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CHAPTER 6.2

Minimally Invasive Cardiac Surgery

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Off-Pump and Minimally Invasive Coronary Artery Bypass Grafting

Surgical Considerations

Description: Although coronary artery bypass grafting (CABG) without cardiopulmonary bypass (CPB) was originally proposed more than 5 decades ago, development and advances in CPB resulted in the abandonment of off-pump cardiac surgery by most cardiac centers until the 1990s. The resurgence of off-pump coronary revascularization was due in part to reported adverse effects of CPB, increased comorbidities in an aging population, medical economics, and the development of reliable mechanical stabilization devices (Fig. 6.2-1). From the standpoint of terminology, off-pump coronary artery bypass grafting (OPCAB), applies to all cases of coronary revascularization not using the CPB circuit; and, while it does not refer directly to the surgical approach, most are via conventional median sternotomy. Minimally invasive direct coronary artery bypass grafting (MIDCAB) refers to off-pump coronary revascularization via a small anterolateral thoracotomy incision. Challenges of off-pump coronary revascularization include accurate vascular anastomosis, while minimizing hemodynamic perturbations during the procedure. Interrupting flow to the target artery can → regional ischemia, arrhythmias, and hemodynamic instability; displacing the heart *(Print pagebreak 373)* to expose lateral or posterior arteries may → ventricular compression and profound hemodynamic compromise. Pharmacologic interventions to decrease HR and ischemic preconditioning may facilitate the anastomosis. Although not fully defined, ischemic preconditioning results from exposure to transient myocardial ischemia and is an endogenous adaptation that may mitigate the effects of subsequent prolonged myocardial ischemia. Thus, mechanically occluding the coronary artery for a brief period may confer some protection from ischemic injury associated with coronary occlusion during the anastomosis. Important preop considerations include the number and suitability of distal-target coronary arteries, cardiac and pulmonary status, and other medical comorbidities. The presence of cardiomegaly may limit the degree of intraop cardiac manipulation. The perfusionist is present during the procedure so that rapid conversion to conventional on-pump CABG can be achieved if there is hemodynamic compromise, unsuitable distal target, inability to expose lateral or posterior target vessels, or regional myocardial ischemia. Occasionally, placement of intraaortic balloon pump intraop may facilitate the off-pump approach in a patient with ischemic cardiomyopathy.

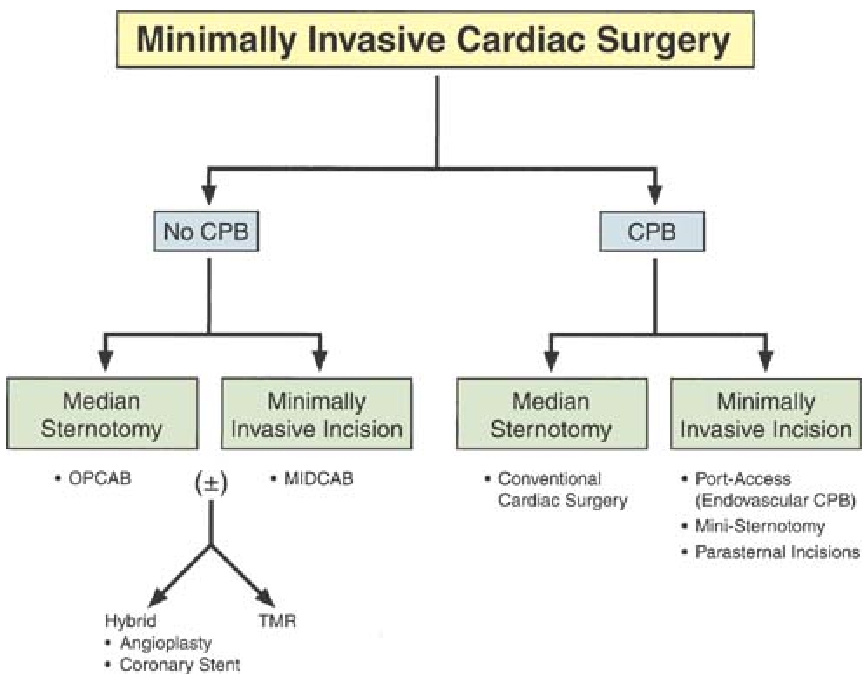

Figure 6.2-1. 1. Manipulation of the heart and placement of a pressure-plate mechanical stabilizer is performed in

preparation for OPCAB. (Reproduced with permission from Estafanous FG, Barash PG, Reves JG: *Cardiac Anesthesia: Principles and Clinical Practice,* 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

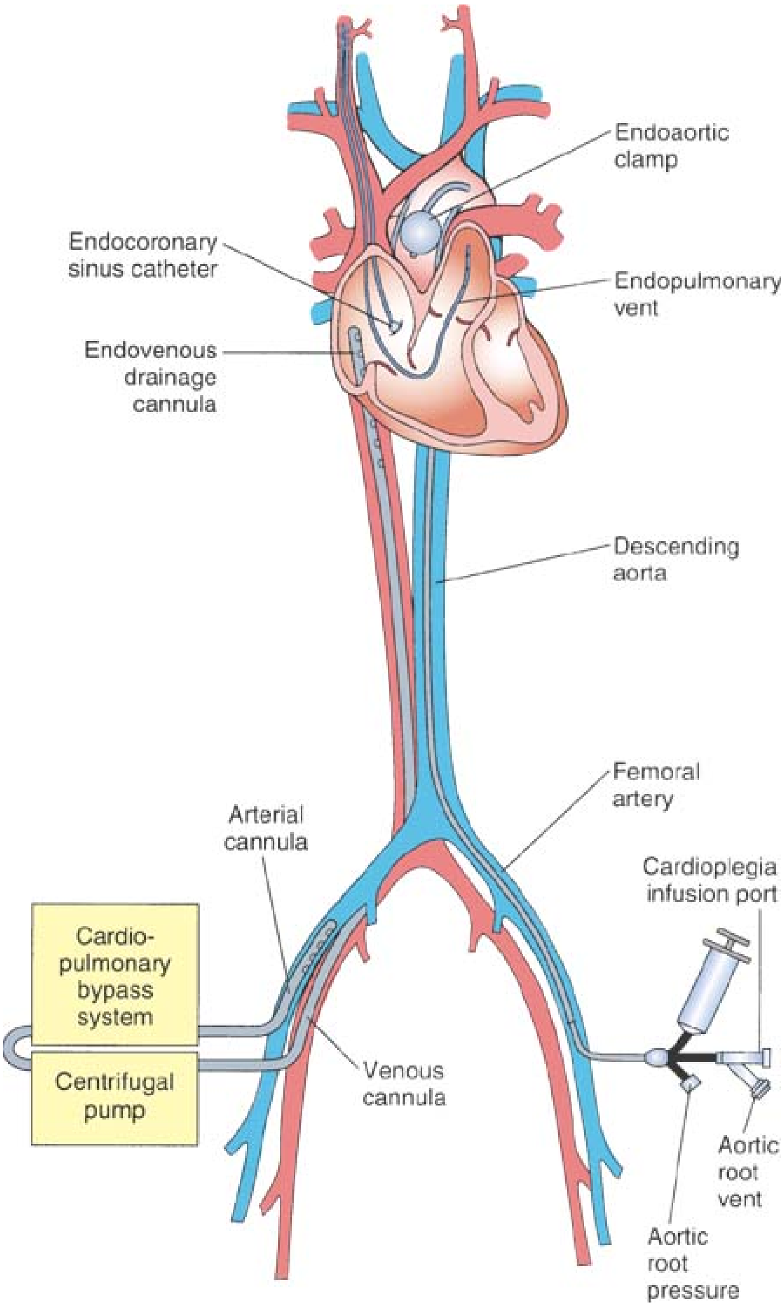

Figure 6.2-2. 2. Incision sites for access to various target coronary arteries in MICAB. (Reproduced with permission from Estafanous FG, Barash PG, Reves JG: *Cardiac Anesthesia: Principles and Clinical Practice,* 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

