**Policy Statement**

**Bridge to Transplantation**
Implantable ventricular assist devices (VADs) with U.S. Food and Drug Administration (FDA) approval or clearance may be considered *medically necessary* when used in accordance with device-specific, FDA-approved indications and contraindication as a bridge to heart transplantation for patients who are currently listed as heart transplantation candidates and not expected to survive until a donor heart can be obtained, or are undergoing evaluation to determine candidacy for heart transplantation.

Implantable VADs with FDA approval or clearance, including humanitarian device exemptions, may be considered *medically necessary* when used in accordance with device-specific, FDA-approved indications and contraindications as a bridge to heart transplantation in children 16 years old or younger who are currently listed as heart transplantation candidates and not expected to survive until a donor heart can be obtained, or are undergoing evaluation to determine candidacy for heart transplantation.

**Total Artificial Hearts**
Total artificial hearts (TAHs) with FDA-approved devices may be considered *medically necessary* when used in accordance with device-specific, FDA-approved indications and contraindications as a bridge to heart transplantation for patients with biventricular failure who meet all of the following criteria:

I. Have no other reasonable medical or surgical treatment options
II. Ineligible for other univentricular or biventricular support devices
III. Currently listed as heart transplantation candidates or are undergoing evaluation to determine candidacy for heart transplantation
IV. Not expected to survive until a donor heart can be obtained.

**Destination Therapy**
Implantable VADs with FDA approval or clearance may be considered *medically necessary* when used in accordance with device-specific, FDA-approved indications and contraindications as destination therapy with end-stage heart failure patients who meet both of the following criteria:

I. Ineligible for human heart transplant for one or more of the following reasons:
   A. Age greater than 65 years
   B. Insulin-dependent diabetes with end-organ damage
   C. Chronic renal failure (serum creatinine greater than 2.5 mg/dL for greater than or equal to 90 days)
   D. Presence of other clinically significant condition (e.g., chronic irreversible hepatic, renal, or respiratory failure; systemic infection; coagulation disorders; life-limiting disease [cancer, neurologic damage, dialysis dependency]; uncorrected valvular disease; failure of medical compliance; chronic illicit drug or alcohol dependency; psychiatric condition leading to failure of medical compliance; inadequate psychosocial support)
   E. One of the following REMATCH Study criteria:
      A. New York Heart Association (NYHA) class IV heart failure for greater than or equal to 60 days
      B. New York Heart Association class III or IV for 28 days, received greater than or equal to 14 days of support with intra-aortic balloon pump or dependent on intravenous inotropic agents, with 2 failed weaning attempts.
Postcardiotomy Setting/Bridge to Recovery
Implantable VADs with FDA approval or clearance may be considered **medically necessary** when used in accordance with device-specific, FDA-approved indications and contraindication in the postcardiotomy setting in patients who are unable to be weaned off cardiopulmonary bypass.

**Other Indications**
Other applications of implantable VADs or TAHs are considered **investigational**, including, but not limited to:

I. Use of TAHs as destination therapy
II. Use of non-FDA-approved or cleared implantable ventricular assist devices (VADs) or total artificial hearts (TAHs)

Percutaneous ventricular assist devices (pVADs) are considered **investigational** for all indications.

**NOTE**: Refer to Appendix A to see the policy statement changes (if any) from the previous version.

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**Policy Guidelines**

Only 2 ventricular assist devices (VADs) have approval from the U.S. Food and Drug Administration (FDA) for the pediatric population. The DeBakey VAD Child device and the Berlin Heart EXCOR Pediatric VAD have FDA approval through the humanitarian device exemption process. The DeBakey VAD is indicated for use in children ages 5 to 16 years who are awaiting a heart transplant (i.e., a bridge to transplant) while the Berlin Heart EXCOR VAD is indicated for children with severe isolated left ventricular or biventricular dysfunction who are candidates for cardiac transplant and require circulatory support.

In general, candidates for bridge to transplant implantable VADs are those who are considered appropriate heart transplant candidates but who are unlikely to survive the waiting period until a human heart donor is available. Some studies have included the following hemodynamic selection criteria: either a left atrial pressure of 20 mm Hg or a cardiac index of less than 2.0 L/min/m while receiving maximal medical support. Patients with VADs are classified by the United Network for Organ Sharing as status I (i.e., persons who are most ill and are considered the highest priority for transplant).

The median duration for time on the device is between 20 days and 120 days.

Contraindications for bridge to transplant VADs and total artificial hearts include conditions that would generally exclude patients for heart transplant. Such conditions are chronic irreversible hepatic, renal, or respiratory failure; systemic infection; coagulation disorders, and inadequate psychosocial support. Due to potential problems with adequate function of the VAD or total artificial heart, implantation is also contraindicated in patients with uncorrected valvular disease. See Blue Shield of California Medical Policy: Heart Transplant for further discussion of heart transplant candidacy.

In addition, patients must have sufficient space in the thorax and/or abdominal cavity for the device. In the case of the CardioWest Temporary Total Artificial Heart, this excludes patients with body surface areas less than 1.7 m² or who have a distance between the sternum and 10th anterior rib of less than 10 cm, as measured by computed tomography scan.

New York Heart Association (NYHA) Classification (American Heart Association, 2011):
- **Class III**: Patients with cardiac disease resulting in marked limitation of physical activity. They are comfortable at rest. Less than ordinary activity causes fatigue, palpitation, dyspnea or anginal pain

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• Class IV: Patients with cardiac disease resulting in inability to carry on any physical activity without discomfort. Symptoms of heart failure or the anginal syndrome may be present even at rest. If any physical activity is undertaken, discomfort increases.

Pediatric Ventricular Assist Devices (U.S. Food and Drug Administration [FDA] Inclusion and Exclusion Criteria for the Berlin Heart EXCOR® Pediatric VAD):

• Inclusion Criteria:
  o Severe heart failure refractory to optimal medical therapy (New York Heart Association [NYHA] Functional Class IV for subjects ≤ 6 years) and has met at least one of the following criteria:
    ▪ Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) Patient Profile status 1 or 2
    ▪ Pre-implant Extracorporeal Membrane Oxygenation (ECMO) or VAD
    ▪ Failure to wean from cardiopulmonary bypass
  o Listed for cardiac transplantation
  o Two-ventricle circulation
  o Age 0 to 16 years
  o Weight 3 to 60 kilograms
  o Device must be FDA approved for this indication

• Exclusion Criteria:
  o Supported on ECMO ≥ 10 days
  o Cardiopulmonary Resuscitation (CPR) ≥ 30 minutes within 48 hours prior to device implantation
  o Mechanical aortic valve
  o Complex congenital or unfavorable anatomy
  o Irreversible non-cardiac end-organ damage
  o Documented heparin-induced thrombocytopenia (HIT) or coagulation disorder
  o Active infection
  o Life-limited disease
  o Stroke within past 30 days or congenital central nervous system (CNS) abnormality with risk of intra-cerebral bleeding
  o Psychiatric disease with a high likelihood for non-compliance

Coding

The following CPT codes are specific to this procedure:

• 33975: Insertion of ventricular assist device; extracorporeal, single ventricle
• 33976: Insertion of ventricular assist device; extracorporeal, biventricular
• 33977: Removal of ventricular assist device; extracorporeal, single ventricle
• 33978: Removal of ventricular assist device; extracorporeal, biventricular
• 33979: Insertion of ventricular assist device, implantable intracorporeal, single ventricle
• 33980: Removal of ventricular assist device, implantable intracorporeal, single ventricle

Effective January 1, 2021, the following CPT codes have been revised:

• 33990: Insertion of ventricular assist device, percutaneous, including radiological supervision and interpretation; left heart, arterial access only
• 33991: Insertion of ventricular assist device, percutaneous, including radiological supervision and interpretation; left heart, both arterial and venous access, with transseptal puncture
• 33992: Removal of percutaneous left heart ventricular assist device, arterial or arterial and venous cannula(s), at separate and distinct session from insertion
• 33993: Repositioning of percutaneous right or left heart ventricular assist device with imaging guidance at separate and distinct session from insertion

Effective January 1, 2021, there are new CPT codes that represent devices available for right heart pVAD that is inserted using only venous access.
• **33995**: Insertion of ventricular assist device, percutaneous, including radiological supervision and interpretation; right heart, venous access only
• **33997**: Removal of percutaneous right heart ventricular assist device, venous cannula, at separate and distinct session from insertion

The following CPT codes specifically describe total artificial hearts:
• **33927**: Implantation of a total replacement heart system (artificial heart) with recipient cardiectomy
• **33928**: Removal and replacement of total replacement heart system (artificial heart)
• **33929**: Removal of a total replacement heart system (artificial heart) for heart transplantation (List separately in addition to code for primary procedure)

Removal of the device prior to heart transplantation (CPT codes 33977 and 33978) is considered part of the global fee and incidental to the heart transplant.

The following category III CPT codes refer to an implantable counterpulsation ventricular assist system from NuPulse called iVAS which is not yet FDA approved:
• **0451T**: Insertion or replacement of a permanently implantable aortic counterpulsation ventricular assist system, endovascular approach, and programming of sensing and therapeutic parameters; complete system (counterpulsation device, vascular graft, implantable vascular hemostatic seal, mechano-electrical skin interface and subcutaneous electrodes)
• **0452T**: Insertion or replacement of a permanently implantable aortic counterpulsation ventricular assist system, endovascular approach, and programming of sensing and therapeutic parameters; aortic counterpulsation device and vascular hemostatic seal
• **0453T**: Insertion or replacement of a permanently implantable aortic counterpulsation ventricular assist system, endovascular approach, and programming of sensing and therapeutic parameters; mechano-electrical skin interface
• **0454T**: Insertion or replacement of a permanently implantable aortic counterpulsation ventricular assist system, endovascular approach, and programming of sensing and therapeutic parameters; subcutaneous electrode
• **0455T**: Removal of permanently implantable aortic counterpulsation ventricular assist system; complete system (aortic counterpulsation device, vascular hemostatic seal, mechano-electrical skin interface and electrodes)
• **0456T**: Removal of permanently implantable aortic counterpulsation ventricular assist system; aortic counterpulsation device and vascular hemostatic seal
• **0457T**: Removal of permanently implantable aortic counterpulsation ventricular assist system; mechano-electrical skin interface
• **0458T**: Removal of permanently implantable aortic counterpulsation ventricular assist system; subcutaneous electrode
• **0459T**: Relocation of skin pocket with replacement of implanted aortic counterpulsation ventricular assist device, mechano-electrical skin interface and electrodes
• **0460T**: Repositioning of previously implanted aortic counterpulsation ventricular assist device; subcutaneous electrode
• **0461T**: Repositioning of previously implanted aortic counterpulsation ventricular assist device; aortic counterpulsation device
• **0462T**: Programming device evaluation (in person) with iterative adjustment of the implantable mechano-electrical skin interface and/or external driver to test the function of the device and select optimal permanent programmed values with analysis, including review and report, implantable aortic counterpulsation ventricular assist system, per day
• **0463T**: Interrogation device evaluation (in person) with analysis, review and report, includes connection, recording and disconnection per patient encounter, implantable aortic counterpulsation ventricular assist system, per day
Description

A ventricular assist device (VAD) is mechanical support attached to the native heart and vessels to augment cardiac output. The total artificial heart (TAH) replaces the native ventricles and is attached to the pulmonary artery and aorta; the native heart is typically removed. Both the VAD and TAH may be used as a bridge to heart transplantation or as destination therapy in those not candidates for transplantation. The VAD has also been used as a bridge to recovery in patients with reversible conditions affecting cardiac output.

Related Policies

- Extracorporeal Membrane Oxygenation for Adult Conditions
- Heart Transplant
- Heart/Lung Transplant

Benefit Application

Benefit determinations should be based in all cases on the applicable contract language. To the extent there are any conflicts between these guidelines and the contract language, the contract language will control. Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

Some state or federal mandates (e.g., Federal Employee Program [FEP]) prohibits plans from denying Food and Drug Administration (FDA)-approved technologies as investigational. In these instances, plans may have to consider the coverage eligibility of FDA-approved technologies on the basis of medical necessity alone.

Regulatory Status

A number of mechanical circulatory support devices have been approved or cleared for marketing by the U.S. Food and Drug Administration (FDA). These devices are summarized in Tables 1 and 2 and discussed in the following sections.

**Table 1. Available Mechanical Circulatory Support Devices**

<table>
<thead>
<tr>
<th>Device</th>
<th>Manufacturer</th>
<th>Approval Date</th>
<th>FDA Clearance</th>
<th>PMA, HDE, or 510(k) No.</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoratec IVAD</td>
<td>Thoratec</td>
<td>Aug 2004</td>
<td>PMA Supp</td>
<td>P870072</td>
<td>Bridge to transplant and postcardiomy</td>
</tr>
<tr>
<td>DeBakey VAD® Child</td>
<td>MicroMed</td>
<td>Feb 2004</td>
<td>HDE</td>
<td>H030003</td>
<td>Bridge to transplant in children 5-16 y</td>
</tr>
<tr>
<td>HeartMate II</td>
<td>Thoratec</td>
<td>Apr 2008</td>
<td>PMA</td>
<td>P060040</td>
<td>Bridge to transplant and destination</td>
</tr>
<tr>
<td>CentriMag</td>
<td>Levitonix (now Thoratec)</td>
<td>Oct 2008</td>
<td>HDE</td>
<td>H070004</td>
<td>Postcardiomy</td>
</tr>
<tr>
<td>Berlin Heart EXCOR® Pediatric VAD</td>
<td>Berlin</td>
<td>Dec 2011</td>
<td>HDE</td>
<td>H100004</td>
<td>Bridge to transplant</td>
</tr>
<tr>
<td>HeartWare® Ventricular Assist System</td>
<td>HeartWare</td>
<td>Dec 2012</td>
<td>PMA</td>
<td>P100047</td>
<td>Bridge to transplant</td>
</tr>
<tr>
<td>HeartMate 3 Left Ventricular Assist System</td>
<td>Thoratec</td>
<td>Aug 2017 Oct 2018</td>
<td>PMA P160054</td>
<td>P160054/S008</td>
<td>Bridge to transplant Destination</td>
</tr>
</tbody>
</table>

FDA: U.S. Food and Drug Administration; HDE: humanitarian device exemption; PMA: premarket approval.
Ventricular Assist Devices
In 1995, the Thoratec® Ventricular Assist Device System (Thoratec Corp.) was approved by the FDA through the premarket approval process as a bridge to transplantation in patients with end-stage heart failure. The patient should meet all of the following criteria:
- candidate for cardiac transplantation,
- imminent risk of dying before donor heart procurement, and
- dependence on, or incomplete response to, continuous vasopressor support.

