwer RMHJ. Preoperative prediction of prolonged stay in the intensive care unit for coronary bypass surgery. Eur J Cardiothorac Surg 2004; 25: 203–207.

110) Syed A, Fawzy H, Farag A, Nemlander A. Comparison of Pulmonary Gas Exchange in OPCAB Versus Conventional CABG. Heart Lung and Circulation 2004169; 13:168–172.

111) Racz MJ, Hannan EL, Isom OW, Subramanian V A, Jones RH, Gold JP, Ryan TJ, Hartman A, Culliford AT, Bennett E, Lancey RA, Rose EA. A Comparison of Short- and Long-Term Outcomes After Off-Pump and On-Pump Coronary Artery Bypass Graft Surgery With Sternotomy. JACC 2004;43(4): 557-64.

TABLES AND FIGURES

Table 1: Preoperative Characteristics (Categorical Variables)

	OPCAB (N=199)			CABG-CPB (N=143)			
	Available data	Factor Present	%	Available data	Factor Present	%	P value
Gender(F)	50		25.1	38		26.6	0.76
Gender(M)	149		74.9	105		73.4	
Obesity	141	42	30	118	34	29	0.76
MI	197	109	55.3	141	83	58.9	0.52
Hypertension	198	129	65.1	142	98	69	0.46
DM	197	60	30.4	142	51	35.9	0.29
COPD	196	27	13.8	141	10	7.1	0.05
Renal Failure	195	6	3	141	3	2.1	0.6
Previous CVA	192	6	3.1	141	4	2.8	0.88
Smoking	196	148	75.5	142	102	71.8	0.45
Hyper CHL	197	115	58.4	141	83	58.9	0.93
PVD	195	18	9.23	141	14	9.92	0.83
CAD Family History	194	134	69	143	79	55.2	0.01
Pre-op Aspirin	195	166	85.1	137	117	85.4	0.95
NYHA I	197	27	13.7	138	19	13.8	0.74
II		70	35.5		49	35.5	
III		67	34		41	29.7	
IV		33	16.8		29	21	
CCS I	197	9	4.6	139	1	0.7	0.15
II		41	20.8		25	18	
III		80	40.6		55	40	
IV		67	34		58	41.7	
AF	195	18	9.2	138	11	8	0.69
IABP	189	18	9.5	133	17	12.8	0.36
Previous cardiac Operation	197	11	5.6	137	4	2.9	0.25

Previous PCI	199	27	13.6	143	11	7.7	0.09

Legend

- MI: Myocardial Infarction
- COPD: Chronic Obstructive Pulmonary Disease
- CVA: Cerebro-Vascular Accident
- HyperCHL: Hypercholesterolaemia
- PVD: Peripheral Vascular Disease
- CAD: Coronary Artery Disease
- NYHA: New York Heart Association
- CCS. Canadian Cardiovascular Society
- AF: Atrial Fibrillation
- IABP: Intra-aortic balloon pump
- PCI: Percutaneous Coronary Intervention

Table 2: Preoperative Characteristics (Continuous Variables)

	OPCAB (N=199)					CABG-CPB (N=143)					
	Available data	Min	Max	Mean	ST Dev	Available data	Min	Max	Mean	ST Dev	P value
Age(years)	199	23.4	84.3	59.2	10.54	142	33.9	84.8	60.1	9.66	0.42
BMI	141	17.1	47.4	28.3	4.65	118	19.3	40.6	28.1	4	0.76
ASI(Days)	146	0	17	3.51	3.16	96	0	14	3.06	2.73	0.26
LVEF	187	13	88	56.9	14.74	133	20	92	56.7	13.4	0.91
Pre-op Creatinine	164	43	525	96.5	50.7	121	49	164	90.7	24.8	0.25

Legend

- BMI: Body Mass Index
- ASI: Aspirin Stoppage Interval
- LVEF: left Ventricular Ejection Fraction

Table 3: Intra-Operative Characteristics (Categorical Variables)

	OPCAB(N=199)			CABG-CPB(N=143)			
	Available Data	Factor Present	%	Available Data	Factor Present	%	P Value
Priority of Operation Elective	199	131	65.8	139	78	56.1	0.17
Urgent		53	26.6		50	36	
Emergency		15	7.5		11	7.9	
Cell Saver Use	196	51	26	140	9	6.4	0
IABP use	198	17	8.6	139	24	17.3	0.03

Legend
IABP: Intra-aortic balloon pump

Table 4: Intra-Operative Characteristics (Continuous Variables)

	OPCAB(N=199)					CABG-CPB(N=143)					
	Available data	Min	Max	Mean	ST Dev	Available data	Min	Max	Mean	ST Dev	P Value
Distal Anastomoses	196	1	5	3.31	0.9	139	1	5	3.45	0.83	0.15
CPB Duration (Minutes)						118	12	432	123.4	47	
Aortic Cross-clamp Duration(Minutes)						89	33	128	76.7	18.4	

