Multivessel Coronary Artery Bypass Grafting Without Cardiopulmonary Bypass

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Multivessel coronary artery bypass grafting (CABG) without cardiopulmonary bypass, commonly known as off-pump CABG (OPCAB), has been gaining acceptance as a surgical procedure for complete surgical coronary revascularization. The successful reports of "beating heart" CABG using full sternotomy by Bennetti,\(^1\) Buffolo,\(^2\) and Pfister,\(^3\) and using minimal access approaches by Subramanian\(^4\) and Calafiore,\(^5\) has led to the development of stabilizer retractor platforms that enable successful coronary-artery conduit anastomoses. The primary goal of surgical coronary artery revascularization, regardless or whether or not cardiopulmonary bypass is used, is successful complete CABG with low hospital morbidity and mortality, and long-term patency of grafts to ensure long-term, coronary event-free and quality patient survival. Achieving this goal without the potential complications of cardiopulmonary bypass is under investigation in many centers. In March 1999, we embarked on a committed OPCAB program, and currently we perform more than 97% of our CABG procedures without cardiopulmonary bypass.

Patient Selection

All CABG patients are potential candidates for OPCAB multivessel surgery with the absolute exception of two patient subsets. Patients with a deep intramyocardial left anterior descending (LAD) artery traversing on the right ventricular endocardium or with a coronary artery that requires an extensive long endarterectomy will usually require cardiopulmonary bypass for successful grafting.

Candidates for OPCAB surgery may include patients needing multiple grafts, including sequential coronary anastomoses; those with poor left ventricular; those with large cardiomegaly hearts; those with low ejection fraction (<30%); those with acute myocardial ischemia and/or recent myocardial infarction; those with poor diabetic distal vessels; and those requiring short endarterectomies (<3 cm), atioventricular (AV) groove anastomoses, and multiple arterial grafts.

As one begins an OPCAB program, selecting patients with normal-sized hearts, good left ventricular function, good distal targets, and requiring only grafting of anterior (LAD and diagonals) and posterior (right coronary artery [RCA]), posterior descending artery (PDA), posterior lateral ascending artery [PLA]) vessels is advised. As comfort with the technique increases, the surgeon can expand patient selection to include those with good ventricular function requiring circumflex artery revascularization. Eventually, the surgeon can select patients with more difficult anatomy and pathology, such as those patient subsets mentioned earlier.

Anesthesia and Intraoperative Monitoring

To perform successful OPCAB surgery, the surgeon and cardiac anesthesiologist must work closely as a team throughout the entire procedure. Standard cardiac anesthetic techniques for induction and maintenance of anesthesia are used. Because many OPCAB patients are extubated on the operating room (OR) table or less than 4 hours postoperatively in the intensive care unit (ICU), OPCAB patients usually receive a lower narcotic dosage than cardiopulmonary bypass patients. Hemodynamic monitoring with a radial arterial line, oxymetric Swan-Ganz catheter, electrocardiography (ECG), indwelling urinary catheter, and transesophageal echocardiography (TEE) are standard on every OPCAB case. Oxymetric Swan-Ganz monitoring of potential deteriorating mixed venous saturations may be the earliest indicator of hemodynamic deterioration. Pulmonary pressure and thermodilution cardiac output are not always indicative of hemodynamic compromise when the heart is mechanically dislocated. TEE is used for evaluation of left ventricular function, regional wall motion, and valvular abnormalities. Assessment of the degree of aortic valve and/or mitral valve regurgitation, which may worsen with manipulation of the heart, is critical information. For instance, in a patient with an ejection fraction of 30%, 1 to 2+ mitral regurgitation and moderately elevated pulmonary pressures, the anesthesiologist may choose an intraoperative phosphodiesterase inhibitor to improve left ventricular function and decrease mitral regurgitation and pulmonary pressures before manipulation of the heart—possibly preventing conversion to cardiopulmonary bypass.