In 1998, supplemental approval for this device was given for the indication of postcardiotomy patients unable to be weaned from cardiopulmonary bypass. In June 2001, supplemental approval was given for a portable external driver to permit excursions within a 2-hour travel radius of the hospital when accompanied by a trained caregiver. In 2003, supplemental approval was given to market the device as Thoratec® Paracorporeal VAD. In 2004, supplemental approval was given to a modified device to be marketed as the Thoratec® Implantable VAD for the same indications. In 2008, supplemental approval was given to rescind Paracorporeal VAD use.

In August 2016, HeartWare® recalled its VAD Pumps due to a design flaw that was deemed by the FDA as potentially causing serious injuries or death (class I recall). The devices affected were manufactured and distributed from March 2006 and May 2018. FDA product codes 204 and 017.

A class I recall was issued for the HeartMate 3™ in April 2018 affecting all manufacturing dates. FDA product code: DSQ.

Total Artificial Heart
In 2004, the temporary CardioWest™ Total Artificial Heart (SynCardia Systems) was approved by the FDA through the premarket approval process for use as a bridge to transplant in cardiac transplant-eligible candidates at risk of imminent death from biventricular failure. This device is also intended for use inside the hospital. In 2010, the FDA approved a name change to SynCardia Temporary Total Artificial Heart. FDA product code: LOZ.

In 2006, the AbioCor® Implantable Replacement Heart System (Abiomed) was approved by the FDA through the humanitarian device exemption (H040006) process for severe biventricular end-stage heart disease patients who are not cardiac transplant candidates and who:
- are younger than 75 years of age;
- require multiple inotropic support;
- are not treatable by left VAD destination therapy; and
- are not weanable from biventricular support if on such support.

In addition to meeting other criteria, patients who are candidates for the AbioCor® TAH must undergo a screening process to determine if their chest volume is large enough to hold the device. The device is too large for approximately 90% of women and for many men.

Percutaneous Ventricular Assist Devices (Circulatory Assist Devices)

<table>
<thead>
<tr>
<th>Device</th>
<th>Manufacturer</th>
<th>Approval Date</th>
<th>FDA Clearance</th>
<th>PMA, 510(k) No.</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>TandemHeart® Cardiac Assist</td>
<td>Sep 2005</td>
<td>510(k)</td>
<td>K110493</td>
<td>Temporary left ventricular bypass of ≤6 h</td>
<td></td>
</tr>
<tr>
<td>Impella® Recover LP 2.5</td>
<td>Abiomed</td>
<td>May 2008</td>
<td>510(k)</td>
<td>K063723</td>
<td>Partial circulatory support using extracorporeal bypass control unit for ≤6 h</td>
</tr>
<tr>
<td>Impella 2.5 System</td>
<td>Abiomed</td>
<td>Mar 2015</td>
<td>PMA</td>
<td>P140003</td>
<td>Temporary ventricular support for ≤6 h</td>
</tr>
</tbody>
</table>

FDA: U.S. Food and Drug Administration; PMA: premarket approval.
Comparative Efficacy of Left Ventricular Assist Devices

The mechanism of operation of left VADs has changed since their introduction. The earliest devices were pulsatile positive displacement pumps. These pumps have been largely replaced by axial continuous-flow pumps. More recently centrifugal continuous-flow pumps have also been introduced.

The evidence of the comparative efficacy of centrifugal continuous-flow vs axial continuous-flow devices consists of 2 randomized controlled trials of 2 different centrifugal continuous-flow devices. The MOMENTUM 3 trial compared HeartMate 3 centrifugal continuous-flow device with the HeartMate II axial continuous-flow device in patients indicated for circulatory support as a bridge to transplant or destination therapy. HeartMate 3 received PMA approval as a bridge to transplant therapy in August 2017 and as destination therapy in October 2018. The destination therapy indication was based on 2-year results from MOMENTUM 3, which showed superiority of the HeartMate 3 device compared to HeartMate II on the composite primary outcome, survival at 2 years free of disabling stroke or reoperation to replace a malfunctioning device (relative risk 0.84; 95% confidence interval 0.78–0.91, p<0.001). Prevalence of stroke at 2 years was lower in the HeartMate 3 than the HeartMate II group (10.1% vs 19.2%; P=0.02). Measures of functional capacity and Health-Related Quality of Life did not differ between the 2 devices at 6 months. The ENDURANCE trial compared HeartWare centrifugal continuous-flow device with the HeartMate II axial continuous-flow device in patients indicated for circulatory support as destination therapy. HeartWare is FDA approved as a bridge to transplantation device. Both trials found the centrifugal device to be noninferior to the axial device for the primary, composite outcome including measures of survival, freedom from disabling stroke, and freedom from device failure. While there are fewer device failures with the centrifugal devices without a significant increase in disabling stroke, the HeartWare device was associated with increased risk of any stroke over a period of 2 years.

The evidence on the comparative efficacy of continuous-flow vs pulsatile-flow devices consists of a randomized controlled trial and several nonrandomized comparative studies. The randomized controlled trial reported fairly large differences in a composite outcome measure favoring the continuous-flow devices, with increases in revision and reoperation rates for the pulsatile device group being the largest factor driving the difference in outcomes. Other nonrandomized comparative studies, including a database study with large numbers of patients, have not reported important differences in clinical outcomes between devices.

Rationale

Background
Heart Failure
Heart failure may be the consequence of a number of etiologies, including ischemic heart disease, cardiomyopathy, congenital heart defects, or rejection of a heart transplant. The reduction of cardiac output is considered to be severe when systemic circulation cannot meet the body's needs under minimal exertion. Heart transplantation improves quality of life and has survival rates at 1, 3, and 5 years of about 91%, 85%, and 78%, respectively. The number of candidates for transplants exceeds the supply of donor organs; thus the interest in the development of mechanical devices.

Treatment
Ventricular Assist Devices
Implantable VADs are attached to the native heart, which may have enough residual capacity to withstand a device failure in the short term. In reversible heart failure conditions, the native heart may regain some function, and weaning and explanting of the mechanical support system after months of use has been described. VADs can be classified as internal or external, electrically or pneumatically powered, and pulsatile or continuous-flow. Initial devices were pulsatile, mimicking the action of a beating heart. More recent devices may use a pump, which provides continuous flow. Continuous devices may move blood in a rotary or axial flow.
At least one VAD system developed is miniaturized and generates an artificial pulse, the HeartMate 3 Left Ventricular Assist System.2

Surgically implanted VADs represent a method of providing mechanical circulatory support for patients not expected to survive until a donor heart becomes available for transplant or for whom transplantation is contraindicated or unavailable. VADs are most commonly used to support the left ventricle but right ventricular and biventricular devices may be used. The device is larger than most native hearts, and therefore the size of the patient is an important consideration; the pump may be implanted in the thorax or abdomen or remain external to the body. Inflow to the device is attached to the apex of the failed ventricle, while outflow is attached to the corresponding great artery (aorta for the left ventricle, a pulmonary artery for the right ventricle). A small portion of the ventricular wall is removed for insertion of the outflow tube; extensive cardiotomy affecting the ventricular wall may preclude VAD use.

**Total Artificial Hearts**

Initial research into mechanical assistance for the heart focused on the TAH, a biventricular device that completely replaces the function of the diseased heart. An internal battery required frequent recharging from an external power source. Many systems use a percutaneous power line, but a transcutaneous power-transfer coil allows for a system without lines traversing the skin, possibly reducing the risk of infection. Because the native heart must be removed, failure of the device is synonymous with cardiac death.

A fully bioprosthetic TAH, which is fully implanted in the pericardial sac and is electrohydraulically actuated, has been developed and tested in 2 patients but is currently experimental.3

**Percutaneous Ventricular Assist Devices**

Devices in which most of the system's components are external to the body are for short-term use (6 hours to 14 days) only, due to the increased risk of infection and need for careful, in-hospital monitoring. Some circulatory assist devices are placed percutaneously (i.e., are not implanted). They may be referred to as pVADs. A pVAD is placed through the femoral artery. Two different pVADs have been developed, the TandemHeart and the Impella device. In the TandemHeart System, a catheter is introduced through the femoral vein and passed into the left atrium via transseptal puncture. Oxygenated blood is then pumped from the left atrium into the arterial system via the femoral artery. The Impella device is introduced through a femoral artery catheter. In this device, a small pump is contained within the catheter placed into the left ventricle. Blood is pumped from the left ventricle, through the device, and into the ascending aorta. Adverse events associated with pVAD include access site complications such as bleeding, aneurysms, or leg ischemia. Cardiovascular complications can also occur, such as perforation, myocardial infarction, stroke, and arrhythmias.

**Literature Review**

Evidence reviews assess the clinical evidence to determine whether the use of technology improves the net health outcome. Broadly defined, health outcomes are the length of life, quality of life (QOL), and ability to function—including benefits and harms. Every clinical condition has specific outcomes that are important to patients and managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of technology, two domains are examined: the relevance, and quality and credibility. To be relevant, studies must represent one or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and credibility of the evidence depend on study design and conduct, minimizing bias and
confounding that can generate incorrect findings. The randomized controlled trial (RCT) is preferred to assess efficacy; however, in some circumstances, nonrandomized studies may be adequate. RCTs are rarely large enough or long enough to capture less common adverse events and long-term effects. Other types of studies can be used for these purposes and to assess generalizability to broader clinical populations and settings of clinical practice.

This literature review assesses 3 devices: (1) ventricular assist devices (VADs), (2) total artificial hearts (TAHs), and (3) percutaneous VADs (pVADs). This review addresses the short-term use of the devices as a bridge to recovery or transplantation. Left VADs (LVADs) and TAHs are also evaluated as longer-term destination therapies for patients who are not transplant candidates.

**Ventricular Assist Devices as a Bridge to Heart Transplant for End-Stage Heart Failure**

**Clinical Context and Therapy Purpose**

The purpose of VADs as a bridge to a heart transplant in patients who have end-stage heart failure is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The question addressed in this evidence review is: Does the use of a VAD as a bridge to heart transplant improve the net health outcome in individuals with end-stage heart failure?

The following PICO was used to select literature to inform this review.

**Population**

The relevant population of interest is individuals with end-stage heart failure. A subset of patients who receive a VAD as a bridge to transplantation has demonstrated improvements in their cardiac function, sometimes to the point that they no longer require the VAD. This results in the use of VAD as a bridge to recovery.

**Interventions**

The therapy being considered is a VAD as a bridge to heart transplant.

Implantation of a VAD is performed in a hospital setting with specialized staff who are equipped to perform the surgical procedure and manage postsurgical intensive care.

**Comparators**

The following therapy is currently being used to make decisions about individuals with end-stage heart failure: optimal medical therapy without VADs.

**Outcomes**

The general outcomes of interest are overall survival (OS), device malfunction, heart failure, respiratory dysfunction, arrhythmias, and infection.

Time-to-transplant is of interest, as is the short-term outcome ranging from 30 days to 1 year.

**Study Selection Criteria**

To assess efficacy outcomes, we included comparative controlled prospective trials, with a preference for RCTs and systematic reviews of RCTs.

In the absence of such trials, we included comparative observational studies, with a preference for prospective studies.

To assess long-term outcomes and adverse effects, we included single-arm studies that captured longer periods of follow-up and/or larger populations.
Review of Evidence

Ventricular Assist Devices as Bridge to Recovery

**Prospective Studies**

VADs may have a role in bridging patients to recovery, particularly if there is reverse remodeling of the left ventricle. Several studies have investigated the role of VADs in bridging patients to decision for transplant eligibility. One clearly defined population in which the potential for myocardial recovery exists is in the postcardiotomy setting.

Acharya et al (2016) reported on patients who underwent VAD placement for acute myocardial infarction (AMI) who were enrolled in the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) registry, a prospective national registry of U.S. Food and Drug Administration (FDA) approved durable mechanical circulatory support (MCS) devices. Patients who had an AMI as the admitting diagnosis or a major myocardial infarction (MI) as a hospital complication that resulted in VAD implantation (n=502) were compared with patients who underwent VAD implantation for non-AMI indications (n=9727). Patients in the AMI group were generally sicker at baseline, with higher rates of smoking, severe diabetes, and peripheral vascular disease but had fewer cardiac surgeries and recent cardiovascular hospitalizations. Most AMI patients (53.8%) were implanted with a “bridge to candidacy” strategy. At 1 month post-VAD, 91.8% of the AMI group were alive with the device in place. At 1 year post-VAD, 52% of the AMI group were alive with the device in place, 25.7% had received a transplant, 1.6% had their VAD explanted for recovery, and 20.7% died with the device in place.

Two additional 2016 publications from the INTERMACS registry reported on cardiac recovery in patients implanted with LVADs. Wever-Pinzon et al (2016) included adults registered between March 2006 and June 2015 excluding those who had a right VAD only, TAH, or prior heart transplant (n=15631). One hundred twenty-five of these patients had an a priori bridge to recovery LVAD strategy. Cardiac recovery occurred in 192 (1.3%) of the LVAD patients overall and in 14 (11.2%) of the bridge to recovery patients. Topkara et al (2016) reported a similar analysis of 13454 INTERMACS adults with implants between June 2006 and June 2015 without TAH or pulsatile-flow LVAD or heart transplant. Device explant rates for cardiac recovery were 0.9% at 1-year, 1.9% at 2-year, and 3.1% at 3-year follow-up. An additional 9% of patients demonstrated partial cardiac recovery.

