Advanced Hemodynamic Support

27

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Introduction

The advances in interventional cardiology have resulted in the shift towards PCI as opposed to CABG in high-risk complex lesions, especially in surgically non-amenable lesions. The use of LV assist devices has increased the odds of success and has decreased mortality, morbidity, and overall healthcare costs [1–4]. Cardiogenic shock complicates 5–8% of STEMI and is a major cause of in-hospital mortality up to 50% [5]. Unloading of the myocardium mechanically may limit infarct size, maintain end-organ perfusion, and decrease myocardial oxygen demand [6–8].

Commonly Used Advanced Hemodynamic Support

A good percutaneous circulatory support device should be placed without significant complications and provide an output of >2 L/min for hours to days without an external blood circuit. The two commonly used are Intra-Aortic Balloon Pump (IABP) (Fig. 27.1) and Impella 2.5 LP/CP systems (Abiomed). Tandem Heart is now infrequently used. Table 27.1 highlights the indications of hemodynamic support in PCI. Table 27.2 shows our selection algorithm for the type of hemodynamic support device.

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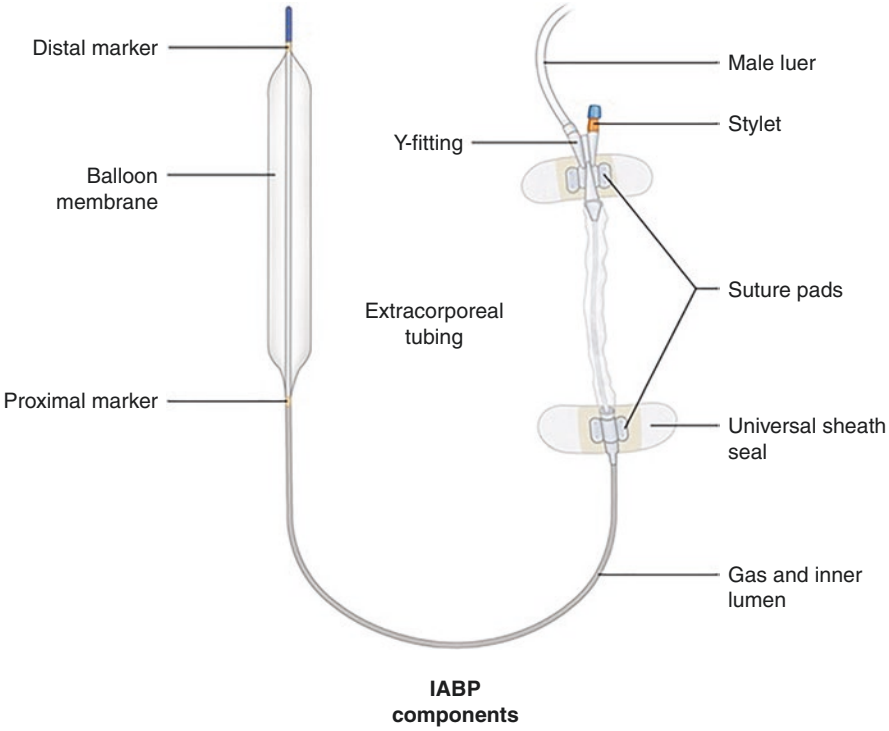


Fig. 27.1 Intra-aortic balloon pump (IABP)

Table 27.1 Indications for hemodynamic support in PCI

Indications
Cardiogenic shock
Severe LV dysfunction
Mechanical complications of an AMI
Complex coronary lesions (such as unprotected left main disease, complex multivessel disease, last remaining conduit vessel, and bypass graft disease)
As a bridge to further therapy:
Prophylaxis in patients with severe left main coronary artery stenosis
Intractable myocardial ischemia
Refractory heart failure
Intractable ventricular arrhythmia

Table 27.2 Algorithm for LV support device use

LVEF	Simple PCI	Complex PCI
>35%	No support	IABP
20–35%	IABP	Impella
<20%	Impella	Impella

Intra-Aortic Balloon Pump (IABP)

IABP is used in 30% of patients undergoing complex PCIs in the USA and requires a patient to have a certain level of residual left ventricular function to be effective. It is an over-the-wire balloon catheter with a fiber optic sensor for beat-to-beat adjustment and accuracy. It could be implanted with relative ease and low cost with a low complication rate.

