Thoracic and Cardiovascular Surgery

Teaching Off-Pump Coronary Artery Bypass Surgery

Michael E. Halkos, MD, and John D. Puskas, MD

Off-pump coronary artery revascularization requires a unique skill set and a different conduct of operation compared with on-pump coronary artery bypass. Not only must the surgeon perform anastomoses on the beating heart, but he/she must understand the hemodynamic consequences of cardiac positioning and stabilization, the effects of regional ischemia on hemodynamic function, contractility, and arrhythmias, and the importance of anesthesia and grafting sequence given variants of anatomy and clinical conditions. Given these differences, the ability to teach off-pump coronary artery bypass to residents and surgeons places unique demands on the teaching surgeon. In this article, we review the available literature about the safety and efficacy of teaching off-pump coronary artery bypass to residents, discuss the fundamentals for training residents, and review the future of simulation and new training paradigms and the impact this will have on current training methods.

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Over the past decade, several randomized trials have documented the safety and efficacy of off-pump coronary artery bypass (OPCAB).[1-7] Although these relatively smaller trials did not show a mortality benefit for OPCAB compared with on-pump coronary artery bypass (ONCAB), they did consistently demonstrate lower blood transfusion requirements, decreased ventilator times, and shorter intensive care and hospital lengths of stay. In larger retrospective analyses from state registries[8,9] as well as from the Society of Thoracic Surgeons National Database,[10] OPCAB has been associated with a lower operative mortality as well as a reduction in perioperative morbidities, specifically, stroke, renal failure, and respiratory failure. Therefore, OPCAB may be the preferred strategy for revascularization in a majority of patients. Although low-risk patients will likely have excellent morbidity and mortality outcomes with either an on- or an off-pump approach, higher risk patients, such as those with pulmonary disease, renal insufficiency, and extensive aortic atherosclerosis, may benefit more from avoiding both the systemic effects of cardiopulmonary bypass as well as the aortic manipulation with cannulation and aortic clamping.

Division of Cardiothoracic Surgery, Clinical Research Unit, Emory University School of Medicine, Atlanta, Georgia.

Address reprint requests to John D. Puskas, MD, Emory University School of Medicine, 550 Peachtree Street, Crawford and Long Hospital, 6th Floor, Medical Office Tower, Atlanta, GA 30308. E-mail: john.puskas@emoryhealthcare.org

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Preoperative Planning

It is important to consider patient and anatomic variables that may influence the conduct of the operation. Primarily, the clinical condition of the patient, the urgency of the operation, and the ventricular function need to be carefully assessed to determine whether an off-pump approach will be practical. Although patients operated on more acutely may benefit from an off-pump approach, it is important to teach the resident the thought process as well as prepare a backup plan should this approach be poorly tolerated. Patients with left ventricular dysfunction from a recent infarct pose a more difficult challenge than those with chronic ventricular dysfunction, with the former being much more sensitive to cardiac manipulation and displacement. Additionally, a different approach is required when evaluating the cardiac catheterization. During on-pump cases, the location and number of vessels requiring bypass usually suffice during evaluation of the catheterization films. However, when planning for OPCAB, particular attention needs to be paid to the collateralizing vessel, intramyocardial vessels, the size of the distal targets, the degree of stenosis, the complexity of coronary disease, and the number of lateral wall vessels requiring grafting. Furthermore, the sequence of grafting must be planned carefully to avoid critical ischemia and cardiovascular collapse (Table 1). For example, in patients with an occluded right

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Table 1 Preferred Sequence of Grafting

Perform anastomosis to completely occluded or collateralizing vessel first.
If LAD is not collateralizing vessel, perform LIMA-LAD anastomosis first to allow for anterior wall perfusion during lateral and inferior wall positioning.
Proximal anastomoses can be performed first to allow for perfusion of target vessels after each distal anastomosis. This can be helpful when cardiac positioning is not well-tolerated.
Bewared of large RCA with moderated proximal stenosis. Acute occlusion can cause bradycardia and hypotension. Be prepared for intracoronary shunt and epicardial pacing.
Patients with moderate MR may not tolerate prolonged cardiac displacement, which can exacerbate MR, lead to elevated PA pressures and subsequent hemodynamic deterioration. Grafting the culprit vessel causing papillary muscle dysfunction should be performed early in the procedure.

