Patient Care in Cardiac Surgery

Third Edition

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Notice

The indications and dosages of all drugs in this book have been recommended in the medical literature and conform to the practices of the general medical community. The medications described do not necessarily have specific approval by the Food and Drug Administration for use in the diseases and dosages for which they are recommended. The package insert for each drug should be consulted for use and dosage as approved by the FDA. Because standards for usage change, it is advisable to keep abreast of revised recommendations, particularly those concerning new drugs.

Preface

When asked to write a third edition of *Patient Care in Cardiac Surgery*, our initial reaction was that insufficient change had occurred since 1976 to justify a new edition. However, after stepping back from our daily immersion in the field, we realized that although major changes have occurred, their development has been so gradual as to be almost unnoticed. It is this inexorable chipping away at problems that characterizes current progress in cardiac surgery. Opportunities are few for any major advances comparable to those that took place twenty years ago. Nevertheless, progress has been real and change has been considerable. Consequently, what began as a revision quickly became a wholesale rewriting of this book.

Since publication of the second edition, new operative techniques and methods of care have evolved. The use of cardioplegic solutions for intraoperative myocardial protection has substantially decreased the need for postoperative hemodynamic support. Nitroprusside is now more commonly administered than are catecholamines. The concept of afterload reduction has come of age. New drugs are now part of our standard armamentarium. Cardiac output monitoring by thermodilution has become more commonplace. Intraoperative heparinization has achieved a sounder scientific basis through the use of activated clotting time. In addition, we have continued to learn how to care for children with complex cardiac anomalies. As a consequence of these and other improvements, operative mortalities have been dramatically reduced for cases of almost every type of lesion.

This updated edition, like its predecessors, is intended as a practical guide for those actually providing patient care before, during, and after cardiac surgery. Its purpose is not to be encyclopedic but rather to present our personal approaches to cardiac care problems. Accordingly, the references are meant to be useful, not all-inclusive.

We would once again like to thank all of our colleagues at the University of Michigan, the Massachusetts General Hospital, the National Heart Institute, and the Hospital for Sick Children, Great Ormond Street, London, whose ideas have contributed immeasurably to the evolution of the concepts presented in this book.

D. M. B.
W. G. A.

Contents

1. Preparation for Operation

General Plan

Accurate and complete anatomic and physiologic diagnosis forms the cornerstone of the successful operative treatment of heart disease. Most patients being considered for cardiac surgery have been previously evaluated by a cardiologist. Before an operation can be logically planned, the data from the cardiologist's evaluation must be reviewed to ascertain that it is both complete and current. In most institutions this review takes place in a combined medical-surgical conference at which the plan of management is formulated before the patient is admitted for surgery. Ideally, the anesthetists and nurses who will be participating are present at the conference as well. This procedure minimizes the chances of overlooking important facts that may affect the outcome.

The preoperative data required vary according to the patient's disease. Some patients are accepted for operation without catheterization; e.g., an older child with a clear-cut patent ductus arteriosus, coarctation of the aorta, or atrial septal defect, and some adults with clear-cut aortic stenosis, aortic regurgitation, or uncomplicated mitral stenosis. However, most patients should have echocardiograms and a complete right and left heart catheterization with angiograms appropriate to the suspected conditions. In some institutions radionuclide scans are obtained to assess ventricular function, uniformity of myocardial perfusion, distribution of pulmonary blood flow, or the magnitude of intracardiac shunts. Electrophysiologic studies or Holter monitoring should be performed for patients with arrhythmias or conditions in which postoperative arrhythmias are likely to be a problem (such as a transposition of the great vessels). Graded exercise testing is a semiquantitative means of objectively evaluating the functional extent of myocardial ischemia in patients with coronary artery disease. It should be part of the basic preoperative data in patients who have not had a recent infarction and who do not have severe unstable angina (in which instances the test would be hazardous) [171, 235]. The pressure-rate product at which angina or electrocardiographic changes occur during exercise testing provides a useful guide to the anesthesiologist (see p. 20). These various studies provide baseline information that is valuable not only in patient management but also in assessment of the operation's results.

