Strategies for Maintaining Hemodynamic Stability

During Off-Pump Coronary Artery Bypass

Surgical and Anesthetic Considerations
from the Cardiac Surgery Team at

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MCV00024675 REVA

Introduction

Research suggests off-pump coronary artery bypass (OPCAB) surgery is associated with improved outcomes when compared to on-pump coronary artery bypass. Large population studies have shown OPCAB reduces patient morbidity and mortality, decreases the incidence of acute renal failure, reduces transfusions, improves post-surgery neurological outcomes, decreases postoperative stroke risk, and shortens recovery times when compared with on-pump surgery.[1-9]

When adopting off-pump surgery, surgeons and anesthesiologists are commonly concerned with managing patient pressures and preventing hemodynamic instability. During conventional coronary bypass surgery, which uses cardiopulmonary bypass and cardioplegic arrest, the heart-lung machine provides hemodynamic support for the patient and surgeons can manipulate the heart as needed without regard for impacting the hemodynamic stability of the patient. But during OPCAB, the cardiac surgery team must adopt new techniques to handle a beating heart and the variations in hemodynamics that can occur when performing this type of procedure.

Thanks to advances in surgical and anesthetic techniques and the rapid development of stabilizers, apical suction devices and other technologies, clinicians can use a variety of strategies to prevent and manage hemodynamic instability during OPCAB. Today, OPCAB is a standard procedure in many medical facilities. Experienced cardiac centers, such as The Lankenau Medical Center (LMC) (Philadelphia, PA), have improved outcomes by having:

- a dedicated, multidisciplinary heart team;
- standardized protocols for preoperative, intraoperative, and postoperative care; and
- a continuous quality improvement program that provides ongoing evaluation and refinement of the entire patient care process.[10]

Of the almost 300 coronary artery bypass surgeries performed every year at LMC, cardiac surgeons perform 98% off pump, and less than 0.5% of these procedures require conversion to on-pump bypass. Moreover, those procedures that did require conversions resulted in positive outcomes and zero mortality in all patients.

Since adopting OPCAB in 2000, the LMC cardiac surgery team has used a variety of strategies for maintaining hemodynamic stability during OPCAB. This paper describes these strategies, and offers surgical and anesthetic considerations for clinicians interested in adopting off-pump coronary artery bypass.

Pre-Procedure Planning

Pre-procedure planning is critical in maintaining hemodynamic stability during OPCAB. A successful OPCAB procedure starts with teamwork, commitment and communication. The cardiac surgery team must approach OPCAB with a completely different mindset than on-pump procedures. It is essential to educate every member of the team, including the surgeon, anesthesiologist, surgical assistant, nurse and perfusionist, in OPCAB protocols and the difference between conventional CABG and OPCAB.

> **Beating Heart Tip:**
>
> The cardiac surgery team must approach OPCAB with a completely different mindset than on-pump procedures.

Before the procedure, the cardiac surgery team must also plan what to do in the event of an emergency, and be prepared to go on cardiopulmonary bypass, if needed. LMC's philosophy is that conversions to on-pump bypass are a matter of safety and should not be viewed as a failure when performing OPCAB.

The anesthetic management of the patient's hemodynamics during OPCAB is often more challenging than during conventional on-pump CABG. It requires a dedicated anesthesiologist who is vigilant in anticipating surgical interventions, skilled in hemodynamic management, and willing to communicate closely and continuously with the cardiothoracic surgeon.

During the procedure, the surgeon should plan to communicate to the anesthesiologist prior to displacing the heart, occluding a coronary artery, when inserting or removing a shunt, and especially when reperfusing the heart.

Likewise, the anesthesiologist should plan to inform the surgeon when administering vasopressors or inotropes, if there are ST segment or rhythm disturbances, if the heart rate becomes suddenly or severely bradycardic, and if the blood pressure is not responding to pharmacologic interventions.

Hemodynamic instability can usually be prevented or easily managed by anticipating and communicating about issues that can impact the heart's ability to fill and pump. The following considerations should be reviewed before starting off-pump surgery:

- The individual patient's coronary anatomy, the extent of cardiac ischemia, and how those factors could impact hemodynamics during cardiac manipulation.
- Sequencing of coronary revascularization. In general, surgeons choose a grafting strategy with the goal of improving blood flow and myocardial oxygenation during subsequent anastomoses and cardiac displacement.
- Patient history and preoperative blood pressure. The surgeon and anesthesiologist should jointly decide what blood pressure parameters will be adequate for the patient during OPCAB. For example, a patient with chronic high blood pressure would probably require a higher intraoperative blood pressure, while a patient with lower preoperative blood pressure would likely tolerate lower pressures during the procedure.

