Off Pump CABG Anesthetic and Surgical Consideration

Vipin Mehta*

Department of Anesthesia, Critical Care and Pain Medicine, Massachusetts General Hospital, USA

*Corresponding author: Vipin Mehta, Department of Anesthesia, Critical Care and Pain Medicine, Massachusetts General Hospital, 55 Fruit Street, Clinics 309, Boston

Received: December 18, 2013; Accepted: February 03, 2014; Published: February 10, 2014

Abstract

Introduction and background: Off pump cardiac coronary artery bypass graft (OPCABG) reached its peak usage at around 25% in 2004. Since then, there has been a decline in use of this technique to a level much below its peak. In contrast, the OPCABG’s percentage of total coronary artery bypass graft (CABG) surgery is much higher in Brazil, India (over 90%), Japan (over 60%), China and many other Asian countries. However, its application is still being debated for several decades.

OPCABG is technically demanding both for anesthesiologists and surgeons, but since it is still widely used there is continuing need to contrast its results and benefits with conventional bypass. This review will look at the technique, challenges, and literature related to off pump surgery, and will specifically address effects on graft patency, inflammatory response, neurological and cognitive deficits, early discharge, long-term survival and quality of life. Also reviewed will be anesthetic and surgical techniques and results for off-pump, minimally invasive, and robotic surgery.

Methods and results: This was reviewed was accomplished by a comprehensive retrieval of literature published over last two decades by Pubmed and Google Scholar. A systematic search was done to look for publications featuring a large number of cases. The goal of the inclusion criteria was to derive information from articles published in major anesthesia and surgical journals. In order to make this review comprehensive, articles describing history, evolution of off-pump surgical technique, graft patency, and early and late outcome data were included. Published meta-analyses were also reviewed to find outcome differences between off-pump and on-pump coronary bypass surgery regarding rates of atrial fibrillation, neurological deficit, and cognitive deficit. Also reviewed is literature on robotic minimally invasive techniques providing complete revascularization with or without coronary angioplasty and intracoronary stents performed in the cardiac catheterization laboratory.

Publications or reviews from the early years of off-pump surgery (1990-2000) were mostly not included; primarily because the technique has significantly evolved in the past decade as a result of the development of new surgical and anesthetic devices and significantly increased experience amongst the providers with stated techniques. Some references were included to provide a historical basis of the technique. For example, early off-pump surgery primarily involved a 1-2 vessel coronary bypass grafting to the left anterior descending coronary artery and/or its diagonal branch. Currently used equipment and devices used to facilitate surgery were not available. In contrast, the current goal in the majority of modern OPCABG surgery is to achieve complete revascularization of all the diseased coronary arteries. This may include revascularization performed by the catheterization laboratory prior to or immediately after off-pump surgery.

Conclusion: This review concludes that most of the studies showed reduced length of stay, operative morbidity and mortality. There has been consistent evidence showing decreased incidence of bleeding and coagulopathy in patients who had off -pump coronary bypass surgery compared to on-pump surgery. There is also some evidence of a decreased incidence of neurological complications and cognitive dysfunction following off-pump coronary bypass surgery, especially when aorta is not manipulated. Also, off-pump bypass will continue to be the indicated technique when cannulation of the aorta is contraindicated.

Introduction

The mid-20th century, off-pump coronary artery bypass was the primary bypass surgery performed in the world. The development of extracorporeal cardiopulmonary bypass (CPB) in the 1950s and 1960s allowed surgeons to perform bypass procedure under safer, more optimal operating conditions and on-pump CABG predominated. An early mention of OPCABG was in 1957, when Bailey and a year later Longmire reported the first coronary revascularization on beating heart [1]. Kolesov reported using the LIMA for coronary bypass without the pump in 1967 [2,3]. By 2001, 18.6% of coronary bypass procedures were done without going on bypass, according to the 2001 registry compiled by The Society of Thoracic Surgeons.