The etiology of hemodynamic deterioration is myocardial ischemia during coronary artery occlusion and/or excessive displacement and compression of the heart. Brief "trial" periods of 2 to 3 minutes of coronary occlusion while the anesthesiologist monitors the pa-
tient's hemodynamic parameters is usually all that is necessary to determine whether a particular heart position will be tolerated while a coronary anastomosis is completed. Pharmacologic agents such as neosynephrine to increase arterial perfusion pressure, nitroglycerine to reduce volume in a full heart and improve coronary flow, phosphodiesterase inhibitors to improve contractility and decrease pulmonary hypertension, and beta-blocking agents to lower the heart rate are used as needed. Crystalloid fluid volume replacement is given judiciously to prevent hemodilution. An autologous cell saver is used routinely for multivessel OPCAB, as 300 to 1000 cc of blood can be salvaged secondary to hemorrhage from sternal marrow, coronary arteriotomies, and surgical sites. The patient’s body temperature is maintained by increasing temperature and providing intravenous fluid warmers, warmed-humidified ventilation, a heated bed blanket, and warm irrigation in the surgical field. Maintaining close to normothermic body temperature is crucial if the patient is to be extubated in the OR after the procedure. Local anesthesia (e.g., Marcaine) is injected into the sternal wound to decrease early postoperative pain.

Surgical Approach

Because the OPCAB technique produces periods of myocardial ischemia from coronary artery occlusion during anastomotic grafting, the order of grafting is important and must be carefully planned based on the patient’s preoperative coronary angiogram. Before each anastomosis, the surgeon needs to evaluate whether enough myocardium is at ischemic risk during coronary artery occlusion to pose a risk for hemodynamic deterioration. We have developed some guidelines:

1. Perform the LAD or diagonal-LAD grafting first to revascularize the septum and anterior wall, except in moderate (<80% stenosis) LAD disease with a total RCA occlusion, graft the RCA or the PDA/PLA first to reperfuse the inferior wall collateralized from the LAD.

2. In large, dominant RCA vessels that are not totally occluded, use an intracoronary shunt or distal perfusion to prevent heart block.

3. Shunt large, moderately stenosed (<80%) intermediate ramus arteries, because the combination of anterolateral ischemia and mediolateral displacement of the heart with right ventricular outflow tract compression can lead to rapid hemodynamic deterioration.

4. In patients with acute myocardial ischemia, critical (>90%) left main disease with or without total RCA occlusion, or a large heart with low ejection fraction, graft the LAD first with minimal manipulation of the heart. Excessive manipulation can quickly lead to global ischemia and the need for conversion to cardiopulmonary bypass. Deep pericardial sutures can be placed after LAD grafting.