The indications for operation vary according to the particular lesion [57, 61, 63, 134, 199, 288–291]. In general, valve replacement with a prosthesis is not warranted until a patient either is severely

limited in activity (NYHA Class III or IV) or has symptoms such as angina or syncope with aortic stenosis that may presage sudden death. The principal indication for coronary artery bypass surgery is intractable angina pectoris. The operation may prolong life and improve ventricular function [201] in patients with more than one severely narrowed coronary artery, but this is still debated [228]. Recent experience with multivessel disease appears to favor surgery over medical therapy in terms of life expectancy. There is statistical evidence that operation improves life expectancy in patients with occlusion of the main left coronary artery [326]. Unstable (so-called preinfarction) angina, acute myocardial infarction, and postinfarction cardiogenic shock are other conditions for which operation may be beneficial. In those patients with congenital defects who remain asymptomatic, operation is usually undertaken in the preschool years to prevent the occurrence in later life of cardiac decompensation or complications such as endocarditis, irreversible pulmonary arterial damage, or cerebrovascular accidents. More than half of all babies born with congenital heart disease have severe symptoms and die during infancy unless treated. Cardiac catheterization and either palliative or totally corrective operations (according to the lesion and the skill of the surgical team) frequently must be performed as emergency procedures in infants, since they are often rapidly deteriorating when brought to the hospital.

During the period of preoperative evaluation patients with congestive heart failure are started on a program of rest, diuretics, digitalis, and salt and fluid restriction. Ideally, patients should be operated on when there is no evidence of congestive heart failure and when they have reached their dry weight. This may require weeks of preparation but is certainly worthwhile, since patients appear to tolerate operation better when free of congestive heart failure [371]. Some patients are so ill, however, that they will not respond to treatment of pneumonia, myocardial infarction, a metabolic abnormality, or the like until their cardiovascular function is improved by operation. With this group operation must be undertaken despite inadequate preparation. Severely cyanotic patients and patients in a state of low cardiac output from critical valvular stenosis or from acute valvular regurgitation rarely benefit from medical (nonoperative) therapy and so should be operated on promptly. Vigorous preoperative therapy may precipitate electrolyte imbalances, dehydration, intravascular thrombosis, and other hazards. During prolonged bedrest we administer subcutaneous heparin in low doses to adults (5000 u q12h) to prevent pulmonary embolism. Furthermore, blood volume depletion consequent to excessive diuresis may cause a patient to tolerate anesthesia poorly, necessitating transfusion. Surgical candidates are

often cachectic, and fevers are common; certainly, occult malignant disease or subacute endocarditis must be ruled out before an elective operation is recommended.

Generally, a minimum of six weeks is allowed for the healing of a myocardial infarction before operation. The mortality accompanying elective coronary bypass surgery has been shown to decrease progressively during the first two months following acute infarction, from a level of more than six times the normal rate during the first week, to three times the normal rate during the next three weeks, and normal levels after one month [106]. A waiting period of several months before operation is preferred following successful treatment of subacute bacterial endocarditis. Although it was once thought that active bacterial endocarditis was an absolute contraindication to valve replacement, it is now clear that operation must be carried out promptly in patients with repeated embolization, failure of antibiotic control, or severe congestive heart failure from acute valvular regurgitation due to infection. Prostheses inserted in these cases usually do not become infected [33, 261, 375]. In fact, operation may be the only means of curing drug-resistant endocarditis, especially that of fungal origin. Similarly, refractory cardiogenic shock following myocardial infarction is now regarded as an indication for emergency operation (e.g., infarctectomy, coronary artery reconstruction, correction of a mechanical defect, or a combination of these procedures).

When a patient is admitted to the surgical service, the house officer must determine whether the record contains all data pertaining not only to the proposed operation but also to subsequent review [21]. Cardiac surgery is still in its developmental phase, and so it is important that detailed records be kept for future study. The history and physical examination must be thorough. In addition to a detailed account of the patient's cardiac status, his respiratory, gastrointestinal, renal, neurologic, and peripheral arterial functions must be documented because each directly affects surgical therapy. For example, significant aortoiliac atherosclerosis may indicate that femoral artery cannulation for bypass would be unwise and that perfusion of the aortic arch would be safer. A history of gastrointestinal bleeding from benign causes might favor the choice of a prosthetic valve not requiring long-term postoperative anticoagulant therapy. If the patient is to undergo an aortocoronary bypass graft, the saphenous veins must be evaluated and a history of phlebitis sought.