Abbreviations

LIMA: Left Internal Mammary Artery; RIMA: Right Internal Mammary Artery; PDA: Posterior Descending Artery; CABG: Coronary Artery Bypass Grafting; OPCABG: Off-Pump Coronary Artery Bypass Graft; LAD: Left Anterior Descending; MIDCABG: Minimal Invasive Direct Coronary Artery Bypass Graft; EKG: Electrocardiogram; TEE: Tran Esophageal Echocardiography; PFO: Patent Foramen Ovale; BHACAS: Beating Heart Against Cardioplegic Arrest Study; CPB: Cardio Pulmonary Bypass; HRQoL: Health-Related Quality of Life; MACE: Major Adverse Cardiac-related Event
Since the 1980s, there has been a resurgence of OPCAB fueled by the prospect of possibly avoiding the morbidities associated with CPB, aortic cannulation/clamping, hypothermic cardiopulmonary arrest, and systemic hemodilution. To assess this claim, this review will revisit some of the literature on benefits and limitations of OPCAB. Also reviewed are the techniques of anesthetic management, surgical techniques, and immediate postoperative management of patients undergoing standard, minimally invasive, and robotic OPCAB.

Early evolution of the surgical technique

Early off pump bypass surgery of the 1960s was predominately a single-vessel bypass procedure from the left internal mammary artery (LIMA) to the left anterior descending (LAD) division of the left coronary artery. Occasionally, bypass was made to the left coronary artery’s diagonal branch using side-to-side anastomosis with the LIMA, or using a separate vein graft anastomosed to the aorta using a side clamp [6]. Initially, pharmacological means were used to facilitate the anastomosis. The heart rate was slowed down with the use of boluses or continuous infusion of esmolol. The distal LAD anastomosis was performed with a lap-pad/surgical pack under the ventricle to get better exposure. Adenosine boluses were used to stop heart for few seconds to facilitate distal anastomosis [7].

In the next decades, Cardiothoracic Systems, Medtronic, Genzyme and several companies made major advances in developing stabilizers that allowed anastomoses to be performed more safely. Some devices stabilize the distal anastomosis site by compressing and other devices, such as the Octopus (Medtronic, Minneapolis, MN, USA), use suction to stabilize distal anastomosis site [8].

Grafting distal vessels in the beating heart was considered inaccessible in a beating heart without compromising hemodynamics, and this was especially a concern in patients with poor ventricular function. Several techniques were developed during this period to make this possible including the use of deep pericardial sutures to allow the manipulation and rotation of heart to access otherwise inaccessible vessels during beating heart surgery [9,10,11]. In patients with dilated ventricles, the use of gauze and pack to compress right ventricle allowed exposure of target vessels. The opening of the right pleura in some cases was beginning to be employed to get exposure without compromising hemodynamics. The development of the apical suction device allowed further rotation and manipulation of heart, allowing access to distal right and circumflex artery branches [12,13,14]. Devices to facilitate aorto-saphenous anastomosis also developed during these times. This allowed distal anastomosis to be performed without partially clamping the aorta [15,16].

In selected cases, silastic sutures were placed around target coronary artery to reduce bleeding and increase visibility to perform anastomosis [17]. This was not without consequences, however, as it increases the risk of myocardial ischemia and unstable hemodynamics. This severe myocardial ischemia was seen more often when the target coronary had 60-80% stenosis and was poorly collateralized. The clamping of an even less severely stenotic right coronary can cause AV node ischemia and complete heart block. In that case, anastomosis of more distal area beyond bifurcation is done first. In general, the more severely stenosed artery is anastomosed first. With the development of intracoronary shunts (1-3mm), this problem was alleviated to some extent. Placement of intracoronary shunts maintains some perfusion of distal territory and allows anastomosis to be performed safely [18].

Modern surgical technique

The current approaches to OPCABG will now be reviewed. Many of the centers have started using a median sternotomy approach as all the coronary arteries can be addressed with single incision. As previously addressed, this was made possible with advancement in equipment such as stabilizers, apical and non-apical suction devices, and intracoronary shunts. As the experience of surgeons and anesthesiologist grew, complete revascularization using this approach was possible in most of cases.

Harvesting of the LIMA can be done directly or with use of robotic instruments such as the Da Vinci Surgical System and its predecessor the Zeus Robotic Surgical System (Intuitive Surgical, Sunnyvale, CA, USA). The right mini-thoracotomy approach is used to access the right internal mammary artery (RIMA), which is anastomosed to the right coronary artery (RCA). A posterolateral thoracotomy is used to access and graft the circumflex artery and obtuse marginal vessels using a venous conduit [19]. The subxiphoid approach is also used in some centers to access the gastro-epiploic artery to anastomose to the right coronary artery or posterior descending artery (PDA) [20].

