Patient selection and technical considerations for off-pump coronary surgery

Amit N. Patel, MD, MS, Federico Benetti, MD, and Baron Hamman, MD

The first successful operations on the coronary arteries were done without the assistance of extracorporeal circulation. Many published reports described operations performed while the heart continued beating (1–8). Advances in cardiopulmonary bypass (CPB) technology, myocardial protection, and cardiopulmonary support allowed surgeons to operate on these arteries with greater precision.

It is widely accepted that the single most important development in cardiac surgery was the introduction and refinement of extracorporeal circulation via CPB. Event-free survival rates in cardiac surgery dramatically improved with advancements in myocardial protection that allowed operating in a quiet, motionless, and bloodless field.

More recently, advances in 2 competing strategies, coronary artery bypass grafting (CABG) surgery and catheter-based intervention, have led to many debates regarding the optimal treatment of ischemic coronary artery disease. CABG has resulted in longer survival, better quality of life, and long-term event-free survival in patients with multivessel coronary artery disease (9–11).

But what is old is new again. The option of not using the pump was the underlying assumption in the development of the concept of minimally invasive coronary surgery. Reports regarding systemic effects of CPB abound in the literature of the past 17 years. Such effects include hematologic, metabolic, pulmonary, cardiac, and cognitive dysfunctions (12–21).

MINIMALLY INVASIVE CORONARY SURGERY

First out of necessity and then due to the clinical benefits, Benetti (22, 23) and Buffolo (24) repopularized off-pump coronary revascularization (OPCAB) during the period from 1978 to 1991. They developed the OPCAB technique and used it to revascularize all arteries of the heart. The key advance that allows for off-pump suturing is the development of stabilization devices, which greatly enhance the surgeon's skills.

The standard incision in coronary artery surgery has been the median sternotomy. Other approaches have been used, including the 1) left anterolateral thoracotomy with mammary and proximal ascending aorta connection, 2) right anterolateral thoracotomy with proximal ascending aorta connection and distal right coronary artery anastomosis, 3) posterolateral thoracotomy with proximal descending aorta connection, and 4) partial sternotomy for the mammary left anterior descending (LAD) artery anastomosis. Thoracoscopy was used for the first time in 1994 to dissect the mammary artery without opening the pleural cavity, connecting to the LAD through a small left anterior thoracotomy (25–27). This began the minimally invasive era of cardiac surgery.

A new series of technological developments later came to the market and made possible the reproduction of this technique on a larger scale (28–31). The minimally invasive direct coronary artery bypass (MIDCAB) was proven in a prospective multicenter study that yielded the same quality and patency rate in patients who underwent mammary-to-LAD connection with stabilization devices with and without pump anastomosis (32). Today, coronary surgery on the beating heart (OPCAB-MIDCAB) is performed daily all over the world. Long series of patients confirm the initial experience showing the advantages of this procedure.

INDICATIONS

The coronary arteries are on the surface of the heart. This location enables easy access for performing complete revascularization with the assistance of stabilization and exposure devices. The majority of patients requiring CABG, therefore, can benefit from beating-heart procedures. However, the learning curve in OPCAB must be considered since beating-heart coronary surgery is a completely different operation, one that requires a completely different mindset than traditional on-pump coronary surgery. Beating-heart coronary surgery requires a true team approach. Both the surgeon and the anesthesiologist must work in concert to attain a smooth, safe, and efficient operation.

The ideal patient for beating-heart coronary surgery has the following characteristics:

1. >1.5-mm distal vessel diameter
2. Good ventricular function
3. Hemodynamic stability
4. Anterior wall anastomosis, i.e., LAD artery or the diagonal artery
5. <6.5-cm distance between the posterior table of the sternum fully exposed by the mammary retractor and the pericardium over the LAD area

From the Departments of Surgery (Patel) and Cardiothoracic Surgery (Hamman), Baylor University Medical Center, Dallas, Texas; and the Benetti Foundation, Buenos Aires, Argentina (Benetti).

Corresponding author: Amit N. Patel, MD, MS, Department of Surgery, Baylor University Medical Center, 101 N. Brookside Drive, Suite 102, Dallas, Texas 75214 (e-mail: anpatel72@hotmail.com).

More difficult cases can be attempted initially if an experienced off-pump surgeon is assisting. The patients to avoid early in the learning curve are those with the following characteristics:

1. Hemodynamic instability
2. Involvement of the intramyocardial vessels
3. Vessels <1.5 mm
4. Cardiomegaly, a cardiothoracic ratio >0.7 (when attempting posterolateral wall grafting)
5. Those requiring grafting of the large proximal right coronary arteries before the posterior descending arteries

After completing 50 cases successfully—which is defined as >90% patency based on intraoperative flow measurements in vessels with a distal runoff of >1.5 mm and a conduit-to-distal artery ratio of <5—the indications can be expanded to all patients except those who are brought to the operating room in cardiac arrest and need the pump.