Temperature Management

Maintaining normothermia is extremely important in optimizing patient outcomes and hemodynamic stability during OPCAB. Preoperative hypothermia can increase the risk of myocardial infarction, wound infection, blood loss, extended anesthesia care, and prolonged recovery and hospitalization.[11-14]

Preventing unintentional hypothermia should begin well before the patient comes to the perioperative area. To preserve body temperature and maintain normothermia throughout the perioperative process, clinicians should utilize the following passive and active warming techniques:

- The patient should arrive in the OR holding area wearing blankets and a hypothermia prevention cap. Ideally, the patient's temperature should be 37°C when arriving for surgery.
- In the OR holding area, place a warming device (e.g., Arizant Bair Hugger™ blanket) on the patient to help maintain the patient's temperature. When prepping the patient, the staff should be cognizant of keeping the patient covered as much as possible, and should only uncover and prep a small section of the body at a time.
- Preheat the OR to 72°F before set-up begins. Once the patient is in the OR, be sure to cover the patient while the anesthesiologist places the lines.
- Before starting the procedure, apply a Cath Lab blanket (e.g., Arizant Bair Hugger blanket) around the patient's head and sides. This surrounds the patient with warm air and provides unrestricted access to the chest and legs. The room temperature can then be cooled to a comfortable level for the surgical team.
- Intraoperatively, the surgical team should use warmed irrigants, warmed IV fluids and a blood warmer. The anesthesiologist should also warm and humidify ventilator gases using an airway heat/moisture exchanger.

Procedural Considerations

During OPCAB, the surgeon must continuously look at the heart to see how it is working and be cognizant of its physiology and functions. Sometimes picking up the heart can restrict blood flow in the coronary arteries or cause mitral valve dysfunction. The surgeon can make a huge impact on the hemodynamics of a patient with even a tiny adjustment in how the heart is positioned, where the devices are placed, or how far the chest cavity is opened.

When choosing an anesthetic technique, the anesthesiologist must provide hemodynamic stability, maintain normothermia and consider rapid emergence and early extubation of the patient in the operating room. Fast track anesthesia with early extubation is currently the most commonly employed practice for OPCAB surgery, and research suggests it is safe, cost effective and has many potential benefits. Studies show no evidence of increased cardiopulmonary morbidity or mortality associated with fast track anesthesia and early extubation. Benefits of early extubation include improved post-operative hemodynamic performance, earlier patient mobilization, reduced risk of ventilator-associated pneumonia, reduced ventilator-related costs, shorter ICU time, and decreased hospital length of stay.[15-22] At LMC, early extubation and early patient mobilization play an important role in obtaining good patient outcomes after OPCAB. In the last 10 years, approximately 78% of LMC's OPCAB patients have been extubated in the operating room.

It is vitally important that the anesthesiologist continually observes and treats the hemodynamic and rhythm responses that can occur from cardiac manipulation and regional ischemia during OPCAB. Before the surgeon manipulates the heart, the anesthesiologist should achieve the optimal heart rate and blood pressure for each anastomosis. Many times, the anesthesiologist can achieve hemodynamic goals through fluid management and the use of table positioning. For example, using Trendelenberg will fill the heart maximally and increase blood pressure. Or rolling the table to the right allows gravity to pull the heart over and provides access to the back wall when the surgeon works on the diagonal and circumflex vessels. When necessary, the anesthesiologist should use small boluses of neosynephrine or levophed to support blood pressure and cardiac output, but should make every effort to avoid significant inotropic or vasopressor support.