There are many potential modifiers to this standard technique. In minimally invasive direct coronary artery bypass graft (MIDCABG) surgery the LIMA is anastomosed to the LAD and/or diagonal branch via a left anterior mini-thoracotomy approach [6,21]. An anterolateral 6-10 cm incision is placed underneath the left nipple at the 4th –5th intercostal space. Thoracoscopy and minimally invasive techniques such as the previously mentioned robotic systems have been used to minimize incision, expedite early extubation, and expedite discharge.

Hybrid procedures involving a combined surgical and percutaneous approach to coronary vascularization have also been increasingly employed [22].

Current peri-operative monitoring standards and anesthetic considerations

Anesthetic and hemodynamic management evolved at the same pace to make this procedure possible safely and has contributed equally in allowing complete coronary revascularization [23]. Anesthetic management of these cases involves management of respiratory and hemodynamic changes with anesthetic plan to allow early extubation [24,25]. The basic standard regimen involves electrocardiogram (EKG) monitoring in leads II and V5, oxygen saturation monitoring, end tidal carbon dioxide monitoring, inhalation control, gas monitoring, direct arterial catheter placement, and central venous access. Pacing pulmonary artery (PA) catheters can allow atrial or ventricular pacing if needed. Electrode pads for defibrillation and cardioversion are placed when thoracotomy approach is used.

Monitoring for ischemia during the procedure is vital. EKG and transesophageal echocardiography (TEE) is utilized for this diagnosis. TEE images may not be easily obtained due to cardiac manipulation
and interference by surgical lap sponges interposed between the heart and echo probe [26]. Though TEE is useful for heart size, volume, motility, and valve regurgitation, it is also useful to diagnose presence of patent foramen ovale (PFO) in patients with refractory hypoxemia. High right atrial pressures are created during cardiac manipulations, and an undiagnosed PFO can cause right to left intra-cardiac shunting. The EKG may also not be accurate when the heart is manipulated for exposure of the lateral and right coronary vessels. Other commonly employed devices include pacing Swan-Ganz catheters and Swan-Ganz catheters with continuous cardiac output and central venous oxygen saturation monitoring capability.

Analysis of values obtained during cardiac monitoring in OPCABG requires awareness of many unique variables. As previously mentioned, surgeon may need to elevate and rotate the heart to give access to the desired vessels, potentially causing severe hypotension and myocardial ischemia. Anastomosis stabilization devices compress the heart and reduce stroke volume. Surgical manipulation to access lateral wall vessels and posterior vessels can distort atrioventricular valves causing regurgitation and sometimes stenosis of valves. Atrial size and pressure may increase with concurrent low ventricular volume and pressure, requiring higher filling pressure to preserve cardiac output. As well, it is important to be aware that PA pressures may not be as reliable due to extreme OR table tilt angles necessary to allow better access to distal vessel sites. PA pressure may also be high due to compression and manipulation of heart by surgeons.

Other anesthetic considerations include patient temperature. The patient is kept warm using forced-air warming blankets, IV fluid warmers, and warm irrigation fluid. The airway is secured in a standard manner; however, double lumen tubes or bronchial blockers may be needed in cases of thoracotomy and/or robotic assisted OPCABG. Appropriate use of Tredelenberg positioning, vasoconstrictors, inoconstrictors, inodilators like phosphodiesterase inhibitors and I.V fluids keeps patient stable, prevents myocardial ischemia, and preserve myocardial function during these manipulations and anastomosis. As always, good communication between surgeon and anesthesiologists is very important in coordinating the preemptive treatment of low perfusion pressure.

Of note, preconditioning by inducing brief period of ischemia followed by reperfusion has shown to protect against subsequent ischemia. This benefit can also be achieved by use of 1-2 MAC of halogenated inhalation anesthetic agents. Heparin anticoagulation management depends on the surgical plan. If only 1-2 vessel CABG is planned target ACT of 200-300 is considered acceptable. For several graft anastomosis, using OPCABG with a mid sternotomy approach, the ACT is targeted at 400. As the procedure closes, protamine is given in small doses and ACT is checked aiming for the pre-operative baseline.