OPERATIVE STEPS

Before proceeding with beating-heart coronary surgery, a number of concerns must be addressed in the mind of the surgeon:

- Do not touch the heart unless absolutely necessary.
- Think before acting.
- Keep the heart warm.
- Be ready to sew immediately once setup is complete.
- Wait to stabilize the patient before acting.
- Study the anatomy before acting.
- Work as a team with the anesthesiologist.
- Elongate the ventricle before moving the heart.
- Do not dissect the arteries too much.
- Use the blower/mister only when necessary.
- Apply correct tension for occlusion.
- Do not force the shunt.
- Apply adequate pressure for stabilization.
- Be careful with the right coronary artery.
- Do not position the heart in awkward positions for a long time.
- If you do the distal anastomosis first, try not to inject anything down the graft.
- Be careful when placing and removing the stabilizer.
- Do not move the stabilizer once positioned.

PROCEDURE

A sternotomy is performed. All conduits are harvested as for traditional CABG. The left internal mammary artery should be made as long as possible to help avoid excessive tension when the heart is elevated after the LAD graft is completed.

Heparin (3 mg/kg, the same dose used for CPB) is administered. The target activated coagulation time is >400 seconds. The heart must be kept warm by irrigating it with warm sterile saline solution.

After completing dissection of the mammary artery and preparing the conduits, the pericardium is opened by using a "hockey stick" incision. This entails an incision from the left of the main pulmonary artery down to the apex of the left ventricle to the junction between the right pleural space and the diaphragmatic pericardium. Another incision is made to complete the reflection of the pericardium from the pulmonary artery to the aorta. Pericardial stitches are placed backhand 1 to 2 cm from the left border of the pericardium for positioning of the LAD anastomosis. The heart is then repositioned with the surgeon's hand, and an exposure device is placed at the apex of the heart. This step marks the first time the heart is actually touched during the operation. Additional pericardial sutures may be placed for positioning as needed for exposure to allow completion of the other anastomosis by using stabilizers.

The left internal mammary artery–to–LAD graft is performed first. The posterolateral wall and the right side of the heart can be revascularized in any order according to the patient's anatomy. Proximal anastomosis of the conduit should be performed first when possible. This enables immediate blood flow to the coronary arteries. However, this requirement is not absolute when performing OPCAB.

Measurement of blood flow through the conduit is recommended after each anastomosis is completed. Flow must be measured again when protamine has been given to reverse the heparin. Drainage catheters are placed, and the chest incision is closed in the standard fashion.

CONCLUSION

OPCAB has been established as a safe and effective procedure. It involves a totally different mindset for the surgeon than CABG with CPB. Indications for OPCAB depend on the experience and comfort level of the surgeon. Currently, a multitude of devices are available for both exposure and stabilization to allow efficient performance of this operation. Therefore, most patients should be considered candidates for OPCAB.

---

1. Vineberg AM. Development of anastomosis between coronary vessels and transplanted mammary artery. *Med Assoc J* 1954;71:594.
2. Westaby S, Benetti FJ. Less invasive coronary surgery: consensus from the Oxford meeting. *Ann Thorac Surg* 1996;62:924–931.
3. Goetz RH, Rohman M, Haller JD, et al. Internal mammary-coronary anastomosis: a moisture method employing tantalum rings. *J Thorac Cardiovasc Surg* 1961;41:378–386.
4. Sabiston DC Jr. The William F. Rienhoff, Jr. lecture. The coronary circulation. *Johns Hopkins Med J* 1974;134:314–329.
5. Kolessov VI. Mammary artery-coronary artery anastomosis as method of treatment for angina pectoris. *J Thorac Cardiovasc Surg* 1967;54:535–544.
6. Ankeny JL. Editorial: To use or not to use the pump oxygenator in coronary bypass operations. *Ann Thorac Surg* 1975;19:108–109.
7. Garrett HE, Dennis EW, DeBakey ME. Aortocoronary bypass with saphenous vein graft. Seven-year follow-up. *JAMA* 1973;223:792–794.
8. Trapp WG, Bisarya R. Placement of coronary artery bypass graft without pump oxygenator. *Ann Thorac Surg* 1975;19:1–9.
9. Jones RH, Kesler K, Phillips HR III, Mark DB, Smith PK, Nelson CL, Newman MF, Reves JG, Anderson RW, Califf RM. Long-term survival benefits of coronary artery bypass grafting and percutaneous transluminal angioplasty in patients with coronary artery disease. *J Thorac Cardiovasc Surg* 1996;111:1013–1025.
10. Jones EL, Craver JM, Guyton RA, Bone DK, Hatcher CR Jr, Riechwald N. Importance of complete revascularization in performance of the coronary bypass operation. *Am J Cardiol* 1983;51:7–12.
11. Califf RM, Mark DB. Percutaneous intervention, surgery, and medical therapy: a perspective from the Duke Databank for Cardiovascular Diseases. *Semin Thorac Cardiovasc Surg* 1994;6:120–128.
12. Westaby S, Johnsson P, Parry AJ, Blomqvist S, Solem JO, Alling C, Pillai R, Taggart DP, Grebenik C, Stahl E. Serum S100 protein: a potential marker for cerebral events during cardiopulmonary bypass. *Ann Thorac Surg* 1996;61:88–92.

