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Ronald D. Miller

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SIXTH EDITION

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* Contents and authorship are tentative, and subject to change on publication.

CHAPTER

66 Anesthesia for Robotic Surgery

Ervant V. Nishanian and Berend Mets

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Summary

Robotic surgery is the resulting transformation of the minimally invasive surgical evolution. Robotic devices are being introduced to surgery because they allow unprecedented control and precision of surgical instruments in minimally invasive procedures. The anticipated benefits of robotic or robot-assisted surgery to the patient include less pain and trauma, shorter hospital stays, quicker recovery, and a better cosmetic result. With these technologic innovations, new anesthetic implications for patient care are being discovered. As surgery evolves into the robotic era, anesthesiologists must keep abreast of these changes and their impact on patient care and safety.

First-generation surgical robots are being installed in a number of operating rooms around the world. These are not true autonomous robots that perform surgical tasks; rather, they are mechanical "helping hands" that offer assistance in various fields of surgery. These machines still require human intervention to operate or to provide input instructions. Robotic devices are here to help surgeons, not to replace them.

HISTORY

Robots were first developed by the National Aeronautics and Space Administration (NASA) for use in space exploration.² These devices, or telemanipulators, were capable of doing manual tasks aboard a spacecraft or out in space. The slave devices were controlled electronically from a remote master control on Earth or aboard a spacecraft. Telemanipulators were used extensively aboard NASA's Space Shuttle missions between 1983 and 1997. Research in trajectory and missile guidance systems eventually led to highly precise targeting mechanisms. Precision pointing at targets, such as the Earth and stars, was crucial for Spacelab telescope experiments. Telemanipulators such as the Instrument Pointing System (IPS) was specifically designed for extreme accuracy (± 1.2 arcsec).³ Scientists at NASA Ames Research Center were responsible for developing virtual reality. The idea took root with contributions of VPL, a visual programming language, and Dataglove.⁴ Their integration made it possible to interact with three-dimensional virtual scenes. However, it took the integration of robotic engineering and virtual reality to develop a dexterous

6 Section IV – Subspecialty Management

Mitral Valve Surgery

In 1997, two independent groups reported the first robotically assisted mitral valve repair.^{45,46} In November 2002, the FDA approved the use of robot-assisted surgery in performing mitral valve repairs. Mitral valves repair, initially done through mini-thoracotomy incisions, could be done completely with a closed chest. However, mitral valve replacements may still require a small thoracotomy to introduce the new prosthetic valve.

Anesthetic Implications for Mitral Valve Surgery

Mitral valve surgery employing robotic devices are being done at a few cardiac centers in the United States and Europe. The anesthetic techniques and other relevant considerations have been described previously.⁴⁷ Patients are initially evaluated by cardiac catheterization to estimate the degree coronary artery stenosis and to assess valve function. Severe mitral regurgitation is a mechanical problem that requires surgery for cure. Most patients are medically treated with afterload reducers, such as angiotensin-converting enzyme (ACE) inhibitors if they are hypertensive. An enlarged left atrium is often susceptible to atrial fibrillation. Patients with persistent atrial fibrillation may be taking anticoagulants concomitantly with therapy for rate control. Chronic elevation in left atrial pressure may manifest with pulmonary hypertension, which may be further exacerbated by obstructive lung disease. Severe pulmonary hypertension renders a patient unsuitable for robotic surgery.⁴⁸

Patients are provided with a large peripheral intravenous line. Light sedation with midazolam and local anesthesia is offered before the placement of bilateral radial arterial lines. The patient is routinely monitored with ECG leads II and V5, pulse oximetry and a right radial artery pressure line to exclude endovascular aortic balloon misplacement. Modern ECG monitors can provide automatic ST segment analysis for the detection of ischemia. After ample oxygenation, the patient is anesthetized with a combination of midazolam, fentanyl, and isoflurane. On muscle relaxation, the trachea is intubated with a double-lumen endotracheal tube (Table 66-1). Proper tube position is confirmed by bronchoscopy. A TEE probe is inserted to assess heart and valve function and to guide central line placement. A mid-esophageal, bicaval view at 90 degrees is used for guidance in positioning the superior vena cava (SVC) and inferior vena cava (IVC) cannulas (Fig. 66-7). Initially, a left, 9-Fr introducer catheter is inserted by means of the

Seldinger technique, and an 8-Fr pulmonary artery catheter is floated into the pulmonary artery. Next, the right neck is prepared for insertion of a percutaneous, 17-Fr Biomedicus cannula. It is inserted directly into the internal jugular vein using the Seldinger technique, and its proper placement is confirmed by TEE. Experience shows that the long transthoracic aortic cross-clamp may impinge and occlude the SVC. For this reason, an armored SVC neck cannula provides resistance to occlusion or kinking. At the time of insertion, the cannula is flushed with 5000 units of heparin to ensure its patency. The cannula is anchored with a purse-string suture at the skin and secured with Kerlix gauze wrapped around the head.

