

Technical Tips and Pitfalls in OPCAB Surgery: The Buffalo Experience

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ABSTRACT

The Center for Minimally Invasive and Robotic Heart Surgery has performed more than 1,500 off-pump coronary artery bypass (OPCAB) procedures since 1995. The operation has changed significantly based on experience and development of new tools. These improvements have made the operations safer and applicable to more patients. No patients are presently scheduled for on-pump bypass surgery in our center. The purpose of this paper is to describe some of the problems and pitfalls we have experienced and how to avoid them.

INTRODUCTION

The technique for OPCAB has been significantly modified since 1995, but at present a relatively standard procedure has emerged. We are also fully aware that OPCAB per se was developed years ago and that successful off-pump coronary surgery has been performed by pioneers in South America [Benetti 1991] long before the re-invention of the procedure in North America. Of course, the learning experience continues and there has been constant improvement in the tools utilized. Many of the modifications have occurred to overcome technical problems that were not anticipated. The purpose of this presentation is to help others steepen their learning curve and thereby avoid some of the most common mistakes. We have divided this brief paper in what we believe are the most important steps in OPCAB surgery.

Selection

In our center, all coronary artery bypass grafting (CABG) patients are scheduled for OPCAB. We do get a significant

percentage of high-risk patients and our cardiologists often refer patients who have been turned down for standard CABG [D'Ancona 1999a]. Although the "highest risk patient gets the most benefits" we recommend avoiding this potential "trap" in the start up phase for new programs. The margin is less in high-risk cases and it is easy to get into trouble. Although OPCAB is starting to become "mainstream", there is still skepticism and the procedure may be blamed in cases of an unfavorable result. In our opinion, all patients benefit from OPCAB vs. standard CABG. It is recommended to start an OPCAB program by selecting favorable patients who should do very well and then expand to the more challenging and high-risk cases.

"Ideal" patients for OPCAB

1. Good distal vessels.
2. Good left ventricular function.
3. No ongoing ischemia.
4. No critical left main disease.

We also recommend the "novice" OPCAB surgeon be careful with patients with only one target when the other vessels are ungraftable and totally occluded. This situation can rapidly turn into a very difficult management situation with severe ischemia and unstable hemodynamics. Also, do not hesitate to go on pump in case of trouble. This is not a defeat and should not cause major problems when the patient is converted in a controlled fashion.

Medical management

The patient should be well controlled at the time of surgery if at all possible. Patients with acute and ongoing ischemia are difficult to manage intra-operatively. Although some of the most aggressive OPCAB surgeons in South America are tackling patients in full cardiac arrest with OPCAB techniques, we certainly do not advocate this approach. Patients should be medically stable on calcium channel, beta-blocking agents, nitrates and other drugs as needed. With modern pharmacological therapy, almost all patients with coronary artery disease can be successfully stabilized.

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We routinely give aspirin and Plavix preoperatively to interfere with platelet-function. Since there is no cardiopulmonary bypass (CPB) to cause platelet dysfunction and a fibrinolytic stage, we believe it is important to interfere with platelet function to improve graft patency. Although we have no hard data, there is increasing evidence and concern about the so-called hypercoagulable state in OPCAB surgery [Mariani 1999].

In very unstable patients with ongoing ischemia we occasionally use intra aortic balloon pumping (IABP) preoperatively. IABP can make the unstable patient nonischemic and make OPCAB a nice hemodynamically simple experience in the most severe cases.

Anesthesia

An informed and interested anesthesiologist is crucial for success. The following pitfalls can make OPCAB an extremely challenging and frustrating experience. The experienced cardiac anesthesiologist or nurse anesthetist will anticipate and treat hemodynamic changes ahead of time, thereby making the whole procedure smooth with few peaks of valleys in the blood pressure. A two-way communication between anesthesiologist and surgeon must take place on a continuous basis. Specific issues are summarized below:

1. Volume management. This is an important issue and will cause major problems if not handled properly. The OPCAB patient does not get a big fluid load through the pump-prime and fluid added into the pump and is therefore frequently given inadequate amounts of fluids. Relative hypovolemia will make it virtually impossible to position the heart. The reaction of the inexperienced will be to give higher doses of inotropes or vasoconstrictors. Such drugs in high doses will cause ischemia, arrhythmias and possibly end organ damage.
2. Blood loss. Although it has been shown that OPCAB may save blood-products in coronary surgery, there are several pitfalls. The management of bleeding, shed blood, and volume infusion requires careful attention. Otherwise severe anemia and bleeding diathesis may result. This is especially important when multiple grafts are done and if meticulous hemostasis is not observed during harvesting of arterial conduits. Excellent hemostasis should be assured before administration of heparin. The shed blood is in general saved and washed by the "Cellsaver", which will remove the clotting factors and platelets. If four, five or six grafts are done, loss of blood can become a major issue and the patient occasionally requires packed red cells and even components. This can in most cases be avoided by the precise and compulsive surgeon.
3. Blood pressure and hemodynamic management. Although we have demonstrated only relatively minor hemodynamic changes during heart positioning when the "single stitch" technique is utilized [D'Ancona 2000a], there is frequently a need for pharmacological intervention to stabilize the blood pressure. We prefer to use vasoconstrictors such as nor-epinephrine or neosynephrine to increase blood pressure and nitroglycerin

to decrease it. Beta-blockers are used to reduce the heart rate but are seldom needed. Calcium-channel blockers are used routinely to reduce spasm in arterial grafts.

Monitoring

1. Arterial line and central venous pressure (CVP) are mandatory. We have occasionally performed OPCAB without monitoring any invasive pressures but this is quite nerve wrecking for the surgeon and is not recommended.
2. Pulmonary artery catheter is helpful in unstable patients and patients with low ejection fraction or mitral regurgitation. Some centers use pulmonary artery catheters routinely while we have tried to use them selectively. When significant volume infusions and the use of vasoconstrictors and inotropes are anticipated, pulmonary artery pressure monitoring may be very useful in prevention and management of ischemia.
3. Transesophageal echo is seldom utilized in our center in OPCAB operations, but may help in the evaluation of the aorta and the left ventricular function as well as regional wall motion abnormalities.
4. Electro-encephalography and continuous svO₂ monitoring has been used extensively by the Tampa-group [Novitzky 2000] and may have an important role in the prevention of adverse CNS-events secondary to hypotension. We do not have experience with this methodology but are planning to initiate such monitoring for our cardiac patients.

Incisions

In the term OPCAB, we include all off-pump CABG. Although the majority of the cases are done through a median sternotomy, there is an important role for alternate incisions. In primary cases the incision may be limited to obtain a truly minimally invasive procedure and a superior cosmetic result. In reoperations the choice of incision may have major influence on overall outcomes and complications [Miyaji 1999, D'Ancona 2000b]. The planning of such operations is crucial since the exposure is limited and the purpose, especially in the reoperative minimally invasive procedure, is to limit dissection and minimize positioning, which can cause tension and embolization of old grafts.

For LAST-MIDCAB operations, the left internal mammary artery (LIMA) obviously has to be present and the left anterior descending artery (LAD) must be of reasonable quality and not intramuscular.

Minimally invasive procedures to the right coronary artery (RCA) using the gastroepiploic artery [GrandJean 1996] require careful evaluation of the abdominal status.

Positioning

In the standard OPCAB with multi-vessel bypasses, we use the "LIMA-stitch" (after Ricardo Lima, Recife, Brazil). This stitch has been well described [Karamanoukian 1999] and is also called deep pericardial stitch by some. In our modification, a gauze pack is fixed to the posterior pericardium. By pulling on the gauze the heart is lifted. The heart

rests on the gauze-pad. All vessels may be exposed using this technique [Karamanoukian 1999].

The potential dangers of this positioning technique are:

1. Damage to the left pulmonary veins may cause bleeding.
2. The gauze pack may cause compression of the circumflex or its branches if too much traction is utilized. In a patient dependent on the circumflex (relatively uncommon in our experience) we perform grafting of LAD first. In very unstable or critical circumstances, we perform the LAD-anastomosis with minimal elevation of the heart. Other groups are solving this problem by doing circumflex first, basing the perfusion on the native LAD. We believe that it is more dangerous to do major elevation of the heart prior to LAD grafting, especially if the lesion in LAD or left main is severe.

Alternative positioning technique

We previously utilized the positioning technique described by Dr. Gerard Guardion to perform ablation of aberrant atrioventricular connection of the posterior heart. Dr. Antonio Calafiore modified this technique and included gauze tapes passed through the transverse sinus and under the vena cava. These tapes were then used for heart positioning. The major danger of this method was the potential of exerting direct pressure on the left main coronary with severe ischemic and hemodynamic collapse.