Contraindications

- Severe aortic insufficiency.
- Aortic aneurysm.
- Aortic dissection.
- Limb ischemia.

Complications

- Table 27.3 details potential complications associated with IABP use.

Balloon Size

- 35 cm balloon if patient's height is <5 ft.
- 40 cm balloon if patient's height is between 5 and 6 ft (most commonly used).
- 50 cm balloon if patient's height is >6 ft.

Table 27.3 Potential complications of IABP

Access site complications	Aortic dissection	Limb ischemia	Thrombocytopenia
Bleeding	–	–	Check CBC daily
Infection	Prevent by inserting balloon over wire	Avoid by using the smallest sheath size and use the limb with the strongest pulse	Asses for HIT
Vascular complications	Assess daily for pain between shoulder blades	Use Xylocaine for spasm	Decrease or stop heparin
Compartment syndrome	Remove IABP and surgery for repair if needed	Bypass graft for the affected extremity if needed and change insertion site to the opposite limb	Transfuse platelets as needed

Access

- Obtain optimal femoral access or use preexisting access to place the 7 Fr or 8 Fr sheath that comes with a balloon pump kit.
- Sheathless in morbid obesity or scarring of the groin.
- Use a shallow angle of insertion <45°.
- Advance catheter in small steps of less than 1 in. at a time to avoid kinking.
- If kinking is suspected, reposition by pulling back half an inch.

Balloon Preparation Before Insertion

- Open the tray and do not remove the balloon from the T handle sheath.
- Attach the one-way valve to male Luer fitting of IABP catheter (Fig. 27.2) and a 60 cc syringe.
- Negative pressure on the balloon (about 30 cc) × 2 with the balloon tip remaining inside the sheath and detach the syringe only leaving the one-way valve in place of the IABP (Fig. 27.3).
- Remove stylet, and flush the inner lumen with 3–5 cc of flush solution. Elevate flush bag at least 3 ft above transducer and connect to pressure @ 300 mmHg to maintain a 3 cc/h continuous flow through the inner lumen of the IABP (Fig. 27.4).

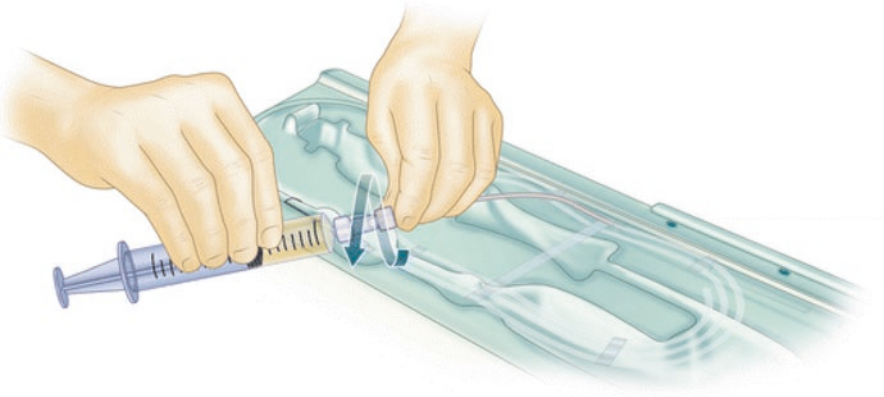


Fig. 27.2 Attach the one-way valve to the main Luer fitting of the IABP catheter and a 60 cc syringe