Anesthetic management is planned to allow rapid emergence and early extubation as this allows for early patient mobilization and early discharge from the unit. Intercostal, paravertebral, thoracic epidural regional anesthesia and analgesia have been used especially for patients undergoing thoracotomy. Some centers have used intra-thecal opioids for post-operative pain management [27]. Dexmethetomidine has also been used during and immediately after the procedure and has allowed early extubation and good pain control [28,29]. Hemodynamics, cardiac output, and perfusion pressure are managed by appropriate use of volume, norepinephrine, other inotropes and phosphodiesterase inhibitors.

Graft Patency Assessment Techniques

The two most commonly used techniques to assess coronary artery bypass graft patency in current clinical practice are intraoperative fluorescence imaging (IFI) and transit-time flowmetry (TTFM) [30,31]. Both IFI and TTFM detect graft flow but are not sensitive to detect minor flow and nonocclusive abnormalities.

IFI is based on the fluorescent properties of indocyanine green (ICG) dye. As ICG is injected intravenously, it binds to plasma proteins and when illuminated with a near infrared light source at 806 nm emits light with a wavelength at 830 nm. This fluorescence is captured on a charged couple device video camera. The incidence of allergic reaction to ICG is strongly dose-dependent with greatest incidence with doses in excess of 0.5 mg/kg, and is reported to be approximately 1:40000 and said to be more common in patients allergic to iodine. A bolus of 1ml of 2.5mg/ml of ICG is injected into central venous catheter and flushed with saline, immediately after the injection laser power is activated and images are recorded on the hard drive. Detection of dye passing forward through the bypass graft confirms patency. IFI only provides a semi-quantitative assessment of graft flow.

TTFM, on the other hand, uses a flow probe, which surrounds the graft and has two ultrasound probes and a fixed reflector. Integrated transit time measuring difference between the duration for signal to travel between the two transducers is used to measure flow volume. Measured variables include mean graft flow, a diastolic flow index, and a pulsatility index. In general, diastolic flow index should no more than 50% of mean flow. Diastolic flow is predominant flow of all grafts but is often greater in left coronary grafts. The pulsatility index reflects the resistance of graft flow and is derived from the difference between maximum and minimum flow divided by the mean flow. A pulsatility index over 5 indicates poor flow through graft. Although TTFM gives more objective assessment of flow, it is less sensitive than IFI for detection of poor graft flow.

Special consideration of robotics and off-pump surgery

Damiano, et al in 2000 published their experience in LIMA to LAD anastomoses using Zeus system. Only 2 out of 10 needed revascularization manually [32]. In another and larger series published a year later by group in Leipzig, Germany, over 100 cases of endoscopic coronary artery bypass surgery were analyzed. Out of 35 patients who had totally endoscopic coronary artery bypass surgery (TECAB), only 8 were performed off pump. 18% of the on-pump procedures required fully sternotomy. 6 out of 8 off-pump cases needed full sternotomy as well [33]. In the same year, Kappert successfully performed TECAB 78% of the time in their series on LIMA to LAD bypass procedures [34].

Shrivastava et al presented a retrospective study using a hybrid approach combining percutaneous intervention with robotic TECAB using the 3rd generation Da Vinci Surgical System. They could perform
successfully perform TECAB before percutaneous intervention in 73% of their patients and praised the robotic system for visibility and ease of use [35,36].

Prolonged period of lung isolation using double lumen tube or bronchial blockers is necessary for robotics endoscopic surgery, and hence careful selection of patients is necessary and patients with poor lung function may have to be excluded.

Analysis and interpretation

The OPCABG procedure is not without controversy. If there is to be further widespread use of the procedure, there must be a careful analysis of results. Following is a review of a series of articles that analyze the OPCABG procedure for a variety of variables.