Positioning must always be performed in close cooperation with the anesthesiologist. If the desired position is not tolerated, the heart should be placed back in its normal position and the situation reassessed. Anesthesia should then be given time to volume load the patient or pharmacologically improve the hemodynamic state. Usually the second time will be better with the same or slightly different position. The key element is to be patient especially early on during the teams learning curve.

Stabilization

We have mainly used pressure stabilization and have been satisfied with this method. There are certain important pitfalls with this type of stabilization, however.

1. Perforation of the heart with the stabilizing fork. Although we have not had this complication, it is a definite danger. It is very important that the surgeon and the assistant perform the placement and removal of the stabilizer foot together; one person should be holding the heart and the second handling the stabilizer.
2. Removing the device can cause avulsion of the graft. This is a real danger especially when the stabilizer bar is placed cephalad. If the stabilizer bar is placed caudal, the danger of graft avulsion is less but the stabilization may be less satisfactory. When great care is taken on removing the device after grafting, this complication is usually avoided.
3. If too little pressure is applied, there may be motion between the stabilizer foot and the heart. This will cause a “sawing action” and damage to the epicardium and to cardiac veins.

4. If too much pressure is applied, cardiac output may potentially be impaired. We have studied this and found it to be uncommon. Remember more pressure does not necessarily improve stabilization.
5. Another more common pitfall is obstruction of another vessel during grafting. This is most common if the diagonal branch of LAD is stabilized. The stabilizer can easily occlude the LAD itself, causing ischemia and hemodynamic problems. The best way to avoid this is to graft LAD first with a different conduit (usually the mammary artery). This potential problem is the main reason we are reluctant to graft diagonal and LAD with sequential LIMA-grafts. A T-configuration is in general much safer.

Preparing for grafting

When the heart is positioned and the conduits ready, grafting must be performed in a relaxed controlled atmosphere or the case will quickly get out of hand. A proximal snare is placed to obstruct the vessel. The heart and hemodynamics are now observed for two to three minutes to evaluate if the patient will tolerate obstruction of the vessel to be grafted. After such “pre-conditioning” the actual grafting may proceed.

Everything must now be prepared: blower, shunts, and suction. An open vessel bleeding is siphoning the distal vessel and may thereby be causing ischemia. It is therefore much better to shunt, distally snare, or use a simple intraluminal obstructor, than leaving the distal vessel open. This concern is especially important for the right coronary artery.

Tools utilized during grafting

1. Blower. This is an essential tool of great value but dangerous if used incorrectly. The gas flow must be misted with saline. The flow of gas must not be too high since damage to the endothelium may occur. If unmisted air is used damage to the vessel is obvious. An experienced assistant must still do the blowing. There is a great need for a surgeon-controlled blower, which would make blowing an easier and safer part of the operation.
2. Snares. We always use a proximal snare and have continued to use 4-0 polypropylene, compressed pledgets, and rubber tourniquets to accomplish obstruction. This snare must be placed far enough “upstream” to create enough space for the anastomosis. If possible, avoid heavily diseased vessel areas for the snare to avoid vessel cracking or incomplete obstruction. Occasionally the suture may damage a septal perforator. In such case the snare is removed and a new one placed in another location. A distal snare is occasionally used but we prefer to use a shunt or obstructor.
3. Shunts. There are in principle two types of shunts local- and aortocoronary-shunts which both have their advantages and pitfalls.
 - a) Local-shunts. These T-shaped shunts tend to have a small internal diameter and, since they are shunting from an area that is distal to the coronary obstruction,

tion, the flow in such shunts can be questioned. The limited studies that have been done on such shunts (personal communication) have shown that the flow in such shunts is indeed very low. Our own personal experience is that such shunts do prevent severe ischemia when they are used properly. In heavily diseased vessels, shunts can cause dissection and serious intimal damage and may be better avoided.

- b Aortocoronary-shunts. We have used "homemade" shunts consisting of a large bore catheter in the aorta, IV tubing, and an olive tipped plastic cannula for coronary insertion. Although this system provides a higher-pressure head at the distal coronary level, there is still no control of the flow. When blood pressure decreases, flow in the shunt will also decrease. In general, however, these shunts work very well. We have usually applied them during RCA grafting.