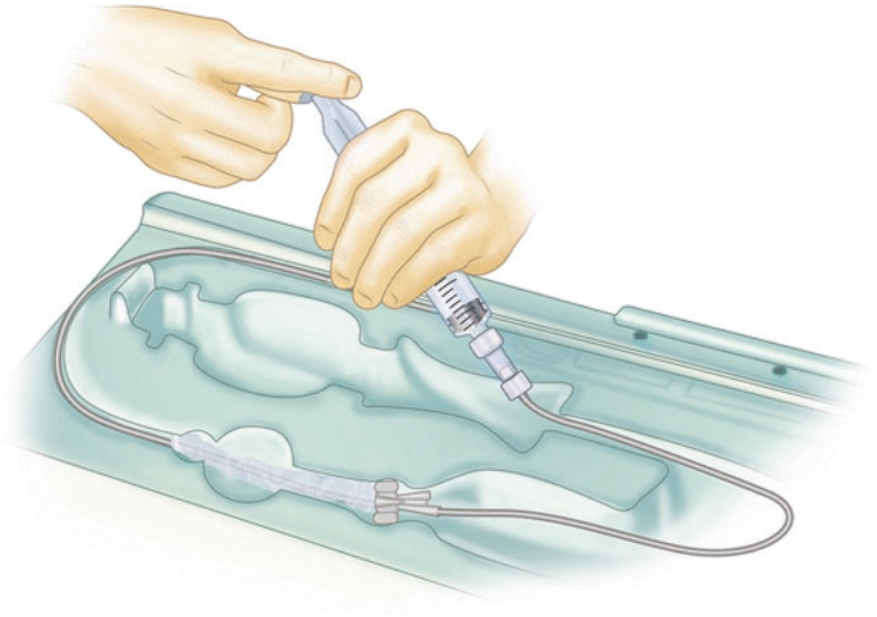


Fig. 27.3 Negative pressure on the balloon

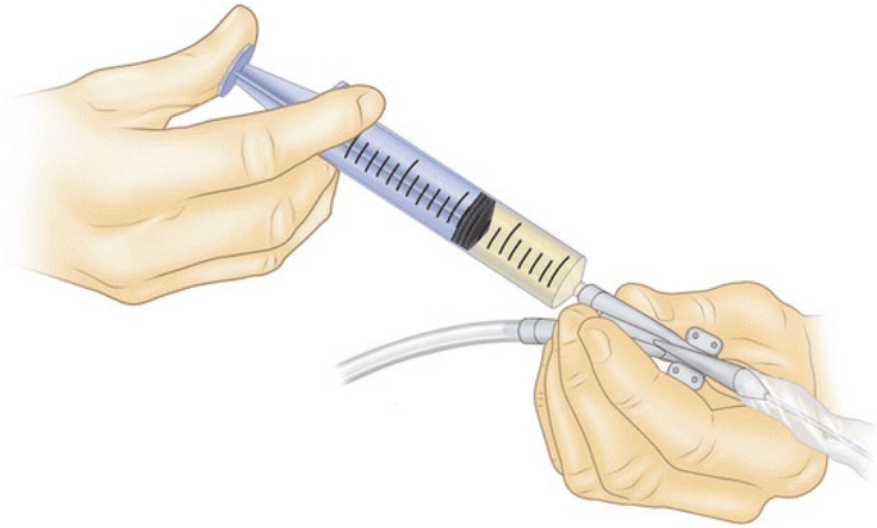


Fig. 27.4 Flush the inner lumen

Balloon Insertion

- Place an 8Fr catheter in the femoral artery with needle insertion at <45° angle (Fig. 27.5).
- Remove IABP by pulling straight from the T handle. Do not dip, wipe, or handle the membrane before insertion (Fig. 27.6).
- Advance 0.018″ wire to the level of the aortic arch. Using small short movements, advance the balloon over the wire until the distal tip is at the level of the carina. The proximal tip should be above the renal arteries.