Intracoronary shunts are used in 10% to 15% of cases. Proximal anastomosis can be performed before distal anastomosis or after grafting of critical distal coronary arteries to perfuse the myocardium and prevent ischemic complications. With proper planning and use of these methods, distal perfusion techniques should not be needed. If the integrity of the coronary anastomosis is in question, an intraoperative coronary flowmeter (CTS Coronary Flowmeter System, CTS-Guidant, Cupertino, CA) can be used to assess graft patency and flow.
A full midline sternotomy incision is made extending inferior to the xiphoid, to enable wide lateral retraction of the sternum. As the retractor is opened, the right sternum is pulled anteriorly while the left sternum is pushed posteriorly. This allows for possible displacement of the apex of the heart under the right sternum during circumflex vessel grafting. The incision is extended inferiorly another 4 cm if right gastroepiploic artery harvesting is needed. The pericardium is opened widely along the diaphragm and extended down to the inferior vena cava to increase the laxity of the right pericardium. This decreases right heart compression when the heart is displaced to the right. The entire right pleural space may be opened to displace the heart into the right pleural space when grafting circumflex arteries or large hearts. No right-sided pericardial sutures are placed; these sutures would increase right pericardial tension and potential mechanical compression of the right heart, leading to hemodynamic deterioration.
Left superficial pericardial sutures are placed to pull the pericardium up to the left sternum. The apex of the heart is gently pulled right lateral and anterior to expose the left posterior pericardium. Deep pericardial sutures are placed in three positions: just medial to the inferior vena cava (IVC) in the diaphragmatic pericardium, between the IVC and the left inferior pulmonary vein under the posterior left atrium, and just anterior to the left inferior pulmonary vein below the left phrenic nerve. The heart is gently retracted and placed back into the pericardial well with each suture placed to prevent prolonged hemodynamic compromise. Having the anesthesiologist briefly hold mechanical ventilation will increase exposure for this step. These deep pericardial sutures are then pulled to varying degrees of tension, displacing the heart for exposure of the desired coronary artery. The surgeon must avoid taking deep bites through the pericardium with these sutures, as puncture of the left lung and hilar structures can occur. The sutures should remain below the left phrenic nerve to prevent injury.
LAD and diagonal anastomosis. The deep pericardial sutures are gently pulled to bring the LAD midline and up into the surgical field. The coronary artery is palpated and the anastomosis site inspected. Silastic tapes are placed proximal and distal to the anastomosis site. The retractor (CTS Access Ultima System; Guidant-CTS, Cupertino, CA) is slid into position to stabilize the coronary artery. Gentle compression around the LAD on the left ventricle can achieve stabilization without compromising hemodynamics.
Coronary anastomosis. The proximal Silastic tapes are gently crossed, and the distal tapes are gently pulled inferiorly (not crossed) to decrease coronary blood flow. Excessive crossing of distal tapes may injure the coronary artery. The epicardium over the vessel is dissected with a scalpel or scissors. The arteriotomy is performed with an iris blade. After the arteriotomy is extended with coronary scissors; lateral 6-0 silk retraction sutures may be used to open the arteriotomy and increase stabilization if necessary. The in-situ left internal mammary artery is anastomosed to the LAD or sequentially to the diagonal-LAD in the standard fashion. A CO₂ mist blower is used to briefly blow away coronary blood and improve visibility during suture placement. An intracoronary shunt may be used to perfuse the distal artery during the procedure to prevent myocardial ischemia. Intracoronary shunts can also be used to improve visibility if excessive blood flow from collaterals or septal perforators occurs.
Circumflex anastomoses. The deep pericardial sutures are pulled to further displace the heart to the right. The apex of the heart may be placed into the right pleural space to improve exposure of the lateral wall. The site for anastomosis of the intermediate ramus or obtuse marginal vessel(s) is determined. Silastic tapes are placed, and the stabilizing arm is positioned. The arm is usually positioned as parallel to the vessel as possible, to minimize its movement. This is important with hypertrophied, hyperdynamic ventricles that exert outward force against the retractor. The anastomosis is completed as shown in 3. After sequential radial artery anastomoses are performed, the stabilizer is carefully hacked out from the sequential segment, to prevent disruption and pulling on the anastomoses.
PDA and PLA anastomosis. The IVC deep pericardial suture is pulled inferiorly, and the patient is placed in Trendelenburg position to displace the apex of the heart toward the ceiling. Silastic tapes are placed, and the stabilizing arm is positioned around the desired posterior vessel, taking care to avoid excessive stabilizer compression that displaces the apex of the heart superiorly, which can cause hemodynamic compromise. This position is usually well tolerated even in patients with low ejection fraction. Sequential grafting to the PDA and PLA is commonly performed. The right gastroepiploic artery can also be brought through a diaphragmatic slit to access the PDA.
RCA anastomosis. The left deep pericardial sutures are loosened to position the heart in its normal anatomical position. Deep right inferior pericardial sutures are placed to pull up the right heart anteriorly. Silastic tapes are placed proximally and distally around the distal RCA. The proximal tape is pulled toward the surgeon, to bring the RCA upward. The distal tape is pulled (not crossed) inferiorly to flatten the RCA horizontally. The stabilizing arm is then placed around the RCA. The acute margin of the right ventricle may need to be retracted to the left with a pledgeted suture to increase exposure. In situ right internal mammary or vein grafting is then done in standard fashion. Proximal anastomoses are done in standard fashion with a partial occlusion clamp. Deairing of the aorta is performed after all proximal grafts are completed with retrograde radial artery flow before the partial occlusion clamp is released.
Postoperative Care

Standard postoperative institutional cardiac surgery fast-track protocols are implemented. Compared to postcardiopulmonary bypass patients, OPCAB patients are extubated earlier, require less inotropic support, have lower volume replacement requirements without postpump diuresis, and maintain higher postoperative hemoglobin levels. In our series, the need for blood product transfusions is 65% lower than for on-pump CABG cases.

Postoperative pain is controlled with intraoperative local anesthetic injection of the sternal incision, intravenous nonsteroidal anti-inflammatory agents such as Ketorolac, and judicious use of intravenous narcotics to avoid respiratory depression. Most patients are extubated in the OR or within 4 hours of surgery. Most patients are ambulating within 24 hours.

The length of hospital stay is usually 3 to 4 days, with social issues and postoperative atrial fibrillation (still occurring in 25% of OPCAB patients) the primary factors delaying discharge.

Conclusion

The OPCAB technique has become the standard method of surgical revascularization for multiple grafting at our institution, performed in more than 97% of our CABG procedures. The operative mortality in more than 800 OPCAB procedures performed since the start of our OPCAB program is 1.4%.

Reports from other centers6-9 demonstrate comparable mortality rates, decreased postoperative bleeding, and lower costs in OPCAB patients compared to conventional cardiopulmonary bypass CABG patients. Larger retrospective series and randomized trials are presently underway to evaluate hospital and long-term results, with particular emphasis on graft patency and neurologic complications.

REFERENCES


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