The teeth should not be overlooked when the patient is examined on admission. Generally, all necessary dentistry should be completed before operation, especially in patients in whom prosthetic materials are to be used for the cardiac repair, since implantation of

a prosthetic device greatly increases the danger of endocarditis [94]. Major dental work frequently leads to significant bacteremia [333] in which the principal organisms are diphtheroids and alpha streptococci; so therapeutic doses of penicillin should be administered. In order to avoid the hazard of endocarditis, elective operation is not performed in the presence of any oral infection, incomplete healing of the gums following denial extraction, or other infection.

Figure 1-1 illustrates a typical set of orders for an adult patient admitted to the hospital for cardiac surgery. Laboratory studies of all patients being considered for open cardiotomy should include a chest x-ray film, electrocardiogram (ECG), complete blood cell count, blood typing, and urinalysis, as well as measurement of creatinine or blood urea nitrogen and electrolyte levels. In addition, in all cases of patients with right ventricular failure or a history of hepatic dysfunction, levels of the following should be determined: bilirubin, lactic acid dehydrogenase, serum glutamic oxaloacetic transaminase, alkaline phosphatase, and serum proteins. A lipid profile, serum cholesterol determination, and glucose tolerance test should be ordered, under conditions standardized according to hospital protocol, for patients with coronary atherosclerosis. Patients with urologic disease should have a urine culture and creatinine clearance determination. Those with atrial fibrillation should undergo thyroid studies.

Plasma coagulation factors and the fibrinolytic system are evaluated by measuring the partial thromboplastin time, prothrombin time, thrombin clotting time, euglobulin clot lysis time, and fibrinogen concentration. A platelet count is performed. As platelet function is difficult to assess, most hospitals do not attempt it routinely. If a history of unusual bleeding or bruising is obtained, the clot retraction or bleeding time can be tested or more sophisticated platelet function tests carried out with the aid of hematology consultants. Aspirin is known to inhibit platelet function for five days after ingestion. In one study, aspirin intake resulted in significantly increased postoperative chest tube drainage [274]. Therefore, aspirin and other platelet-inhibitory agents should not be administered within a week of operation.

A worksheet (see Fig. 1-2) can greatly aid the house officer in organizing these data.

Patients in heart failure are digitalized preoperatively. Some surgeons also prophylactically digitalize patients who are not in heart failure, although there is little evidence that this is beneficial [399]. A short-acting preparation such as digoxin is used before operation, because the drug levels of digitoxin and digitalis leaf are less rapidly controllable. It has been suggested that digitalization may improve

Medication orders	Noted	All other orders	Noted
Digoxin: _____ mg PO QD		VS: _____ Record BP in both arms	
Stop diuretics			
Stop digoxin 1 day preop.		DIET: _____	
Nembutal 100 mg PO hs PRN		Weigh daily & record in pt's chart	
Laxative of choice			
		Daily chest physical therapy	
		Daily pHisoHex showers	
		50 cc of blood to the blood bank	
		Hct, WBC, differential	
		Na, K, Cl, CO_2, BUN, FBS	
		Creatinine, PBI	
		SGOT, LDH, TP & A/G, alk. phos., VDB d/t, cholesterol, lipid electrophoresis	
		Hinton test	
		Platelets, PT, PTT, TCT, fibrinogen, euglobulin clot lysis	
		Urinalysis	
		ECG	
		Chest film PA & lateral	

Figure 1-1. Typical orders for adults on admission for cardiac surgery. Many of the laboratory tests can be omitted in some patients.

Date of surgery

Vital signs			BP Rt. arm Lt. arm		Pulse	Resp.	Weight
Routine studies							
Hct							
WBC							
Diff.	P	B	L	M	E	Baso	Atyp L
Urine	Sp. gr.		WBC		RBC	Bact	
	Alb		Bile		Gluc	Acetone	
Stool for guaiac							
Hinton							
Blood bank—sample				<5 days		<24 hr	
Electrolytes—Na			K	Cl		CO_2	Repeat K
Blood sugar—FBS				2 hr pc			

Renal function	**Liver function**
BUN	Bili
Creatinine	Alk. phos
24 hr creatinine	SGOT
clearance	LDH
Urine culture	TP a/g
Bleeding studies	**Lipid profile**
Platelet count	Cholesterol
Prothrombin time	Lipids
PTT	**Thyroid function**
TCT	
Euglobulin clot lysis	
Fibrinogen	