After the patient's pelvis is positioned supine and the right shoulder is tilted 30 degrees to the left, transcutaneous defibrillation and pacing pads are applied. The surgeon can then determine proper location for port access, which may vary according to a patient's body habitus.

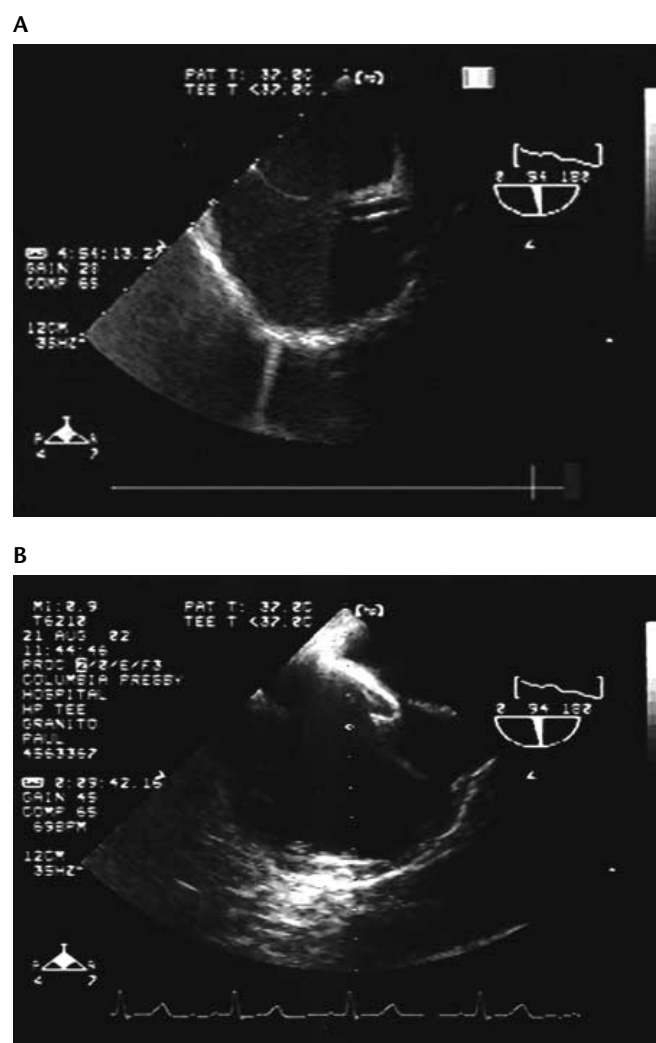


Figure 66-7 A, Ultrasound image of the superior vena cava cannula. B, Ultrasound image of a bicaval view depicting the inferior vena cava containing a J guidewire. Both views are helpful in correctly placing cardiopulmonary bypass venous cannulas.

Table 66-1 One-lung ventilation strategy

Use $\text{FIO}_2 = 1.0$.
Begin one-lung ventilation with pressure control ventilation, maintaining a plateau pressure of $<30 \text{ cm H}_2\text{O}$.
Adjust the respiratory rate so that PaCO_2 approaches 40 mm Hg .
Check arterial blood gas pressure.
Apply continuous positive airway pressure to nonventilated lung.
Apply positive end-expiratory pressure to ventilated lung.

Coronary Artery Bypass Grafting

All patients are evaluated preoperatively by TEE to exclude the possibility of persistent left SVC or patent foramen ovale. Table 66-3 lists the major exclusion criteria for robotic coronary artery bypass grafting. The iliac and femoral arteries should also be evaluated for their size by echo Doppler ultrasonography.³⁰

Patients are prepared and monitored for anesthesia in a manner similar to that for mitral valve surgery (see “Mitral Valve Repair”). Monitoring of the right radial artery pressure tracing is imperative when using an endovascular balloon-occlusion catheter. After the patient is asleep, inspired oxygen tension and expired carbon dioxide are monitored. TEE is used routinely as the standard of care for determination of cardiac function and for confirming catheter placement. Pulmonary artery catheters are judiciously used in the appropriate patient population, but the data that the catheter provide may be redundant when TEE data are available. The patient is positioned the same as for internal mammary artery takedown, and trocar positions are placed as depicted in Figure 66-8.

