Chapter 12
Use of Echocardiography in Patients with Intracardiac Devices

Edward Chu, Karthik Seetharam, Brandon W. Calenda, and Farooq A. Chaudhry[†]

Abstract Intracardiac ventricular assist devices (VADs) are increasingly being used in the management of patients with severe heart failure refractory to medical therapy. In the CCU, echocardiography is utilized to confirm appropriate position and function of intracardiac VAD components as part of routine surveillance or in response to concerning signs and symptoms. This chapter will focus on the use of echocardiography in adult patients with durable continuous-flow left ventricular assist devices (LVADs) as well as short-term, percutaneous left- and right-sided Impella VADs.

Keywords Impella · Assist devices · Heart failure

Introduction

Intracardiac ventricular assist devices (VADs) are increasingly being used in the management of patients with severe heart failure refractory to medical therapy. In the CCU, echocardiography is utilized to confirm appropriate position and function of intracardiac VAD components as part of routine surveillance or in response to concerning signs and symptoms. This chapter will focus on the use of echocardiography in adult patients with durable continuous-flow left ventricular assist devices (LVADs) as well as short-term, percutaneous left- and right-sided Impella VADs. First-generation, pulsatile-flow surgical LVADs are no longer implanted and will not be discussed. Durable right ventricular assist devices do not contain intracardiac components and will also not be discussed.

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Dedication: This chapter is dedicated to the memory of Dr. Farooq Chaudhry who was a cherished colleague in the Division of Cardiology at Mount Sinai hospital. His untimely passing in 2017 has left a void in our hearts and minds.

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E. Herzog, E. Argulian (eds.), *Echocardiography in the CCU*,
https://doi.org/10.1007/978-3-319-90278-4_12

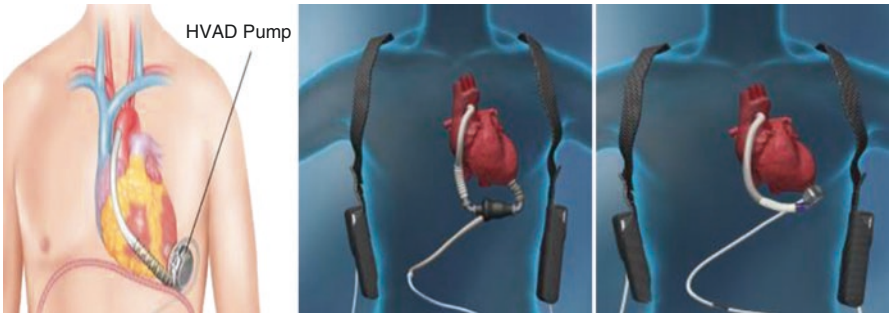

Fig. 12.1 FDA-approved CF LVADs: the HVAD, HeartMate II, and HeartMate III (far right)

Echocardiography in Continuous-Flow Left Ventricular Assist Devices

LVADs are indicated for use in patients with severe heart failure as a bridge to native heart recovery, a bridge to eventual heart transplant, or a destination therapy in those who are not heart transplant candidates. The LVADs currently approved by the FDA are the HeartWare HVAD and the Thoratec HeartMate II and III (Fig. 12.1).

The notable components of a continuous-flow LVAD include an inflow cannula that is inserted into the left ventricular apex, an outflow cannula that is inserted into the ascending aorta, an extracardiac pump that receives blood from the inflow cannula and delivers blood through the outflow cannula, and a driveline that runs from the pump to a wearable controller.

When to Consider Echocardiography

After LVAD implantation, echocardiographic examination can be performed for routine surveillance, in response to concerning signs, symptoms, or device alarms, or to optimize LVAD settings as part of a ramp study. During each echocardiographic examination, the LVAD speed (in rotations per minute, rpm) and blood pressure should be recorded as these conditions can alter the degree of unloading of the left ventricle. Comparisons of serial echocardiograms should also be made in the context of the LVAD speed and blood pressure. Echocardiographic examination of patients with LVADs includes the standard views as well as LVAD-specific views that interrogate the inflow cannula and outflow cannula, assess the impact and sequelae of left ventricular unloading by the LVAD, and evaluate for potential LVAD-related complications such as suction, aortic regurgitation, and thrombus formation.

Echocardiography for Routine Surveillance

The purpose of a surveillance echocardiogram is to trend baseline LVAD and native heart anatomy and function over time to ensure appropriate response to LVAD therapy and to detect subclinical LVAD or native heart abnormalities. After LVAD implantation, surveillance transthoracic echocardiograms should be performed prior to discharge from index hospitalization, 1 month after initial implant, every 3 months after initial implant in the first year, and every 6–12 months after the first year [1].

Echocardiography in Response to Signs, Symptoms, or Device Alarms

There should be a low threshold to perform echocardiographic examination in response to a deterioration in clinical status and/or new controller alarms as LVAD malfunction or inappropriate patient response to LVAD therapy can be fatal if not addressed. Common LVAD alarms include notifications related to changes in pulsatility index, changes to flow, suction triggers, and high-power consumption. LVAD-related complications detectable by echocardiography include intracardiac thrombus formation, intravascular hemolysis from motor-related shear stress, suction events, new or worsening aortic regurgitation, and inappropriate unloading conditions. These conditions will be further discussed in the section titled "Abnormal Findings on Echocardiogram."

