and current recommendations for LVADs are primarily based on level C evidence (i.e., consensus based). The goal of LVAD therapy is to support cardiac function and maintain adequate end-organ perfusion to provide meaningful recovery and quality of life. In the acute setting (e.g., cardiogenic shock), a LVAD may be placed temporarily, either as a bridge to decision for a longer-term VAD and assessment of alternative management options or as a bridge to recovery if the heart failure is deemed reversible (e.g., viral myocarditis, nonischemic cardiomyopathy). Patients with chronic heart failure who have failed maximal medical therapy and are candidates for transplantation may receive a LVAD as a bridge to transplantation while awaiting the availability of a donor heart. Survival from the time of implantation of the cardiac assist device to the time of cardiac transplantation varies from 51% to 71% worldwide.

In patients with lifestyle-limiting heart failure despite maximal medical therapy who are not candidates for transplantation, a LVAD may be indicated for destination therapy. In this setting, the LVAD is placed indefinitely to maintain tissue perfusion and improve quality of life or, in some cases, until recovery is achieved or the patient becomes a candidate for heart transplantation. Destination therapy is the most common indication for LVAD placement; approximately 40% of all VADs placed in 2012 were for that purpose.

Before implantation of any MCS device, medical and psychosocial factors as well as operative risk factors should be taken into consideration and assessed by a multidisciplinary team devoted to such longitudinal care. VADs are not recommended for patients with irreversible end-organ damage and without anticipation of meaningful improvement in quality of life.

Table 11-3 lists the VADs currently approved by the U.S. Food and Drug Administration (FDA). Several types of VADs that can be placed percutaneously or surgically in the acute setting exist for longer support. In general, LVADs decompress the left ventricle by draining blood into the aorta using a mechanical pump; they also contain a power source, such as a portable battery pack, and a cardiac and device monitoring system (Fig. 11-3). First-generation LVADs were pneumatically driven pulsatile pumps that drew blood from the apex of the heart and ejected it into the proximal aorta. The Heartmate XVE (Thoratec Corp., Pleasanton, Calif.), a first-generation LVAD, was approved by the FDA in 1994 as a bridge to transplantation. Although these pulsatile pumps are considered more physiologic, they are bulky and technically difficult to implant because they require a large body surface area, and they have a high incidence of infection and pump thrombosis. These flaws led to the development of the smaller, second-generation LVADs that were driven by axial or centrifugal pumps to provide continuous flow of blood from the left ventricle apex into the aorta (Fig. 11-4; see Fig. 11-3).

TABLE 11-3 MECHANICAL CIRCULATORY SUPPORT DEVICES APPROVED FOR USE IN THE UNITED STATES

TYPE	DEVICE
DURABLE DEVICES	
Continuous flow	Thoratec HeartMate II
	HeartWare HVAD
	MicroMed DeBakey Child VAD
Pulsatile extracorporeal	Thoratec PVAD
	Heart Excor
Pulsatile intracorporeal	HeartMate IP
	HeartMate VE
	HeartMate XVE
	Thoratec IVAD
	NovaCor PC
	NovaCor PCq
Total artificial heart	SynCardia CardioWest
	AbioCor TAH
TEMPORARY DEVICES	
Short-term devices	Abiomed AB5000
	Abiomed BVS 5000
	Levitronix Centrimag
	Biomedicus
	Tandem Heart

Data from Kirklin JK, Naftel DC, Kormos RL, et al: Fifth INTERMACS annual report: risk factor analysis from more than 6,000 mechanical circulatory support patients, J Heart Lung Transplant 32:141–156, 2013.

In the United States, two continuous-flow pumps are currently approved by the FDA: the HeartMate II (Thoratec), an axial pump LVAD, for destination therapy and as a bridge to transplantation, and the HeartWare (HeartWare CT, HeartWare, Inc., Miami Lakes, Fla.), a centrifugal pump LVAD, as a bridge to transplantation. Improved survival and technical ease of implantation have become the hallmarks of these pumps, rendering the use of the first-generation pumps almost obsolete. Nevertheless, the risks of infection, thrombosis, and stroke are considerable.

Increased use and improved survival rates have brought to light new complications associated with the second-generation pumps. The diminished left ventricular excursion and low pulsatility of continuous-flow pumps are associated with the development of gastrointestinal arteriovenous malformations and acquired von Willibrand's disease. Such complications can lead to potentially catastrophic gastrointestinal bleeding because these patients require chronic anticoagulation. Risk factors for increased mortality in patients with continuous-flow pumps include older age and associated fragility, renal dysfunction, respiratory dysfunction, right-sided heart failure, and history of previous or concomitant cardiac surgery at the time of device implantation. Third-generation LVADs, which use hydrodynamic or electromagnetic pump technology with few moving parts, are currently under investigation.

Surgical management of heart failure is a continually evolving field, and further technological advances are needed to address issues of size, infection, thrombosis, and diminished pulsatility. A multidisciplinary approach involving cardiac surgeons, cardiologists, intensivists, anesthesiologists, perfusionists, and specialized nurses and social workers is essential to ensure successful management of the LVAD patient and the family. Continuous emphasis on the education and training of the patient, family, local paramedics, among others, requires meticulous coordination among all team members to ensure successful outpatient management, avoid potentially lethal complications, and provide improved patient safety and health outcomes.

Total Artificial Heart

The first successful application of a TAH in humans was by Denton Cooley, in 1969, to wean a 47-year-old male patient off CPB. The TAH functioned for 64 hours until successful cardiac