Mortality and morbidity, cost effectiveness, and graft patency

Nathoe and Dijk. In a multicenter, randomized trial, randomly assigned 139 patients with predominantly single or double-vessel coronary disease to on-pump surgery and 142 to off-pump surgery. Cardiac outcome and cost effectiveness were determined one year after surgery. The rate of freedom from death, stroke, myocardial infarction, and coronary re-intervention at one year was 90.6 percent after on-pump surgery and 88.0 percent after off-pump surgery. Graft patency was 93 percent after on-pump surgery and 91 percent after off-pump surgery. On-pump surgery was associated with $1,839 in additional direct costs per patient ($14,908 vs. $13,069, which is a difference of 14.1 percent) and an increase in quality-adjusted years of life of 0.83 as compared with 0.82. In low-risk patients, there was no difference in cardiac outcome at one year between on pump and off pump CABG. Off-pump surgery was more cost effective but not necessarily safer [37].

Angelini. Performed the 199 patient Beating Heart Against Cardioplegic Arrest Study (BHACAS) randomized controlled trial comparing of OPCABG versus CABG. They followed patients for 6–8 years and looked at health-related quality of life (HRQoL) and assessed graft patency using multidetector computed tomographic coronary angiography analysis. Patients were followed up through the National Health Service Strategic Tracing Service and by annual questionnaire for major adverse cardiac-related events (MACEs). MACEs criteria were recurrent angina, myocardial infarction and revascularization (operation or angioplasty). Survivors were sent HRQoL questionnaires annually, including the Seattle Angina Questionnaire and the Coronary Revascularisation Outcome Questionnaire. Ultimately, they found no differences between the on pump and off pump CABG groups in graft patency, survival, freedom from MACEs, and HRQoL results 6 to 8 years after surgical intervention [38].

Reston, et al. looked at randomized and nonrandomized controlled studies on off pump surgeries and performed meta-analyses of short term (<3 months) and midterm (3-25 months) outcomes after OPCABG. They concluded that a shorter length of stay and reduced operative morbidity and mortality was associated with OPCABG versus CABG [39].

Yacoub, et al. in retrospective study assessed the efficacy of the OPCABG technique in multi-vessel myocardial revascularization in 1398 high-risk patients between 1996 and 2001. Two hundred and eighty-six patients had OPCABG, while 1112 patients received on-pump CABG. The CPB patients received 2.8±1.2 grafts per patient while OPCABG patients received 2.8±0.5 grafts per patient. They reported significantly reduced incidence of peri-operative myocardial infarction and other major complications, reduced intensive care unit stay, and reduced mortality using the OPCABG technique for multi-vessel myocardial revascularization in high-risk patients [40].

The Takase group in their 2010 study published compared hospital mortality, 5 year survival, cardiac death, and cardiac and non-cardiac complications between octogenarians and a younger group of patients undergoing OPCABG. They reported 81% survival at 5 years and 92% rate of freedom from cardiac death in the octogenarians, compared with the younger group (95% an 98% respectively). The incidence of cardiac events at 5 years reported was 85% in octogenarians and 94% in younger cohort. They concluded off pump could be safely performed in octogenarians with excellent early and late outcomes [41].

The Van Dijk group looked at cardiac outcome and quality of life one month after surgery. 281 patients were randomly assigned between on and off pump CABG in their multicenter trial. Cardiac outcome was determined by survival free of stroke, myocardial infarction and coronary re-intervention. A similar number of distal anastomoses were done per patient in both groups (2.4 in off pump versus 2.6 in on pump group). 3% of the off-pump procedure needed blood products as compared 13% of the on pump procedures. The off-pump group had a 41% less release of creatine kinase muscle-brain isoenzyme. 93% of the off-pump group and 94.2% of the on-pump group was surviving free from cardiovascular events. No mortality was reported in either group at one month. Short term mortality was concluded to be similar in off and on-pump CABG [42].

Neurological complications and cognitive status post cardiac surgery

Van Dijk and group conducted a multicenter randomized controlled trial on 281 low-risk CABG patients between 1998 and 2000. They followed their patients for 5 years. The patients were randomly assigned to receive either off-pump (n of 142) or on-pump (n of 139) CABG surgery. Cognitive status 5 years after surgery was determined by using 10 standardized validated neuropsychological tests. They also looked at cardiovascular events (all-cause mortality, stroke, myocardial infarction, and coronary re-intervention), anginal status, and quality of life. 62 (50.4%) of 123 in the off-pump group and 59 (50.4%) of 117 in the on-pump group had cognitive decline. Thirty off-pump patients (21.1%) and 25 on-pump patients (18.0%) had cardiovascular events. No patient developed angina. They concluded no difference in cognitive decline between on and off pump CABG [43].