Legend
CPB: Cardiopulmonary Bypass

Table 5: Target and Conduits Vessels

	OPCAB(N=199)			CABG-CPB (N=143)			
Conduit	Available data	Factor Present	%	Available data	Factor Present	%	P Value
LIMA	196	183	93.4	138	124	90	0.35
RIMA	196	12	6.1	138	1	0.7	0.01
SVG	196	144	73.5	138	131	95	0
RA	196	49	25	138	16	11.6	0
GEPA	196	2	1	138	0	0	0.11
Targets							
LAD	195	191	98	138	136	98.5	0.68
Diagonals	196	106	54.1	138	75	54.3	0.96
OM	196	152	77.5	138	117	84.8	0.1
Ramus	196	27	13.8	138	16	11.6	0.56
RCA	196	9	4.6	138	18	13	0.01
PDA	196	123	62.7	138	75	54.3	0.12
PLWB	196	12	6.1	138	8	5.8	0.9
Sequential Grafts	196	104	53.1	138	63	45.7	0.24
TAR	196	51	26	138	6	4.3	0

Legend

LIMA: Left Internal Mammary Artery
RIMA: Right Internal Mammary Artery
SVG: Saphenous Vein Graft
RA: Radial Artery
GEPA: Gastroepiploic Artery
TAR: Total arterial revascularisation
LAD: Left Anterior Descending Artery
OM: Obtuse marginal artery
RCA: Right Coronary Artery
PDA: Posterior Descending Artery
PLWB: Posterolateral wall

Table 6: Postoperative Characteristics (Categorical Variables)

	OPCAB(N=199)			CABG-CPB (N=143)			
	Available data	Factor Present	%	Available data	Factor Present	%	P Value
MI	199	5	2.5	142	1	0.7	0.21
Renal Failure	199	8	4	142	10	7	0.22
Septicaemia	199	3	1.5	143	8	5.6	0.04
Pneumonia	199	17	8.5	143	10	7	0.6
DSW Infection	199	1	0.5	143	6	4.2	0
CVA	199	2	1	143	8	5.6	0.01
AF	199	4	2	143	6	4.2	0.24
Re-exploration for Haemorrhage'	199	2	1	143	4	2.8	0.24
Death	199	6	3	143	13	9	0.02

Legend
MI: Myocardial Infarction
DSW: Deep Sternal Wound Infection
CVA: Cerebro-Vascular Accident
AF: Atrial Fibrillation

Table 7: Postoperative Characteristics (Continuous Variables)

	OPCAB (N=199)					CABG-CPB (N=143)					
	Available data	Min	Max	Mean	ST Dev	Available data	Min	Max	Mean	ST Dev	P Value
ICU Duration(hours)	166	7	1147	80.7	115.6	116	10	1250	104.1	177	0.1
MV Duration(hours)	171	0	576	22.38	45.1	126	3	1200	38.3	112.2	0.09
ICU Blood loss(ml)	170	175	3730	808.5	484.2	125	360	3050	988.2	541.6	0
RBC Transfusion(Units)	40	1	5	1.72	0.72	69	1	19	2.66	2.64	0.03
Postoperative Ward Stay (Days)	163	1	40	5.5	4.35	107	1	71	7.4	9	0.01

Legend
ICU: Intensive Care Unit
MV: Mechanical Ventilation
RBC: Red Blood Cell

Table 8: Follow up Characteristics (Categorical Variables)

	OPCAB(N=199)			CABG-CPB(N=143)			
	Available data	Factor Present	%	Available data	Factor Present	%	P Value
Angina Recurrence	98	18	18.4	98	20	20.4	0.72
MACE	98	20	20.4	98	23	23.5	0.61

Legend
MACE: Major Adverse Cardiac Event

Table 9: Follow Up Characteristics (Continuous Variables)

	OPCAB (N=199)					CABG-CPB(N=143)					
	Available data	Min	Max	Mean	ST Dev	Available data	Min	Max	Mean	ST Dev	P Value
Follow up Duration(months)	98	0.25	91	18	22.8	98	1	89	15.3	21.1	0.43
Angina-Recurrence Interval(months)	18	1	26	8.3	6.89	14	1.5	86	23.4	24.7	0.02

Table 10: Comparison of This Study's Figures with The Literature (Pre-operative Characteristics: Categorical variables)