Echocardiogram to Optimize LVAD Speed

An echocardiogram to optimize LVAD speed and its immediate effect on left heart function, known as unloading conditions, relative to baseline conditions is known as a ramp study. Ramp studies are often performed as part of routine surveillance or in response to concerning clinical features. Poor response to specific ramp study protocols can be suggestive of LVAD pump thrombosis [2].

During a ramp study, the unloading conditions as determined by the LV internal diastolic dimension (LVIDd), interventricular septum (IVS) orientation, aortic valve opening frequency/duration, and MR severity are tracked as the LVAD speed is incrementally increased to establish a LVAD minimum speed, maximum speed, and optimal speed. Relative to baseline measurements, the minimum speed is defined as the speed below which the LVIDd is increased and the IVS becomes shifted more rightward, aortic valve opening becomes more frequent, and the MR becomes more severe. Relative to baseline measurements, the maximum speed is defined as the speed above which the LVIDd is reduced and IVS shifts leftward leading to inflow cannula turbulence, obstruction or suction events, and the aortic valve ceases to open. The optimal speed occurs below the maximum speed when the aortic valve opening occurs with a frequency determined by the LVAD medical team (e.g., every third cardiac cycle).

Normal Findings on Echocardiogram

LVAD-specific transthoracic echocardiographic views are used to assess the inflow cannula, outflow cannula, and left heart unloading conditions. Standard views of native heart structures can be used to evaluate for LVAD-related complications such as aortic regurgitation, vegetations, and intracardiac thrombus.

Inflow Cannula

The inflow cannula, typically implanted at or near the cardiac apex, is best visualized on transthoracic echocardiogram in the parasternal long-axis or apical views. Although direct visualization may be challenging due to image quality or device material artifact, several parameters should be identified.

On direct visualization, the inflow cannula should be free of any adherent masses. Color Doppler assessment should demonstrate laminar flow from the left ventricle to the outflow cannula. Inflow should not be impeded by the interventricular septum. Pulsed and CW Doppler should demonstrate low-velocity, continuous flow throughout the cardiac cycle. Due to intrinsic left ventricle contractility, the waveform will always be somewhat pulsatile, even when the ventricle is appropriately off-loaded and the aortic valve does not open. In a normally functioning device, peak systolic velocity should be less than 1.5 m/s [1]. Accurate Doppler interrogation of the inflow cannula frequently requires off-axis, individualized views to ensure an angle of interrogation parallel to flow.

Of note, in the HVAD, and at times the HeartMate III, color and spectral Doppler may be severely limited or unavailable due to Doppler artifact caused by the proximity of the impeller to the inflow cannula [1].

Outflow Cannula

Unlike the inflow cannula, which can be seen on standard TTE views, the outflow cannula requires atypical views. The aortic anastomosis is best visualized on transthoracic echocardiogram in a high left parasternal long-axis view. In some patients, this can also be seen in a supraclavicular or suprasternal view. Similar to the inflow cannula, pulsed and CW Doppler profiles should be obtained. The waveform will again show mild pulsatility with continuous flow throughout diastole. Although there are no clear benchmarks for abnormal peak systolic velocity at the outflow cannula, normal velocities should generally be less than 2 m/sec[1].

Unloading Conditions

Left heart unloading conditions are a means of assessing the extent to which the failing, dilated left ventricle has been decompressed and bypassed by the LVAD. This is largely modulated by the speed of the LVAD. Loading conditions are best appreciated in the parasternal long-axis and the apical four-chamber views. An optimally unloaded left ventricle should display the following characteristics:

- The LV internal diastolic dimension (LVIDd) should be significantly reduced compared with the preimplantation echo.
- The interventricular septum should be midline or shifted toward the left ventricle as compared with the preimplantation echo. The septum should not be bowing toward or obstructing the inflow cannula.
- The aortic valve should not open with every cardiac cycle (although the ideal frequency of aortic valve opening is often patient and physician dependent).
- Mitral regurgitation should be less than that seen on the preimplantation echo.
- Tricuspid regurgitation and RVSP should be less than that seen on the preimplantation echo.

Abnormal Findings on Echocardiogram

There are a number of key, pathologic echocardiographic findings which are important to recognize, whether the echo is performed for routine follow-up or to investigate concerning signs or symptoms. These findings must be integrated with the clinical situation and device alarms to arrive at an appropriate diagnostic plan.

Excessive Unloading and Suction Events

As discussed above, when the LV is appropriately unloaded, the LVIDd decreases and the IVS shifts leftward, and the aortic valve opens infrequently or not at all. Taken to extremes, the LV cavity can become small and underfilled, leading to significant leftward shift of the interventricular septum. This can lead to "suction events," in which nearby endocardium (typically septum) is transiently pulled into the path of the inflow cannula, leading to impaired flow through the inflow cannula and ventricular arrhythmias due to local irritation of the "sucked in" endocardium. Intermittent high velocities at the inflow cannula can be seen. Suction events can result from inappropriately high LVAD speeds and may be exacerbated by conditions of decreased LV preload, as may be seen in hypovolemia, RV failure, or cardiac tamponade. This typically manifests as low-flow alarms on the VAD.