Jensen. Performed cognitive testing on 120 elderly patients before surgery, 90 of which also underwent re-testing at 1 year, using a neuropsychological test battery that included seven parameters from four tests. Two or more positive results out of the seven were considered as cognitive dysfunction. Cognitive dysfunction was found in 19% in the off-pump group and 9% in the on-pump group. They reported no significant differences in the incidence of cognitive
between 2002 and 2006. They compared differences in neurological postoperative neurological complication following off-pump CABG operative period was similar [52].

Fewer post-op neurological complications in off-pump group without factors for neurological complications. In this report, they concluded 14.0; 95% confidence interval, 2.7-72.5) were the predominant risk factors for neurological complications [51].

Further studies were conducted by Hannan [47] and Nishyama [48] group who found some decrease in early neurological complications in off-pump group [47,48]. On the other hand, Kennedy. Did not find any difference between 2 groups [50].

It has been theorized that manipulation of the aorta may result in neurologic dysfunction. Oren Lev-Ran looked if CABG without touching the aorta changes neurological complications when compared to CABG that uses side clamps for proximal anastomosis. Of 700 patients, 29 patients had CABG done with aortic-no-touch technique and aortic side clamps were applied to 271 patients undergoing CABG. Only 1 patient in the aortic no-touch technique had a stroke (0.2%) as compared to a much higher number in the side clamp CABG group (2.2%, p=.01). They concluded that, if it is possible, avoid aortic manipulation in off pump CABG, as there is evidence that this reduces incidence of post operative neurological complications [51].

To follow that data, Matsura, recently reported a study looking at impact of aortic manipulation during off pump CABG on neurological complications. Out of 336 cases of off-pump CABG, the aorta was not touched in 264 (group A) and side clamp was used in 72 (group B) for proximal anastomosis. They followed patients for 2.9±2.5 years. Only one patient had a post-operative stroke in each group (p=0.38). They reported significantly lower freedom from neurological complications in group A (p=0.0006). Risk factors for neurological complications were determined using Cox hazard model, which showed that aortic manipulation (P=0.004; odds ratio, 6.18; 95% confidence interval, 1.8-21.6) and preoperative atrial fibrillation (P=0.001; odds ratio, 14.0; 95% confidence interval, 2.7-72.5) were the predominant risk factors for neurological complications. In this report, they concluded fewer post-op neurological complications in off-pump group without aortic manipulation, although the incidence of stroke immediate post operative period was similar [52].

Finally, Vallety MP. Prospectively looked at 1758 patients for postoperative neurological complication following off-pump CABG between 2002 and 2006. They compared difference in neurological complications in the immediate postoperative period between CABG done without aortic manipulation with off-pump CABG done with aortic manipulation for proximal graft anastomosis. Perioperative neurological deficit in aortic no-touch technique for CABG was 0.25% as compared with 1% when aorta was manipulated using a side clamp or proximal aorto-conduit device. They concluded that fewer neurological complications follow off-pump CABG if the aorta is not manipulated during the procedure [53].

**Coagulopathy and Blood Product Requirements**

Nader, reviewed 126 patients for perioperative bleeding and blood products requirement between off-pump and on-pump CABG patients. Bleeding was less in the off-pump group (2312±212 mL) compared to the on-pump group (3251±155 mL). They concluded reduced perioperative bleeding with off pump patients (p<0.05) [54].

Casati, studied selected haemostatic variables in patients undergoing on and off-pump surgery. Plasma D-dimer concentration was five times higher in on pump CABG. Increased plasminogen activation during cardiopulmonary bypass was observed. Platelet count was found to be lower in on-pump CABG, and remained lower even 24 hours post surgery. Haemostatic profile was similar on both groups 24 hrs post CABG [55].

Paparella, evaluated activation of coagulation and fibrinolytic systems on 32 randomly assigned patients. They followed patients till postoperative day six. Thirty-two patients were randomly assigned to on-pump or off-pump coronary artery bypass grafting. They found an increased thrombin formation and higher D-dimer numbers in the on pump group (p<.001). During first 24 hours post-bypass, bleeding time was higher in on-pump group (p<.001). They also concluded that off pump patients had normally functioning platelets and decreased fibrinolytic activation [56].