	Study		Literature		
Variable	**OPCAB (%)**	**CABG-CPB (%)**	**OPCAB (%)**	**CABG-CPB (%)**	**References**
Age					
Female Gender	25.1	26.6	15.8-23.6	19-20.4	46, 72,74,75
Previous MI	55.3	58.9	28-69	30-78	78,79,80
Hypertension	65.1	69	48.8-70	40-56.4	72,73,74,75
DM	30.4	35.9	18-45.5	14-50.5	76,78,81,82,83
Renal Failure	3	2.1	3.2-9.7	0.38-8.7	72, 84, 85, 86, 87
Previous CVA	3.1	2.8	6-9	3-12.7	84, 88,89,90,91,92
Smoking	75.5	71.8	43-72.9	46.2-78	73,78,88 ,93
Hyper CHL	58.4	58.9	25.4-91.5	20-84.9	72,73,74,75,82,83
PVD	18	10	4-27.3	10.2-18	75,79,83,89,94
COPD	13.8	7.1	3.2-16.6	4.1-19.7	74,77,79,83,85,86
CAD Family History	69	55.2	25-60	23-57.2	7,27,29,83,95
Pre-op Aspirin	85.1	85.4	88-100	75-100	88,96
Pre-op AF	9.2	8	5-25.8	2.7-14.2	74,77,78,83,91,97
NYHA III/IV	50.8	50.7	2-64.8	1-58.8	41,47,79,98
CCS III/IV	74.6	81.7	12-72.2	10-72.3	41,47,74,79,82
Pre-op IABP	9.5	12.8	1-10	4-11.6	46,74,79,80,81,94
Previous Cardiac Operation	5.6	2.9	0-7.9	0-8	46,72,75,76,77,79,80,83,90,99
Previous PCI	13.6	7.7	7-30	10-21	34,41,79

Legend

- MI: Myocardial Infarction
- COPD: Chronic Obstructive Pulmonary Disease
- CVA: Cerebro-Vascular Accident
- HyperCHL: Hypercholesterolaemia
- PVD: Peripheral Vascular Disease
- CAD: Coronary Artery Disease
- CCS. Canadian Cardiovascular Society
- AF: Atrial Fibrillation
- IABP: Intra-aortic balloon pump
- PCI: Percutaneous Coronary Intervention
- NYHA: New York Heart Association

APPENDIX

Proforma for Off-Pump Coronary Bypass Grafting Outcomes

1) Hosp No:
2) Age:
3) Gender:
4) Weight (kgs):
5) Height(cm):
6) BMI:

Pre-op Data

7) Risk factors: Yes/No
    a) MI
    b) Hypertension
    c) DM
    d) COPD
    e) Renal failure
    f) Previous CVA
    g) Smoking
    h) Hypercholesterolaemia
    i) Peripheral vascular disease / Carotid disease. Previous TIA / Stroke
    j) Family History
8) Pre-op anticoagulant use;
    a) Aspirin ; Days stopped pre-op:
    b) Warfarin

9) Pre-op AF; Yes/No
10) Pre-op Mitral regurgitation / other valve pathology
11) Pre-op medication:
12) Pre-op NYHA Class:
13) Pre-op CCS Class:
14) LVEF;
    a) < 30
    b) 30-49
    c) > 50
15) Duration of angina:
16) Investigations;
    a) Hb:
    b) INR:
    c) HIV status
    d) HBV status
    e) Creatinine:
17) Indication for surgery:
18) Preop IABP; Yes/No
19) Previous cardiac operation; Yes/No
20) Elective / Urgent / Emergency

Intra-Op Data

21) CPB: Yes/No
22) Conversion to ONCAB: Yes/No
23) Reason for conversion:
24) CPB duration (minutes):
25) Aortic Cross-clamp time (minutes)
26) Intra-aortic balloon pump use: Yes/No
27) Cell Saver Use: Yes/No
28) No of Grafts
29) Graft Distribution: tick appropriate one

	Grafts
a) LAD	A) LIMA
b) RCA/PDA	B) Radial
c) OM	C) SVG
d) D	D) RIMA
e) PLWB	
f) Ramus	

Post-operative data

30) ICU Duration (hours):
31) Duration of Ventilation (hours)
32) Blood loss in ICU (ml):
33) Blood transfusion ICU;
    a) RBCs
    b) FFP
    c) Cryoprecipitate
    d) Platelets
34) Complications (tick appropriate one)
    a) Post-op MI; Yes/No
    b) Renal failure (Creatinine:>200)
       Any dialysis? Yes/No
    c) Sepsis;
    d) Pneumonia
    e) Deep sternal infection
    f) Superficial Wound infection
    g) Other
    h) Neurological
    i) Stroke
       Other
    j) Re-operation:
    k) Incomplete revascularization:
    l) Atrial fibrillation: Yes/No
    m) Death:
    n) Cause of Death:
35) Post-op ward stay (days):

Follow-up

36) Length of Follow-up (months):
37) Angina recurrence: Yes/No
38) If (38) Yes: When?
39) MI recurrence: Yes/No
40) If (40) yes: When?
41) Coronary angiography performed – when
42) Death / Morbidity/ Major Adverse Cardiac Event (MACE);