Excessive unloading, with its leftward shift of the septum, alters RV geometry with multiple potential downstream effects. Progressive RV dysfunction can result from increased RV end-diastolic volume, impaired RV systolic function, and increased tricuspid regurgitation.

Inadequate Unloading

The characteristics of an inadequately unloaded LV include a minimal or absent decrease in LVIDd, rightward-shifted IVS, increased mitral regurgitation, increased right-sided pressures, and aortic valve opening with every cardiac cycle. This can result from inappropriately low LVAD speeds or pump malfunction. This frequently manifests as high-flow alarms on the VAD.

Thrombosis

LVAD thrombosis is a feared complication in the care of patients with durable LVADs. Pump thrombosis is usually not directly visualized on echocardiography, and its presence must be inferred from the available data. Pump thrombosis usually manifests with signs of inadequate unloading, along with increased speed and power requirements, as may be demonstrated during a ramp study [2]. Other supportive signs include reduced inflow or outflow cannula Doppler velocities. If thrombosis or obstruction is localized to the outflow graft, increased peak systolic velocities may be seen on Doppler interrogation of the outflow tract. This is associated with high-flow alarms on the VAD.

Cardiac Tamponade

Although the features of cardiac tamponade are well described elsewhere in this text, there are some unique features to tamponade in the presence of LVAD which bear mentioning. In the postoperative state, there may be pericardial hematoma rather than free-flowing effusion. Both the LV and RV may appear underfilled, and typical features of ventricular interdependence may not be seen. Valve inflow velocities, specifically mitral inflow velocities, often do not have excessive respiratory variation due to the presence of the LVAD. Thus, in the presence of low-flow alarms and significant clinical suspicion, one should not depend upon "classic" features of tamponade to make the diagnosis.

Echocardiography in Impella Ventricular Assist Devices

The Abiomed portfolio of Impella heart pumps, including the left heart systems Impella 2.5, 5.0, CP, and LD, as well as the right heart Impella RP, are short-term ventricular assist devices used to augment cardiac output in critically ill patients

with advanced heart failure or undergoing complex cardiac intervention. Correct positioning of the Impella catheter in the ventricular outflow tract and associated great vessel is critical for proper device functioning. During initial implantation, fluoroscopy is necessary to guide placement of the Impella catheter. After implantation, catheter-related complications can develop, leading to hemodynamic instability and activation of device alarms. In these acute situations, echocardiography is commonly used to reassess catheter position and function.

Impella 2.5, 5.0, CP, and LD [3, 4]

The left heart Impella catheter systems, including the Impella 2.5, 5.0, CP, and LD, are indicated for use in patients with ongoing cardiogenic shock immediately after myocardial infarction or open-heart surgery. The Impella 2.5 and CP can be additionally used in patients with depressed left ventricular ejection fraction ≤35% without three-vessel disease or ≤30% with three-vessel disease and undergoing high-risk percutaneous coronary intervention. The Impella 2.5, 5.0, and CP catheter systems can be implanted percutaneously, whereas the Impella LD can only be implanted surgically (Fig. 12.2).

When to Consider Echocardiography

Transthoracic or transesophageal echocardiogram allows for simultaneous visualization of the inlet and outlet areas of the left heart Impella catheters and is the preferred imaging modality for routine position surveillance or in response to signs,