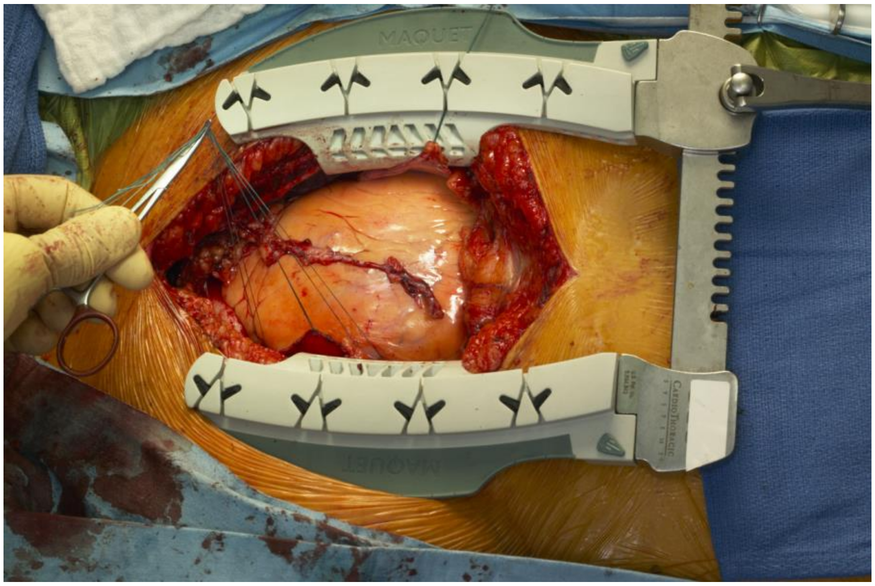
Beating Heart Tip:

Prior to heart manipulation and positioning, elevate the blood pressure at least 20% above baseline using IV vasopressor bolus and use Trendelenberg positioning as needed.

Coronary Artery Exposure

During OPCAB, the surgeon needs good coronary artery exposure and must be able to position the heart without compressing, or limiting its natural ability to pump. Prior to positioning the heart, first assess anatomic structures in the chest cavity, including the sternum, pleura and pericardial edge, which can compress the heart and lead to decreased cardiac output and hemodynamic instability during OPCAB.

Figure 1: Take Down Pericardial Stay Sutures to Assess Chest Cavity



- Take down the pericardial stay sutures from the retractor on the right side (see Figure 1.) This allows the heart to easily lie into the right chest or against the right pleura. Because positioning the heart usually involves lifting and pulling it up to the right, surgeons must be cognizant of the sternum and the pericardial stay sutures, as these can limit exposure and place pressure on the heart. Make sure the sutures are totally loose, which is easily done using a small hemostat to hold them. The surgeon can leave the sutures up on the left side.

- Assess room in the chest cavity. Palpate to determine if there are any restrictions on the right side from the sternum, pericardium or pleural edge when the heart is pulled up and over to the right to access the lateral branches.

- If the sternum, pericardium or pleura restricts pulling over the heart, it might be necessary to cut down the pericardium at the right diaphragmatic edge, almost to the phrenic nerve, or to open the pleural cavity. How far the pericardium needs to be opened depends on how it feels during palpation.

- Likewise, make sure not to place sponges, or pericardial sutures behind the heart, as these could potentially compress the left ventricle and limit the heart's ability to fill and pump. If there are no restrictions on the heart, proceed with the anastomoses.

Sequence of Grafting

The sequence of coronary artery grafting also plays a key role in maintaining hemodynamic stability during OPCAB. In general, the grafting sequence is based on the patient's coronary artery disease pattern, and surgeons chose a grafting strategy with the goal of improving blood flow, myocardial oxygenation and overall cardiac performance during subsequent anastomoses and cardiac displacement.

Mentally review the degree of coronary ischemia prior to performing each anastomosis. In general, surgeons first graft the left internal mammary artery (LIMA) to the left anterior descending (LAD) artery in an effort to restore blood flow to the largest coronary distribution of the heart and because it requires the least manipulation of the heart. The LIMA to the LAD is the most important graft to start with as it is the easiest to position. If severe ischemia is a concern, consider performing the LIMA to the LAD in situ without the positioner, and open the chest widely to achieve exposure or insert an aortic cannula and be prepared to go on pump, if necessary.

Surgeons at LMC use the XPOSE™ Access Device to position and graft coronary arteries in the following sequence:

- LIMA to LAD
- Diagonals
- Posterior Descending Artery (PDA)
- Right Coronary Artery
- Proximals
- Circumflex/Ramus

Ischemic Preconditioning

Another way to prevent hemodynamic instability is through ischemic preconditioning. Preceding bypass, the surgeon can precondition the beating heart by creating brief, nonlethal periods of ischemia to the myocardium using silastic tourniquet, or by picking up the heart with the XPOSE Access Device. This conditions the heart to better tolerate a subsequent prolonged episode of ischemia during coronary artery bypass and decreases the possibility of hemodynamic impairment due to myocardial ischemia. In order to precondition the heart during OPCAB, surgeons should take the following steps:

- Pick-up the heart using the positioner.
- Elongate it in line with the arteries to be bypassed, and then pull it up as necessary. Be cognizant of not bending or folding the heart in any way. Keep it straight in the direction of the target arteries.
- Monitor the heart rate, EKG, and hemodynamics during this period.
- If the heart does not hemodynamically tolerate this position, put the heart down for a while and let it rest.
- Allow the heart to rest until the hemodynamics and EKG are restored, then pull it up again into a similar position. Modifying the position slightly can make a big difference in the hemodynamics. After pre-positioning, the heart should hemodynamically adjust to the decreased flow in subsequent attempts to position the heart and should better tolerate more prolonged episodes of ischemia.
- Complete the anastomosis.

Surgeons can also use coronary shunts to maintain blood flow during anastomoses and minimize hemodynamic instability from myocardial ischemia. If there is ischemia or low blood pressure during an anastomosis, a shunt allows the surgeon to safely put the heart back in the pericardium and reperfuse the patient with little blood loss through the arteriotomy.

Positioning the Heart

For optimal hemodynamics, a good rule of thumb for positioning the heart is to make sure it is pulled out of the pericardium to expose the LAD, and is elongated and in line with the LAD. This maintains the long axis dimension of the ventricles and maximizes the heart's ability to maintain stroke volume. This is most easily accomplished using a vacuum positioner placed on the apex of the heart.

The exact placement of the positioner vacuum cone depends on the target artery and the exposure required to reach that artery. However, the surgeon may have to make several adjustments in positioner placement to determine the ideal location. Even a small adjustment in how the heart is positioned can have a large impact on the hemodynamics of a patient.

Where the stabilizer and positioner are placed and how far the chest cavity is opened are often overlooked factors in maintaining hemodynamic stability. Using a positioner even for the LIMA-to-LAD anastomosis or tilting the operating table to the right can bring the heart out of the chest without the need for pads or sponges underneath the heart, which can compress the left ventricle and compromise filling.

Beating Heart Tip:

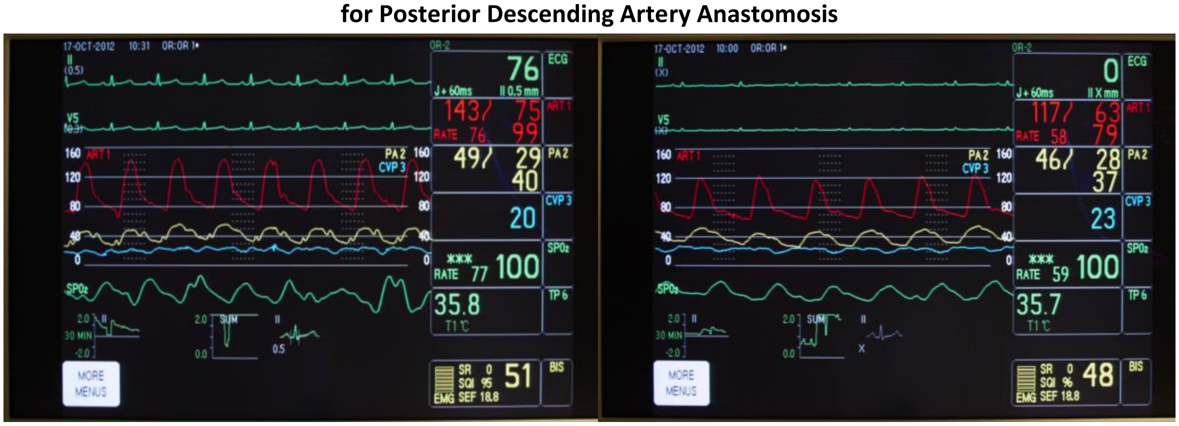
Blood Pressure Goal Proximal Anastomosis:

- SBP 80-100 mmHg and/or mean arterial pressure 60-70 mmHg
- Reverse Trendelenberg and small IV vasodilator bolus (e.g. nitroglycerin 40 mcg) as needed can be sufficient

Surgeons should also be cognizant of not bending or folding the heart in any way. The exception to this rule is for anastomoses of the right coronary artery and circumflex/ramus arteries, which require elevation and slight bending in order to access the target vessels.