In a prospective multicenter study to assess myocardial recovery in patients with LVAD implantation as a bridge to transplant, Maybaum et al (2007) evaluated 67 patients with heart failure who had LVAD implantation for severe heart failure. After 30 days, patients demonstrated significant improvements compared with their pre-LVAD state in left ventricular ejection fraction (17.1% vs 34.12%, p<0.001), left ventricular end-diastolic diameter (7.1 cm vs 5.1 cm, p<0.001), and left ventricular mass (320 g vs 194 g, p<0.001), respectively. However, only 9% of patients recovered sufficiently to have their LVAD explanted.

**Retrospective Studies**

Agrawal et al (2018) conducted a retrospective cohort study evaluating the 30-day readmissions of 2510 patients undergoing LVAD implantation. Of the patients who met the inclusion criteria, 768 (31%) were readmitted within 30 days after surviving initial index hospitalization. Cardiac causes accounted for 23.8% of readmissions, 13.4% due to heart failure, and 8.1% to arrhythmias. Infection (30.2%), bleeding (17.6%), and device-related causes (8.2%) comprised the 76.2% of noncardiovascular causes for readmission.

Takayama et al (2014) reported outcomes for a retrospectively defined cohort of 143 patients who received a CentriMag Right Ventricular Assist Device as a "bridge to decision" for refractory cardiogenic shock due to a variety of causes. Patients were managed with a bridge to decision algorithm. Causes of cardiogenic shock included failure of medical management (n=71), postcardiotomy shock (n=37), graft failure after heart transplantation (n=2), and right ventricular failure postimplantable LVAD (n=13). The device configuration was biventricular in
67% isolated right VAD in 26%, and isolated LVAD in 8%. After a mean duration of support of 14 days (interquartile range, 8-26 days), 30% of patients had a myocardial recovery, 15% had device exchange to an implantable VAD, and 18% had a heart transplant.

**Ventricular Assist Devices as Bridge to Heart Transplant**

The insertion of a VAD will categorize its recipient as a high-priority heart transplant candidate. The available evidence on the efficacy of VADs in bridging patients with refractory heart failure to transplant includes single-arm series, which generally have reported high success rates in bridging to transplant.

**Adult Patients**

**Systematic Reviews**

Older systematic reviews concluded that VADs can provide an effective bridge to transplantation.18,19

**Prospective Studies**

Slaughter et al (2013) reported combined outcomes for patients included in the HeartWare bridge to transplant study previously described and a continued-access protocol granted by the FDA.20 The study included 322 patients with heart failure, eligible for a heart transplant, who received the HeartWare (140 patients from the original study; 190 patients in the continued-access protocol who were monitored to the outcome or had completed 180-day follow-up at the time of analysis). Survival rates at 60, 180, and 360 days were 97%, 91%, and 84% respectively. The most common adverse events were respiratory dysfunction, arrhythmias, sepsis, and driveline exit-site infections. Patients generally had improvements in QOL measures.

**Case Series**

Strueber et al (2011) published a case series of 50 patients awaiting heart transplantation treated with HeartWare Ventricular Assist System, which is a smaller, continuous-flow centrifugal device implanted in the pericardial space.21 Patients were followed until transplantation, myocardial recovery, device explant, or death. The median duration of time on the VAD was 322 days. Nine patients died: 3 from sepsis, 3 from multiple organ failure, and 4 from hemorrhagic stroke. At the end of follow-up, 20 (40%) patients had undergone transplant, 4 (8%) had had the pump explanted, and the remaining 17 (34%) continued on pump support. The most common complications were an infection and bleeding: 21 (42%) patients had infections, 5 (10%) had sepsis, while 15 (30%) patients had bleeding complications, 10 (20%) of whom required surgery.

Aaronson et al (2012) reported on results of a multicenter, prospective study of a newer generation LVAD, the HeartWare. The study enrolled 140 patients awaiting heart transplantation who underwent HeartWare implantation. A control group of 499 subjects comprised patients drawn from the INTERMACS database, which collects data on patients who receive FDA approved durable MCS devices. The study's primary outcome was defined as survival on the originally implanted device, transplantation, or explantation for ventricular recovery at 180 days. Secondary outcomes were comparisons of survival between groups and functional, QOL, and adverse event outcomes in the HeartWare group. Success on the primary outcome occurred in 90.7% of the HeartWare group and 90.1% of controls (p<0.001, noninferiority with a 15% margin). Serious adverse events in the HeartWare group included, most commonly, bleeding, infections, and perioperative right heart failure.

In 5 reports published from 2007 to 2008, with sample sizes ranging from 32 to 279 patients, most participants received the continuous-flow device as a bridge to transplantation.22,23,24,25,26 Survival rates at 6 months ranged between 67% and 87%, and between 50% and 80% at 1 year. These rates were similar to those reported from the INTERMACS registry.27 A study by Patel et al (2008) compared HeartMate I with HeartMate II recipients at a single-center, finding similar rates of 1 year survival and subsequent development of right heart failure.28 Serious adverse events occurring after HeartMate II implantation include bleeding episodes requiring reoperation, stroke, infection, and device failure.
Aissaoui et al (2018) published an observational study comparing 224 patients in Germany and France with end-stage heart failure who received VAD (group I, n=83) or heart transplantation or medical therapy as first treatment options (group II, n=141). The estimated 2-year survival was 44% for group I and 70% for group II (p<0.001).

Two reports from registries of patients who received the HeartMate 3 device have been published recently. Schmitto et al (2019) reported 2-year outcomes in 50 patients who received the device as a bridge to transplant. Survival rates at 6 months, 1 year, and 2 years were 92%, 81%, and 74%, respectively, and the total stroke rate over 2 years was 24%. Gustafsson et al (2018) reported 6-month outcomes of 482 patients; 66% of patients received the VAD as a bridge to transplant, 26% as destination therapy, 2% as a bridge to recovery, and 6% as a bridge to transplant candidacy or decision. Results were not separately reported by indication. The 6-month survival rate was 82% (95% CI 79% to 85%). Three patients received a transplant. The incidence of stroke was 6.1%.

**Pediatric Patients**

The FDA approved EXCOR Pediatric VAD is available for use as a bridge to cardiac transplant in children. The FDA approval was based on data from children who were part of the initial clinical studies of this device. Publications have reported positive outcomes for children using VADs as a bridge to transplantation.

**Registry Studies**

Bulic et al (2017) identified all U.S. children between 1 and 21 years of age at heart transplant between 2006 and 2015 who had dilated cardiomyopathy and were supported with an LVAD or vasoactive infusions alone at the time of transplant from the Organ Procurement and Transplant Network registry (n=701). Functional status as measured by the median Karnofsky Performance Scale score at heart transplant was higher for children receiving LVAD (6) compared with vasoactive infusion (5; p<.001) and children receiving LVAD were more likely to be discharged from the hospital at the time of transplant. The percentage of children having a stroke at the time of transplant was higher in those receiving LVAD (3% vs 1%, p=0.04).

Wehman et al (2016) reported on posttransplant survival outcomes for pediatric patients who received a VAD, extracorporeal membrane oxygenation (ECMO), or no MCS, in the pretransplant period. The study included 2777 pediatric patients who underwent heart transplant from 2005 to 2012 who were identified through the United Network for Organ Sharing database, of whom 428 were bridged with VADs and 189 were bridged with ECMO. In unadjusted analysis, the actuarial 5-year survival rate was highest in the direct-to-transplant group (77%), followed by the VAD group (49%) and then the ECMO group (35%). In a proportional hazards model to predict time to death, restricted to the first 4 months posttransplant, ECMO bridging was significantly associated with a higher risk of death (adjusted hazard ratio, 2.77 vs direct-to-transplant; 95% confidence interval [CI], 2.12 to 3.61; p<0.001). However, a model to predict time to death excluding deaths in the first 4 months posttransplant, the bridging group was not significantly associated with risk of death.

Fraser et al (2012) evaluated the EXCOR device among 48 children, ages 16 or younger, with 2-ventricle circulation who had severe heart failure, despite optimized treatment, and were listed for a heart transplant. Patients were divided into 2 groups based on body surface area; a historical control group of children, receiving circulatory support with ECMO from the Extracorporeal Life Support Organization registry, were matched in a 2:1 fashion with study participants based on propensity-score matching. For participants in cohort 1 (body surface area <0.7 m²), the median survival time had not been reached at 174 days, while in the matched ECMO comparison group, the median survival was 13 days (p<0.001). For participants in cohort 2 (body surface area range, 0.7 to <1.5 m²), the median survival was 144 days compared with 10 days in the matched ECMO group (p<0.001). Rates of adverse events were
high in both EXCOR device cohorts, including major bleeding (cohort 1, 42%; cohort 2, 50%), infection (cohort 1, 63%; cohort 2, 50%), and stroke (29% of both cohorts).

**Noncomparative Studies**

Blume et al (2016) published the first analysis of the Pediatric Interagency Registry for Mechanical Circulatory Support, which is a prospective, multicenter registry that collects data on patients who are under age 19 at the time of implant, and includes those implanted with either durable or temporary VADs. At analysis, the registry included 241 patients; of them, 41 were implanted with a temporary device only, leaving 200 patients implanted with VADs for this study. Most patients (73%) had an underlying diagnosis of cardiomyopathy. At the time of implantation, 64% were listed for transplant, while 29% were implanted with a “bridge to candidacy” strategy. A total of 7% were implanted with a destination therapy strategy. Actuities survival at both 6 months and 1 year was 81%. By 6 months, 58% of patients had received transplants.

Almond et al (2013) reported results from a prospective, multicenter registry to evaluate outcomes in children who received the EXCOR device as a bridge to transplant. This study included a broader patient population than the Fraser et al (2012) study (discussed above). All patients were followed from the time of EXCOR implantation until transplantation, death, or recovery. The study included 204 children, 67% of whom received the device under compassionate use. Survival at 12 months on EXCOR support was 75%, including 64% who survived to transplantation, 6% who recovered (device explanted and the patient survived 30 days), and 5% who were alive with the device in place. In a follow-up study that evaluated 204 children from the same registry, Jordan et al (2015) reported relatively high rates of neurologic events in pediatric patients treated with the EXCOR device (29% of patients), typically early in the course of device use.

Chen et al (2016) reported on a retrospective, single-center series of pediatric patients with continuous-flow VADs, with a focus on outpatient experiences. The series included 17 children implanted with an intracorporeal device from 2010 to 2014. Eight (47%) patients were discharged after a median postimplant hospitalization duration of 49 days. Adverse events were common in outpatients, most frequently major device malfunction (31% [5/16] events) and cardiac arrhythmias (31% [5/16] events). At the time of analysis, 4 patients had received an orthotopic heart transplant, 2 were on ongoing support, and 1 each had been transferred or died.

Another retrospective, single-center series of pediatric patients, conducted by Conway et al (2016), reported on outcomes with short-term continuous-flow VADs, including the Thoratec PediMag or CentriMag, or the Maquet RotaFlow. From 2015 to 2014, 27 children were supported with 1 of these devices, most commonly for congenital heart disease (42%). The median duration of support was 12 days, and 67% of all short-term continuous-flow VAD runs (19 of 28 runs) led to hospital discharge.

**Effects of Pretransplant Ventricular Assist Devices on Transplant Outcomes**

Published studies continue to report that the use of a VAD does not compromise the success of a subsequent heart transplant and, in fact, may improve posttransplant survival, thus improving the use of donor hearts. A systematic review by Alba et al (2011) examined the evidence on the effect of VADs on posttransplant outcomes. Reviewers included 31 observational studies that compared transplant outcomes in patients who did and did not have pretransplant VAD. Survival at 1 year was more likely in patients who had VAD treatment, but this benefit was specific to patients who received an intracorporeal device (relative risk, 1.8; 95% CI, 1.53 to 2.13). For patients treated with an extracorporeal device, the likelihood of survival did not differ from patients not treated with a VAD (relative risk=1.08; 95% CI, 0.95 to 1.22). There was no difference in the risk of rejection rates between patients who did and did not receive LVAD treatment.
Deo et al (2014) reported no significant differences in outcomes for 37 bridge to transplant patients with a VAD and 70 patients who underwent a heart transplant directly. Data from the United Network for Organ Sharing Network, reported by Grimm et al (2016), suggested that patients bridged to transplant with an LVAD have better outcomes than those bridged with TAHs or biventricular assist devices. Using the United Network for Organ Sharing database, Davies et al (2008) reported on the use of VADs in pediatric patients undergoing heart transplantation. Their analysis concluded that pediatric patients requiring a pretransplantation VAD have long-term survival similar to those not receiving MCS.

Section Summary: Ventricular Assist Devices as a Bridge to Heart Transplant for End-Stage Heart Failure
Questions remain about defining and identifying the population most likely to experience cardiac recovery with VAD placement. One clearly defined population in which the potential for myocardial recovery exists is in the postcardiotomy setting. The current evidence is insufficient to identify other heart failure patient populations that might benefit from the use of an LVAD as a specific bridge to recovery treatment strategy.

In adults, the evidence on the efficacy of VADs as a bridge to transplant consists of uncontrolled trials, registry studies, and case series. In children, the evidence consists of several uncontrolled trials and a trial with historical controls. Collectively, these studies have reported that substantial numbers of patients have survived to transplant in situations in which survival is historically low. Despite the lack of high-quality controlled trials, this evidence supports a finding that outcomes are improved in patients because they have no other treatment options.