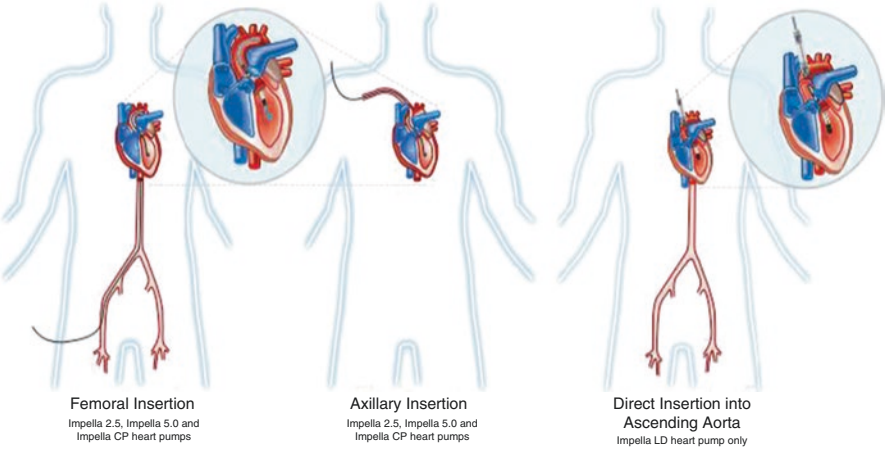

Fig. 12.2 Implantation techniques for left heart Impella pumps

Table 12.1 Concerning indicators of left heart Impella pump malfunction

Symptoms	Chest discomfort, shortness of breath, palpitations, light-headedness, and loss of consciousness
Vital signs	Hypotension, tachycardia, and hypoxemia
Physical exam	Features of left-sided heart failure (lung crackles, new S3 or S4 murmur, etc.)
ECG/telemetry	PVC, NSVT, VT/VF
Labwork	Markers of poor perfusion (increased lactate, decreased pH, etc.), markers of hemolytic anemia (decreased hemoglobin/hematocrit, increased LDH, decreased haptoglobin, etc.)
Cardiac imaging (CXR, CT, MRI, etc.)	Movement of Impella catheter on serial studies
Impella Controller display	Abrupt change in the placement signal (waveform or pressure reading) Abrupt change in motor current (waveform or current reading) Abrupt change in flow reading
Impella catheter position alarms	Including but not limited to: Impella position in the ventricle Impella position wrong Impella position unknown Impella outflow blocked Impella flow reduced Suction

symptoms, and device alarms concerning for Impella malfunction. Similar to intra-aortic balloon pumps and endotracheal tubes, the Impella catheter can migrate as a result of excess "slack" or patient movement or inadvertently from necessary medical care. Displacement and/or obstruction of the catheter inlet and outlet areas can lead to blood flow disturbances which may in turn cause electrical and mechanical cardiac dysfunction. The following signs, symptoms, and device features may be indicative of Impella catheter malfunction (Table 12.1):

Normal Position on Echocardiogram

The distal portion of the left heart Impella catheters is notable for the motor housing unit, blood outlet area, a 6–8 cm cannula, a blood inlet area, and a pigtail end in the Impella 2.5, 5.0, and CP or a straight end in the Impella LD. The cannula for the Impella 2.5, 5.0, and CP catheters is longer and contains a slight bend, whereas the cannula for the Impella LD catheter is shorter and straight (Fig. 12.3).

Visualization of both the distal catheter inlet and outlet orientation in the left ventricular outflow tract and ascending aorta is best achieved with parasternal long-axis transthoracic echocardiogram view or with long-axis transesophageal view. When properly positioned in the heart, the inlet area should be in the left ventricular outflow tract approximately 3.5 cm below the aortic valve, and the outlet area should be distal to the aortic valve in the ascending aorta. The catheter inlet area can be distinguished by faint railroad track markings, whereas the outlet area is hyperechoic in appearance relative to the adjacent cannula. Except for the cannula which

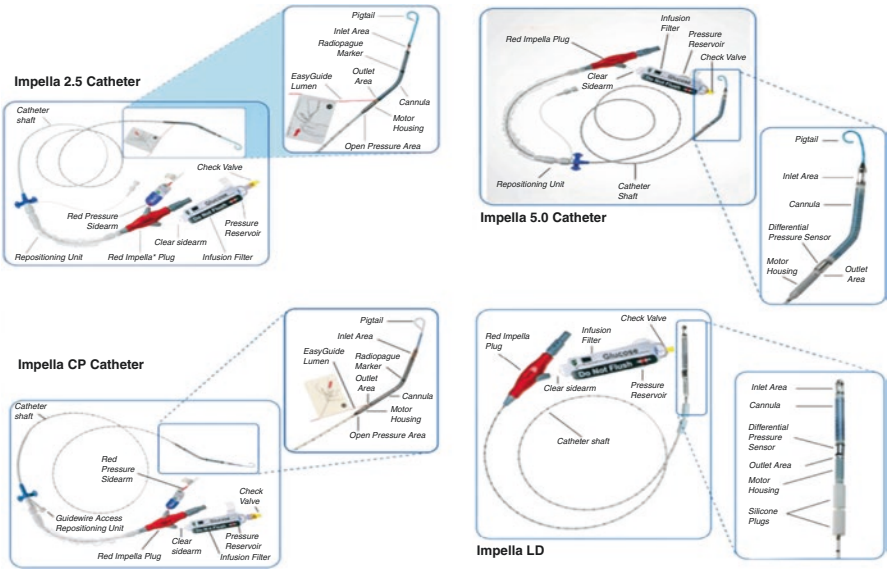

Fig. 12.3 Anatomy of left heart Impella catheters

is in contact with the aortic valve leaflets, no portion of the distal Impella catheter should be in contact with cardiac structures, including the left ventricular wall and mitral valve apparatus (Figs. 12.4 and 12.5).

Color Doppler analysis over the correctly positioned outlet area will show a dense mosaic pattern consistent with turbulent blood flow above the aortic valve in the ascending aorta (Fig. 12.6).

Abnormal Findings on Echocardiogram

The most common catheter-related abnormalities detected on echocardiogram are the presence of adherent masses and changes to catheter position. Masses adherent to the catheter surface are most concerning for thrombus or infected vegetation. By protocol, patients with an implanted left heart Impella catheter should be receiving anticoagulation with a goal ACT 160–180 s to prevent thrombus formation. Infected vegetation should be considered in individuals with signs and symptoms of endocarditis, including fever and positive blood cultures.