For conventional **OPCAB**, a standard median sternotomy is made (Fig. 6.2-2). If the internal mammary artery (IMA) is to be used as a graft, it is harvested in the usual fashion. The patient is partially heparinized, and an intravenous bolus of lidocaine is given. A sternal retractor with attachments for coronary stabilization is placed (Fig. 6.2-1). If vein grafts are used, the proximal anastomoses may be performed at this point or later, after the completion of the distal anastomoses, using a partial side-biting aortic cross-clamp. During the period of partial aortic clamping, BP typically is lowered to reduce potential complications associated with the use of the clamp. The goal of the operation is to establish adequate perfusion of the most critical vascular bed first. Provided it is a target vessel, the LAD artery is often approached first because an IMA graft (or vein graft) can provide immediate perfusion and requires minimal cardiac manipulation to construct the anastomosis. Mechanical coronary artery stabilizers, based on local myocardial compression (Fig. 6.2-1) or vacuum suction (Fig. 6.2-3) and attached to the retractor, provide stable local epicardial motion restraint, thereby facilitating the anastomosis. After stabilization, the artery is occluded (following a period of ischemic preconditioning), and an arteriotomy is made. Equipment that minimizes blood in the operative site includes standard suction attachments, temporary intracoronary shunts, vessel occluders, and “blower-misters” that displace blood by delivering a combination of gas (CO_2) and heparinized saline. The distal anastomosis is then performed. The patient is monitored closely at this point for any signs of myocardial ischemia and/or hemodynamic instability. To expose the lateral and posterior target vessels, manipulation of the heart is necessary and may not be well tolerated. During lateral and posterior pericardial suture placement, the surgeon displaces and compresses the heart, resulting in temporary hemodynamic compromise. Ventilation may need to be decreased temporarily to facilitate this maneuver. Additional exposure techniques include the use of an apical suction device to facilitate cardiac manipulation with potentially less hemodynamic compromise, Trendelenburg position and tilting the operating table to the right, release of right pericardial stay sutures, opening of the right pleura, and incising the right pericardium, and placement of laparotomy sponges. The target vessel is stabilized again, ischemic preconditioning is carried out, and the artery is opened. After construction of the distal anastomosis, the graft is relieved of any residual air before securing the sutures and the proximal anastomosis performed if not already done so as noted earlier. Graft flow is assessed using a Doppler flow probe.

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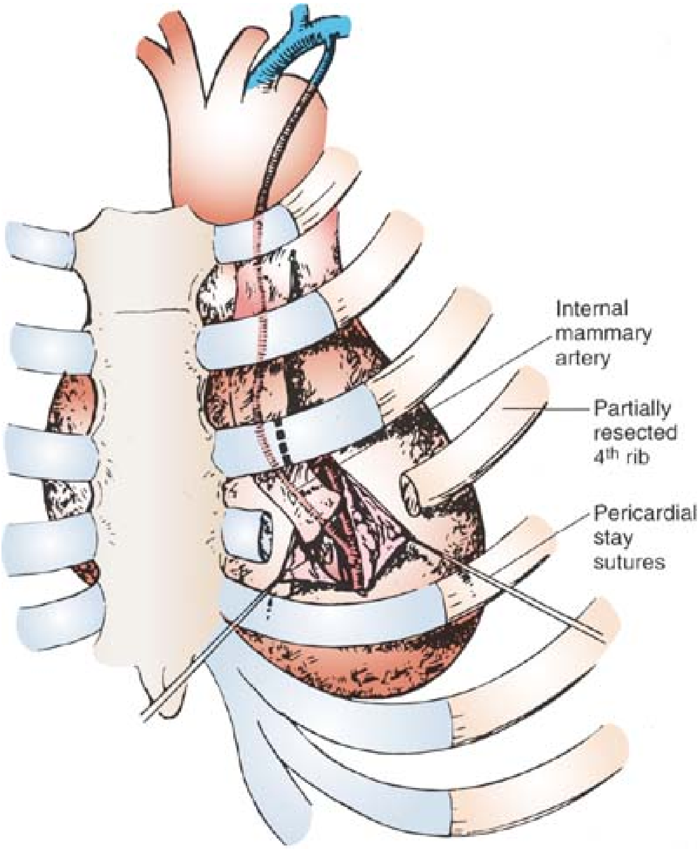

Figure 6.2-3. 3. The Octopus stabilizer (Medtronic, Minneapolis MN) uses a series of suction cups on two fixed arms that adhere to the epicardial surface and reduce myocardial motion at the anastomotic site during OPCAB. (Reproduced with permission from Estafanous FG, Barash PG, Reves JG: *Cardiac Anesthesia: Principles and Clinical Practice,* 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Summary of Procedures

Position	Supine (Fig. 6.2-4)
Incision	Median sternotomy (OPCAB); alternatively, limited left anterolateral thoracotomy (MIDCAB) (Fig. 6.2-2)
Antibiotics	Cefazolin 1 g iv
Surgical time	3–4 h
Closing considerations	No special considerations. Patients often can be extubated in OR.
EBL	200–400 mL (consider using Cell-Saver)
Postop care	ICU for cardiac monitoring ± ventilator management; less volume required than with conventional CABG.

Mortality	0–5% (higher with increasing age)
Morbidity	AF: 10–30% Pulmonary insufficiency: 3–5% Reoperation for bleeding: 1–4% Cardiac (e.g., myocardial infarction): 0–4% Mediastinal infection: 1–2% Neurologic (cerebrovascular accident): 1–2% Renal dysfunction: 1–2% IABP use: 0–2%
Pain score	4–6

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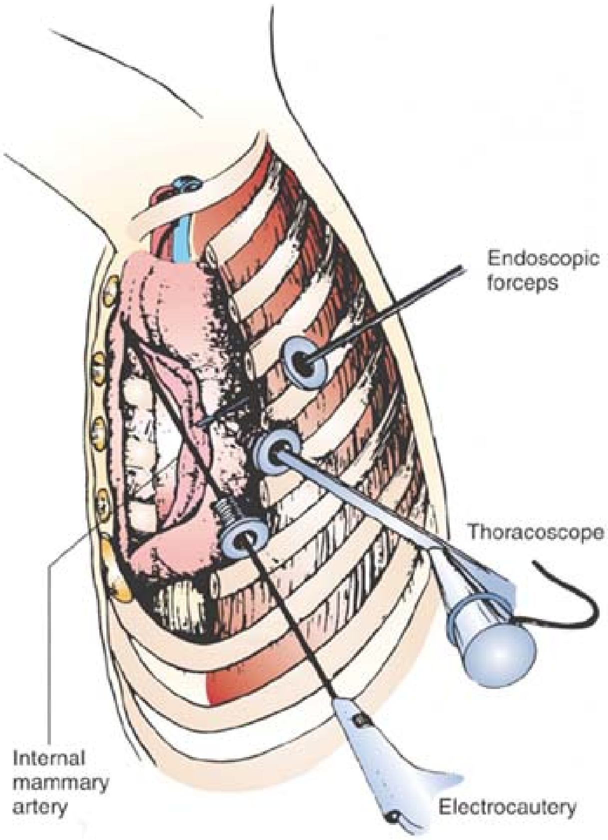

