most adults, the diseased valve is replaced with a prosthesis, although some forms of valve disease, such as mitral valve regurgitation or mitral stenosis without significant valvular or chordal calcification, may be amenable to repair. Because prosthetic heart valves are associated with a number of complications (e.g., thrombosis, endocarditis, hemolysis), the decision to proceed with valve surgery should made only after the risks of valve replacement have been weighed against the potential benefits of symptom relief and improved survival.

Valve surgery is performed in a manner similar to CABG, with most cases requiring a median sternotomy, CPB, and cardioplegic arrest. Minimally invasive surgery through a modified sternotomy or thoracotomy incision may be possible in selected patients with isolated aortic or mitral valve disease. Operative mortality for all techniques ranges from 1% to 8% for most patients with preserved left ventricular function and good exercise capacity. The risk of surgery increases with advancing age, depressed left ventricular ejection fraction, presence of severe coronary artery disease, and replacement of multiple valves. Symptomatic patients usually have significant clinical improvement after valve surgery; however, long-term survival is strongly dependent on the patient's preoperative functional status and ventricular function.

Mechanical Circulatory Support and Cardiac Transplantation

The term *mechanical circulatory support* refers to total or partial mechanical support of the heart to allow for continued circulation of blood and adequate tissue perfusion. John H. Gibbon performed the first clinical application of mechanical circulatory support in 1953 when he used a CPB machine for closure of an atrial septal defect. The ability to operate on a motionless and bloodless field led to the birth of cardiac surgery as a discipline and spawned the current era by providing a surgical alternative approach for the treatment of coronary artery disease, valvular heart disease, and diseases of the great vessels.

Since the advent of the CPB machine, several mechanical support systems have become available, including intra-aortic balloon pumps (IABP), extracorporeal membrane oxygenators (ECMO), ventricular assist devices (VADs), and total artificial hearts (TAHs). Because the surgical management of heart failure continues to evolve, this section focuses on the indications and associated complications of left VADs (LVADs), especially in relation to heart transplantation. Further details on the disease process and medical management of heart failure are covered in Chapter 6.

Cardiopulmonary Bypass

A CPB procedure not only circumvents the normal functions of the heart and lungs during an operation but enables surgery to be carried out in a bloodless and motionless field while simultaneously providing adequate oxygenation of blood and perfusion of end organs. The heart is arrested with the use of a cardioplegic solution of blood or normal saline that is highly concentrated with potassium. Aside from creating a motionless surgical field, cardiac arrest and cooling of the heart provide cardiac protection against ischemia by decreasing metabolic demand during bypass. Other important functions of the CPB are intraoperative regulation of blood volume and pressure, cooling and rewarming of the patient, administration of medications, filtering the blood, and providing rapid laboratory analysis of blood samples to achieve successful CPB surgery

In a schematic diagram of standard CPB circuit shown in Figure 11-2, deoxygenated blood is first drained from the right side of the heart by cannulas placed in the inferior and superior venae cavae. The blood is transported into a reservoir and then pumped through a heat exchanger, oxygenator, and filtration unit before it is returned through a cannula into the ascending aorta for whole-body circulation. Peripheral cannulation is achieved through the femoral vessels or the axillary artery or both, the latter approach being reserved for complex aortic arch surgery or in instances when standard cannulation of the great vessels is not possible.

The CPB operation is well tolerated by most patients. Similar to MCS devices discussed later, the secondary complications from contact of circulating blood with the synthetic surface of the circuit promote the activation of inflammatory pathways, systemic responses, and hypercoagulability. All patients undergoing CPB require heparin anticoagulation to a goal activated clotting time of at least 480 seconds. Corticosteroids may be administered to suppress the inflammatory response, and protamine is routinely used for reversal of heparin before decannulation. Postoperatively, patients should be monitored for heparin-induced thrombocytopenia (see also Chapter 54).

Extracorporeal Membrane Oxygenation

ECMO is the use of a simplified CPB circuit for temporary life support in patients with reversible cardiac or respiratory failure in the intensive care unit. The mechanical oxygenation and organ perfusion allows for cardiopulmonary recovery. Improved survival has been demonstrated in neonates and adults with isolated pulmonary or cardiac failure for whom maximal medical therapy has failed. As with CPB, cannulas are placed in the right side of the heart to drain blood into the ECMO circuit for oxygenation, but blood can be returned to either the right heart or the arterial system (the proximal or distal aorta). Return of blood to the right heart (i.e., veno-venous ECMO) is indicated for patients with isolated pulmonary failure. In patients with pulmonary and concomitant cardiac failure with hemodynamic instability, veno-arterial ECMO is used to return oxygenated blood to the proximal aorta to augment cardiac output and recovery. Patients on veno-arterial ECMO require anticoagulation. As with CPB, complications associated with ECMO include bleeding, thromboembolism, and heparin-induced thrombocytopenia.

Intraaortic Balloon Pump

The physiologic basis of an IABP is to provide counterpulsation and to improve the peripheral oxygen demands in the patient with a failing heart. Common indications for IABP are hemodynamic support during or after heart catheterization, cardiogenic shock, weaning from CBP, preoperative stabilization in high-risk patients, refractory unstable angina, refractory ventricular failure, and mechanical complications due to acute MI.

A helium-filled balloon is placed percutaneously or under direct vision through the femoral artery into the thoracic aorta, just distal to the left subclavian artery. The balloon is