Minor position fluctuations of the left heart Impella catheter from the motion of nearby blood flow and surrounding cardiac structures are unlikely to have any functional consequence on device operation or patient hemodynamic parameters. Major position changes necessitating catheter adjustment occur when the catheter inlet area moves above the aortic valve, the catheter outlet area moves below the aortic valve, or a contact between the catheter and nearby cardiac structures leads to device or cardiac displacement. Echocardiography can be used to detect and guide repositioning of the Impella catheter in each of these three situations.

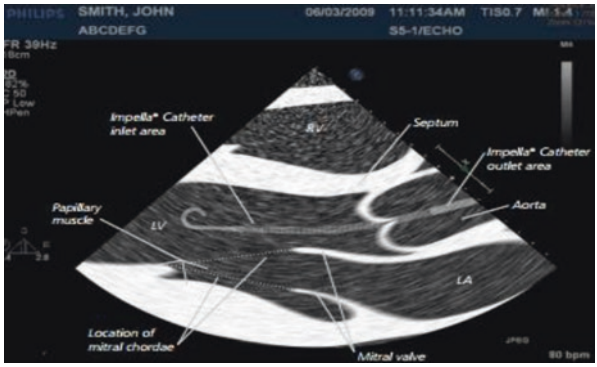

Fig. 12.4 Correct Impella catheter position on transthoracic echocardiogram parasternal long-axis view

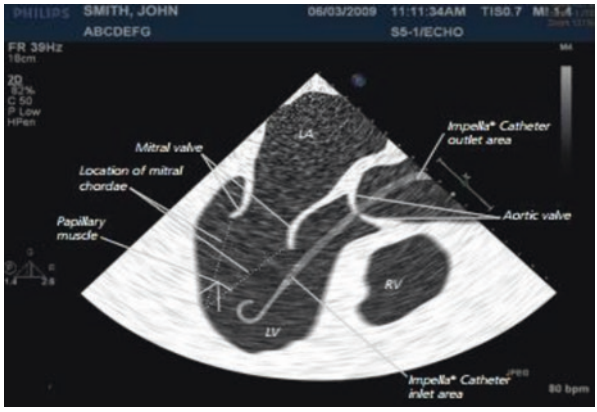

Fig. 12.5 Correct Impella catheter position on transesophageal echocardiogram long-axis view

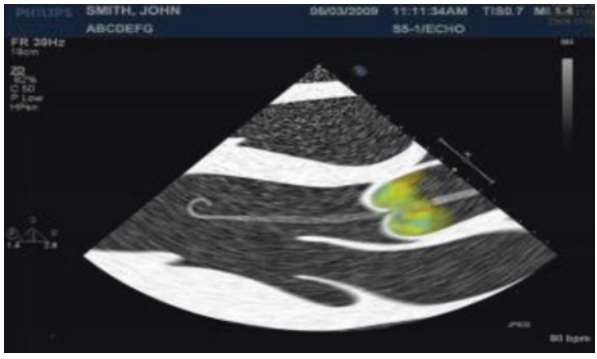

Fig. 12.6 Correct Impella catheter position on transthoracic echocardiogram parasternal long-axis view with color Doppler flow

Impella Catheter Moves Too Far into the Left Ventricle

If the Impella catheter has migrated too far into the left ventricle, the outlet area may be incorrectly positioned below the aortic valve. Blood flow from the catheter inlet area to the outlet area is recycled within the left ventricle, and there is no augmentation of cardiac output. On echocardiogram, the most distal end of the Impella catheter will appear below the midpoint of the left ventricular cavity and close to the LV apex. The radiopaque portion of the outlet area will appear within the left ventricular outflow tract (Fig. 12.7).

Impella Catheter Moves Too Far Out of the Left Ventricle

If the Impella catheter has migrated too far out of the left ventricle, the inlet area may be incorrectly positioned above the aortic valve. Blood flow from the catheter inlet area to the outlet area is recycled within the thoracic aorta, and there is no augmentation of cardiac output. On echocardiogram, the terminal portion of the Impella catheter will appear above the midpoint of the left ventricular cavity and in extreme cases entirely out of the left ventricle. The railroad track appearance of the inlet area will appear within the ascending aorta. If the Impella catheter is completely out of the left ventricle, it should not be repositioned into the left ventricle without the use of a guidewire under fluoroscopic guidance (Fig. 12.8).

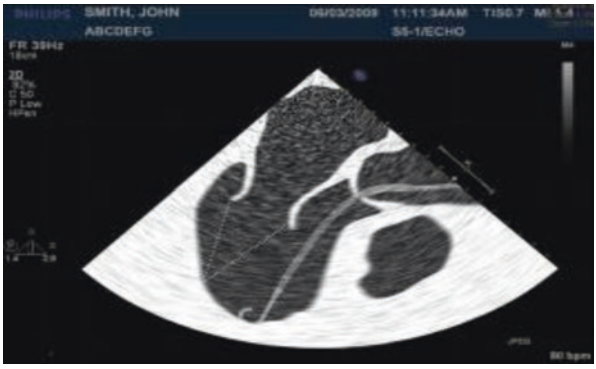

Fig. 12.7 Impella catheter too far into the left ventricle on transesophageal echocardiogram