Figure 6.2-4. 4. OR configuration for MICAB. (Reproduced with permission from Estafanous FG, Barash PG, Reves JG: *Cardiac Anesthesia: Principles and Clinical Practice,* 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Patient Population Characteristics

Age range	40 to > 90 yr
Male:Female	3:2
Incidence	150,000/yr in the United States.
Etiology	Multifactorial for atherosclerosis
Associated conditions	HTN; diabetes; PVD; COPD; cigarette smoking

Anesthetic Considerations for MICAB/OPCAB

Preoperative

Preop assessment is similar to that used for standard CABG patients (see p. 344). Relative contraindications for MICAB include: low EF, morbid obesity, previous cardiac surgery, AF, and COPD. It is important to know the coronary artery anatomy and the planned surgical procedure and sequence. For example, proximal surgical occlusion of a coronary artery with high grade distal disease may be poorly tolerated as compared with severe proximal disease with collateralization.

Premedication	Adequate control of preop anxiety using midazolam (titrated to effect) may reduce periop tachycardia.

Intraoperative

Anesthetic technique: GETA. For MICAB, selective lung ventilation with DLT, Univent ETT, or bronchial blocker. Unlike CABG on CPB, the anesthetic demands for OPCABG are somewhat different, as CPB will not be providing hemodynamic support. Positioning of the heart for access to the target vessel, as well as mechanical stabilization of the heart to immobilize the vessel for accurate anastomosis tend to produce hemodynamic compromise. In particular, elevation of the LV apex to allow access to lateral and posterior wall vessels can limit LV filling and obstruct RV outflow tract. Additionally, ↓ TV may be necessary to prevent obstruction of visualization. Snares may be placed around the coronary target vessel to create a dry operative field; however, this may provoke regional ischemia. Many of these changes are assessed by intraop TEE, and they may require resuscitative measures with volume loading, *(Print pagebreak 376)* vasoconstriction and inotropic support (e.g., dopamine). Interventions on the RCA are particularly prone to arrhythmias and appropriate antiarrhythmics and pacing should be available. For further discussion, see Intraoperative considerations for CABG, p. 345.

Induction	As for CABG surgery (see p. 345). For MICAB, these patients will undergo a small anterior thoracotomy, and the aim is to extubate them at the end of the procedure or shortly thereafter. Thus, the dose of narcotic should be moderate (e.g., fentanyl 5–15 mcg/kg). Long-acting muscle relaxants should be avoided for the same reason. Consider spinal narcotics (e.g., morphine 0.3–0.5 mg).	
Maintenance	Since early extubation is planned, volatile agents or propofol should be used and the overall dose of narcotic reduced. Remifentanil infusion may also be useful.	
Emergence	For further discussion, see Postoperative Considerations for CABG, p. 347. If the patient is not suitable for extubation in the OR, a DLT may be exchanged for a conventional ETT (over a tube changer) before transport to ICU.	
Blood and fluid requirements	See CABG surgery (p. 346).	Without the use of CPB, hemodilution from the pump prime is avoided.
Monitoring	See CABG surgery (p. 346).	Central venous access. PA catheters are useful for detecting ischemia in patients with poor LV function. If a continuous CO thermodilution catheter is used, consideration must be given to the large delays in data display. ST segment analysis.
	TEE	Useful for detecting ischemia and LV dysfunction. Views may be limited by surgical positioning of the heart within the chest.
	Anticoagulation	Heparin should be administered before surgical coronary artery occlusion.
	Ischemic preconditioning Temporary occlusion → ischemia	Prior to occlusion, ischemic preconditioning may be accomplished with surgical manipulation and by pharmacologic means (e.g., isoflurane, sevoflurane). This is a great opportunity to consider how well transient ischemia is tolerated. During grafting, the vessel is temporarily occluded to avoid flooding the field with blood. The myocardium distal to this may become ischemic.

	ECG, TEE.	TEE imaging will be affected by surgical mechanical manipulation of the heart and ECG voltage may be decreased.
Special considerations	Cardiac positioning →↓ CO	Cardiac output may be markedly reduced by the combination of heart positioning and coronary artery occlusion. Vasoconstriction may be required to maintain adequate blood pressure. Patients poorly responsive to vasoconstrictors may have extremely depressed cardiac output and severe acidosis. Inotropic support or intra-aortic balloon pumping may be necessary.
	Coronary artery shunt	Surgical placement of a coronary artery shunt may be necessary. Treatment of rhythm disorders with pharmacologic agents, pacing, or defibrillation may be required. The capability to institute CPB rapidly should exist. A rest period with the heart returned to the normal position within the chest should be considered following each anastomosis to restore cardiac output and permit resolution of acidosis.
Positioning	and pad pressure points. eyes.	

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Postoperative

Complications	See CABG surgery (p. 347). Premature extubation	
Pain management	Same as CABG surgery (p. 347).	Intrathecal narcotics or intercostal blocks (MICAB) placed at the end of surgery may aid in early extubation.
Tests	See CABG surgery (p. 347).	

Suggested Readings – Surgeon's

1. Baumgartner FJ, Gheissari A, Capouya ER, et al: Technical aspects of total revascularization in off-pump coronary bypass via sternotomy approach. *Ann Thorac Surg* 1999; 67:1653–8.

2. Cartier R, Brann S, Dagenais F, et al: Systematic off-pump coronary artery revascularization in multivessel disease: Experience of three hundred cases. *J Thorac Cardiovasc Surg* 2000; 119:221–9.

3. Hannan EL, Wu C, Smith CR, et al: Off-pump versus on-pump coronary artery bypass surgery: rences in short-term outcomes and in long-term mortality and need for subsequent revascularization. *Circulation* 2007 116(10):1145–52.

4. Hirose H, Amano A, Takahashi A: Off-pump coronary artery bypass grafting for elderly patients. *Ann Thorac Surg* 2001; 72:2013–9.

5. Mack M, Bachand D, Acuff T, et al: Improved outcomes in coronary artery bypass grafting with beating-heart techniques. *J Thorac Surg* 2002; 124:598–607.

6. Novitsky D, Bowen TE, Larsen A, et al: Aiming towards complete myocardial revascularization without cardiopulmonary bypass: A systematic approach. *Heart Surg Forum* 2002; 5:214–20.

7. Sabik JF, Gillinov AM, Blackstone EH, et al: Does off-pump coronary surgery reduce morbidity and mortality? *J Thorac Cardiovasc Surg* 2002; 124:698–707.

Suggested Readings – Anesthesiologist's

1. Ankeney JL, Goldstein DJ: Off-pump bypass of the left anterior descending artery: 23- to 34-year follow-up. *J Thorac Cardiovasc Surg* 2007; 133:149–1503.

2. Arom K, Flavin T, Emery R, et al: Safety and efficacy of off-pump coronary artery bypass grafting. *Ann Thorac Surg* 2000; 69:704–10.