ECG—rate rhythm axis
reading
stress test

X-rays
Chest—PA, lateral

Pulmonary function
ABG—PO_2 PCO_2 pH
PFT—1st sec VC VC MVV
Conclusion

Catheterization Data

Figure 1-2. House officer's worksheet for preoperative preparation.

myocardial function at the completion of cardiac repair [62]. Also, the ventricular rate is somewhat easier to control in patients digitalized preoperatively who develop atrial fibrillation postoperatively, a common occurrence [76, 354, 355]. However, the likelihood of postoperative ventricular irritability is greatly reduced if the patient is not fully digitalized [115, 255, 292, 354]. Extracorporeal circulation cannot be relied on to wash out digitalis, because tissue levels have been shown not to change during bypass. Accordingly, digoxin is discontinued one day before operation unless the inotropic effects of digitalis are deemed imperative for that particular patient or unless the patient has atrial fibrillation with a relatively fast response that may become unmanageable at operation if digitalis is omitted [76]. Longer-acting preparations should be withheld for several days.

It is not yet clear whether there is a true total body potassium deficiency in patients with chronic congestive heart failure [284]. However, it is a distinct clinical impression that omission of diuretics and oral administration of potassium salts for several days before operation helps avoid serious electrolyte imbalances and consequent arrhythmias even when serum potassium values are normal [101, 142, 327]. Edema usually will not develop in these few days if rigid salt and fluid restriction is maintained and the patient is at rest.

Other drugs a patient is taking that affect the cardiovascular system should be discontinued as far in advance of operation as possible to allow their effects to abate. Propranolol and sodium warfarin (Coumadin) pose special problems requiring individualized solutions (see pp. 9–13). A sedative often should be administered the night before operation to patients with angina, to reduce anxiety. Diazepam has been shown to have a nitroglycerin-like effect [102] and is the agent of choice.

Finally, to obtain maximal cooperation from the patient and to aid in the prevention of postoperative psychosis, the staff should orient the patient (and also a child's parents) to the intensive care unit, monitoring equipment, nursing routines, oxygen masks, and function of the tubes and catheters that will be used in the postoperative period. The possibility and function of prolonged endotracheal intubation and tracheostomy should be discussed. Instruction should be given in proper deep breathing, coughing, and leg exercises. Figure 1-3 illustrates a checklist that can be used by the nurses as a guideline for preoperative teaching. Devices such as dolls, puppets, and cartoons have proven useful in preparing children for operation.

Typical preoperative orders are shown in Figure 1-4. Nearly every cardiac surgical unit in the world uses prophylactic antibiotics [94], although their efficacy is hard to establish [135]. A broad-spectrum bactericidal drug, such as methicillin or cephazolin, is given in-

Checklist for Cardiac Surgery Preoperative Teaching

Does this patient know and understand?	Yes	No	Needs teaching	Sig RN
1. No smoking	☐	☐	☐	☐
2. Daily weights, sodium-restricted diet, and strict fluid limit	☐	☐	☐	☐
3. Role of chest therapist	☐	☐	☐	☐
4. How to turn, cough, deep breathe, and exercise legs	☐	☐	☐	☐
5. Pulmonary function tests	☐	☐	☐	☐
6. Cardiac catheterization (if necessary)	☐	☐	☐	☐
7. Routine chest x-rays, blood work, ECGs, pre- and postoperatively	☐	☐	☐	☐
8. Preoperative prep incl. medications and effect, skin shave, enema, Foley catheter, CVP line	☐	☐	☐	☐
9. Responsibility for personal effects	☐	☐	☐	☐
10. Preanesthesia room	☐	☐	☐	☐
11. Personnel and environment of the surgical intensive care unit, visiting regulations for family, duration of stay	☐	☐	☐	☐
12. Routine equipment encountered postoperatively incl. IVs, blood transfusions, endotracheal tube, respirator, monitor, chest tubes, etc.	☐	☐	☐	☐
13. Transfer to convalescent ward	☐	☐	☐	☐
14. Progression of activity	☐	☐	☐	☐
15. Normal feelings after surgery	☐	☐	☐	☐

Figure 1-3. Checklist for nurses. Courtesy of the Nursing Service, Massachusetts General Hospital.

tramuscularly the night before operation, on call to the operating room, and then intravenously for only a few days until all intravenous lines, chest tubes, etc., have been removed [164]. This schedule assures adequate blood levels of antibiotic during the period when risk of infection is greatest [75], and appears to be a reasonable prophylactic antibiotic regimen. The antibiotics chosen should be directed at the sensitivities of the bacterial flora resident in that hospital. The patient should bathe or shower with a bacteriostatic soap the night before operation.