When cardiopulmonary bypass is anticipated, the left femoral artery is cannulated with a 17- or 21-Fr Remote Access Perfusion (RAP) catheter (Fig. 66-9) with an aortic occlusion balloon. Exclusion criteria for endovascular cardiopulmonary bypass are contained in Table 66-4. This catheter allows anterograde flow of 4 or 5 L/min, respectively. The cannula has a separate lumen for delivering cardioplegia to the aortic root beyond the occlusion of the balloon. The aortic cannula is positioned in the ascending aorta, 2 cm above the aortic valve, with TEE guidance (Fig. 66-10). The endovascular balloon is inflated with a volume equal to the diameter (in milliliters) of the sinotubular junction of the aorta. A

Table 66-3 Exclusion criteria for robotically assisted endoscopic coronary artery bypass grafting

Contraindication to one lung ventilation
Age older than 80 years
Ejection fraction higher than 40%
Severe noncardiac health issues
Severe peripheral vascular disease
Myocardial infarction for more than 7 days
Previous thoracic surgery, pleural adhesions, or emergency surgery
Calcified left anterior descending artery or diffuse disease
Intramyocardial left anterior descending artery
Morbid obesity, with a body mass index of more than 32
Large heart within the left chest

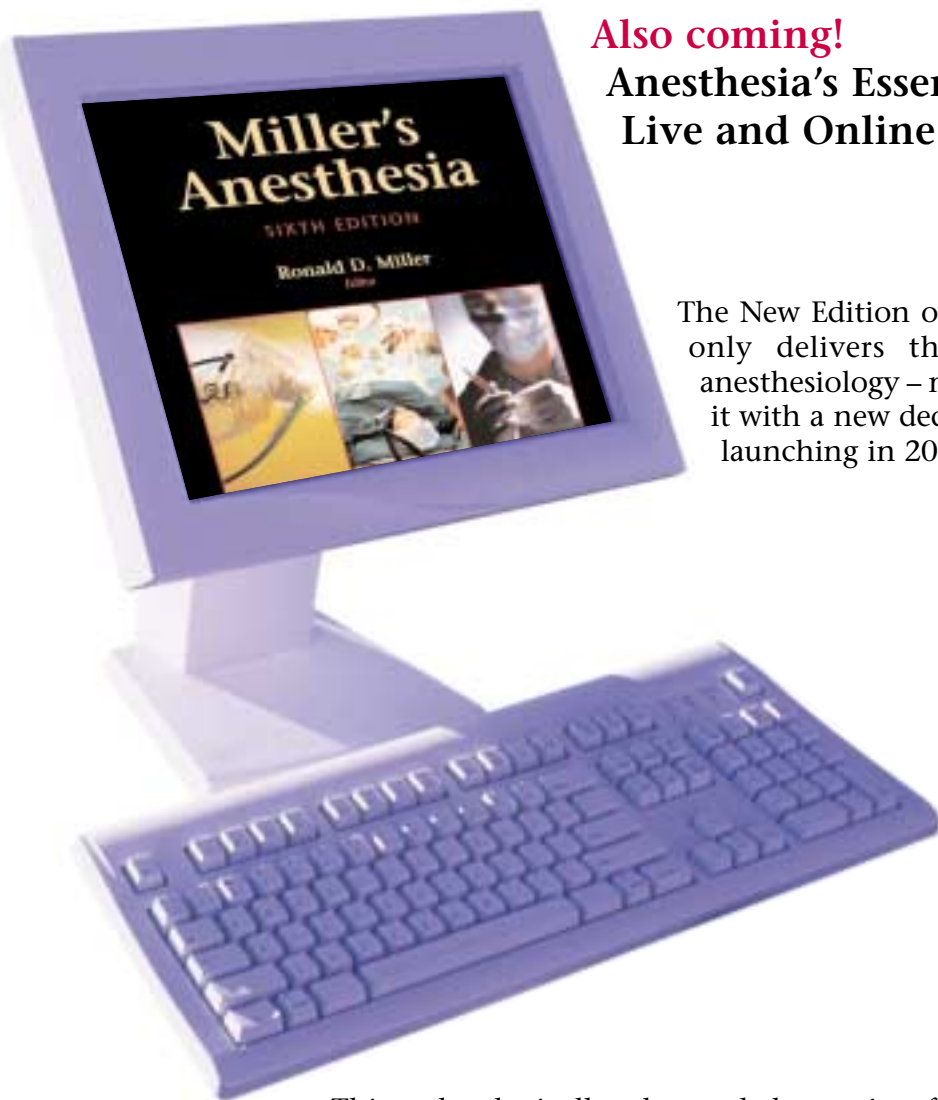
Table 66-4 Contraindication for endovascular cardiopulmonary bypass system

Major vascular disease of the ileac, femoral, and abdominal aorta found by Doppler ultrasound
Severe atherosclerosis
Aortic diameter greater than 4 cm
Moderate to severe aortic valve incompetence

balloon pressure above 300 mm Hg usually provides complete occlusion of the aorta.³² Residual flow around the balloon can be seen and monitored with color flow on TEE. The use of bilateral radial artery lines is useful in detecting the migration of the occlusion balloon toward the innominate artery. Proximal migration of the balloon can most easily be seen with TEE, preventing balloon herniation through the aortic valve.

After full cannulation and being poised for cardiopulmonary bypass, the right lung is allowed to collapse

Figure 66-8 Incision ports for coronary artery bypass grafting. Trocars are placed in the third, sixth, and eighth intercostal spaces. Similar port positions are used for bilateral internal mammary artery dissection.



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