3. Diegeler A, Matin M, Kayser S, et al: Angiographic results after minimally invasive coronary bypass grafting using the minimally invasive direct coronary bypass grafting (MIDCAB) approach. *Eur J Cardiothoracic Surg* 1999; 15:680–4.

4. Fukui T, Takanashi S, Hosoda Y, et al: Early and midterm results of of-pump coronary artery bypass grafting. *Ann Thorac Surg* 2007; 83:115–9.

5. Greenspun HG, Adourian UA, Fonger JD, et al: Minimally invasive direct coronary artery bypass (MIDCAB): surgical techniques and anesthetic considerations. *J Cardiothorac Vasc Anesth* 1996; 10(4):507–9.

6. Kessler P, Neidhart G, Bremerich DH, et al: High thoracic epidural anesthesia for coronary artery bypass grafting using two different surgical approaches in conscious patients. *Anesth Analg* 2002; 95:791–7.

7. Motallebzadeh R. Bland JM, Markus HS, et al: Neurocognitive function and cerebral emboli: randomized study of on-pump versus off-pump coronary artery bypass surgery. *Ann Thorac Surg* 2007; 83: 475–82.

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8. Nierich AP, Diephuis J, Jansen EWL, et al: Embracing the heart: Perioperative management of patients undergoing off-pump coronary artery bypass grafting using the Octopus tissue stabilizer. *J Cardiothorac Vasc Anesth* 1999; 13:123–9.

9. Place DG, Peragallo RA, Carroll J, et al: Postoperative atrial fibrillation: a comparison of off-pump coronary artery bypass surgery and conventional coronary artery bypass graft surgery. *J Cardiothorac Vasc Anesth* 2002; 16:144–8.

10. Puskas JD, Kilgo PD, Kutner M, et al: Off-pump techniques disproportionately benefit women and narrow the gender disparity in outcomes after coronary artery bypass surgery. *Circulation* 2007; 116 (suppl):I-192–99.

11. Puskas JD, Williams WH, Mahoney EM, et al: Off-pump vs conventional coronary artery bypass grafting: early and 1-year graft patency, cost, and quality-of-life outcomes: a randomized trial. *JAMA* 2004; 291:1841–849.

12. Raja SG, Berg GA: Impact of off-pump coronary artery bypass surgery on systemic inflammation: current best available evidence. *J Card Surg* 2007; 22:445–55.

13. Roosens C, Heerman J, De Somer F, et al: Effects of off-pump coronary surgery on the mechanics of the respiratory system, lung, and chest wall: Comparison with extracorporeal circulation. *Crit Care Med* 2002; 30:2430–7.

14. Sabik JF, Blackstone EH, Lytle BW, et al: Equivalent midterm outcomes after off-pump and on-pump coronary surgery. *J Thorac Cardiovasc Surg* 2004; 127:142–8.

15. Siegel LC, Hennessy MM, Pearl RG: Delayed time response of the continuous cardiac output pulmonary artery catheter. *Anesth*

Analg 1996; 83:1173–7.

16. Sisilio E. Marino MR, Juliano G, et al: Comparison of on pump and off pump coronary surgery: risk factors for neurological outcome. *Eur J Cardiothorac Surg* 2007; 31:1076–80.

17. Straka Z, Brucek P, Vanek T, et al: Routine immediate extubation for off-pump coronary artery bypass grafting without thoracic epidural analgesia. *Ann Thorac Surg* 2002; 74:1544–7.

18. Vassiliades TA Jr, Reddy VS, Puskas JD, et al: Long-term results of the endoscopic atraumatic coronary artery bypass. *Ann Thorac Surg* 2007; 83:979–84.

19. Virmani S, Tempe DK: Anaesthesia for off-pump coronary artery surgery. *Ann Card Anaesth* 2007 10(1): 65–71.

Port-Access Coronary Revascularization

Surgical Considerations

Description: Advances in videoscopic technology have led to less invasive approaches in the treatment of many general and thoracic surgical disorders. The development of less invasive surgery has resulted in alternative and novel approaches to cardiac surgery, including port-access cardiac surgery and off-pump coronary revascularization. The port-access approach was developed in the mid-1990s and is used less frequently in the current setting because of its complexity. With the development of robotic (or total endoscopic) techniques, the port-access technology is being employed as a means to achieve cardiopulmonary bypass and cardioplegic arrest. Using a port-access approach, the surgeon can perform cardiac operations (e.g., CABG) and valve surgery in a motionless, bloodless field through smaller chest incisions. This approach typically relies on peripheral CPB (femoral artery and femoral vein cannulation, Fig. 6.2-6). The femoral artery is cannulated with a 19–23 Fr Y-shaped cannula, which permits arterial inflow *(Print pagebreak 379)* and insertion of the endoaortic clamp. Venous drainage is provided by the 22–25 Fr cannula, introduced through a femoral vein. Drainage may be augmented by 20–40%, using vacuum-assisted venous drainage or a centrifugal venous drainage pump placed between the venous cannula and the reservoir. The port-access system includes a 10.5 Fr endoaortic "clamp" (EAC), a triple-lumen catheter with an inflatable balloon at its distal end. This clamp is positioned in the ascending aorta using fluoroscopy and TEE guidance. The lumen used for balloon inflation is connected to a manometer to monitor balloon pressure. Cardioplegic solution is delivered through a central lumen, which also acts as an aortic root vent after cardioplegia delivery. A third lumen serves as an aortic root pressure monitor. Additionally, a percutaneous PA venting catheter, placed via the jugular approach, helps in ventricular decompression. The left internal mammary artery (IMA) is harvested under direct vision (Fig. 6.2-7) or with video-assisted thoracoscopy (VAT) (Fig. 6.2-8). After peripheral CPB is achieved, the EAC provides aortic occlusion and cardioplegic arrest. Exposure of the lateral and posterior aspects of the heart is easily accomplished in the arrested heart, thereby permitting two- and three-vessel coronary revascularization. Notably, if the ascending aorta is accessible, a dual-armed, Y-shaped cannula can be placed directly into the ascending aorta with one arm of the cannula connected to the arterial inflow of the CPB circuit and the other arm as a conduit for introducing the EAC.

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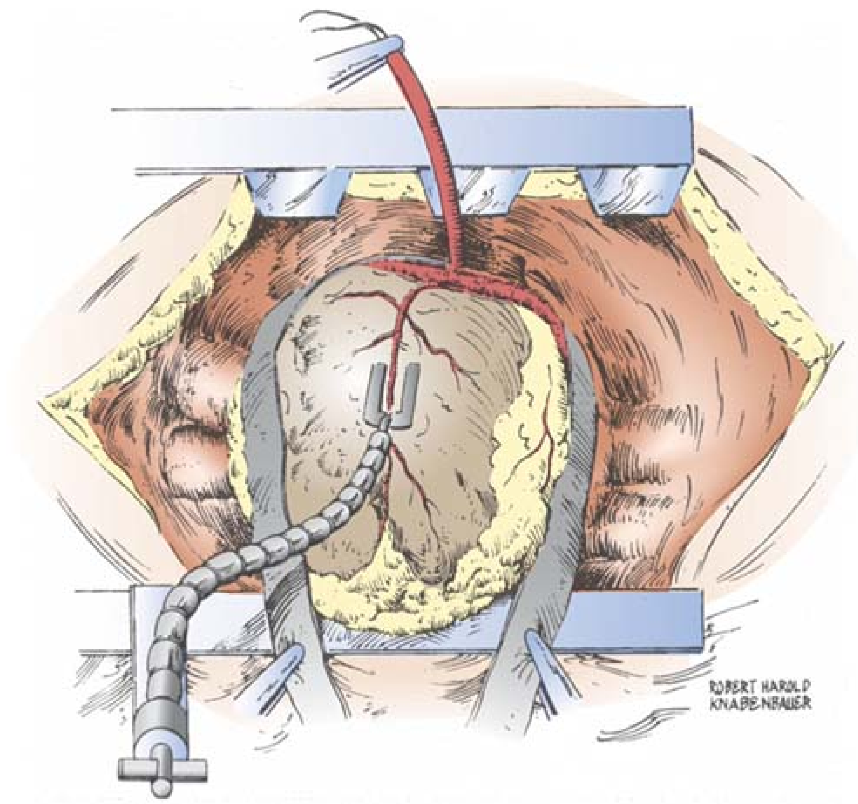

