Thoracic and Cardiovascular Surgery

Off-Pump Coronary Artery Bypass: Techniques, Pitfalls, and Results

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In an attempt to advance the surgical treatment of coronary artery disease, surgeons sought a way to offer the proven benefits of coronary revascularization and avoid the side effects of cardiopulmonary bypass by performing revascularization in the beating heart (off-pump coronary artery bypass). This review will describe the development and refinement of the technique, pitfalls to its widespread adoption, and an up-to-date assessment of current results.
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Since its first description in the 1960s, coronary artery bypass (CAB) has been one of the most scrutinized procedures in healthcare. As patients referred for CAB become more complex, off-pump CAB or off-pump coronary artery bypass (OPCAB) has gained increased attention. This review will describe the development and refinement of the technique, pitfalls to its widespread adoption, and an assessment of current results.

Development of OPCAB Technique

Kolesov[1] is credited with the first description of CAB in 1964, when he created a left internal mammary artery anastomosis to the left anterior descending (LAD) artery without cardiopulmonary bypass. Since then, the practice of performing CAB through a median sternotomy using cardiopulmonary bypass and cardioplegic arrest [on-pump coronary artery bypass (ONCAB)] has been the gold standard for surgical revascularization of the heart for decades.[2-4] Extensive investigation over the years has resulted in a reduction of the negative physiological effects of cardiopulmonary bypass, and led to improved clinical outcomes. Despite these efforts, significant deleterious effects on the hematologic, pulmonary, renal, and neurologic systems remained.

In an attempt to advance the surgical treatment of coronary artery disease, surgeons sought a way to offer the proven benefits of coronary revascularization, and yet avoid the side effects of cardiopulmonary bypass by performing revascularization on the beating heart off pump. Even as on-pump coronary surgery was developing, there were descriptions of the operation performed without the pump.[5,6] Early reports in the USA began in the early 1990s.[7,8] Early innovators in the field included Michael Mack and Jim Edgerton in Dallas, John Puskas in Atlanta, Jim Hart in Harrisburg, and Joe Sabik in Cleveland. Though techniques varied slightly, early results were generally favorable when compared with ONCAB, with similar graft patency and lower complication rates and shorter hospital stays.[9-12]

Improvements in results paralleled an increase in surgeon experience and the development of more effective technologies to allow improved stabilization and visualization. This refinement in techniques and enabling devices has allowed expansion of the application of OPCAB to a wider range of patients, and continued to improve results. Surgeons were able to perform OPCAB on more difficult to visualize lateral wall targets. OPCAB was offered not only on the sick patient with left ventricular dysfunction or diffuse coronary calcification, but also to the elective low-risk patient. In experienced hands it can now be universally applied, and in some centers it is an important part of the standard of care for surgical myocardial revascularization.

Technique of OPCAB

Many descriptions of the techniques common to OPCAB procedures are available.[13-15] These include technical aspects, such as incision, patient positioning and preparation, expo-

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sure and visualization of target vessels, conduit selection and harvest, anticoagulation protocols, and suture technique, and will be discussed here. Most of these revolve around the 3 main tenets of successful OPCAB: adequate exposure of the operative site without hemodynamic compromise, complete stabilization of the target vessel, and excellent visualization of the anastomotic area. Equally important topics related to patient factors and decision-making, including patient selection, anesthetic management, prevention of ischemia, grafting sequence, reoperative strategies, and medical management will be discussed later in this review under the section concerning pitfalls to adoption and their avoidance.

Adequate Exposure Without Hemodynamic Compromise

Incision

The vast majority of OPCAB cases are performed through standard median sternotomy. This provides excellent exposure to the entire heart and allows the mobility to create excellent hemodynamic stability and target vessel exposure and visualization. Later in this section, we will present an advanced alternative through a limited access, small left anterior thoracotomy that may be an attractive alternative for selected patients and highly experienced surgeons.