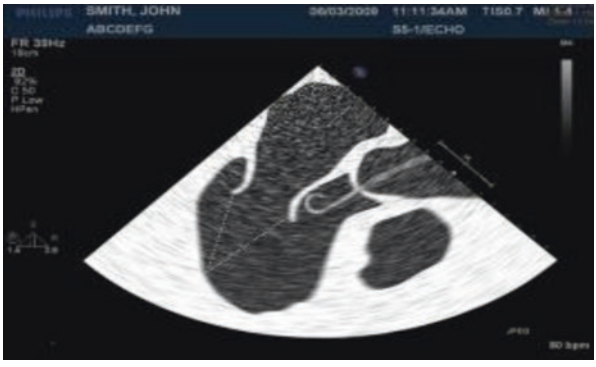

Fig. 12.8 Impella catheter too far out of the left ventricle on transesophageal echocardiogram

Impella Catheter in Contact with Cardiac Structures

If a portion of the Impella catheter is caught on or against a cardiac structure, it may lead to partial or complete obstruction of the catheter inlet and/or outlet causing hemolysis, low pump flow, and suction events. Irritation of the left ventricular wall by the catheter can lead to ventricular ectopy, NSVT, or VT/VF. Entanglement of the catheter in the chordae tendineae or papillary muscles can disrupt mitral valve function resulting in mitral regurgitation. Similar entanglement of the distal pigtail in the aortic leaflets can result in aortic regurgitation. On echocardiogram, the Impella catheter will be found against the endocardium and moving simultaneously with cardiac systole and diastole. In some cases, gentle manipulation of the proximal Impella catheter from the percutaneous access site may be sufficient in relieving contact of the distal catheter from adjacent cardiac structures. If there is risk of damaging adjacent cardiac structures or extensive entanglement, the use of a guidewire may be required (Fig. 12.9).

Impella RP [4, 5]

The right heart Impella RP is indicated for use in patients with acute right heart failure, defined by echocardiographic criteria global RV hypokinesis, TAPSE score ≤14 mm, RV base diameter >42 mm, or RV mid-cavity diameter >35 mm, after LVAD implant, MI, heart transplant, or open-heart surgery. The Impella RP is the first short-term percutaneous right ventricular assist device (Fig. 12.10).

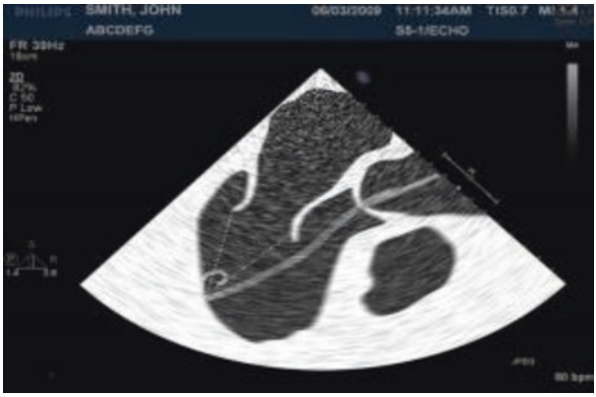

Fig. 12.9 Impella catheter in contact with the left ventricular wall on transesophageal echocardiogram

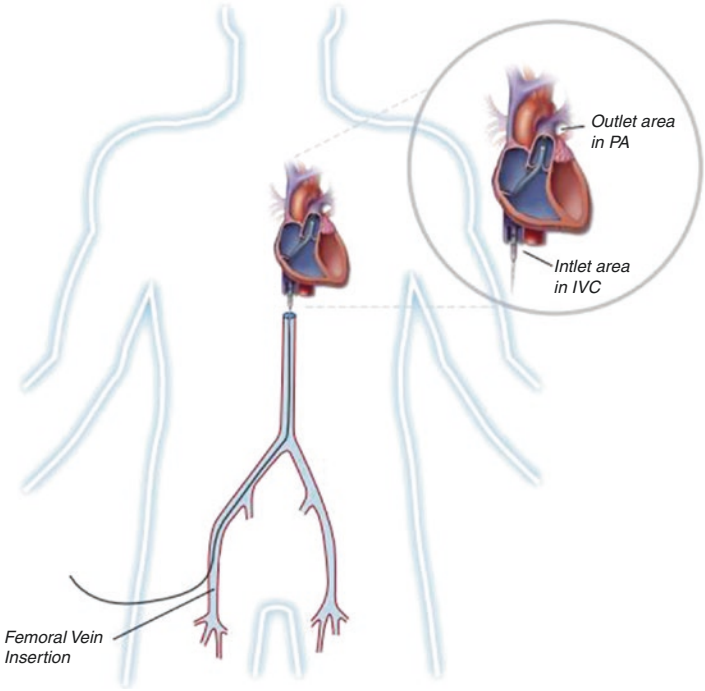

Fig. 12.10 Implantation techniques for Impella RP

When to Consider Echocardiography

Daily chest X-ray is the preferred imaging modality for position surveillance of the Impella RP catheter as echocardiogram is unable to simultaneously display both the inlet and outlet areas in the same view. However, the position of the inlet and outlet areas can be separately evaluated by echocardiogram in greater detail than can be provided by chest X-ray. Similar to the left heart Impella catheters, the Impella RP catheter can migrate as a result of excess "slack" and patient movement or inadvertently from necessary medical care. Displacement and/or obstruction of the catheter inlet and outlet areas can lead to blood flow disturbances which may in turn cause electrical and mechanical cardiac dysfunction. The following signs, symptoms, and device features may be indicative of Impella RP catheter malfunction (Table 12.2).