Figure 6.2-5. 5. Variations in coronary artery bypass and valvular heart surgery, with minimally invasive techniques. CPB = cardiopulmonary bypass. OPCAB = off-pump coronary artery bypass. MIDCAB = minimally invasive direct coronary artery bypass. TMR = transmyocardial revascularization. (Redrawn with permission from Estafanous FG, Barash PG, Reves JG: *Cardiac Anesthesia: Principles and Clinical Practice,* 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

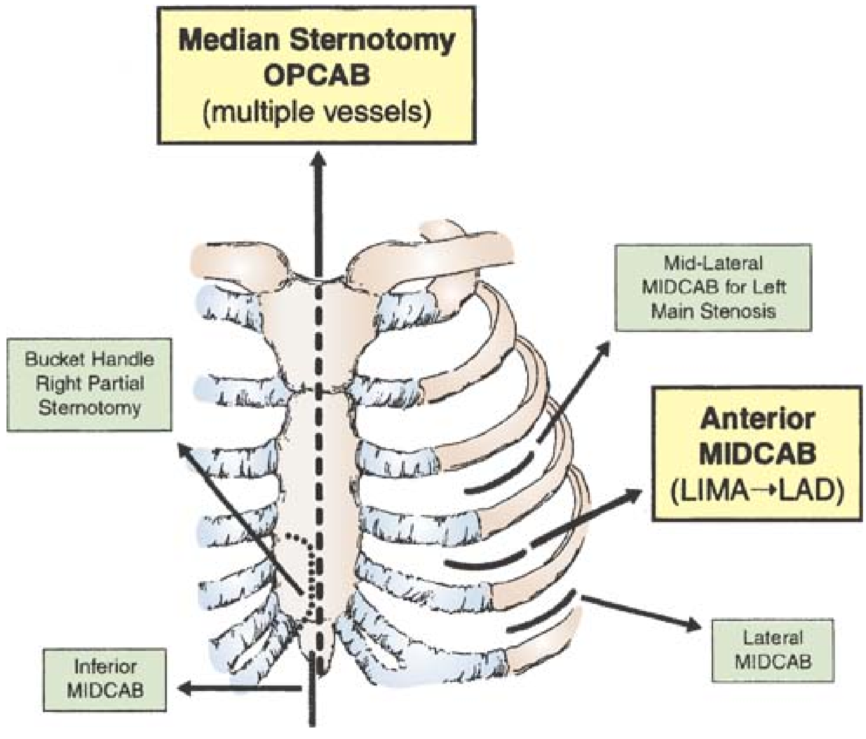

Figure 6.2-6. 6. The port-access cardiopulmonary bypass (CPB) system. Femoro-femoral (fem-fem) CPB is utilized, and a centrifugal pump augments venous drainage. The endoaortic balloon occlusion catheter is inflated in the ascending aorta, and antegrade cardioplegia is delivered through the central lumen. The endopulmonary vent assists in ventricular decompression. (Redrawn with permission from Fann JI, Pompili MF, Stevens JH, et al: Port-access cardiac surgery with cardioplegic arrest. *Ann Thorac Surg* 1997; 63:S35–9.)

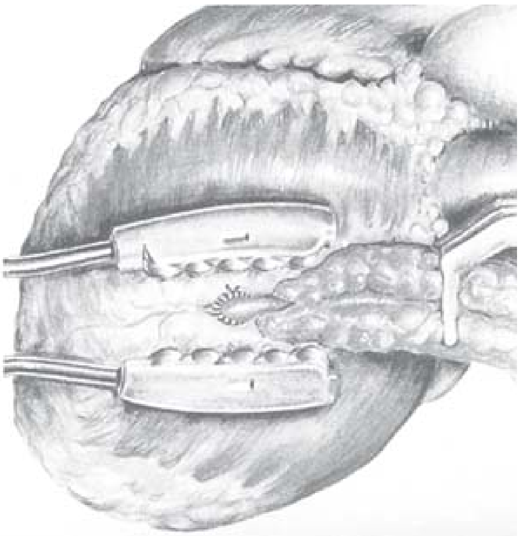

Figure 6.2-7. 7. The left IMA-to-left anterior descending artery anastomosis is performed under direct vision. Stay sutures suspend the pericardium and bring the heart into view. (Redrawn with permission from Acuff TE, Landreneau RJ, Griffith BP, et al: Minimally invasive coronary artery bypass grafting. *Ann Thorac Surg* 1996; 61:135–7.)

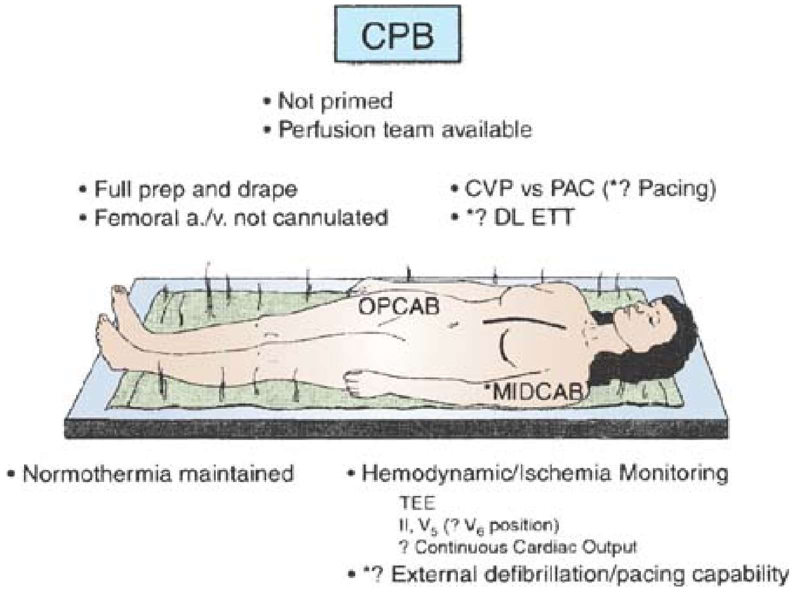

Figure 6.2-8. 8. Dissection and harvesting of the left IMA using a thoracoscopic approach. (Redrawn with permission from Acuff TE, Landreneau RJ, Griffith BP, et al: Minimally invasive coronary artery bypass grafting. *Ann Thorac Surg* 1996; 61:135–7.)