Ventricular Assist Devices as Destination Therapy for End-Stage Heart Failure
Clinical Context and Therapy Purpose
The purpose of VADs as destination therapy in patients who have end-stage heart failure is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The question addressed in this evidence review is: Does the use of a VAD as destination therapy improve the net health outcome in individuals with end-stage heart failure?

The following PICO was used to select literature to inform this review.

Population
The relevant population of interest are individuals with end-stage heart failure.

Interventions
The therapy being considered is a VAD as destination therapy.

Implantation of a VAD is performed in a hospital setting with specialized staff who are equipped to perform the surgical procedure and manage postsurgical intensive care.

Comparators
The following therapy is currently being used to make decisions about managing individuals with end-stage heart failure: optimal medical therapy without VADs.

Outcomes
The general outcomes of interest are OS, device malfunction, heart failure, respiratory dysfunction, arrhythmias, and infection.

Time of interest ranges from 6 months to 2 years following implantation of VAD as destination therapy.
Study Selection Criteria

To assess efficacy outcomes, we included comparative controlled prospective trials, with a preference for RCTs and systematic reviews of RCTs.

In the absence of such trials, we included comparative observational studies, with a preference for prospective studies.

To assess long-term outcomes and adverse effects, we included single-arm studies that captured longer periods of follow-up and/or larger populations.

Review of Evidence

Systematic Reviews

The evaluation of VADs as destination therapy was informed by a Blue Cross Blue Shield Association Technology Evaluation Center (TEC) Assessment (2002) that offered the following observations and conclusions:

- The available evidence comes from a single, well-designed and rigorously conducted randomized trial, Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure, known as the REMATCH study. The trial was a cooperative effort of Thoratec, Columbia University, and the National Institutes of Health.
- The trial found that patients with end-stage heart failure who are not candidates for cardiac transplantation had significantly better survival on a VAD compared with treatment by optimal medical therapy. Median survival was improved by approximately 8.5 months. Serious adverse events were more common in the VAD group but they appear to be outweighed by this group's better outcomes on function; New York Heart Association functional class was significantly improved, as was the QOL among those living to 12 months.
- VAD patients spent a greater relative proportion of time inside the hospital than medical management patients do but the survival advantage would mean a longer absolute time outside the hospital.

Park et al (2005) published reports on the extended 2-year follow-up of patients from the REMATCH trial, which found that survival and QOL benefits were still apparent. In addition, their reports, and other case series have suggested continuing improvement in outcomes related to ongoing improvements in the device and patient management. However, the durability of the HeartMate device used in the REMATCH trial was a concern (e.g., at a participating institution, all 6 long-term survivors required device change-outs).

Nonrandomized Comparative Studies

A prospective observational study called the Risk Assessment and Comparative Effectiveness of Left Ventricular Assist Device and Medical Management in Ambulatory Heart Failure Patients study, reported by Estep et al (2015), compared LVAD support (n=97) with optimal medical therapy (n=103) for patients with heart failure not requiring inotropes also found superior survival and health-related QOL in LVAD-treated patients. Twelve-month, as-treated, event-free actutimes survival was 80% in the LVAD group and 63% in the best medical therapy group (p=0.022). Two-year results were reported by Starling et al (2017). At the end of 2 years, 35 (34%) medical therapy patients and 60 (62%) LVAD patients were alive on their original therapy; 23 medical management patients received LVADs during the 2 years. The LVAD-treated patients continued to have higher as-treated, event-free actutimes survival (70% vs 41%, p<0.001), although there was no statistical difference in intention-to-treat survival (70% vs 63%, p=0.31).

In an FDA required postapproval study of the HeartMate II device for destination therapy, which included the first 247 HeartMate II patients identified as eligible for the device as destination therapy, Jorde et al (2014) found that outcomes and adverse events did not differ significantly from those of the original trial, which compared patients who received the HeartMate II with earlier-generation devices. Survival rates in the postapproval cohort were 82% and 69% at 1 and 2 years postoperatively, respectively.
After the release of the REMATCH trial results, Rogers et al (2007) published results from a prospective, nonrandomized trial comparing LVAD as destination therapy with optimal medical therapy for patients with heart failure who were not candidates for a heart transplant. Fifty-five patients who had New York Heart Association functional class IV symptoms and who failed to wean from inotropic support were offered a Novacor LVAD; 18 did not receive a device due to preference or device unavailability and served as a control group. The LVAD-treated patients had superior survival rates at 6 months (46% vs 22% \( p=0.03 \)) and 12 months (27% vs 11% \( p=0.02 \)), along with fewer adverse events.

Arnold et al (2016) analyzed 1638 patients receiving LVADs as destination therapy between May 2012 and September 2013. Results were selected from the INTERMACS registry and assessed for poor outcomes. Poor outcome was defined as death or mean Kansas City Cardiomyopathy Questionnaire overall score less than 45 throughout the year after implantation. Analyses included inverse probability weighting to adjust for missing data. About 22.4% of patients died within the first year after implantation, and an additional 7.3% had persistently poor QOL; 29.7% met the definition of poor outcome. Poor outcomes were more common in those patients having higher body mass indices, lower hemoglobin levels, previous cardiac surgery, history of cancer, severe diabetes, and poorer QOL preimplant.

**Section Summary: Ventricular Assist Devices as Destination Therapy for End-Stage Heart Failure**

The highest-quality evidence on the efficacy of LVADs as destination therapy in patients who are not transplant candidates is the REMATCH trial. This multicenter RCT reported that the use of LVADs led to improvements in survival, QOL, and functional status. This evidence supports a finding that health outcomes are improved with LVADs in this patient population.

**Total Artificial Heart as a Bridge to Transplant for End-Stage Heart Failure**

**Clinical Context and Therapy Purpose**

The purpose of a TAH as a bridge to a heart transplant in patients who have end-stage heart failure is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The question addressed in this evidence review is: Does the use of a TAH as a bridge to heart transplant improve the net health outcome in individuals with end-stage heart failure?

The following PICO was used to select literature to inform this review.

**Population**

The relevant population of interest are individuals with end-stage heart failure.

**Interventions**

The therapy being considered is a TAH as a bridge to heart transplant.

Implantation of a TAH as a bridge to transplant is performed in a hospital setting with specialized staff who are equipped to perform the surgical procedure and manage postsurgical intensive care.

**Comparators**

The following therapy is currently being used to make decisions about managing individuals with end-stage heart failure: optimal medical therapy without a TAH.

**Outcomes**

The general outcomes of interest are OS, device malfunction, heart failure, respiratory dysfunction, arrhythmias, and infection.
Implantation of a VAD is performed in a hospital setting with specialized staff who are equipped to perform the surgical procedure and manage postsurgical intensive care.

**Study Selection Criteria**
To assess efficacy outcomes, we included comparative controlled prospective trials, with a preference for RCTs and systematic reviews of RCTs.

In the absence of such trials, we included comparative observational studies, with a preference for prospective studies.

To assess long-term outcomes and adverse effects, we included single-arm studies that captured longer periods of follow-up and/or larger populations.

**Review of Evidence**

**Nonrandomized Trials**
The FDA approval of the CardioWest TAH was based on the results of a nonrandomized, prospective study of 81 patients. Patients had failed inotropic therapy, had a biventricular failure, and thus were not considered appropriate candidates for an LVAD. The rate of survival to transplant was 79%, which was considered comparable with the experience with LVAD in patients with left ventricular failure. The mean time from entry into the study until transplantation or death was 79.1 days.

**Case Series**
Case series have been reported on outcomes for the TAH as a bridge to transplant. For example, Copeland et al (2012) reported on 101 patients treated with the SynCardia artificial heart as a bridge to transplant. All patients either met established criteria for MCS or were failing medical therapy on multiple inotropic drugs. Mean support time was 87 days (range, 1-441 days). The rate of survival to transplant was 68.3% (69/101). Of the 32 deaths before the transplant, 13 were due to multiorgan failure, 6 were due to pulmonary failure, and 4 were due to neurologic injury. Survival rates after transplant at 1, 5, and 10 years, respectively, were 76.8%, 60.5%, and 41.2%.

**Section Summary: Total Artificial Heart as a Bridge to Transplant for End-Stage Heart Failure**
There is less evidence on the use of TAH as a bridge to transplant compared with the use of LVADs. The type of evidence on a bridge to transplant is similar to that for LVADs (i.e., case series reporting substantial survival rates in patients without other alternatives). Therefore, similar to LVADs, this evidence is sufficient to conclude that TAH improves outcomes for these patients and TAH is a reasonable alternative for patients who require a bridge to transplantation but who are ineligible for other types of life-prolonging support devices.

**Total Artificial Heart as Destination Therapy for End-Stage Heart Failure**

**Clinical Context and Therapy Purpose**
The purpose of a TAH as destination therapy in patients who have end-stage heart failure is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The question addressed in this evidence review is: Does the use of a TAH as destination therapy improve the net health outcome in individuals with end-stage heart failure?

The following PICO was used to select literature to inform this review.

**Population**
The relevant population of interest are individuals with end-stage heart failure.

**Interventions**
The therapy being considered is a TAH as destination therapy.
Implantation of a TAH as destination therapy is performed in a hospital setting with specialized staff who are equipped to perform the surgical procedure and manage postsurgical intensive care.

**Comparators**
The following therapy is currently being used to make decisions about managing individuals with end-stage heart failure: optimal medical therapy without TAHs.

Time of interest ranges from 6 months to 2 years following implantation of a TAH as destination therapy.

**Outcomes**
The general outcomes of interest are OS, device malfunction, heart failure, respiratory dysfunction, arrhythmias, and infection.

**Study Selection Criteria**
To assess efficacy outcomes, we included comparative controlled prospective trials, with a preference for RCTs and systematic reviews of RCTs.

In the absence of such trials, we included comparative observational studies, with a preference for prospective studies.

To assess long-term outcomes and adverse effects, we included single-arm studies that captured longer periods of follow-up and/or larger populations.

**Review of Evidence**

**Case Series**
Data on the artificial heart are available from the FDA approval information and from a published article describing results for the first 7 patients. The FDA indicated that its decision on the AbioCor implantable heart was based on the manufacturer's (Abiomed) laboratory and animal testing and on a small clinical study of 14 patients conducted by Abiomed. Study participants had a 1-month survival prognosis of not more than 30%, were ineligible for cardiac transplants and were not projected to benefit from VAD therapy. The study showed that the device was safe and likely to benefit people with severe heart failure whose death was imminent and for whom no alternative treatments were available. Of the 14 patients studied, 12 survived the surgery. Mean duration of support for the patients was 5.3 months. In some cases, the device extended survival by several months (survival was 17 months in 1 patient). Six patients were ambulatory; 1 patient was discharged home. Complications included postoperative bleeding and neurologic events. No device-related infections were reported.

Torregrossa et al (2014) reported on 47 patients who received a TAH at 10 worldwide centers and had the device implanted for more than 1 year. Patients were implanted for dilated cardiomyopathy (n=23), ischemic cardiomyopathy (n=15), and "other" reasons (n=9). Over a median support time of 554 days (range, 365-1373 days), 34 (72%) patients were successfully transplanted, 12 (24%) patients died while on device support, and 1 (2%) patient was still supported. Device failure occurred in 5 (10%) patients. Major complications were common, including systemic infection in 25 (53%) patients, driveline infections in 13 (27%) patients, thromboembolic events in 9 (19%) patients, and hemorrhagic events in 7 (14%) patients. Two of the deaths occurred secondary to device failure.

**Section Summary: Total Artificial Heart as Destination Therapy for End-Stage Heart Failure**

There is less evidence on the use of TAH as destination therapy compared with the use of LVADs. Although TAHs show promise as destination therapy in patients who have no other treatment options, the available data on their use is extremely limited. Currently, the evidence base is insufficient to support conclusions about TAH efficacy in this setting.
Pericutaneous Ventricular Assist Devices for Cardiogenic Shock

Clinical Context and Therapy Purpose

The purpose of pVADs in patients who have cardiogenic shock is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The question addressed in this evidence review is: Does the use of a pVAD as a bridge to heart transplant improve the net health outcome in individuals with end-stage heart failure?

The following PICO was used to select literature to inform this review.

**Population**
The relevant population of interest are individuals with cardiogenic shock.

**Interventions**
The therapy being considered is pVADs.

Implantation of a pVAD is performed in a hospital setting with specialized staff equipped to perform the surgical procedure and manage postsurgical intensive care.

**Comparators**
The following therapy is currently being used to make decisions about managing individuals with cardiogenic shock: intra-aortic balloon pump (IABP).

**Outcomes**
The general outcomes of interest are OS, device malfunction, heart failure, respiratory dysfunction, arrhythmias, and infection.

Timing of interest ranges from perioperative events to 30-day mortality outcomes.

**Study Selection Criteria**
To assess efficacy outcomes, we included comparative controlled prospective trials, with a preference for RCTs and systematic reviews of RCTs.

In the absence of such trials, we included comparative observational studies, with a preference for prospective studies.

To assess long-term outcomes and adverse effects, we included single-arm studies that captured longer periods of follow-up and/or larger populations.

**Review of Evidence**

**Systematic Reviews**
Romeo et al (2016) reported on a systematic review and meta-analysis that evaluated various percutaneous mechanical support methods, including pVADs, for patients with cardiogenic shock due to AMI who were undergoing revascularization (Tables 3 and 4). Reviews included 3 RCTs (described below) comparing pVADs with IABPs, along with 3 comparative observational studies. A major limitation noted by the review authors was the small sample size of the RCTs. Observational studies were included in meta-analyses, with subgroup analyses by study design reported (see Table 4). In the comparison of pVADs with IABP, reviewers found that in-hospital mortality (the primary outcome of the analysis) was non-significantly increased in the pVAD group. Subgroup analysis did not find significant differences in estimates from RCTs and observational studies, and CIs overlapped. There was no significant heterogeneity within RCTs or observational studies. The relative risk reduction was -17.23%, translating to 8 more deaths per every 100 patients treated with pVADs instead of IABP.
Table 3. Characteristics of a Systematic Review Evaluating pVADs vs IABPs for Cardiogenic Shock

<table>
<thead>
<tr>
<th>Study</th>
<th>Dates</th>
<th>Trials</th>
<th>Participants</th>
<th>N</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romeo et al (2016)</td>
<td>1997-2015</td>
<td>6</td>
<td>Patients receiving IABP or pVADs</td>
<td>271</td>
<td>3 RCT and 3 observational</td>
</tr>
</tbody>
</table>

pVAD: percutaneous ventricular assist device; IABP: intra-aortic balloon pump; RCT: randomized controlled trial.