Hemodynamic goals during OPCAB can vary by patient, the type of anastomosis and the degree to which the surgeon must bend the heart in order to reach the target vessels. Figure 2 shows general hemodynamic goals before and after positioning the heart for the posterior descending artery anastomosis. Figure 3 shows positioner placement and general positioning guidelines by type of anastomosis during beating heart surgery.

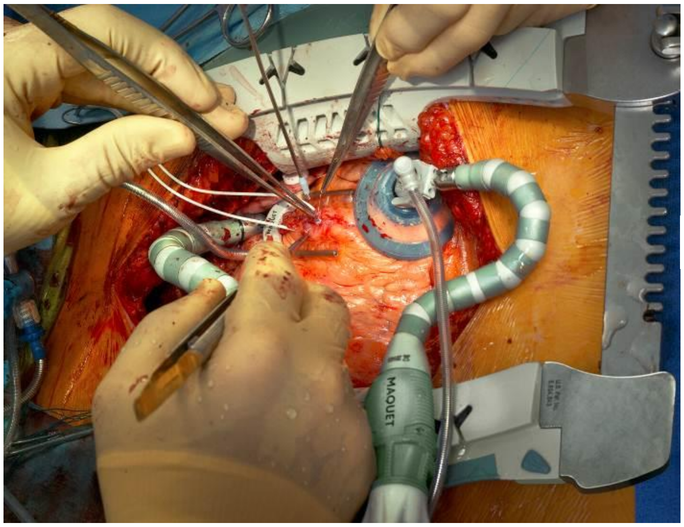
Figure 2: Hemodynamic Goals: Pre- and Post-Positioning of the Heart for Posterior Descending Artery Anastomosis



Pre-PDA Positioning

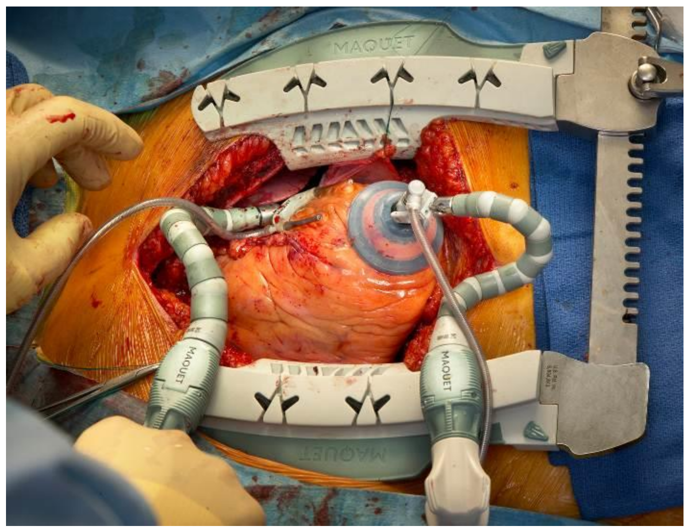
Post-PDA Positioning

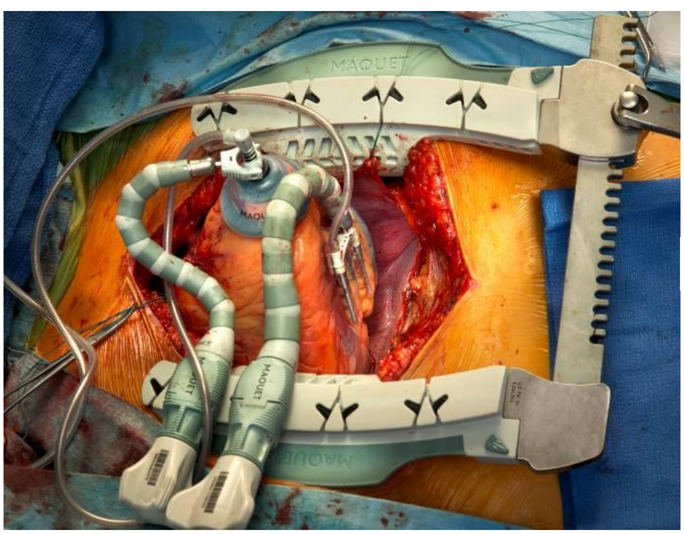
Figure 3: Positioner Placement and General Positioning Guidelines for OPCAB, by Type of Anastomosis



LIMA to LAD

Diagonal





PDA

Lateral/Posterior Portion of the Heart

Although displacing the heart to expose the circumflex marginal arteries can be one of the most challenging aspects of OPCAB, surgeons can successfully bypass these vessels and maintain hemodynamic stability by using enabling devices such as the XPOSE Access Device and ACROBAT V Stabilizer. These devices allow surgeons to securely lift and easily position the heart while providing better access and control for hard-to reach target vessels.