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Table 6. 2-1. Common Abbreviations Used in Minimally Invasive Cardiac Surgery

Abbreviation	Definition
MICS	Minimally invasive cardiac surgery
MICAB	Minimally invasive coronary artery bypass (includes OPCAB, MIDCAB. port-access, and mini-sternotomy techniques)
OPCAB	Off-pump coronary artery bypass (“beating heart surgery”: median sternotomy)
MIDCAB	Minimally invasive direct coronary artery bypass (direct vision, no sternotomy, CPB, or cardioplegia)
MIDCABG	Minimally invasive direct coronary artery bypass graft (same as MIDCAB)
	Minimally invasive thoracoscopically assisted coronary artery

MITACAB	bypass
VADCAB	Video-assisted direct coronary artery bypass
LAST	Left anterior small thoracotomy
PACAB	Port-access coronary artery bypass (also called Port-CAB, Port-CABG)
TECAB	Totally endoscopic coronary artery bypass grafting

Usual preop diagnosis: CAD

Summary of Procedures

Position	Supine
Incision	4th interspace, left anterior thoracotomy for CABG; may need to resect 4th rib; may need thoracoscopy for IMA harvest.
Special instrumentation	TEE and fluoroscopy
Unique considerations	CPB used with peripheral femoral cannulation; percutaneous insertion of PA vent and retrograde cardioplegic catheter.
Antibiotics	Cefazolin 1–2 g iv at induction
Surgical time	3–5 h
Closing considerations	Assess chest wall for hemorrhage; chest tube insertion. Bupivacaine for field block.
EBL	250–500 mL
Postop care	ICU monitoring; early extubation; may require inotropic support.
Mortality	1–3%, depending on comorbidities
Morbidity	Arrhythmias (including atrial fibrillation): 10% Conversion to sternotomy: 4% MI: 0–4% Reoperation for bleeding: 3% Stroke: 2% Thrombosis of graft (graft failure): Rare Fem-fem bypass complications (e.g., arterial dissection): Rare
Pain score	1–4

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Patient Population Characteristics

Age range	40–80 yr
Male:Female	3:2
Incidence	< 50,000/yr in the United States.
Etiology	Multifactorial for atherosclerosis
Associated conditions	LV dysfunction; COPD; PVD; HTN; diabetes mellitus; cigarette smoking

Anesthetic Considerations

See Anesthetic Considerations for Port-Access Procedures, p. 385.

Suggested Readings

1. Bonatti J, Schachner T, Bonaros N, et al: Technical challenges in totally endoscopic robotic coronary artery bypass grafting. *J Thorac Cardiovasc Surg* 2006; 131:146–53.

2. Casselman FP, LaMeir M, Jeanmart H, et al: Endoscopic mitral and tricuspid valve surgery after previous cardiac surgery. *Circulation* 2007: 116 (suppl): I-270–5.

3. Dogan S, Graubitz K, Aybek T, et al: How safe is the port access technique in minimally invasive coronary artery bypass grafting? *Ann Thorac Surg* 2002; 74:1537–43.

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Also see Suggested Readings for Port-Access Procedures.

Limited Thoracotomy and Port-Access Approach to Mitral Valve Surgery

Surgical Considerations

Description: Although the field of mitral valve surgery has seen marked advances in biomaterials and innovative repair techniques since the early 1960s, the **conventional median sternotomy approach** to access and expose the mitral valve has not changed substantially. Because of the progress in video-assisted surgery, a less invasive approach to cardiac surgery has been developed, and various techniques of mitral valve surgery through **limited thoracotomy** or **upper sternotomy** incisions and a **port-access technique** to achieve cardioplegic arrest are now used in the clinical setting.

Limited thoracotomy: The right thoracotomy incision is a less invasive approach (compared to median sternotomy) for mitral valve procedures (Fig. 6.2-9). Utilizing hypothermic fibrillatory or cardioplegic arrest, the mitral valve, annulus, and subvalvular apparatus can be visualized directly and the valve procedure carried out. The addition of video-assisted thoracoscopy (VAT) to mitral valve surgery or using robotic technology has resulted in even smaller incisions for these procedures.

Chitwood, et al. have utilized a **"micro-mitral" approach** to mitral valve replacement, using VAT through a limited thoracotomy. Peripheral cardiopulmonary bypass (fem-fem) is used, and a catheter is placed in the coronary sinus *(Print pagebreak 383)* for retrograde cardioplegia delivery. An external aortic cross-clamp is introduced through a separate incision in the chest. After achieving cardioplegic arrest, the mitral valve is replaced with thoracoscopic assistance. Proposed advantages of the micro-mitral approach include the avoidance of a sternotomy, with decreased chest-wall trauma and patient discomfort.

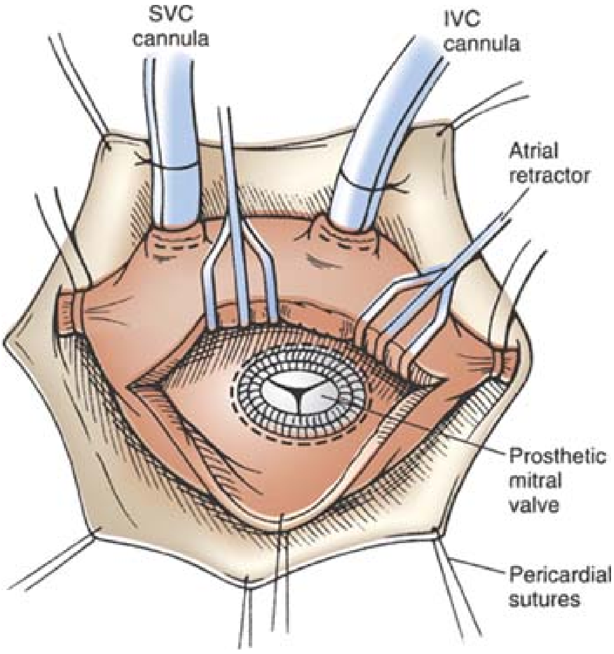

Figure 6.2-9. 9. The right thoracotomy approach with left atriotomy and exposure of the mitral valve area with prosthetic valve in place. (Reproduced with permission from Tribble CG, Killinger WA Jr., Harman PK, et al: Anterolateral thoracotomy as an alternative to repeat median sternotomy for replacement of the mitral valve. *Ann Thorac Surg* 1987; 43:380–2.)

Arom and Emery have described an alternative **partial sternotomy approach** to mitral and aortic valve surgery. The 7-cm partial sternotomy permits aortic and right atrial cannulation for CPB. The external aortic cross-clamp is positioned and a left ventricular vent is placed through the right superior pulmonary vein. Mitral valve exposure is achieved through the dome of the left atrium.