Table 4. Results of a Systematic Review Evaluating pVADs vs IABPs for Cardiogenic Shock

<table>
<thead>
<tr>
<th>Study</th>
<th>In Hospital Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romeo et al (2016)</td>
<td>Total N: 100, Risk ratio (95% CI): 1.06 [0.68, 1.66], I2 (p): 0% (0.83)</td>
</tr>
</tbody>
</table>

Observational Studies

<table>
<thead>
<tr>
<th>Total N</th>
<th>Risk ratio (95% CI)</th>
<th>I2 (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>171</td>
<td>1.16 (0.92, 1.47)</td>
<td>0% (0.062)</td>
</tr>
</tbody>
</table>

All studies

<table>
<thead>
<tr>
<th>Total N</th>
<th>Risk ratio (95% CI)</th>
<th>I2 (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>271</td>
<td>1.14 (0.93, 1.41)</td>
<td>0% (0.92)</td>
</tr>
</tbody>
</table>

pVAD: percutaneous ventricular assist device; IABP: intra-aortic balloon pump; N: sample size; CI: confidence interval; NNH: number needed to harm; RCT: randomized controlled trial.

Randomized Controlled Trials

A total of 4 RCTs have compared pVADs with IABPs for patients who had cardiogenic shock; 3 were included in the Romeo et al (2016) systematic review described above and was published after Romeo et al (2016). The 4 RCTs enrolled a total of 148 patients, 77 treated with a pVAD and 71 treated with an IABP. All 4 trial populations included patients with AMI and cardiovascular shock; 1 trial restricted its population to patients who were postrevascularization in the AMI setting. The primary outcomes reported were 30-day mortality, hemodynamic measures of left ventricle pump function, and adverse events. The trials are summarized in Tables 5 and 6. Some trials reported improvements in hemodynamic and metabolic parameters but none found any reductions in 30-day mortality. The IMPella versus IABP Reduces mortality in STEMI patients treated with primary PCI in Severe cardiogenic SHOCK (IMPRESS) trial reported 6-month mortality outcomes and also found no difference between groups. Bleeding events and leg ischemia were more common in the pVAD groups.

Table 5. Characteristics of RCTs Evaluating pVADs and IABPs for Cardiogenic Shock

<table>
<thead>
<tr>
<th>Study (Registration)</th>
<th>Countries</th>
<th>Sites</th>
<th>Dates</th>
<th>pVAD</th>
<th>Key Eligibility Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burkhoff et al (2006)</td>
<td>U.S.</td>
<td>12</td>
<td>2002-2004</td>
<td>TandemHeart</td>
<td>CS &lt;24 h due to MI or heart failure AMI with CS and intent to revascularize with PCI</td>
</tr>
<tr>
<td>Thiele et al (2005)</td>
<td>Germany</td>
<td>1</td>
<td>2000-2003</td>
<td>TandemHeart</td>
<td>AMI with CS and intent to revascularize with PCI</td>
</tr>
</tbody>
</table>

RCT: randomized controlled trial; AMI: acute myocardial infarction; CS: cardiogenic shock; IABP: intra-aortic balloon counterpulsation; IMPRESS: IMPella versus IABP Reduces mortality in STEMI patients treated with primary PCI in Severe cardiogenic SHOCK; ISAR-SHOCK: Efficacy Study of LV Assist Device to Treat Patients With Cardiogenic Shock; MI: myocardial infarction; PCI: percutaneous coronary intervention; pVAD: percutaneous ventricular assist device;
Table 6. Results of RCTs Evaluating pVADs and IABPs for Cardiogenic Shock

<table>
<thead>
<tr>
<th>Study</th>
<th>30-Day Mortality</th>
<th>60-day Mortality</th>
<th>Bleeding</th>
<th>Leg Ischemia</th>
<th>Other Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ouweeenel et al (2017)</td>
<td>IMPRESS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>Rehospitalization</td>
</tr>
<tr>
<td>pVAD</td>
<td>46%</td>
<td>50%</td>
<td>33%</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>IABP</td>
<td>50%</td>
<td>50%</td>
<td>8%</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>HR (95% CI)</td>
<td>0.96 (0.42 to 2.18)</td>
<td>1.04 (0.47 to 2.32)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>0.49</td>
<td>Increase in cardiac index (L/min/m²)</td>
</tr>
<tr>
<td>pVAD</td>
<td>46%</td>
<td>8%</td>
<td>0%</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>IABP</td>
<td>46%</td>
<td>0%</td>
<td>0%</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Buffkoff et al (2006)</td>
<td>TandemHeart</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>At least 1 adverse event:</td>
</tr>
<tr>
<td>pVAD</td>
<td>47%</td>
<td>42%</td>
<td>21%</td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td>IABP</td>
<td>36%</td>
<td>14%</td>
<td>14%</td>
<td>71%</td>
<td></td>
</tr>
<tr>
<td>Thiele et al (2005)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>Final cardiac index (W/m²)</td>
</tr>
<tr>
<td>pVAD</td>
<td>43%</td>
<td>90%</td>
<td>33%</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>IABP</td>
<td>45%</td>
<td>40%</td>
<td>0%</td>
<td>0.28</td>
<td></td>
</tr>
</tbody>
</table>

CI: confidence interval; HR: hazard ratio; IABP: intra-aortic balloon counterpulsation; IMPRESS: Impella versus IABP Reduces mortality in STEMI patients treated with primary PCI in Severe cardiogenic SHOCK; ISAR-SHOCK: Efficacy Study of LV Assist Device to Treat Patients With Cardiogenic Shock; pVAD: percutaneous ventricular assist devices; RCT: randomized controlled trial.

Observational Studies

Results of a recent comparative observational study conducted by Schrage et al (2019) were consistent with previous evidence in showing no mortality benefit for pVAD over IABP. Using registry data, the researchers retrospectively identified 237 patients who had been treated with the Impella device and matched them to patients who had received IABP as part of an RCT. There was no significant difference between groups in 30-day all-cause mortality (48.5% vs 46.4%, P=0.64). Severe or life-threatening bleeding (8.5% vs 3.0%, P<0.01) and peripheral vascular complications (9.8% vs 3.8%, P=0.01) occurred significantly more often in the Impella group.

Case Series

Case series of patients treated with pVADs as an alternative to IABP in cardiogenic shock have reported high success rates as a bridge to alternative therapies. However, given the availability of RCT evidence, these studies add little to the body of evidence on the efficacy of pVADs for the management of cardiogenic shock.

Section Summary: Percutaneous Ventricular Assist Devices for Cardiogenic Shock

Four RCTs comparing pVAD with IABP in patients with cardiogenic shock failed to demonstrate a mortality benefit for pVAD use and reported higher complication rates associated with pVAD use. Comparative observational studies were consistent with the RCT evidence.

Percutaneous Ventricular Assist Devices for High-Risk Cardiac Procedures

Clinical Context and Therapy Purpose

The purpose of pVADs in patients who undergo high-risk cardiac procedures is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The question addressed in this evidence review is: Does the use of a pVAD improve the net health outcome in individuals who undergo high-risk cardiac procedures?
The following PICO was used to select literature to inform this review.

**Population**
The relevant population of interest are individuals undergoing high-risk cardiac procedures.

**Interventions**
The therapy being considered is a pVAD.

Implantation of a pVAD is performed in a hospital setting with specialized staff who are equipped to perform the surgical procedure and manage postsurgical intensive care.

**Comparators**
The following therapy is currently being used to make decisions about managing individuals who undergo high-risk cardiac procedures: IABP.

**Outcomes**
The general outcomes of interest are OS, device malfunction, heart failure, respiratory dysfunction, arrhythmias, and infection.

Timing of interest ranges from perioperative events to 30-day mortality outcomes.

**Study Selection Criteria**
To assess efficacy outcomes, we included comparative controlled prospective trials, with a preference for RCTs and systematic reviews of RCTs.

In the absence of such trials, we included comparative observational studies, with a preference for prospective studies.

To assess long-term outcomes and adverse effects, we included single-arm studies that captured longer periods of follow-up and/or larger populations.

**Review of Evidence**

**Percutaneous Ventricular Assist Devices as Ancillary Support for High-Risk Percutaneous Coronary Intervention**

**Systematic Reviews**
Two recent systematic reviews have evaluated pVAD as ancillary support for patients undergoing high-risk PCI. Table 7 shows a comparison of the RCTs included in each. Only 1 RCT (PROTECT II) was included in both reviews. In addition to PROTECT II, Ait Ichou et al (2018) included 3 RCTs in patients who received emergent PCI post-MI: IMPRESS, IMPRESS in STEMI, and ISAR-SHOCK. Ait Ichou et al (2018) conducted a systematic review of the Impella device compared to IABP for high-risk patients undergoing PCI (Tables 7 and 8).73 The researchers included 4 RCTs, 2 controlled observational studies, and 14 uncontrolled observational studies published between 2006 and 2016, with a total of 1287 patients. Individual study results were reported with no pooled analyses.

**Table 7. Comparison of RCTs Included in SRs Evaluating pVAD as Ancillary Support for High-Risk PCI**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>O'Neill et al (2012)²⁵, PROTECT II</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Ouweeneel et al 2016 IMPRESS</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Ouweeneel et al (2016) IMPRESS in STEMI²⁶</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Seyfarth et al (2008)³ ISAR-SHOCK</td>
<td>●</td>
<td></td>
</tr>
</tbody>
</table>

RCT: randomized controlled trial; SR: systematic review; pVAD: percutaneous ventricular assist device; PCI: percutaneous coronary intervention.
The range of results identified in the controlled and uncontrolled studies as reported by Ait Ichou et al (2018) are summarized in Table 8. The RCTs found similar rates of all-cause mortality between the Impella device and IABP. One RCT reported higher rates among patients randomized to Impella (7.6% vs 5.9%) but the difference was not statistically significant (P=0.47). Two of the 3 controlled observational studies found higher 30-day mortality rates in patients receiving Impella but the differences were not statistically significant. There was a reduction in major cardiovascular adverse events at 90 days with the Impella device reported in 1 RCT (odds ratio vs IABP: 0.79, 95% CI: 0.64–0.96). Among uncontrolled studies, the rates of all-cause mortality and adverse events were heterogeneous due to differences in study populations and their underlying cardiovascular risk.

Risk of bias assessment determined that 3 of the 4 RCTs were at a low-risk of bias, but they had insufficient power to detect a difference in clinical outcomes. One RCT (IMPRESS in STEMI) was rated as a high-risk of bias due to early termination and widening of inclusion criteria over time. The 2 controlled observational studies had methodological limitations leading to a serious risk of bias, and the other observational studies were at a high-risk of bias due to their uncontrolled study design. After exclusion of low-quality studies, the rates of 30-day mortality, major bleeding, and MI did not change substantially. However, in the group of low-risk of bias studies, the vascular complication rate was higher.

An earlier systematic review and meta-analysis conducted by Briasoulis et al (2016) included studies of both Impella and TandemHeart. Reviewers identified 18 nonrandomized observational studies and a single RCT (PROTECT II). Results are shown in Table 9. In the observational studies, the sample sizes ranged from 7 to 637 patients. In a pooled analysis of the observational trial data, the 30-day mortality rate following Impella-assisted high-risk PCI was 3.5% (95% CI, 2.2% to 4.8%; I²=20%), while that for TandemHeart-assisted high-risk PCI was 8% (95% CI, 2.9% to 13.1%; I²=55%). The pooled vascular complication rates were 4.9% (95% CI, 2.3% to 7.6%) and 6.5% (95% CI, 3.2% to 9.9%) for the Impella and the TandemHeart, respectively. This meta-analysis did not compare pVAD to IABP or other interventions.

### Table 8. Characteristics of SRs Evaluating pVAD as Ancillary Support for High-Risk PCI

<table>
<thead>
<tr>
<th>Study</th>
<th>Dates</th>
<th>Trials</th>
<th>Participants</th>
<th>Devices Included</th>
<th>N (Range)</th>
<th>Design</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ait Ichou et al (2018)</td>
<td>Inception-2016</td>
<td>20</td>
<td>High-risk patients undergoing PCI</td>
<td>Impella</td>
<td>1287 (10-225)</td>
<td>4 RCT, 2 controlled observational, 14 uncontrolled observational</td>
<td>1-42 months</td>
</tr>
</tbody>
</table>

PCI: percutaneous coronary intervention; N: sample size; pVAD: percutaneous ventricular assist device; RCT: randomized controlled trial; SR: systematic review.