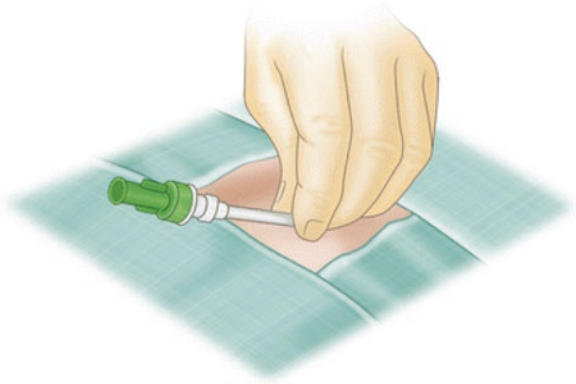


Fig. 27.5 Insert 8 Fr sheath

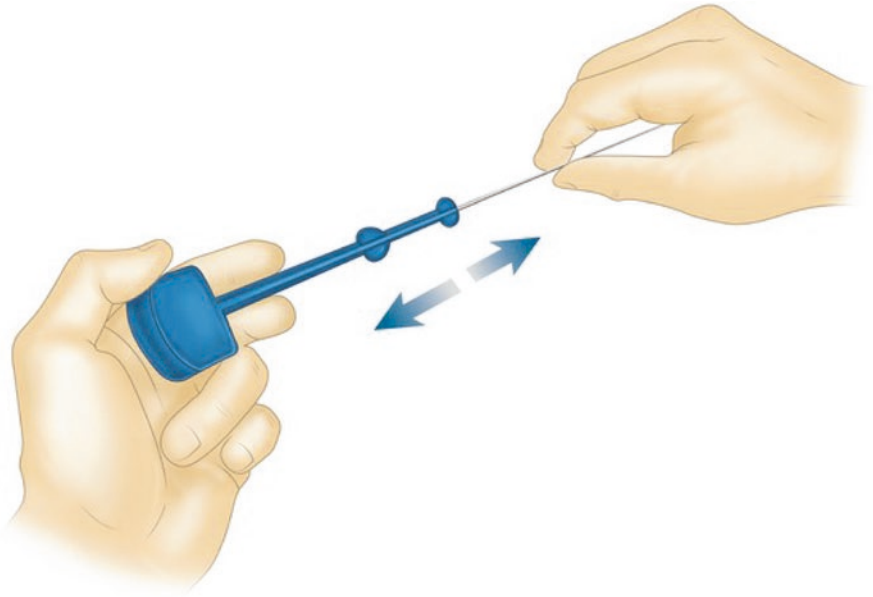


Fig. 27.6 Remove IABP by pulling straight

- Advance sheath seal as far as possible into the hub of the sheath and secure the IABP catheter to the patient's leg using STATLOCK® or sutures (Fig. 27.7).
- Remove guidewire, aspirate back 3–5 cc of blood from the inner lumen and flush with another 5 cc of flush solution (Fig. 27.8).