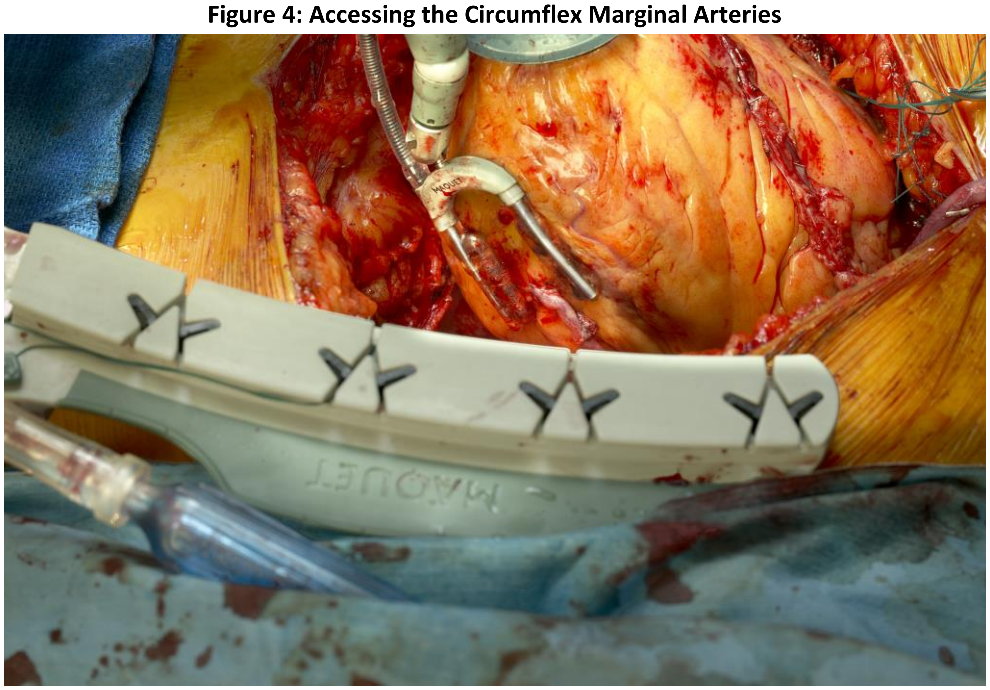
Beating Heart Tip:

Blood Pressure Goal
Distal Anastomosis/Circumflex Marginal Arteries:

- Prior to initially positioning the heart, raise the SBP >135 mmHg using Trendelenberg positioning and IV vasopressor boluses
- If the heart appears to be hypovolemic, consider an IV fluid bolus as well
- Maintain BP within 20% of baseline
- If BP is declining and not responding to IV vasopressor bolus, notify the physician to place the heart back in the pericardium, remove the positioner, and allow the BP to return to baseline.
- Prior to repositioning the heart the second time, raise the systolic BP to >145 mmHg

To perform bypass on the circumflex marginal arteries, rotate the OR table to the right as far as safely possible to provide access to the back wall using gravity to pull the heart over. Place the XPOSE™ Access Device halfway between the apex of the heart and the target on the marginal artery (see Figure 4) Retract the heart over in line with the artery and elongate it without bending the heart too radically. Perform the anastomosis. Should the blood pressure or heart rate drop or if multiple vasopressor boluses are required, the surgeon should put the heart down into the pericardium until it reperfuses before picking it up and positioning it again. It is easy for both the anesthesiologist and surgeon to visually inspect the heart and make sure it is contracting well.

Figure 4: Accessing the Circumflex Marginal Arteries



Summary

In summary, surgeons and anesthesiologists can use a variety of strategies for maintaining hemodynamic stability during OPCAB:

- Pre-procedure planning is an essential part of successful OPCAB surgery. The cardiac surgery team must approach OPCAB with a different mindset than on-pump procedures and receive training in OPCAB protocols, including how to handle emergencies. Before each case, review the patient's history, preoperative blood pressure, coronary anatomy, and the extent of cardiac ischemia. The surgeon and anesthesiologist should jointly decide what blood pressure parameters will be adequate for the patient during OPCAB. Close collaboration and good communication between the surgeon and the anesthesiologist are essential in maintaining hemodynamic stability during OPCAB.