### Table 9. Results of SRs Evaluating pVAD as Ancillary Support for High-Risk Percutaneous Coronary Intervention

<table>
<thead>
<tr>
<th>Study</th>
<th>All-Cause Mortality (30 days)</th>
<th>All-Cause Mortality (3 mo.)</th>
<th>All-Cause Mortality (12 mo.)</th>
<th>Stroke (30 days)</th>
<th>Stroke (3 mo.)</th>
<th>Stroke (12 mo.)</th>
<th>Major Adverse Events (30 days)</th>
<th>Major Adverse Events (3 mo.)</th>
<th>Major Adverse Events (12 mo.)</th>
<th>Vascular Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ait Ichou et al (2018)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table: Major Adverse Events for High-Risk Percutaneous Coronary Intervention

<table>
<thead>
<tr>
<th>Study</th>
<th>All-Cause Mortality (30 days)</th>
<th>All-Cause Mortality (3 mo.)</th>
<th>All-Cause Mortality (12 mo.)</th>
<th>Stroke (30 days)</th>
<th>Stroke (3 mo.)</th>
<th>Stroke (12 mo.)</th>
<th>Major Adverse Events (30 days)</th>
<th>Major Adverse Events (3 mo.)</th>
<th>Major Adverse Events (12 mo.)</th>
<th>Vascular Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impella</td>
<td>7.6%</td>
<td>12.1%</td>
<td>15.3%</td>
<td>0%</td>
<td>0.9%</td>
<td>8%</td>
<td>15%</td>
<td>35.1%</td>
<td>26%</td>
<td>37%</td>
</tr>
<tr>
<td>IABP</td>
<td>0%</td>
<td>8.7%</td>
<td>11%</td>
<td>0%</td>
<td>0.9%</td>
<td>4%</td>
<td>40%</td>
<td>40.1%</td>
<td>33%</td>
<td>47%</td>
</tr>
<tr>
<td>Range of effect (controlled studies)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impella</td>
<td>0%</td>
<td>10%</td>
<td>45.5%</td>
<td>0%</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>Briasoulis et al (2016)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impella</td>
<td>54/134</td>
<td>126/134</td>
<td>89/1346</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pooled effect (95% CI)</td>
<td>0.35 (0.022, 0.048)</td>
<td>0.71 (0.043, 0.099)</td>
<td>0.049 (0.023, 0.076)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I2 (p)</td>
<td>20%</td>
<td>63%</td>
<td>78%</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TandemHeart</td>
<td>22/212</td>
<td>11/205</td>
<td>15/205</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pooled effect (95% CI)</td>
<td>0.080 (0.029, 0.131)</td>
<td>0.036 (0.011, 0.061)</td>
<td>0.065 (0.032, 0.099)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I2 (p)</td>
<td>55%</td>
<td>0%</td>
<td>0%</td>
<td>0.865</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CI: confidence interval; IABP: intra-aortic balloon pump; pVAD: percutaneous ventricular assist device; SR: systematic review.

**Section Summary: Percutaneous Ventricular Assist Devices for High-Risk Percutaneous Coronary Intervention**

RCTs, controlled and uncontrolled observational studies, and systematic reviews of these studies have not demonstrated a benefit of pVAD used as ancillary support for patients undergoing high-risk PCI.

**Percutaneous Ventricular Assist Devices for High-Risk Ventricular Tachycardia Ablation**

Reddy et al (2014) reported on outcomes for a series of 66 patients enrolled in a prospective, multicenter registry who underwent VT ablation with a pVAD or IABP. Twenty-two patients underwent ablation with IABP assistance, while 44 underwent ablation with the TandemHeart or Impella pVAD device (non-IABP group). Compared with patients who received support with an IABP, those who received support with a pVAD had more unstable VTs that could be mapped and ablated (1.05 vs 0.32, p < 0.001), more VTs than could be terminated by ablation (1.59 vs 0.91, p = 0.001), and fewer VTs terminated with rescue shocks (1.9 vs 3.0, p = 0.049). More pVAD-supported patients could undergo entrainment/activation mapping (82% vs 59%, p = 0.046). Mortality and VT recurrence did not differ over the study follow-up (average, 12 months).

In a retrospective study, Aryana et al (2014) reported procedural and clinical outcomes for 68 consecutive unstable patients with scar-mediated epicardial or endocardial VT who underwent ablation with or without pVAD support. Thirty-four patients had hemodynamic support...
periprocedurally with a pVAD. Percutaneous VAD- and non-pVAD-supported patients had similar procedural success rates. Compared with non-pVAD-supported patients, patients in the pVAD group had a longer maximum time in unstable VT (27.4 minutes vs 5.3 minutes, \( p < 0.001 \)), more VT ablations per procedure (1.2 vs 0.4, \( p < 0.001 \)), shorter radiofrequency ablation time (53 seconds vs 68 seconds, \( p = 0.022 \)), and a shorter hospital length of stay (4.1 days vs 5.4 days, \( p = 0.013 \)). Over a follow-up of 19 months, rates of VT recurrence did not differ between groups.

**Section Summary: Percutaneous Ventricular Assist Devices for High-Risk Ventricular Tachycardia Ablation**

Two nonrandomized studies have compared VT ablation with pVAD or IABP. In both studies, patients who had pVAD support spent less time in unstable VT than patients without pVAD support. Rates of recurrence of VT was comparable between groups for both studies. The current evidence-based does not support conclusions about the use of pVAD for VT ablation.

**Percutaneous Ventricular Assist Devices for Cardiogenic Shock Refractory to Intra-Aortic Balloon Pump Therapy**

**Clinical Context and Therapy Purpose**

The purpose of pVADs in patients who have cardiogenic shock refractory to IABP therapy is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The question addressed in this evidence review is: Does the use of a pVAD improve the net health outcome in individuals with cardiogenic shock refractory to IABP?

The following PICO was used to select literature to inform this review.

**Population**

The relevant population of interest are individuals with cardiogenic shock refractory to IABP therapy.

**Interventions**

The therapy being considered is the use of a pVAD.

Implantation of a pVAD is performed in a hospital setting with specialized staff who are equipped to perform the surgical procedure and manage postsurgical intensive care.

**Comparators**

The following therapies are currently being used to make decisions about managing individuals with cardiogenic shock refractory to IABP: optimal medical therapy without IABP and other MCS.

**Outcomes**

The general outcomes of interest are OS, device malfunction, heart failure, respiratory dysfunction, arrhythmias, and infection.

Timing of interest ranges from perioperative events to 30-day mortality outcomes.

**Study Selection Criteria**

To assess efficacy outcomes, we included comparative controlled prospective trials, with a preference for RCTs and systematic reviews of RCTs.

In the absence of such trials, we included comparative observational studies, with a preference for prospective studies.

To assess long-term outcomes and adverse effects, we included single-arm studies that captured longer periods of follow-up and/or larger populations.
**Review of Evidence**

**Case Series**

In a large series, Kar et al (2011) treated 117 patients who had severe, refractory cardiogenic shock with the TandemHeart System. Eighty patients had ischemic cardiomyopathy and 37 had nonischemic cardiomyopathy. There were significant improvements in all hemodynamic measures following LVAD placement. For example, the cardiac index increased from 0.52 L/min/m² to 3.0 L/min/m² (p<0.001), and systolic blood pressure increased from 75 mm Hg to 100 mm Hg (p<0.001). Complications were common after LVAD implantation. Thirty-four (29.1%) patients had bleeding around the cannula site, and 35 (29.9%) developed sepsis during hospitalization. Groin hematoma occurred in 6 (5.1%) patients; limb ischemia in 4 (3.4%) patients; femoral artery dissection or perforation in 2 (1.7%) patients; stroke in 8 (6.8%) patients; and coagulopathy in 13 (11.0%) patients.

**Section Summary: Percutaneous Ventricular Assist Devices for Cardiogenic Shock Refractory to Intra-Aortic Balloon Pump Therapy**

Percutaneous VADs have been assessed in uncontrolled studies of patients with cardiogenic shock including those refractory to IABP therapy. The case series have reported high rates of adverse events that may outweigh any potential benefits. As a result, the evidence on pVADs does not demonstrate that the use of VADs is associated with improvements in health outcomes for patients with cardiogenic shock refractory to IABP therapy.

**Summary of Evidence**

**Ventricular Assist Device**

For individuals who have end-stage heart failure who receive a VAD as a bridge to transplant, the evidence includes single-arm trials and observational studies. Relevant outcomes are overall survival (OS), symptoms, functional outcomes, quality of life (QOL), and treatment-related mortality and morbidity. There is a substantial body of evidence from clinical trials and observational studies supporting implantable VADs as a bridge to transplant in patients with end-stage heart failure, possibly reducing mortality as well as improving QOL. These studies have reported that substantial numbers of patients have survived to transplant in situations in which survival would not be otherwise expected. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have end-stage heart failure who receive a VAD as destination therapy, the evidence includes a trial and multiple single-arm studies. Relevant outcomes are OS, symptoms, functional outcomes, QOL, and treatment-related mortality and morbidity. A well-designed trial, with 2 years of follow-up data, has demonstrated an advantage of implantable VADs as destination therapy for patients ineligible for a heart transplant. Despite an increase in adverse events, both mortality and QOL appear to be improved for these patients. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

**Total Artificial Heart**

For individuals who have end-stage heart failure who receive a TAH as a bridge to transplant, the evidence includes case series. Relevant outcomes are OS, symptoms, functional outcomes, QOL, and treatment-related mortality and morbidity. Compared with VADs, the evidence for TAHs in these settings is less robust. However, given the lack of medical or surgical options for these patients and the evidence case series provide, TAH is likely to improve outcomes for a carefully selected population with end-stage biventricular heart failure awaiting transplant who are not appropriate candidates for a left VAD. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have end-stage heart failure who receive a TAH as destination therapy, the evidence includes 2 case series. Relevant outcomes are OS, symptoms, functional outcomes, QOL, and treatment-related mortality and morbidity. The body of evidence for TAHs as
destination therapy is too limited to draw conclusions. The evidence is insufficient to determine the effects of the technology on health outcomes.

**Percutaneous Ventricular Assist Device**

For individuals with cardiogenic shock or who undergo high-risk cardiac procedures who receive a pVAD, the evidence includes randomized controlled trials (RCTs), observational studies, and systematic reviews. Relevant outcomes are OS, symptoms, morbid events, functional outcomes, QOL, and treatment-related mortality and morbidity. Four RCTs of pVAD vs intra-aortic balloon pump for patients in cardiogenic shock failed to demonstrate a mortality benefit and reported higher complication rates with pVAD use. Comparative observational studies were consistent with the RCT evidence. RCTs, controlled and uncontrolled observational studies, and systematic reviews of these studies have not demonstrated a benefit of pVAD used as ancillary support for patients undergoing high-risk cardiac procedures. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals with cardiogenic shock refractory to intra-aortic balloon pump therapy who receive a pVAD, the evidence includes case series. Relevant outcomes are OS, symptoms, morbid events, functional outcomes, QOL, and treatment-related mortality and morbidity. Case series of patients with cardiogenic shock refractory to intra-aortic balloon pump have reported improved hemodynamic parameters following pVAD placement. However, these uncontrolled series do not provide evidence that pVADs improve mortality, and high rates of complications have been reported with pVAD use. The evidence is insufficient to determine the effects of the technology on health outcomes.

**Supplemental Information**

**Clinical Input From Physician Specialty Societies and Academic Medical Centers**

While the various physician specialty societies and academic medical centers may collaborate with and make recommendations during this process, through the provision of appropriate reviewers, input received does not represent an endorsement or position statement by the physician specialty societies or academic medical centers, unless otherwise noted.

In response to requests from Blue Cross Blue Shield Association, input was received from 2 physician specialty societies and 5 academic medical centers in 2014. Vetting focused on the use of percutaneous ventricular assist devices (pVADs) under the American Heart Association and American College of Cardiology guidelines (2013) and on the use of the total artificial heart as destination therapy. All providing input supported the use of implantable VADs as destination therapy subject to the guidelines in the policy statements. Most providing input considered total artificial hearts to be investigational for destination therapy; reviewers noted that there are limited clinical trial data to support the use of total artificial hearts as destination therapy.

Most providing input considered pVADs to be investigational as a “bridge to recovery” or “bridge to decision” and for all other indications. Some reviewers noted that pVADs may improve patients’ hemodynamics better than other alternatives, such as an intra-aortic balloon pump, but are associated with more complications. Some noted that, despite a lack of evidence to indicate that pVADs improve overall outcomes, there may be cases when pVADs may be considered to support intervention or treatment for a life-threatening condition.

**Practice Guidelines and Position Statements**

**American Association for Thoracic Surgery/International Society for Heart and Lung Transplantation**

In 2020, the American Association for Thoracic Surgery and the International Society for Heart and Lung Transplantation published guidelines on selected topics in mechanical circulatory support, including recommendations on the use of pVADs (Table 10). The guideline authors noted, “Compared with IABP, contemporary percutaneous circulatory support devices provide a significant increase in cardiac index and mean arterial pressure; however, reported 30-day outcomes are similar.”
Table 10. 2020 Guidelines on Mechanical Circulatory Support

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>COE</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Percutaneous LV to aorta pumps of appropriate size should be considered for cardiogenic shock from primary LV failure.&quot;</td>
<td>IIA</td>
<td>B</td>
</tr>
</tbody>
</table>

COE: class of evidence; LOE: level of evidence; LV: left ventricular.

**American College of Cardiology Foundation et al**

In 2017, the American College of Cardiology Foundation, American Heart Association (AHA), and Heart Failure Society of America published a focused update of the 2013 recommendations released by the American College of Cardiology Foundation and AHA.80 Left ventricular assist device was 1 of several treatment options recommended for patients with refractory New York Heart Association class III or IV heart failure (stage D). If symptoms were not improved after guidelines-directed management and therapy, which included pharmacologic therapy, surgical management and/or other devices, then left ventricular assist device would be an additional treatment option.

The 2017 update focused on changes in sections regarding biomarkers, comorbidities, and prevention of heart failure, while many of the previous recommendations remained unchanged. The American College of Cardiology Foundation and AHA (2013) released guidelines for the management of heart failure that included recommendations related to the use of MCS, including both durable and nondurable MCS devices.81, The guidelines categorized pVADs and extracorporeal VADs as nondurable MCS devices. Table 11 provides class IIA guidelines on MCS devices.