Normal Position on Echocardiogram

The distal Impella RP catheter is notable for the motor housing unit, blood inlet area, a 16 cm cannula, a blood outlet area, and a pigtail end (Fig. 12.11).

Table 12.2 Concerning indicators of Impella RP malfunction

Symptoms	Chest discomfort, shortness of breath, palpitations, light-headedness, loss of consciousness
Vital signs	Hypotension, tachycardia, hypoxemia
Physical exam	Features of right-sided heart failure (elevated JVD, hepatomegaly, LE edema, etc.)
ECG/telemetry	PVC, NSVT, VT/VF
Labwork	Markers of poor perfusion (increased lactate, decreased pH, etc.), markers of hemolytic anemia (decreased hemoglobin/hematocrit, increased LDH, decreased haptoglobin, etc.)
Cardiac imaging (CXR, CT, MRI, etc.)	Movement of Impella catheter on serial studies
Impella Controller display	Abrupt change in placement signal (waveform or pressure reading) Abrupt change in motor current (waveform or current reading) Abrupt change in flow reading
Impella catheter alarms Note: The Impella RP does *not* have specific position alarms	Alarms suggestive of position change may include: Impella failure Impella stopped Retrograde flow Placement signal not reliable Suction

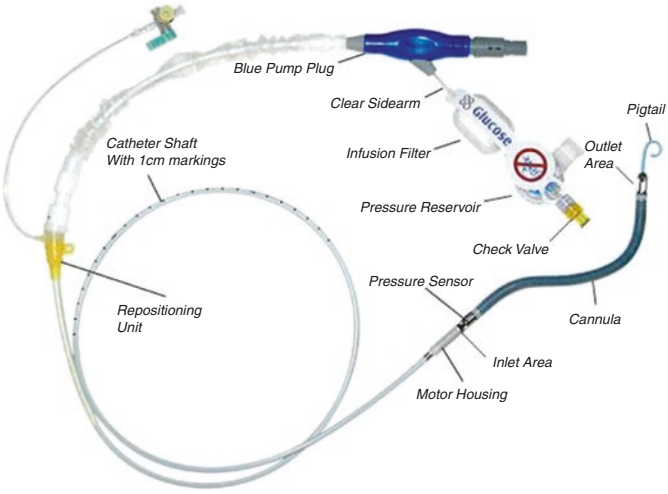

Fig. 12.11 Anatomy of Impella RP catheter

When properly positioned in the heart, there are three bends in the cannula corresponding to the presence of the IVC/RA junction, tricuspid valve, and pulmonic valve. Based on this configuration, the inlet area should rest in the IVC at the level of the diaphragm, and the outlet area should be 2–4 cm distal to the pulmonic valve typically in the pulmonary trunk or left pulmonary artery. This positioning is most readily seen on chest X-ray, as shown below (Fig. 12.12).

On echocardiogram, the Impella RP catheter inlet area can be best seen in the IVC/RA junction from the transthoracic subcostal view or from the trans-

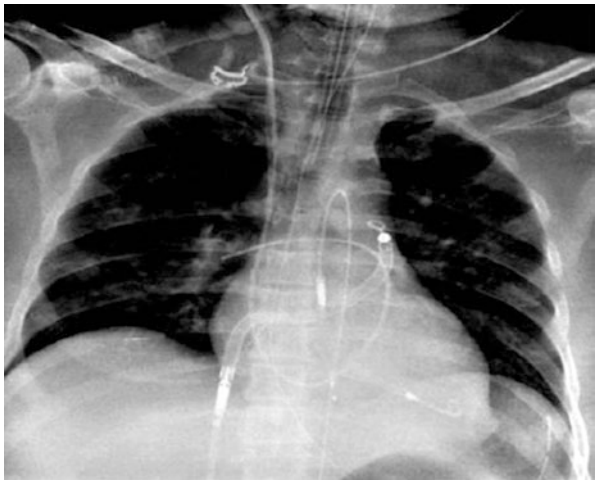

Fig. 12.12 Chest X-ray of correct Impella RP position

esophageal bicaval view. The inlet area can be identified by its faint railroad tracking markings. The Impella RP outlet area can be best seen just beyond the pulmonic valve in the pulmonary trunk from the transthoracic parasternal short-axis view or from the transesophageal mid-esophageal long-axis view. The outlet area can be identified by its hyperechoic appearance and should be 2–4 cm beyond the pulmonic valve. Color Doppler over the inlet and outlet area will reveal mosaic pattern of blood flow turbulence. Except for the cannula which is in contact with the tricuspid and pulmonic valve leaflets, no portion of the terminal Impella catheter should be in contact with cardiac structures, including the right ventricular wall and tricuspid valve apparatus. Representative images of the Impella RP catheter in proper positioning are shown below (Figs. 12.13 and 12.14).