coronary artery with a posterior descending artery supplied by collaterals from the left anterior descending artery (LAD), grafting the LAD first would not only leave the anterior wall ischemic but also disrupt flow to the inferior wall and right ventricle. Thus, a more reasonable approach would involve grafting the posterior descending artery first and then performing a proximal anastomosis to ensure adequate flow while the proximal LAD is occluded during construction of the LAD distal anastomosis. Another scenario that may pose problems is a large moderately stenotic right coronary artery. Not uncommonly, temporary occlusion of this artery will result in profound bradycardia and hypotension resulting in cardiovascular collapse. In these circumstances, the surgeon must be prepared to place an intracoronary shunt or provide temporary epicardial pacing. Additional options include a "proximals first" approach to allow adequate regional perfusion following completion of each distal anastomosis. We will frequently challenge the resident to provide the plan of sequence before the operation.

Anesthesia

With a preliminary plan in place, necessary steps can be taken to prepare for exposure and distal anastomoses. It is imperative to communicate effectively with anesthesia personnel when performing OPCAB. Subtle changes in hemodynamic status, gradual elevation in pulmonary artery pressures, frequent boluses or increased requirement of inotropes and vasopressors to maintain hemodynamic stability, and rhythm changes can herald cardiovascular collapse and arrest and usually can be avoided if these changes are verbalized and discussed at the appropriate time. When manipulating the heart, it is important to announce these abrupt maneuvers to the anesthesia team so that appropriate action can be taken and an inappropriate reaction avoided. In our experience, a well-experienced anesthesia team is essential to maintaining stable hemodynamics and to ensure a smooth, uneventful operation. This communication must be stressed to the participating resident so that he/she can develop an understanding of subtle warning clues that are frequently presented by the anesthesia team.

Exposure

As with any operation, the key to conducting an easy anastomosis is adequate exposure. Several maneuvers have been developed which greatly facilitate off-pump anastomoses. Cardiac positioners and stabilizers have greatly increased the ability to manipulate the heart with minimal hemodynamic compromise. Two different systems are routinely used in our institution, the Medtronic Octopus Tissue Stabilizer and Starfish or Urchin Heart Positioner (Medtronic, Inc, Minneapolis, MN) and the Maquet ACROBAT Stabilizer and XPOSE Positioner (Maquet GmbH & Co, Rastatt, Germany). Cardiac positioner devices are frequently placed off the apex, especially to the left of the apex, to expose the lateral wall and branches of the left circumflex coronary artery. They are generally placed on the apex to expose the anterior wall (LAD territory) and inferior wall (posterior descending territory) of the heart and may be placed on the acute margin to expose the right coronary artery. Because these suction-based cardiac positioning devices pull the apex in the appropriate direction rather than pushing it, the heart is not compressed, functional geometry is maintained, and cardiac positioning is usually well-tolerated. The coronary stabilizer devices can then be placed with minimal tension on the epicardium to allow for an area of regional stability. The anterior wall vessels often require only the coronary stabilizer for adequate exposure. The stabilizer is positioned along the caudal aspect of the retractor toward the left, with the retractor arm placed out of the way to prevent interference during the anastomosis. The location of these devices on the sternal retractor also requires consideration. For the lateral and inferior wall vessels, the cardiac positioner is usually placed on the surgeon's side at the most cephalad location of the retractor. The coronary stabilizers can then be placed on either side. A general rule is to put the stabilizer in the assistant's way instead of the surgeon's to prevent these devices from obstructing the surgeon's view or interfering with hand positioning during suture placement. Several other facilitating maneuvers aid in exposure during the anastomosis. The pericardium should be opened widely to the left to allow for cardiac displacement. Deep traction sutures along the left allow for the heart to be elevated out of the pericardial well. A deep posterior pericardial traction suture placed approximately two-thirds of the way between the inferior vena cava and left inferior pulmonary vein allows for additional elevation of the heart. Care should be taken to avoid deep bites of pericardium to prevent injury to underlying structures, such as the left lower lobe, aorta, and esophagus. This suture should be covered with a soft rubber catheter to prevent laceration of the epicardium during retraction. Retraction of the "deep" stitch and left pericardial sutures elevates the left side of the heart into the surgeon's view. The pericardium along the right can be dissected along the diaphragm to the insertion of the phrenic nerve or the pleural space opened widely to allow the heart to