Port-access mitral valve surgery: The port-access system has been used successfully in mitral valve surgery via limited thoracotomy incision using special instrumentation or even less invasive robotic technology. To facilitate dissection and to provide adequate exposure of the left atrium, DLT intubation for OLV is used. Under fluoroscopic and TEE guidance, a retrograde cardioplegia catheter is directed into the coronary sinus via an introducer placed in the jugular vein; a PA-venting catheter is inserted through another jugular vein introducer. A limited right thoracotomy is made, with or without dividing the 4th rib, followed by the placement of a soft-tissue retractor. A separate port is placed in the 6th interspace for introduction of a thoracoscope, if necessary. The pericardium is opened anterior to the phrenic nerve. After systemic heparinization, the femoral artery and vein are cannulated. The endoaortic clamp is introduced through the side limb of the femoral arterial cannula and its tip positioned in the ascending aorta. CPB is initiated and systemic hypothermia achieved. The balloon of the endoaortic clamp is inflated, achieving effective aortic occlusion. Cold blood cardioplegia is delivered using the distal port of the endoaortic clamp; retrograde cardioplegia is administered via the coronary sinus catheter. A left atriotomy is made, and an atrial retractor is placed through a separate port. Valve repair or replacement is carried out using specially designed instruments. Before completion of atriotomy closure, deairing maneuvers are accomplished. These include temporarily discontinuing pulmonary and aortic root venting, inflating the lungs to displace residual air, and increasing the patient's blood volume from the venous reservoir. Also, the *(Print pagebreak 384)* patient is placed in a Trendelenburg and left lateral decubitus position for further deairing. The balloon of the endoaortic catheter is deflated, and the catheter is left in place for further deairing through the aortic vent lumen. Temporary ventricular pacing wires are placed. After being weaned from CPB, the patient is decannulated and the anticoagulation reversed.

The overall safety and efficacy of less invasive mitral valve surgery await long-term evaluations and follow-up.

Usual preop diagnosis: Mitral valve disease

Summary of Procedures

	Port-Access	Limited Thoracotomy
Position	Supine, with right side slightly elevated	
Incision	4th interspace limited right thoracotomy; ports for possible thoracoscopy; port for atrial retractor.	± port for aortic cross-clamp
Specialinstrumentation	Specially designed retractors; TEE and fluoroscopy for guiding placement of endopulmonary vent, retrograde cardioplegia catheter, and endoaortic clamp	Specially designed instruments ± thorascopic instruments
Unique considerations	CPB is achieved with peripheral femoral cannulation; placement of endopulmonary vent; placement of retrograde cardioplegia catheter; may require conversion to open procedure.	CPB via femoral artery and vein
Antibiotics	Cefazolin 1–2 g iv at induction	
Surgical time	3–5 h	
Closing considerations	Assess chest wall for hemorrhage.	
EBL	250–500 mL	
Postop care	ICU monitoring; early extubation; may require inotropic support.	
Mortality	1–6%, depending on comorbidities (lower for mitral valve repairs).	
Morbidity	AF:10–40%	
	Chest-wall hemorrhage: 2–9%	–
	Stroke: 1–3%	–
	Conversion to sternotomy: 2%	–
	Vascular injury: Rare	–
	Pneumonia	
	Renal failure	–
Pain score	1–4	4–7

Patient Population Characteristics

Age range	40–70 yr
Male:Female	1:1
Incidence	< 20,000/yr in the United States.
Etiology	Myxomatous mitral valve; rheumatic valve disease; endocarditis; ischemic (papillary muscle dysfunction); mitral annular calcification
Associated conditions	Pulmonary HTN; atrial arrhythmias; CAD; aortic valve disease; tricuspid regurgitation

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Anesthetic Considerations for Port-Access Procedures

Preoperative

As with all anesthetic procedures, the use of the port-access system should not be attempted without appropriate training. Catheter placement and monitoring relies on TEE and/or fluoroscopy. The evaluation of the patient for port-access cardiac surgery should parallel that of patients having conventional cardiac surgery. (For mitral valve surgery, see p. 354; for CABG surgery, see p. 344.)

There are, however, a number of specific conditions which preclude the use of the port-access system:

1. Aortic regurgitation (AR): Although mild-to-moderate AR is not a contraindication, it may make the delivery of antegrade cardioplegia via the endoaortic clamp catheter (EAC) problematic; therefore, insertion of the endocoronary sinus catheter (ESC) is very important. Severe AR is a contraindication.
2. Atherosclerotic disease of the aorta: Perfusion may be associated with embolization of atheromatous plaques (particularly pedunculated lesions).
3. PVD: Femoral bypass may be associated with retrograde arterial dissection. PVD and tortuous femoral and iliac vessels are contraindications to use of femoral arterial cannulation.
4. Thoracic aortic aneurysm/Marfan syndrome: Port-access procedures require passage of the EAC into the thoracic aorta and inflation of the EAC balloon; therefore, aneurysms or a weakened aortic wall are contraindications.
5. Scarring of the pleural cavity (e.g., chest trauma, previous thoracotomy) may make surgical access difficult although the surgical approach may be desirable in the patient with previous median sternotomy.
6. Inability to obtain TEE or fluoroscope imaging, because monitoring and placement of catheters relies on imaging.

Preop evaluation should focus on the underlying pathophysiology (valvular disease vs CAD). In addition, the following aspects should be considered:

Respiratory	OLV is used to facilitate surgical exposure; thus, evaluation of patients with severe lung disease may include CXR, ABG, PFTs (see Thoracic Surgery, pp. 267–332).
Cardiovascular	The vascular system should be evaluated with respect to insertion of the catheters and cannulae for endovascular CPB. Severity of arterial occlusive or atherosclerotic disease should be evaluated (embolization/dissection risk). The possible presence of a persistent left SVC should be considered. **Tests:** CXR; aortography; iliofemoral arteriography; vascular MRI/MRA; vascular ultrasound; TEE
Premedication	As for the underlying condition. Usually, a mild anxiolytic (e.g., midazolam 1–3 mg iv) is sufficient.

Intraoperative

Anesthetic technique: GETA (DLT or BB). Anesthetic technique depends on the underlying pathophysiology (e.g., valvular disease vs CAD). Early extubation and postop pain relief can be facilitated by using intrathecal narcotics (e.g., Duramorph 10 mcg/kg intrathecal) injected before induction.

Induction	Typically, induction can be accomplished with etomidate (0.1–0.3 mg/kg) or propofol (0.5–2 mg/kg), with fentanyl (5–20 mcg/kg) and pancuronium or vecuronium (0.1 mg/kg). The overall length of port-access procedures is similar to or slightly longer than conventional approaches, so that a long-acting muscle relaxant can be used. Intubation is accomplished with a DLT, and its placement is checked by auscultation or bronchoscopy. A bronchial blocker or Univent tube may also be used to provide selective lung ventilation.
Maintenance	With the goal of early extubation, it is important to avoid oversedation. The use of volatile agents or a propofol infusion (25–100 mcg/kg/min) before, during, and after CPB will facilitate early extubation. During dissection of the IMA or exposure of the left atrium, OLV is needed.
	At the end of the procedure, intercostal blocks with ropivacaine or bupivacaine may be placed, and infiltration of the skin incision also is helpful. Extubation in the OR may be appropriate for