Table 11. 2017 Guidelines on Mechanical Circulatory Support

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>COE</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;MCS is beneficial in carefully selected patients with stage D HFrEF in whom definitive management (e.g., cardiac transplantation) or cardiac recovery is anticipated or planned.&quot;</td>
<td>IIA</td>
<td>B</td>
</tr>
<tr>
<td>&quot;Nondurable MCS, including the use of percutaneous and extracorporeal ventricular assist devices (VADs), is reasonable as a &quot;bridge to recovery&quot; or &quot;bridge to decision&quot; for carefully selected patients with HFrEF with acute, profound hemodynamic compromise.&quot;</td>
<td>IIA</td>
<td>B</td>
</tr>
<tr>
<td>&quot;Durable MCS is reasonable to prolong survival for carefully selected patients with stage D HFrEF.&quot;</td>
<td>IIA</td>
<td>B</td>
</tr>
</tbody>
</table>

COE: class of evidence; HFrEF: heart failure with reduced ejection fraction; LOE: level of evidence; MCS: mechanical circulatory support.

These 2013 guidelines also noted:

"Although optimal patient selection for MCS remains an active area of investigation, general indications for referral for MCS therapy include patients with LVEF [left ventricular ejection fraction] <25% and NYHA [New York Heart Association] class III-IV functional status despite GDMT [guideline-directed medical therapy], including, when indicated, CRT [cardiac resynchronization therapy], with either high predicted 1- to 2-year mortality (e.g., as suggested by markedly reduced peak oxygen consumption and clinical prognostic scores) or dependence on continuous parenteral inotropic support. Patient selection requires a multidisciplinary team of experienced advanced HF [heart failure] and transplantation cardiologists, cardiothoracic surgeons, nurses, and ideally, social workers and palliative care clinicians."

**American Heart Association**

In 2012, the AHA published recommendations for the use of MCS.82 These guidelines defined nondurable MCS as intraballoon pumps, extracorporeal membrane oxygenation, extracorporeal VADs, and pVADs. Table 12 lists recommendations made on indications for the use of MCS, including durable and nondurable devices.
Table 12. 2012 Guidelines on Mechanical Circulatory Support

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>COE</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;MCS for BTT indication should be considered for transplant-eligible patients with end-stage HF who are failing optimal medical, surgical, and/or device therapies and at high risk of dying before receiving a heart transplantation.&quot;</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>&quot;Implantation of MCS in patients before the development of advanced HF ... is associated with better outcomes. Therefore, early referral of HF patients is reasonable.&quot;</td>
<td>IIA</td>
<td>B</td>
</tr>
<tr>
<td>&quot;MCS with a durable, implantable device for permanent therapy or DT is beneficial for patients with advanced HF; high 1-year mortality resulting from HF, and the absence of other life-limiting organ dysfunction; who are failing medical, surgical, and/or device therapies; and who are ineligible for heart transplantation.&quot;</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>&quot;Elective rather than urgent implantation of DT can be beneficial when performed after optimization of medical therapy in advanced HF patients who are failing medical, surgical, and/or device therapies.&quot;</td>
<td>IIA</td>
<td>C</td>
</tr>
<tr>
<td>&quot;Urgent nondurable MCS is reasonable in hemodynamically compromised HF patients with end-organ dysfunction and/or relative contraindications to heart transplantation/durable MCS that are expected to improve with time and restoration of an improved hemodynamic profile.&quot;</td>
<td>IIA</td>
<td>C</td>
</tr>
<tr>
<td>&quot;Patients who are ineligible for heart transplantation because of pulmonary hypertension related to HF alone should be considered for bridge to potential transplant eligibility with durable, long-term MCS.&quot;</td>
<td>IIA</td>
<td>B</td>
</tr>
</tbody>
</table>

BTT: bridge to transplant; COE: class of evidence; DT: destination therapy; HF: heart failure; LOE: level of evidence; MCS: mechanical circulatory support.

Heart Failure Society of America

In 2010, the Heart Failure Society of America published guidelines on surgical approaches to the treatment of heart failure. Table 13 lists recommendations on left VADs.

Table 13. Guidelines on Left Ventricular Assist Devices

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>SOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients awaiting heart transplantation who have become refractory to all means of medical circulatory support should be considered for a mechanical support device as a bridge to transplant.&quot;</td>
<td>B</td>
</tr>
<tr>
<td>&quot;Permanent mechanical assistance using an implantable assist device may be considered in highly selected patients with severe HF refractory to conventional therapy who are not candidates for heart transplantation, particularly those who cannot be weaned from intravenous inotropic support at an experienced HF center.&quot;</td>
<td>B</td>
</tr>
<tr>
<td>&quot;Patients with refractory HF and hemodynamic instability, and/or compromised end-organ function, with relative contraindications to cardiac transplantation or permanent mechanical circulatory assistance expected to improve with time or restoration of an improved hemodynamic profile should be considered for urgent mechanical circulatory support as a 'bridge to decision.' These patients should be referred to a center with expertise in the management of patients with advanced HF.&quot;</td>
<td>C</td>
</tr>
</tbody>
</table>

HF: heart failure; SOE: strength of evidence.

Society for Cardiovascular Angiography and Interventions et al

In 2015, the Society for Cardiovascular Angiography and Interventions, the Heart Failure Society of America, the Society of Thoracic Surgeons, and the American College of Cardiology published a joint clinical expert consensus statement on the use of percutaneous mechanical circulatory support (MCS) devices in cardiovascular care. This statement addressed intra-aortic balloon pumps, left atrial-to-aorta assist device (e.g., TandemHeart), left ventricle-to-aorta assist devices (e.g., Impella), extracorporeal membrane oxygenation, and methods of right-sided support. Specific recommendations were not made, but the statement reviews the use of MCS in patients undergoing high-risk percutaneous intervention, those with cardiogenic shock, and those with acute decompensated heart failure.

U.S. Preventive Services Task Force Recommendations

Not applicable.
Medicare National Coverage
Medicare has a national coverage determination (NCD) for artificial hearts and related devices, including VADs.85 The NCD, mandates coverage for VADs in the postcardiotomy setting as long as the following conditions are met:

- The VAD has "approval from the U.S. Food and Drug Administration (FDA)" for postcardiotomy support.
- The VAD is "used according to the FDA-approved labeling instructions."

The NCD also mandates coverage for VADs as a bridge to transplant as long as the following conditions are met:

- The VAD has approval from the FDA for the bridge to transplant indication.
- The VAD is "used according to the FDA approved labeling instructions."
- "The patient is approved for heart transplantation by a Medicare-approved heart transplant center..."
- "The implanting site, if different than the Medicare-approved transplant center, must receive written permission from the Medicare-approved heart transplant center under which the patient is listed prior to implantation of the VAD."

The NCD mandates coverage for VADs as a bridge to transplant as long as the following conditions are met:

- The VAD has approval from the FDA for the destination therapy indication.
- Patient selection:
  - New York Heart Association class IV end-stage left ventricular failure
  - Not candidates for heart transplantation
  - Failed to respond to optimal medical management,
  - Left ventricular ejection fraction<25%, and,
  - Demonstrated functional limitation.

"Beneficiaries receiving VADs for DT [destination therapy] must be managed by an explicitly identified cohesive, multidisciplinary team of medical professionals with the appropriate qualifications, training, and experience.... The team members must be based at the facility and must include individuals with experience working with patients before and after placement of a VAD."

"Facilities must be credentialed by an organization approved by the Centers for Medicare & Medicaid Services."

The NCD mandates coverage for artificial hearts as a bridge to transplant or destination therapy when performed under coverage with evidence development when a clinical study meets the criteria outlined in the Medicare policy.

Ongoing and Unpublished Clinical Trials
Some currently unpublished trials that might influence this review are listed in Table 14.

Table 14. Summary of Key Trials

<table>
<thead>
<tr>
<th>NCT No.</th>
<th>Trial Name</th>
<th>Planned Enrollment</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ongoing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCT01633502</td>
<td>Effects of Advanced Mechanical Circulatory Support in Patients With ST Segment Elevation Myocardial Infarction Complicated by Cardiogenic Shock. The Danish Cardiogenic Shock Trial</td>
<td>360</td>
<td>Jan 2023</td>
</tr>
<tr>
<td>NCT02468778a</td>
<td></td>
<td>716</td>
<td>Dec 2021</td>
</tr>
<tr>
<td>NCTNo.</td>
<td>Trial Name</td>
<td>Planned Enrollment</td>
<td>Completion Date</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>NCT01966458a</td>
<td>A Prospective, Randomized, Controlled, Unblinded, Multi-Center Clinical Trial to Evaluate the HeartWare® Ventricular Assist Device System for Destination Therapy of Advanced Heart Failure</td>
<td>494</td>
<td>Aug 2020</td>
</tr>
<tr>
<td>NCT02232659a</td>
<td>SynCardia 70cc Temporary Total Artificial Heart (TAH-t) for Destination Therapy (DT)</td>
<td>38</td>
<td>Dec 2022</td>
</tr>
<tr>
<td>NCT02326402</td>
<td>THEM E Registry: TandemHeart Experiences and Methods</td>
<td>200</td>
<td>Dec 2020</td>
</tr>
<tr>
<td>NCT01187368a</td>
<td>Prospective Multi-Center Randomized Study for Evaluating the EVAHEART® Left Ventricular Assist System: the COMPETENCE Trial</td>
<td>399</td>
<td>Dec 2024</td>
</tr>
<tr>
<td>NCT02387112</td>
<td>Early Versus Emergency Left Ventricular Assist Device Implantation in Patients Awaiting Cardiac Transplantation</td>
<td>200</td>
<td>Dec 2022</td>
</tr>
<tr>
<td>NCT02459054a</td>
<td>SynCardia 50cc Temporary Total Artificial Heart (TAH-t) as a Bridge to Transplant</td>
<td>72</td>
<td>Jun 2024</td>
</tr>
</tbody>
</table>

NCT: national clinical trial.
a Denotes industry-sponsored or cosponsored trial.

References


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43. TEC Assessment Program. Left ventricular assist devices as destination therapy for end-stage heart failure. 2002;Volume 17;Tab 19.


60. Torreregrossa G, Morshuis M, Varghese R, et al. Results with SynCardia total artificial heart beyond 1 year. ASAIO J. Nov-Dec 2014; 60(6): 626-34. PMID 25158888


Cardiovascular Care: Endorsed by the American Heart Association, the Cardiological Society of India, and Sociedad Latino Americana de Cardiologia Intervencion; Affirmation of Value by the Canadian Association of Interventional Cardiology-Association Canadienne de Cardiologie d’Intervention. J Am Coll Cardiol. May 19 2015; 65(19): e7-e26. PMID 25861963


**Documentation for Clinical Review**

**Please provide the following documentation:**

- History and physical and/or cardiac/transplant consultation report including:
  - Reason for implantable VAD or total artificial heart
  - NYHA functional class and duration of classification
  - Survival expectancy
  - Documentation that patient is on heart transplant list or undergoing evaluation to determine candidacy for heart transplantation
  - Reason patient is ineligible for heart transplantation (if applicable)
  - Age of patient (if requesting pediatric implantable VAD)
  - Hospital progress notes including documentation of current and past treatment(s) and response to treatment(s) including future medical/surgical treatment options
  - Documented ineligibility for other univentricular or biventricular support devices
- FDA approved implantable VAD or total artificial heart being requested

**Post Service (in addition to the above, please include the following):**
- Operative procedure report(s) (if applicable)

**Coding**

This Policy relates only to the services or supplies described herein. Benefits may vary according to product design; therefore, contract language should be reviewed before applying the terms of the Policy. Inclusion or exclusion of codes does not constitute or imply member coverage or provider reimbursement.