13. Robin ED, McCauley RF, Notkin H. Long-term cognitive abnormalities associated with cardiopulmonary bypass (CPB) and the Babel effect. *Chest* 1994;106:278–281.
14. Murkin JM, Martzke JS, Buchan AM, Bentley C, Wong CJ. A randomized study of the influence of perfusion technique and pH management strategy in 316 patients undergoing coronary artery bypass surgery. II. Neurologic and cognitive outcomes. *J Thorac Cardiovasc Surg* 1995;110:349–362.
15. Hilberman M, Derby GC, Spencer RJ, Stinson EB. Sequential pathophysiological changes characterizing the progression from renal dysfunction to acute renal failure following cardiac operation. *J Thorac Cardiovasc Surg* 1980;79:838–844.
16. Zanardo G, Michielon P, Paccagnella A, Rosi P, Calo M, Salandin V, Da Ros A, Michieletto F, Simini G. Acute renal failure in the patient undergoing cardiac operation. Prevalence, mortality rate, and main risk factors. *J Thorac Cardiovasc Surg* 1994;107:1489–1495.
17. Corwin HL, Sprague SM, DeLaria GA, Norusis MJ. Acute renal failure associated with cardiac operations. A case-control study. *J Thorac Cardiovasc Surg* 1989;98:1107–1112.
18. Butler J, Rocker GM, Westaby S. Inflammatory response to cardiopulmonary bypass. *Ann Thorac Surg* 1993;55:552–559.
19. Gailiunas P Jr, Chawla R, Lazarus JM, Cohn L, Sanders J, Merrill JP. Acute renal failure following cardiac operations. *J Thorac Cardiovasc Surg* 1980; 79:241–243.
20. Bhat JG, Gluck MC, Lowenstein J, Baldwin DS. Renal failure after open heart surgery. *Ann Intern Med* 1976;84:677–682.
21. Edmunds LH Jr. Why cardiopulmonary bypass makes patients sick: strategies to control the blood-synthetic surface interface. *Adv Card Surg* 1995; 6:131–167.
22. Benetti FJ. Cirugia cardiaca a sin CEC o parada cardiaca. *Rev de la Federacion Argentina de Cardiologia* 1980;8:3.
23. Benetti FJ. Direct coronary surgery with saphenous vein bypass without either cardiopulmonary bypass or cardiac arrest. *J Cardiovasc Surg (Torino)* 1985;26:217–222.
24. Buffolo E, Andrade JC, Succi J, Leao LE, Gallucci C. Direct myocardial revascularization without cardiopulmonary bypass. *Thorac Cardiovasc Surg* 1985;33:26–29.
25. Benetti FJ et al. Uso de la toracoscopia en cirugia coronaria para diseccion de la arteria mamaria intema. *Prensa Medica Argentina* 1994;81:877–879.
26. Benetti FJ, Ballester C. Use of thoracoscopy and a minimal thoracotomy, in mammary-coronary bypass to left anterior descending artery, without extracorporeal circulation. Experience in 2 cases. *J Cardiovasc Surg (Torino)* 1995;36:159–161.
27. Benetti FJ et al. Coronary revascularization with the arterial conduits via a small thoracotomy and assisted by thoracoscopy, although without cardiopulmonary bypass. *Coronary Revasc* 1995;4:22–24.
28. Benetti FJ, inventor. Method for coronary artery bypass. US patent 5,888,247.
29. Benetti FJ et al, inventors. Access platform for internal mammary dissection. US patent 5,730,757.
30. Benetti FJ et al, inventors. Surgical method for stabilizing the beating heart during coronary bypass surgery. US patent 5,894,843.
31. Benetti FJ et al, inventors. Surgical devices for imposing a negative pressure to fix the position of cardiac tissue during surgery. US patent 5,727,569.
32. Mehran R. Long-term patency of LIMA-LAD beating heart anastomosis (POEM) trial. Presented at the Sixth Annual Current Trends in Thoracic Surgery meeting, Bal Harbor, Fla, January 29, 2000.