Patient Positioning and Preparation

Many target vessels can be adequately exposed with the patient in the supine position. Placing the patient in the Trendelenburg position and rotating the bed to the patient's right (the "OPCAB position"), provides hemodynamic and exposure advantages. Trendelenburg position is known to increase preload and cardiac output, thereby improving hemodynamic stability as the heart is being manipulated for target vessel exposure.[16,17] In this position, gravity helps move the right side of the heart under the right sternal table, allowing exposure of the lateral, posterior, and inferior walls of the left ventricle. This is enhanced by elevating the right side of the retractor with towels, dividing the musculofascial attachments to the distal portion of the right table of the sternum, and extending the pericardiotomy incision near the inferior portion of the right side of the sternum from the diaphragm toward the inferior vena cava. A pericardial retraction suture placed at the leftward limit of the standard inverted-T pericardiotomy and sewn to the skin just below the inferior end of the left side of the sternum will also elevate the heart and accentuate the visualization of the inferolateral portion of the left ventricle without hemodynamic consequence. These maneuvers should be performed in all patients. Additional maneuvers that may be considered to help improve hemodynamics and provide optimum positioning of the heart include opening the right pleural space in its entirety, and removal of the right pleuro-pericardial fat pad.

Exposure of Target Vessels

Excellent exposure of target vessels can be achieved in a variety of ways. Many off-pump surgeons have successfully used a series of deep pericardial sutures in a technique initially described by left internal mammarian artery (LIMA). Heavy silk sutures are placed in the pericardium adjacent to the left superior pulmonary vein, a second directly posterior to the heart near the midline, and a third near the diaphragm just to the left of the inferior vena cava.[18] These can be placed around the left side of the sternal retractor through a Rummel tourniquet, or placed in the pericardial suture stays of a standard sternal retractor. Differential tension on these sutures can expose the high lateral wall of the left ventricle, the lateral or posterolateral wall, and the inferoposterior portion of the heart.[13] The advantage to this system is that it is very cost-effective and can help support the heavy, hypertrophied heart often better than other methods. Care should be taken to avoid creating undo compression of lateral wall vessels by these sutures with positioning, particularly when they are relatively undiseased and collateralized, as this can lead to ischemic changes that are readily reversed by repositioning. A moist lap pad between the sutures and the heart may help to avoid coronary compression and aid in elevation of the heart.

More commonly, commercially-available positioning devices are available to aid in cardiac positioning.[19] Modern positioning devices are on the basis of suction application to the heart and can be positioned on the apex of the heart or off-apex. The key to maintaining hemodynamic stability with these devices is to maintain right ventricular geometry and output while avoiding compression of the right side of the heart with positioning. Constant attention to keeping the heart elongated as it is manipulated will avoid hemodynamic compromise. We advocate the use of these positioning devices in cases where the ventricular function is extremely poor, early in a surgeon's learning curve, and while teaching residents, as extended periods of exposure are possible with minimal hemodynamic compromise.

Complete Stabilization of the Target Vessel

Target vessel visualization is accomplished by mechanical aids to stabilization and commercially available aids to visualization. Mechanical stabilizers that relied on pressure on the myocardium have generally been replaced by devices that rely on suction to accomplish stabilization. These stabilizers typically have 2 arms that are placed on either side of the intended area of anastomosis to provide stabilization. Some devices are designed so the arms distract away from the area of anastomosis as they are tightened, thereby creating stabilization in an additional plane to provide further increase in visibility. Attention should be paid to take full advantage of the suction design of these devices. They are designed to provide stabilization in a "zero-displacement" mode. There should be not much, if any, downward pressure on the myocardium as the device is placed. Downward pressure on the heart will only serve to limit ventricular filling and therefore ejection and should be avoided.

Excellent Visualization of the Anastomotic Area

Visualization of the target vessel is accomplished by assuring that the field is as close to bloodless as possible. This can be