- The sequence of coronary artery grafting also plays a key role in maintaining hemodynamic stability during OPCAB. Before surgery, choose a grafting sequence and strategy based on the patient's coronary artery disease pattern with the goal of improving blood flow, myocardial oxygenation and overall cardiac performance during subsequent anastomoses and cardiac displacement.

- Use passive and active warming techniques to preserve body temperature and maintain normothermia throughout the perioperative process. Preoperative hypothermia can increase the risk of myocardial infarction, wound infection, blood loss, extended anesthesia care, and prolonged recovery and hospitalization.[11-14]

- In order to achieve the full benefits of beating heart surgery, limit the use of preoperative medication. The anesthesiologist should consider rapid emergence and early extubation of the patient in the operating room. Fast track anesthesia with early extubation is currently the most commonly employed practice for OPCAB. Early extubation and early patient mobilization can have a dramatic impact on patient outcomes after OPCAB.

- Before the surgeon manipulates the heart, the anesthesiologist should achieve the optimal heart rate and blood pressure for each anastomosis. While small amounts of neosynephrine or levophed may be necessary to support blood pressure and cardiac output, the anesthesiologist should make every effort to avoid pharmacologic support of the circulation. Many times, the anesthesiologist can achieve hemodynamic goals through fluid management and the use of table positioning.

- Before performing each anastomosis, assess the chest cavity and minimize any restrictions that can cause compression on a beating heart including anatomic structures, sutures, sponges, or devices. Also, mentally review the degree of coronary ischemia prior to each anastomosis. If ischemia is a concern, consider performing the LIMA to LAD with the heart in situ without the positioner and open the chest widely to achieve exposure, or insert an aortic cannula and be prepared to go on pump if necessary.

- Manipulating and positioning the heart can significantly impact hemodynamic stability during OPCAB. The surgeon should constantly look at the heart to see how it's working and be cognizant of its physiology and functions. Sometimes picking up the heart can restrict blood flow in the coronary arteries or cause mitral valve dysfunction. Other times, anatomic structures, such as the sternum or pericardial edge, might be compressing on the heart, or a sponge could potentially limit its ability to fill and pump. Surgeons can make a huge impact on the hemodynamics of a patient with even a tiny adjustment in how they position the heart, where they place the devices, or how far they open up the chest cavity.

- When manipulating the heart, never kink or bend the heart in half, and keep it elevated and elongated to maintain the long axis dimension of the ventricles. Use an apical suction device and a coronary stabilizer to help achieve optimal positioning, minimize myocardial ischemia and improve hemodynamic instability during manipulation of the heart.

- If the heart does not hemodynamically tolerate certain positions, put the heart down and let it rest until the hemodynamics and EKG are restored. By doing so, this also "preconditions" the heart to tolerate longer periods of ischemia during coronary artery bypass. Also called ischemic preconditioning, surgeons can improve hemodynamic instability by creating brief, nonlethal periods of ischemia to the myocardium. Surgeons can also use coronary shunts to maintain blood flow during anastomoses and minimize hemodynamic instability from myocardial ischemia.

- Although displacing the heart to expose the circumflex marginal arteries can be one of the most challenging aspects of OPCAB, surgeons can successfully bypass these vessels and maintain hemodynamic stability by using enabling devices such as the XPOSE Access Device and ACROBAT V Stabilizer. To perform bypass on the circumflex marginal arteries, rotate the OR table to the right as far as safely possible to provide access to the back wall using gravity to pull the heart over. Place the XPOSE Positioner halfway between the apex of the heart and the target on the marginal artery. Retract the heart over in line with the artery and elongate it without bending the heart in half. Perform the anastomosis.

References

1. Polomsky M, He X, O'Brien SM, et al. Outcomes of off-pump versus on-pump coronary artery bypass grafting: Impact of preoperative risk. *Journal of Thoracic and Cardiovascular Surgery.* 2013 May; 145 (5):1193-8.

2. Afilalo J, Rasti M, Ohayon SM, et al. Off-pump vs on-pump coronary artery bypass surgery: An updated meta- analysis and meta-regression of randomized trials. *European Heart Journal.* 2012; 33:1257–1267.

3. Puskas JD, Kilgo PD, Lattouf OM, et al. Off-pump coronary bypass provides reduced mortality and morbidity and equivalent 10-year survival. *Annals of Thoracic Surgery*. 2008 Oct; 86(4):1139-46.