A urinary catheter is inserted before operation in all patients with acquired heart disease and in patients with complicated congenital defects to prevent bladder distention intraoperatively and to allow postoperative monitoring of urinary output. Insertion is best performed after induction of anesthesia in the operating room.

Preoperative Cardiac Surgery Orders

Medication orders	Noted	All other orders	Noted
OPERATION: _____		SCHEDULED FOR: _____	
Kefazol 1 g IM hs and on		NPO after midnight	
call to OR		Shave & prep chin to ankles	
Fleet enema PM before		bilaterally including neck,	
surgery		both axillas, both groins,	
On call sedation will be		pubis, and back	
ordered by anesthesi-		pHisoHex shower after prep	
ologist		Check with blood bank to see	
		if blood sample is there	
		and all bloods are set up	
		Films, addressograph, and VS	
		sheets to OR with chart	

Figure 1-4. Typical preoperative orders for open-heart surgery in adult patient.

Special Problems

Propranolol

Most patients undergoing coronary revascularization have been receiving propranolol, a myocardial depressant. Available evidence suggests that its activity in serum and tissues and its biologic effects are totally dissipated within 48 hours of discontinuance of the drug [241]. Many surgeons believe that it is safe even to continue the drug to within 24 hours of operation [77, 283]. Others believe that it should be discontinued at least two weeks preoperatively [406]. We have been able to demonstrate no intraoperative difference in cardiac output between patients undergoing coronary bypass who received their final dose of propranolol 1 to 2 hours preoperatively and those who received it 48 hours preoperatively [219]. The patients who received propranolol had a lower heart rate and lower incidence of intraoperative hypertension, suggesting that the drug helps to protect the ischemic myocardium during anesthesia. Thus, we routinely continue propranolol preoperatively in patients with *severe* coronary

disease, reducing the dose for a few days (e.g., to 40 mg PO q6h) but giving the last dose orally as part of the on-call medications the day of operation.

We have occasionally encountered, in patients receiving propranolol, major, otherwise unexplained hemodynamic difficulties that were reversed only by glucagon, a specific antidote for propranolol. This leads us to believe that the drug should be discontinued as far in advance of elective operation as possible in patients for whom it is not clearly indicated. This must be done gradually to avoid the risk of rebound phenomenon [357].

Main Left Coronary Lesions

Patients with significant occlusive disease of the main left coronary artery are especially likely to sustain fatal myocardial infarctions or arrhythmias during cardiac catheterization or during anesthesia for bypass surgery. Accordingly, they must be handled with care. For this group, we would certainly recommend the continuance of propranolol up to the day of surgery. Also, the policy of some institutions is to insert an intraaortic balloon before operation so that counterpulsation can be employed for additional protection. We frequently adopt this approach to patients with very unstable angina.

The term *counterpulsation* refers to any support system that raises aortic diastolic pressure and lowers left ventricular systolic pressure in synchrony with the patient's heartbeat. The AVCO-Massachusetts General Hospital (AVCO-MGH) system uses an intraaortic balloon inserted through the common femoral artery [71]. The balloon, which is inflated with helium in diastole and deflated in systole to produce the desired intraaortic pressure changes, has several beneficial effects:

1. Reduction of cardiac work. Cardiac work is defined as pressure × flow or, more precisely, the integral of pressure and flow. By reducing the pressure against which the heart is ejecting (that is, the afterload), counterpulsation reduces the pressure component of cardiac work.
2. Reduction in myocardial oxygen requirements. It is estimated that 70 percent of myocardial oxygen is utilized in developing wall tension during systole. Thus, counterpulsation is especially effective in reducing myocardial oxygen consumption, because it reduces left ventricular systolic pressure.
3. Increase in coronary artery blood flow. Two-thirds of coronary flow occurs in diastole. By raising diastolic pressure, counterpulsation may be effective in increasing coronary flow. According to some

experimental evidence, it may also open unused collateral coronary vessels.
4. Support of mean aortic pressure by increasing diastolic pressure.