Emergence	stable patients. Alternatively, the patient is transported to ICU and ventilated. The DLT may be exchanged for a single-lumen tube when postop mechanical ventilation is required.
Special considerations: Placement/monitoring of endocardiopulmonary system	The port-access system consists of CPB with venous drainage via an endovenous drain (EVD) and an aortic or femoral arterial return cannula, which is Y-ed to accept the EAC. These are placed by the surgeon with the aid of fluoroscopy and/or TEE. Additional drainage of the right side of the heart is accomplished via an endopulmonary vent (EPV) placed by the anesthesiologist. Immediately after intubation and before CVP insertion, a TEE exam should be performed to exclude any contraindication to endo-CPB (e.g., severe AR, aortic atheromatous disease, aortic aneurysm); the size of the ascending aorta should be measured (aids the surgeon in inflation of the aortic balloon); and the coronary sinus should be identified to aid placement of the ESC (coronary sinus catheter). The right IJ vein is then cannulated with two sheaths (9 Fr for EPV and 11 Fr for the ESC). Cardioplegia is delivered in an anterograde fashion via the EAC or retrograde via an ESC, also placed by the anesthesiologist (Fig. 6.2-2).
Placement of ESC	The ESC can be placed with fluoroscopy and/or TEE. The coronary sinus is identified on TEE (transverse view of the right atrium or longitudinal bicaval view). Prior to placement, the patient should be partially anticoagulated with 70 U/kg of heparin. The ESC is placed through the 11 Fr sheath. After the tip of the catheter engages the coronary sinus, the catheter is advanced either directly or over a guiding wire until the occlusion balloon is 2–4 cm inside the sinus. Position is confirmed by inflating the balloon and obtaining ventricularization of the pressure tracing. Careful note should be taken of the volume of fluid required to occlude the coronary sinus (1–2 mL) so that overinflation and possible coronary sinus trauma do not occur. Contrast injection will define the correct positioning of the ESC in the coronary sinus. Care should be taken to avoid injecting contrast too quickly, thus pushing the ESC out of the coronary sinus. A time limit (20–30 min) should be set to pass this catheter, as repeated attempts increase the risk of cardiac injury (e.g., cardiac perforation).
Placement of EPV	The EPV (pulmonary vent) is positioned by advancing the catheter, using balloon flotation with pressure monitoring (as with a Swan-Ganz catheter). Fluoroscopy and/or TEE also may be used.
Placement of EVD	The EVD (venous drain) cannula is placed via the femoral vein into the right atrium over a guide wire. Fluoroscopy or TEE is used to ensure that the wire enters the SVC before advancing the EVD into position. The tip of the EVD should be at the SVC/RA junction or just inside the SVC.
Placement of arterial cannula	The aorta may be cannulated with a "Y" cannula with an incising introducer. For femoral arterial cannulation, a guide wire is advanced under fluoroscopy and no resistance to its passage should be felt. The guide wire is advanced into the descending aorta and its intraluminal position confirmed on TEE prior to advancing the aortic return cannulation into its final position. The perfusionist should confirm normal line pressures with a test bolus of fluid and that normal arterial pulsation is present. These precautions will decrease the likelihood of arterial dissection.
	The EAC (endoaortic clamp) maybe advanced via the "Y" arterial cannula. For a femoral arterial cannula, the EAC is advanced over

Placement of EAC

a guide wire with imaging into the ascending aorta so that the tip of the catheter is just proximal to the sinotubular ridge (2–3 cm above the aortic valve). Position is confirmed by contrast injection and/or TEE. It is also useful to identify the takeoff of the innominate artery in relation to the balloon. Migration of the balloon proximally or distally can occur and, thus, its position needs to be monitored. Monitoring of the pressure in the aortic root via this catheter should show that the mean aortic root pressure is the same as mean radial artery pressure prior to the initiation of bypass.

Sequence of events during endo-CPB

After initiation of bypass, the anesthesiologist should observe the descending aorta to exclude aortic dissection and open the EPV to allow venting. EPV pressures during bypass should be negative (positive pressures may indicate inadequate decompression of the heart
or kinking of the EPV). Once adequate CPB is established and the heart is drained, the EAC balloon can be inflated (balloon pressure = 250–350 mmHg). Occlusion of the aorta is confirmed by a differential between the radial and aortic root pressures and by an aortic root contrast injection. Antegrade cardioplegia is delivered via the EAC with careful monitoring to ensure that the balloon is not displaced distally, thus occluding the innominate artery (see Monitoring of endo-CPB: regional perfusion, below). After cardioplegic arrest, retrograde cardioplegia may be delivered via the ESC, and the left side of the heart may be vented via the EAC. Avoid overventing, high systemic pressures, or high CPB flow, which could displace the EAC toward the aortic valve. Initiation of retrograde cardioplegia should begin with a low flow to avoid displacing the ESC, followed by inflation of the ESC balloon until the pressure in the coronary sinus just starts to rise, indicating coronary sinus occlusion. No further inflation of the balloon should take place. Normal coronary sinus perfusion pressure is < 40 mmHg. After retrograde cardioplegia is delivered, the ESC balloon is deflated. Once the surgery is completed, the EAC balloon is deflated (after deairing procedures, as needed); the heart is reperfused; and the EAC is removed. Prior to weaning from CPB, mobility of the ESC and EPV should be assessed in mitral procedures to ensure that they have not been incorporated in the atrial suture line. Weaning from bypass is routine. The ESC should be removed prior to heparin reversal and the EPV can be replaced with a pulmonary artery catheter, if needed.

Blood and fluid requirements

As for underlying condition:
For mitral valve surgery, see p. 356.
For CABG, see p. 346.

Monitoring

As for underlying condition:
For mitral valve surgery, see p. 356.
For CABG, see p. 346.

Special monitoring considerations for port-access are discussed below. External defibrillator pads should be placed on all patients.

Positioning

Supine
Roll under left chest for CABG and
under right chest for mitral valve.

Distal migration of the EAC (innominate artery occlusion →↓cerebral blood flow) is

		possible, especially while cardioplegia is being delivered when pressure in the aortic root exceeds that in the systemic arterial system. Monitoring for regional perfusion includes:
	Regional perfusion	1. Right-sided arterial pressure—radial, brachial, or axillary. The pump-induced artifact may be of use if roller heads are being used. 2. Bilateral arterial lines—right-sided, plus a second line in the left radial or in the femoral vessels to allow comparison. 3. TEE—EAC visible in the ascending aorta proximal to the innominate artery. 4. Transcranial or carotid artery Doppler. 5. Fluoroscopy
Monitoring of endo-CPB	Proximal EAC balloon migration	Most likely to occur during aortic root venting when the systemic pressure exceeds aortic root pressure. Monitored by TEE.
	Cardiac decompression	TEE can be useful in monitoring for adequate decompression of the heart.
	EAC balloon pressure	This is usually monitored by the perfusionist and ranges from 250–550 mmHg. Decreases in pressure may be 2° proximal migration of the balloon into a wider area of the ascending aorta, rupture of the balloon, or prolapse into the left ventricle. Loss of balloon occlusion is indicated by blood in the surgical field, return of cardiac activity, cardiac distension, increased root venting, and TEE evidence.
	Aortic root pressure	< 80 mmHg while giving cardioplegia; 0–10 mmHg, during venting. Overventing should be avoided, as should venting when the left side of the heart is open, to avoid drawing air into the aortic root.
	Intracardiac air	TEE is very useful for determining that adequate deairing of the heart has occurred.

Complications of endo-CPB	Retrograde aortic dissection Coronary sinus damage EAC balloon migration	
	EAC balloon rupture	Especially 2° sutures placed in the mitral valve annulus.
	Retained EPV in atrial suture line Chest-wall hemorrhage	It is important that the surgeon the chest wall before closure.
	Limb ischemia	May follow femoral cannulation.

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Postoperative

Complications	As for the primary procedure Low CO Chest-wall hemorrhage Problems associated with peripheral cannulation (e.g., dissection, embolization) Perivalvular leak Heart block	See mitral valve surgery (p. 357) or CABG (p. 347).
Pain management	Parenteral narcotics NSAIDs	Pain control is important to facilitate early extubation. Intrathecal narcotics and/or intercostal blocks with wound infiltration may be useful.
Tests	ECG Electrolytes ABG	

Suggested Readings for Port-Access Procedures–Surgeon's

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