4. Angelini GD, Taylor FC, Reeves BC, et al. Early and midterm outcome after off-pump and on-pump surgery in Beating Heart against Cardioplegic Arrest Studies (BHACAS 1 and 2): a pooled analysis of two randomized controlled trials. *Lancet.* 2002; 359:1194–1199.

5. Halkos ME, Puskas JD. Off-pump versus on-pump coronary artery bypass grafting. *Surgical Clinics of North America*. 2009 Aug; 89(4):913-22.

6. Van Dijk D, Jansen EW, Hijman R, et al. Cognitive outcome after off-pump and on-pump coronary artery bypass graft surgery: a randomized trial. *JAMA.* 2002; 287:1405–1412.

7. Puskas JD, Stringer A, Hwang, SN, et al. Neurocognitive and neuroanatomic changes after off-pump versus on-pump coronary artery bypass grafting: Long-term follow-up of a randomized trial. *The Journal of Thoracic and Cardiovascular Surgery*, Vol. 41, Issue 5, May 2011; 1116-1127.

8. Li Z, Denton T, Yeo KK, et al. Off-pump bypass surgery and postoperative stroke: California Coronary Bypass Outcomes Reporting Program. *The Annals of Thoracic Surgery.* Vol. 90, Issue 3, Sept 2010; 763-759.

9. Ishida M, Kobayashi J, Tagusari O, et al. Perioperative advantages of off-pump coronary artery bypass grafting. *Circulation Journal*. Sept 2002; 66(9):795-9.

10. Gobran SR, Goldman S, Ferdinand F, et al. Outcomes after usage of a quality initiative program for off-pump coronary artery bypass surgery: a comparison with on-pump surgery. *Annals of Thoracic Surgery.* 2004; 78:2015-2021.

11. Frank SM, Fleisher LA, Breslow MJ, et al. Perioperative maintenance of normothermia reduces the incidence of morbid cardiac events: a randomized clinical trial. *JAMA.* 1997; 277:1127-34.

12. Kurz A, Sessler DI, Lenhardt RA. Study of wound infections and temperature group: Perioperative normothermia to reduce the incidence of surgical wound infection and shorten hospitalization. *New England Journal of Medicine.* 1996; 334:1209-15.

13. Schmeid H, Kurz A, Sessler DI, et al. Mild intraoperative hypothermia increases blood loss and allogeneic transfusion requirements during total hip arthroplasty. *Lancet.* 1996; 347:289-92.

14. Lenhardt R, Marker E, Goll V, et al. Mild intraoperative hypothermia prolongs postoperative recovery. *Anesthesiology.* 1997; 87:1318-23.

15. Hemmerling TM, Romano G, Terrasini N, et al. Anesthesia for off-pump coronary artery bypass surgery. *Annals of Cardiac Anaesthesia.* 2013; 16L:28-39.

16. Myles PS, Daly DJ, Djaiani G, et al. A systematic review of the safety and effectiveness of fast-track cardiac anesthesia*. Anesthesiology.* 2003; 99:982-7.

17. White PF, Kehlet H, Neal JM, et al. The role of the anesthesiologist in fast-track surgery: From multimodal analgesia to perioperative medical care. *Anesthesia & Analgesia.* 2007; 104:1380-96.

18. Cheng DC. Fast-track cardiac surgery: Economic implications in postoperative care. *Journal of Cardiothoracic and Vascular Anesthesia.* 1998; 12:72-9.

19. Cheng DC, Karski J, Peniston C, et al. Early tracheal extubation after coronary artery bypass graft surgery reduces costs and improves resource use. A prospective, randomized, controlled trial. *Anesthesiology*. 1996; 85:1300-10.

20. Svircevic V, Nierich AP, Moons KG, et al. Fast-track anesthesia and cardiac surgery: A retrospective cohort study of 7989 patients. *Anesthesia & Analgesia.* 2009; 108:727-33.

21. Flynn M, Reddy S, Shepherd W, et al. Fast-tracking revisited: Routine cardiac surgical patients need minimal intensive care. *European Journal of Cardio-Thoracic Surgery.* 2004; 25:116-22.

22. Carli F, Kehlet H, Baldini G, et al. Evidence basis for regional anesthesia in multidisciplinary fast-track surgical care pathways. *Regional Anesthesia and Pain Medicine.* 2011; 36:63-72.