Abnormal Findings on Echocardiogram

The most common catheter-related abnormalities detected on echocardiogram are the presence of adherent masses and changes to catheter position. Masses adherent to the catheter surface are most concerning for thrombus or infected vegetation. By protocol, patients with an implanted Impella RP catheter should be receiving anticoagulation with a goal ACT 160–180 s to prevent thrombus formation. Infected vegetation should be considered in individuals with signs and symptoms of endocarditis, including fever and positive blood cultures.

Minor position fluctuations of the Impella RP catheter from the motion of nearby blood flow and surrounding cardiac structures are unlikely to have any functional consequence on device operation or patient hemodynamic parameters. In addition, migration of the catheter inlet area further into or out of right atrium is also unlikely to cause any significant device or hemodynamic dysfunction as long as the outlet area remains above the pulmonic valve. Major position changes

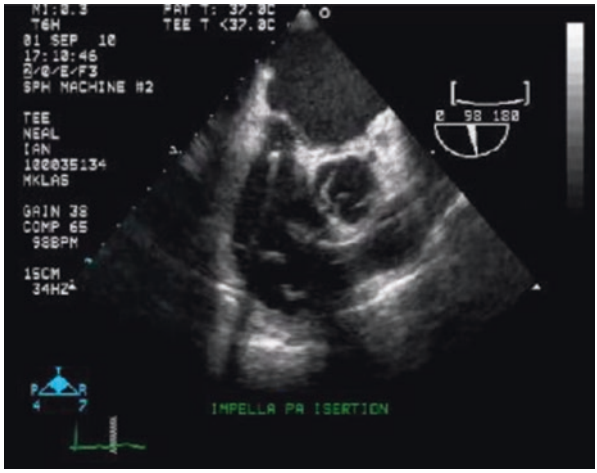

Fig. 12.13 Correct Impella RP catheter position on transesophageal echocardiogram, mid-esophageal long-axis view optimized for right ventricular outflow tract

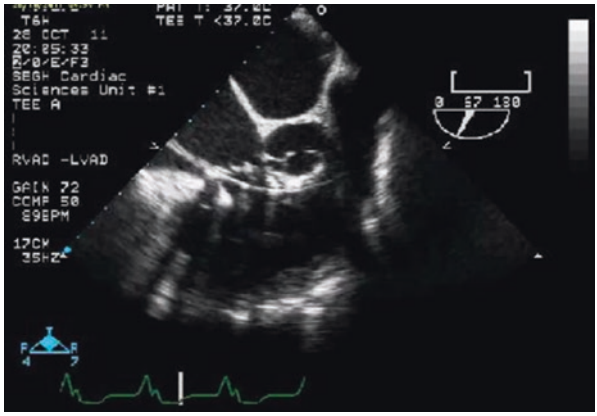

Fig. 12.14 Correct Impella RP catheter position on transesophageal echocardiogram, mid-esophageal long-axis view optimized for tricuspid valve

necessitating catheter adjustment occur when the catheter outlet area moves below the pulmonic valve or contact between the catheter and nearby cardiac structures leads to device or cardiac dysfunction. Echocardiography can be used to detect and guide repositioning of the Impella catheter in each in both of these situations.

Impella Outlet Area Below Pulmonic Valve

If the pigtail of the Impella RP catheter has migrated back toward the right ventricle, the outlet area may become incorrectly positioned below the pulmonic valve. Blood flow from the catheter inlet area to the outlet area becomes recycled within the right ventricle and with no augmentation of cardiac output. On echocardiogram, the

"silver ball" outlet area of the Impella RP catheter will appear in the right ventricular cavity. Color Doppler analysis of the pulmonary trunk or left main pulmonary artery will show absence of the mosaic pattern of blood flow turbulence consistent with the presence of the outlet area. Similar to a Swan-Ganz catheter, the Impella RP catheter can be repositioned at beside with guidance from waveform tracings on the Impella Controller display. Echocardiography and/or CXR can be used to confirm correct placement.

Impella Catheter in Contact with Cardiac Structures

If a portion of the Impella RP catheter is caught on or against a cardiac structure, it may lead to partial or complete obstruction of the catheter inlet and/or outlet causing hemolysis, low pump flow, and suction events. Irritation of the right ventricular wall by the catheter can lead to ventricular arrhythmias. Entanglement of the catheter in the chordae tendineae can disrupt tricuspid valve function resulting in tricuspid regurgitation. Similar entanglement of the distal pigtail in the pulmonic leaflets can result in pulmonic regurgitation. On echocardiogram, the Impella catheter will be found against the endocardium and moving simultaneously with cardiac systole and diastole. Gentle manipulation of the proximal Impella catheter repositioning unit near the percutaneous access site may be sufficient in relieving contact of the distal catheter from adjacent cardiac structures. If there is risk of damaging adjacent cardiac structures or extensive entanglement, the use of a guidewire may be required.

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