The balloon is inserted into the femoral artery through a 3/8-inch woven Teflon graft sewn end to side to the artery. This permits flow to continue down the leg past the insertion site (Fig. 1-5). It is positioned in the aorta (ideally by fluoroscopy) immediately distal to the left subclavian artery. Heparin or dextran (Rheomacrodex, 10 ml/hr) is given to prevent clotting or platelet aggregation on the balloon. (To avoid major bleeding, omit heparin when a balloon is used following open heart surgery.) The balloon is never left motionless in the bloodstream; it is "fluttered" with small volumes when not in use. With these precautions, balloon pumping has been continued for a week without clotting, significant thrombocytopenia, or hemolysis. It is essential that balloon inflation be properly phased so that it occurs on the downslope of the radial artery pressure curve. Deflation must occur just before the onset of ventricular systole, creating a negative pressure trough for left ventricular ejection (Fig. 1-6).

Cardiogenic Shock

At the Massachusetts General Hospital (MGH), as elsewhere, an increasingly aggressive approach has been adopted in the treatment of patients dying of cardiogenic shock, usually following myocardial infarction [347]. When such a patient is admitted to hospital, vigorous attempts are made to reverse the shock state by means of catecholamine support, pacing techniques, volume expansion, correction of metabolic abnormalities, etc., in an environment where cardiovascular performance can be accurately monitored. If these conventional measures fail and if the patient is otherwise a candidate for operation, counterpulsation is begun and cardiac catheterization is performed. If there are bypassable distal coronary branches and if corresponding segments of the left ventricular wall contract, operation is carried out. At MGH, 78 muscle-damaged patients considered operable but dying of cardiogenic shock after myocardial infarction despite employment of all conventional measures have been operated on, with use of the balloon for support; of these, 41 (53%) survived. Post-myocardial infarction patients with similarly severe hemodynamic difficulties and mitral regurgitation from papillary dysfunction, or those with another mechanical problem such as a ventricular septal defect, should receive balloon support and surgical correction; the results are, in general, slightly better than those obtained in patients with muscle failure alone. Other institutions are

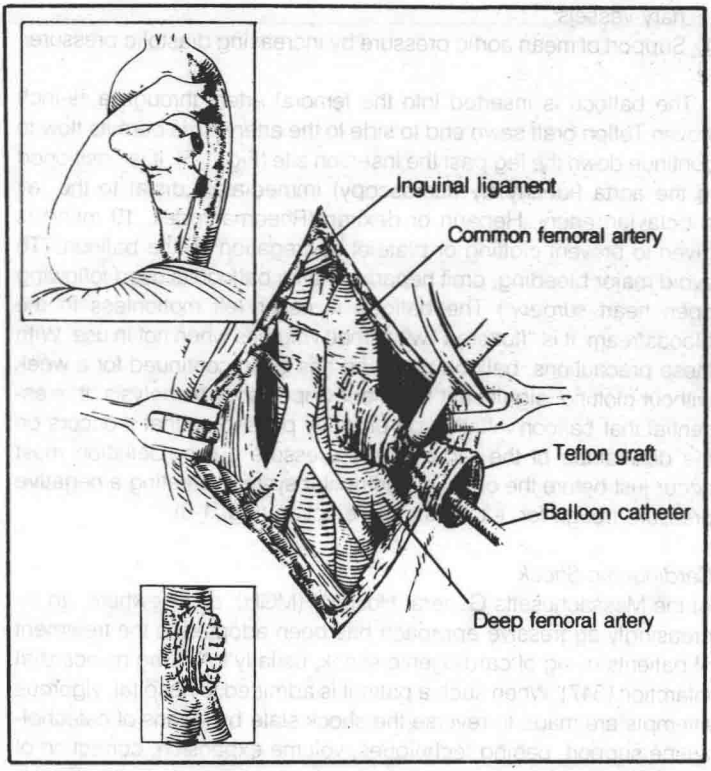

Figure 1-5. Insertion of intraaortic balloon for counterpulsation. A tightly woven ⅜-inch Teflon graft is sewn end to side to common femoral artery. The balloon is then inserted through graft into aorta. It is positioned in thoracic aorta (upper inset), with tip just below left subclavian artery, and secured with multiple heavy ligatures about graft. Wound is closed, burying graft in subcutaneous tissues with skin closed tightly around shaft of balloon catheter. When balloon is removed, graft is trimmed and oversewn (lower inset) and serves as a patch to close femoral artery [209].