Grafting

This is obviously the crucial point of the operation and why the procedure is done in the first place. The surgeon must be in a relaxed comfortable state with a stable patient. Positioning should be excellent and the heart rates should neither be too slow or too fast; 70 to 80 are ideal. We use to slow the heart to make it easier to suture, but with modern stabilizers this is not necessary. Actually a large stroke volume and slow heart rate is not advantageous since motion is increased.

The stabilizer is applied and the vessel opened and controlled. The most important aspects of suturing are listed below:

1. Steady hands. Rest them on the patient but don't rest anything on the heart.
2. Needle position in the needle holder is crucial. The needle must always be positioned to take a gentle non-traumatic curve through the vessel walls.
3. The curve of the needle must be followed to avoid a larger than necessary hole in the intima. Lifting of tissues with the needle is unacceptable, since this will make a big hole or even a tear in the vessel increasing the chance of thrombosis. The positioning of the needle is one of the most important points of the OPCAB procedure, but often not emphasized in discussions. Surgeons who are starting OPCAB often do not realize that suturing is not the same as on-pump. In an arrested heart the vessel can usually be presented to the surgeon in a favorable plane. In OPCAB, the plane of presentation may be quite unusual.
4. Manipulation of the needleholder. We recommend that a Castro-type needle holder is moved by finger-motion primarily and not the wrist. This is an important detail in the prevention of intimal damage.

Graft verification

Graft verification is a must in OPCAB as in all CABG [D'Ancona 1999b]. The initiation of a new graft-technique certainly makes it even more important to have a quality

assurance tool available. We have found transit-time flowmetry to be a simple reliable method for assessment of graft patency. Although the method is very simple and does not require calibration certain technical details must be emphasized.

1. Flow must be measured with and without proximal occlusion. A graft obstructed at the toe may show perfectly normal flow if there is a significant perfusion in proximal direction.
2. Don't rely on mean flow alone. The graft may be compromised with relatively high mean flow. A graft can also be normal with low mean flow. Therefore the diastolic flow pattern must be evaluated.
3. When in doubt an intraoperative "stress-test" may be performed, analyzing flow and curves at higher blood-pressure and/or with injection of vasodilators such as nitroglycerin, papaverine or adenosine.
4. Beware of air bubbles. Presence of air in the graft may simulate organic obstruction. If this is suspected the graft should be milked and the measurement repeated.
5. When a malfunctioning graft is diagnosed, it should be immediately revised to prevent ischemia and hemodynamic problems during the remaining procedure.
6. A graft that is functioning well in the heparinized state may occlude after administration of protamine. Measurement of graft flow should therefore be repeated after heparin reversal.
7. Final graft verification should be done just before chest-closure since grafts that are too short or too long may kink on chest-closure.

Using these principles early, graft patency can be assured and adverse cardiac events during the post-operative phase avoided.

Cardiopulmonary bypass

There is no shame in using the heart-lung machine. CPB is an extremely valuable tool and should be utilized whenever necessary. We do convert in a few cases and have shown that this is not a major detriment in most cases [Soltoski 1998]. It is important to be prepared for this possibility. We always have a non-primed heart lung machine available and a perfusionist present in the room or nearby. When we use CPB we commonly continue to work on the beating heart, just utilizing the hemodynamic support. This makes it very easy and fast to go on pump. Crossclamping and cardioplegia is seldom utilized.

It is very important to avoid the so-called "crashing on pump" that frequently results in major complications from the cannulation or other aspects of the CPB. We also are very afraid of what we call the "double conversion". This occurs when a case originally planned for on-pump is converted to off-pump, due to calcified aorta or other strong contraindications to CPB. When such a patient needs to be converted again to on-pump, chances of major adverse events are very high. In this situation, careful assessment and compromise in the completeness of revascularization should be considered.

CONCLUSION

OPCAB is an old procedure antedating traditional on-pump CABG. Technology was not available at that time, making off-pump CABG difficult and unpredictable in all but the most skillful hands. There has been rapid improvement in technology for OPCAB over the last five years. Stabilization, shunting and graft verification have become simpler and more effective.

We believe the need for CPB in coronary surgery will be more or less eliminated during the next several years and that coronary intervention will be performed on a beating heart in the cath.lab or in the operating room with only occasional use of pumps or other assist-devices.

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