Puskas, studied two hundred unselected patients undergoing surgery and randomly assigned them to undergo either off-pump coronary artery bypass grafting or conventional coronary artery bypass grafting with cardiopulmonary bypass by a single surgeon. They concluded fewer units of blood transfusion requirement and higher hematocrit at discharge on off pump CABG patients. They applied a multivariate analysis and found that cardiopulmonary bypass was independent predictor of transfusion (OR 2.42, p=.0073 ) [57].

**Extubation time and length of stay**

Puskas, reported extubation times and lengths of stay in intensive care unit and hospital using an ultra fast technique anesthesia (UFTA) and a standard technique. The UFTA group had 10 and standard anesthetic had 27 patients. Anesthesia was conducted with propofol, remifentanil, vecuronium, and thoracic epidural analgesia in the UFTA group and thiopental, fentanyl, pancuronium, and isoflurane in the control group. All patients were extubated in UFTA group in the operating room and only 2 of standard group were extubated in the operating room. Patients who were extubated in the operating room required lower nurse-to-patient acuity ratio (1:2) in the ICU. No difference was found in ICU and hospital length of stay Ascione and Dajani, reported earlier extubation after off-pump CABG than
on-pump CABG and found that off-pump patients had shorter length of stay in hospital [57-59].

**Atrial fibrillation post on and off pump coronary bypass surgery**

The incidence of postoperative atrial fibrillation after cardiac surgery ranges between 25-35% after on-pump CABG and 12.9-26% after off-pump surgery. Atrial fibrillation usually occurs within the first postoperative week, with a peak between day 2 and 4 [60]. Creswell looked at 183 patients who had an LIMA-LAD graft for incidence of atrial fibrillation. The incidence of atrial arrhythmia was found to be 18-20% in an off-pump subgroup. Incidence was found to be less than <1% in patients aged 50-60 and 9-10% in patients aged 80-90. 25-40% of patients in total had atrial fibrillation with peak from the 2nd to the 4th day. This number was even higher with concurrent valvular operation [61].

A comprehensive review by Archbold in 2003 could not conclude difference in incidence of atrial fibrillation between off pump and on pump [62]. Ascione R, and Angelini GD, in a prospective randomized meta-analysis looked into outcomes between off pump and on pump cases. They found a decreased incidence of atrial fibrillation as well as a decreased need for blood transfusion, decreased neurological complications, earlier extubation, decreased critical care unit stay and total hospital stay and a lower cost [63]. Recently Dehdilani M, reported smaller incidence of atrial fibrillation after off pump surgery [64].

**Renal dysfunction**

Lofe, et al. found increased markers of glomerular and tubular damage in on-pump patients with renal dysfunction as compared with off pump patients [64]. In 1999, Ascione published a study finding a lower incidence of renal dysfunction evidences by creatinine clearance, urinary microalbumin/creatinine ratio, and renal tubular function (N-acetyl glucosaminidase activity) in OPCABG patients [65].

Chukwuemeka, looked at two thousand seven hundred eleven patients with preexisting renal dysfunction who had on-pump CABG, and 158 patients who underwent off pump surgery between 1999 and 2003. Their results showed that off-pump CABG did not reduce the incidence of renal dysfunction. Thus renal function should not be deciding factor in choosing between on and off pump coronary bypass graft surgery [66].

**Conclusion**

This review summarized the history, technique, anesthetic and surgical management, and presented data comparing off-pump and on-pump coronary bypass surgery. It is clear that debates regarding OPCABG will continue but some conclusions can be made at this time.

There has been evidence of reduced cost, earlier recovery, and lessened blood transfusion requirements. There is data to support that reduced manipulation of the aorta is associated with lower rates of neurologic complication. Otherwise, studies have shown equivocal results for cognitive decline, graft patency, atrial fibrillation incidence, renal dysfunction, and early/late morbidity and mortality between the two procedures.

Further work is needed in a larger volume of patients looking at early and late outcomes with newer and minimally invasive techniques before further conclusions can be achieved.

**References**