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPT</td>
<td>0451T</td>
<td>Insertion or replacement of a permanently implantable aortic counterpulsation ventricular assist system, endovascular approach, and programming of sensing and therapeutic parameters; complete system (counterpulsation device, vascular graft, implantable vascular hemostatic seal, mechano-electrical skin interface and subcutaneous electrodes)</td>
</tr>
<tr>
<td></td>
<td>0452T</td>
<td>Insertion or replacement of a permanently implantable aortic counterpulsation ventricular assist system, endovascular approach, and programming of sensing and therapeutic parameters; aortic counterpulsation device and vascular hemostatic seal</td>
</tr>
<tr>
<td></td>
<td>0453T</td>
<td>Insertion or replacement of a permanently implantable aortic counterpulsation ventricular assist system, endovascular approach, and programming of sensing and therapeutic parameters; mechano-electrical skin interface</td>
</tr>
<tr>
<td>Type</td>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
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<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>0454T</td>
<td>Insertion or replacement of a permanently implantable aortic counterpulsation ventricular assist system, endovascular approach, and programming of sensing and therapeutic parameters; subcutaneous electrode</td>
</tr>
<tr>
<td></td>
<td>0455T</td>
<td>Removal of permanently implantable aortic counterpulsation ventricular assist system; complete system (aortic counterpulsation device, vascular hemostatic seal, mechano-electrical skin interface and electrodes)</td>
</tr>
<tr>
<td></td>
<td>0456T</td>
<td>Removal of permanently implantable aortic counterpulsation ventricular assist system; aortic counterpulsation device and vascular hemostatic seal</td>
</tr>
<tr>
<td></td>
<td>0457T</td>
<td>Removal of permanently implantable aortic counterpulsation ventricular assist system; mechano-electrical skin interface</td>
</tr>
<tr>
<td></td>
<td>0458T</td>
<td>Removal of permanently implantable aortic counterpulsation ventricular assist system; subcutaneous electrode</td>
</tr>
<tr>
<td></td>
<td>0459T</td>
<td>Relocation of skin pocket with replacement of implanted aortic counterpulsation ventricular assist device, mechano-electrical skin interface and electrodes</td>
</tr>
<tr>
<td></td>
<td>0460T</td>
<td>Repositioning of previously implanted aortic counterpulsation ventricular assist device; subcutaneous electrode</td>
</tr>
<tr>
<td></td>
<td>0461T</td>
<td>Repositioning of previously implanted aortic counterpulsation ventricular assist device; aortic counterpulsation device</td>
</tr>
<tr>
<td></td>
<td>0462T</td>
<td>Programming device evaluation (in person) with iterative adjustment of the implantable mechano-electrical skin interface and/or external driver to test the function of the device and select optimal permanent programmed values with analysis, including review and report, implantable aortic counterpulsation ventricular assist system, per day</td>
</tr>
<tr>
<td></td>
<td>0463T</td>
<td>Interrogation device evaluation (in person) with analysis, review and report, includes connection, recording and disconnection per patient encounter, implantable aortic counterpulsation ventricular assist system, per day</td>
</tr>
<tr>
<td></td>
<td>33927</td>
<td>Implantation of a total replacement heart system (artificial heart) with recipient cardiectomy</td>
</tr>
<tr>
<td></td>
<td>33928</td>
<td>Removal and replacement of total replacement heart system (artificial heart)</td>
</tr>
<tr>
<td></td>
<td>33929</td>
<td>Removal of a total replacement heart system (artificial heart) for heart transplantation (List separately in addition to code for primary procedure)</td>
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<tr>
<td></td>
<td>33975</td>
<td>Insertion of ventricular assist device; extracorporeal, single ventricle</td>
</tr>
<tr>
<td></td>
<td>33976</td>
<td>Insertion of ventricular assist device; extracorporeal, biventricular</td>
</tr>
<tr>
<td></td>
<td>33977</td>
<td>Removal of ventricular assist device; extracorporeal, single ventricle</td>
</tr>
<tr>
<td></td>
<td>33978</td>
<td>Removal of ventricular assist device; extracorporeal, biventricular</td>
</tr>
<tr>
<td></td>
<td>33979</td>
<td>Insertion of ventricular assist device, implantable intracorporeal, single ventricle</td>
</tr>
<tr>
<td></td>
<td>33980</td>
<td>Removal of ventricular assist device, implantable intracorporeal, single ventricle</td>
</tr>
<tr>
<td></td>
<td>33981</td>
<td>Replacement of extracorporeal ventricular assist device, single or biventricular, pump(s), single or each pump</td>
</tr>
<tr>
<td></td>
<td>33982</td>
<td>Replacement of ventricular assist device pump(s); implantable intracorporeal, single ventricle, without cardiopulmonary bypass</td>
</tr>
<tr>
<td></td>
<td>33983</td>
<td>Replacement of ventricular assist device pump(s); implantable intracorporeal, single ventricle, with cardiopulmonary bypass</td>
</tr>
<tr>
<td>Type</td>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
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<td>-------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>33990</td>
<td>Insertion of ventricular assist device, percutaneous, including radiological supervision and interpretation; left heart, arterial access only <em>(Code revision effective 1/1/2021)</em></td>
</tr>
<tr>
<td></td>
<td>33991</td>
<td>Insertion of ventricular assist device, percutaneous, including radiological supervision and interpretation; left heart, both arterial and venous access, with transseptal puncture <em>(Code revision effective 1/1/2021)</em></td>
</tr>
<tr>
<td></td>
<td>33992</td>
<td>Removal of percutaneous left heart ventricular assist device, arterial or arterial and venous cannula(s), at separate and distinct session from insertion <em>(Code revision effective 1/1/2021)</em></td>
</tr>
<tr>
<td></td>
<td>33993</td>
<td>Repositioning of percutaneous right or left heart ventricular assist device with imaging guidance at separate and distinct session from insertion <em>(Code revision effective 1/1/2021)</em></td>
</tr>
<tr>
<td></td>
<td>33995</td>
<td>Insertion of ventricular assist device, percutaneous, including radiological supervision and interpretation; right heart, venous access only <em>(Code effective 1/1/2021)</em></td>
</tr>
<tr>
<td></td>
<td>33997</td>
<td>Removal of percutaneous right heart ventricular assist device, venous cannula, at separate and distinct session from insertion <em>(Code effective 1/1/2021)</em></td>
</tr>
<tr>
<td></td>
<td>L8698</td>
<td>Miscellaneous component, supply or accessory for use with total artificial heart system</td>
</tr>
<tr>
<td></td>
<td>Q0477</td>
<td>Power module patient cable for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0478</td>
<td>Power adapter for use with electric or electric/pneumatic ventricular assist device, vehicle type</td>
</tr>
<tr>
<td></td>
<td>Q0479</td>
<td>Power module for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0480</td>
<td>Driver for use with pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td>HCPCS</td>
<td>Q0481</td>
<td>Microprocessor control unit for use with electric ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0482</td>
<td>Microprocessor control unit for use with electric/pneumatic combination ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0483</td>
<td>Monitor/display module for use with electric ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0484</td>
<td>Monitor/display module for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0485</td>
<td>Monitor control cable for use with electric ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0486</td>
<td>Monitor control cable for use with electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0487</td>
<td>Leads (pneumatic/electrical) for use with any type electric/pneumatic ventricular assist device, replacement only</td>
</tr>
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<td></td>
<td>Q0488</td>
<td>Power pack base for use with electric ventricular assist device, replacement only</td>
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<td></td>
<td>Q0489</td>
<td>Power pack base for use with electric/pneumatic ventricular assist device, replacement only</td>
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<td>Q0490</td>
<td>Emergency power source for use with electric ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0491</td>
<td>Emergency power source for use with electric/pneumatic ventricular assist device, replacement only</td>
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<td></td>
<td>Q0492</td>
<td>Emergency power supply cable for use with electric ventricular assist device, replacement only</td>
</tr>
<tr>
<td>Type</td>
<td>Code</td>
<td>Description</td>
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<tr>
<td>-----------------------------</td>
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<td>-----------------------------------------------------------------------------</td>
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<tr>
<td></td>
<td>Q0493</td>
<td>Emergency power supply cable for use with electric/pneumatic ventricular assist device, replacement only</td>
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<tr>
<td></td>
<td>Q0494</td>
<td>Emergency hand pump for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0495</td>
<td>Battery/power pack charger for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0496</td>
<td>Battery, other than lithium-ion, for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0497</td>
<td>Battery clips for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0498</td>
<td>Holster for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0499</td>
<td>Belt/vest/bag for use to carry external peripheral components of any type ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0500</td>
<td>Filters for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0501</td>
<td>Shower cover for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0502</td>
<td>Mobility cart for pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0503</td>
<td>Battery for pneumatic ventricular assist device, replacement only, each</td>
</tr>
<tr>
<td></td>
<td>Q0504</td>
<td>Power adapter for pneumatic ventricular assist device, replacement only, vehicle type</td>
</tr>
<tr>
<td></td>
<td>Q0506</td>
<td>Battery, lithium-ion, for use with electric or electric/pneumatic ventricular assist device, replacement only</td>
</tr>
<tr>
<td></td>
<td>Q0507</td>
<td>Miscellaneous supply or accessory for use with an external ventricular assist device</td>
</tr>
<tr>
<td></td>
<td>Q0508</td>
<td>Miscellaneous supply or accessory for use with an implanted ventricular assist device</td>
</tr>
<tr>
<td></td>
<td>Q0509</td>
<td>Miscellaneous supply or accessory for use with any implanted ventricular assist device for which payment was not made under Medicare Part A</td>
</tr>
</tbody>
</table>

**Policy History**

This section provides a chronological history of the activities, updates and changes that have occurred with this Medical Policy.

<table>
<thead>
<tr>
<th>Effective Date</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>06/13/1997</td>
<td>BCBSA Medical Policy adoption</td>
</tr>
<tr>
<td>06/01/2001</td>
<td>Policy Unchanged</td>
</tr>
<tr>
<td>06/01/2003</td>
<td>MPC accepted as consent through CTAF February 2003, policy updated using BCBSA TEC 2002 Vol. 17, No. 19</td>
</tr>
<tr>
<td>10/01/2005</td>
<td>Policy unchanged; Title modified</td>
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<tr>
<td>12/07/2006</td>
<td>Policy revised, indications changed, adopted BCBSA MPP</td>
</tr>
<tr>
<td>10/28/2009</td>
<td>Coding Update</td>
</tr>
<tr>
<td>01/07/2011</td>
<td>Policy title change from Ventricular Assist Devices and Total Artificial Hearts. Policy revision with position change.</td>
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<tr>
<td>02/22/2013</td>
<td>Coding Update</td>
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<tr>
<td>03/29/2013</td>
<td>Policy revision with position change</td>
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<tr>
<td>07/31/2015</td>
<td>Coding update</td>
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</table>
### Definitions of Decision Determinations

**Medically Necessary:** Services that are Medically Necessary include only those which have been established as safe and effective, are furnished under generally accepted professional standards to treat illness, injury or medical condition, and which, as determined by Blue Shield, are: (a) consistent with Blue Shield medical policy; (b) consistent with the symptoms or diagnosis; (c) not furnished primarily for the convenience of the patient, the attending Physician or other provider; (d) furnished at the most appropriate level which can be provided safely and effectively to the patient; and (e) not more costly than an alternative service or sequence of services at least as likely to produce equivalent therapeutic or diagnostic results as to the diagnosis or treatment of the Member's illness, injury, or disease.

**Investigational/Experimental:** A treatment, procedure, or drug is investigational when it has not been recognized as safe and effective for use in treating the particular condition in accordance with generally accepted professional medical standards. This includes services where approval by the federal or state governmental is required prior to use, but has not yet been granted.

**Split Evaluation:** Blue Shield of California/Blue Shield of California Life & Health Insurance Company (Blue Shield) policy review can result in a split evaluation, where a treatment, procedure, or drug will be considered to be investigational for certain indications or conditions, but will be deemed safe and effective for other indications or conditions, and therefore potentially medically necessary in those instances.

### Prior Authorization Requirements (as applicable to your plan)

Within five days before the actual date of service, the provider must confirm with Blue Shield that the member's health plan coverage is still in effect. Blue Shield reserves the right to revoke an authorization prior to services being rendered based on cancellation of the member's eligibility. Final determination of benefits will be made after review of the claim for limitations or exclusions.

Questions regarding the applicability of this policy should be directed to the Prior Authorization Department at (800) 541-6652, or the Transplant Case Management Department at (800) 637-2066 ext. 3507708 or visit the provider portal at www.blueshieldca.com/provider.

Disclaimer: This medical policy is a guide in evaluating the medical necessity of a particular service or treatment. Blue Shield of California may consider published peer-reviewed scientific literature, national guidelines, and local standards of practice in developing its medical policy. Federal and state law, as well as contract language, including definitions and specific contract provisions/exclusions, take precedence over medical policy and must be considered first in determining covered services. Member contracts may differ in their benefits. Blue Shield reserves the right to review and update policies as appropriate.
Policy Statement: Bridge to Transplantation

Implantable ventricular assist devices (VADs) with U.S. Food and Drug Administration (FDA) approval or clearance may be considered medically necessary when used in accordance with device-specific, FDA-approved indications and contraindications as a bridge to heart transplantation for patients who are currently listed as heart transplantation candidates and not expected to survive until a donor heart can be obtained, or are undergoing evaluation to determine candidacy for heart transplantation.

Implantable VADs with FDA approval or clearance, including humanitarian device exemptions, may be considered medically necessary when used in accordance with device-specific, FDA-approved indications and contraindications as a bridge to heart transplantation in children 16 years old or younger who are currently listed as heart transplantation candidates and not expected to survive until a donor heart can be obtained, or are undergoing evaluation to determine candidacy for heart transplantation.

Total Artificial Hearts

Total artificial hearts (TAHs) with FDA-approved devices may be considered medically necessary when used in accordance with device-specific, FDA-approved indications and contraindications as a bridge to heart transplantation for patients with biventricular failure who meet all of the following criteria:

I. Have no other reasonable medical or surgical treatment options
II. Ineligible for other univentricular or biventricular support devices
III. Currently listed as heart transplantation candidates or are undergoing evaluation to determine candidacy for heart transplantation
IV. Not expected to survive until a donor heart can be obtained.
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**Destination Therapy**

Implantable VADs with FDA approval or clearance may be considered **medically necessary** when used in accordance with device-specific, FDA-approved indications and contraindications as destination therapy with end-stage heart failure patients who meet **both** of the following criteria:

I. Ineligible for human heart transplant for **one or more** of the following reasons:
   A. Age greater than 65 years
   B. Insulin-dependent diabetes with end-organ damage
   C. Chronic renal failure (serum creatinine greater than 2.5 mg/dL for greater than or equal to 90 days)
   D. Presence of other clinically significant condition (e.g., chronic irreversible hepatic, renal, or respiratory failure; systemic infection; coagulation disorders; life-limiting disease [cancer, neurologic damage, dialysis dependency]; uncorrected valvular disease; failure of medical compliance; chronic illicit drug or alcohol dependency; psychiatric condition leading to failure of medical compliance; inadequate psychosocial support)

II. **One** of the following REMATCH Study criteria:
   A. New York Heart Association (NYHA) class IV heart failure for greater than or equal to 60 days
   B. New York Heart Association class III or IV for 28 days, received greater than or equal to 14 days of support with intra-aortic balloon pump or dependent on intravenous inotropic agents, with 2 failed weaning attempts.

**Postcardiotomy Setting/Bridge to Recovery**

Implantable VADs with FDA approval or clearance may be considered **medically necessary** when used in accordance with device-specific, FDA-approved indications and contraindication in the postcardiotomy setting in patients who are unable to be weaned off cardiopulmonary bypass.

**Other Indications**

Other applications of implantable VADs or TAHs are considered **investigational**, including, but not limited to:
POLICY STATEMENT
(No changes)

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<tr>
<td>I. Use of TAHs as destination therapy</td>
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<tr>
<td>II. Use of non-FDA-approved or cleared implantable ventricular assist devices (VADs) or total artificial hearts (TAHs)</td>
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Percutaneous ventricular assist devices (pVADs) are considered **investigational** for all indications.

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