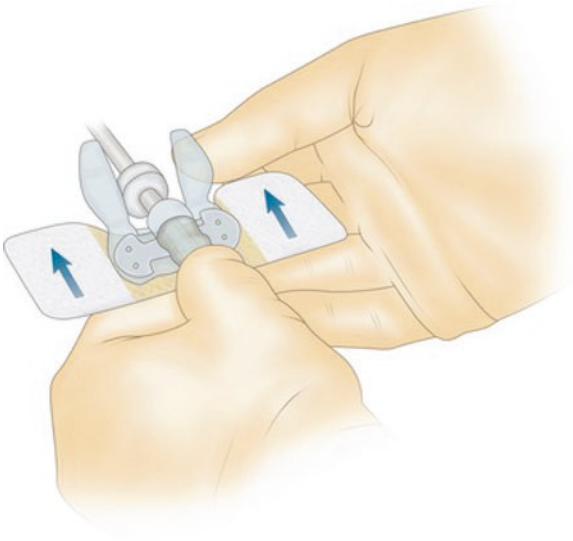


Fig. 27.7 Secure IABP with STATLOCK® or sutures

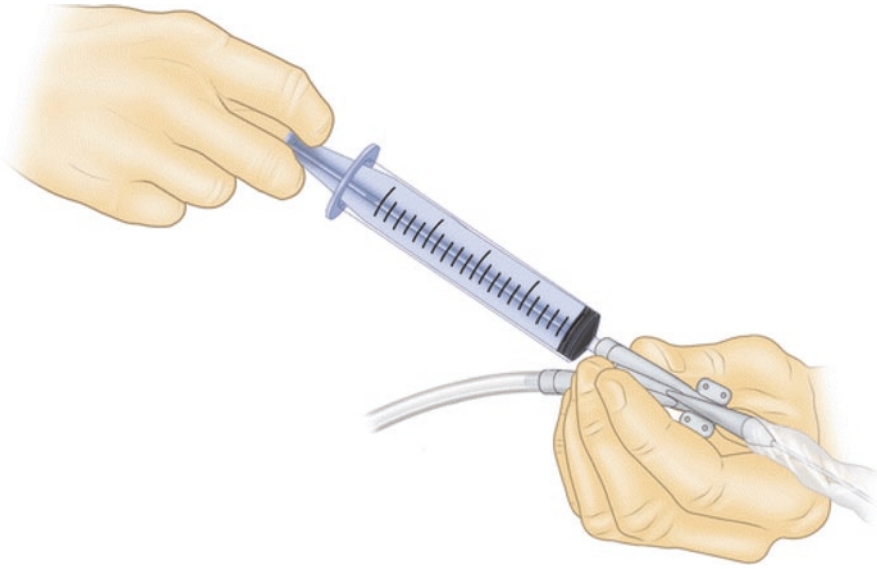


Fig. 27.8 Flush catheter

- Remove one-way valve from the IABP catheter and attach male Luer to female Luer fitting of Pneumatic Module of IABP (Fig. 27.9). Hand over fiber optic cable, if IABP is fiber optic, to the technician (Fig. 27.10).
- Press the "start button."
- Select mode:

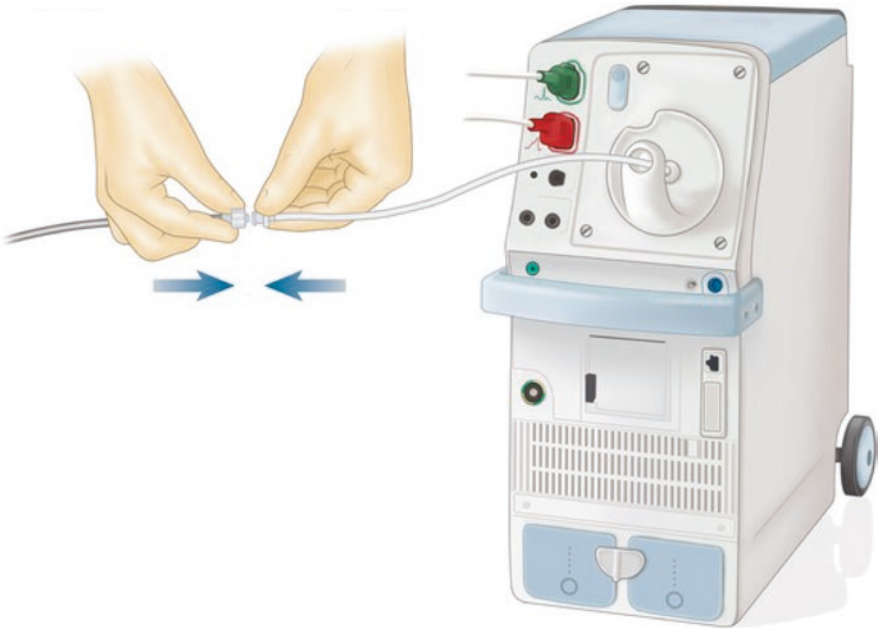


Fig. 27.9 Attach male Luer to female Luer fitting of Pneumatic Module of IABP

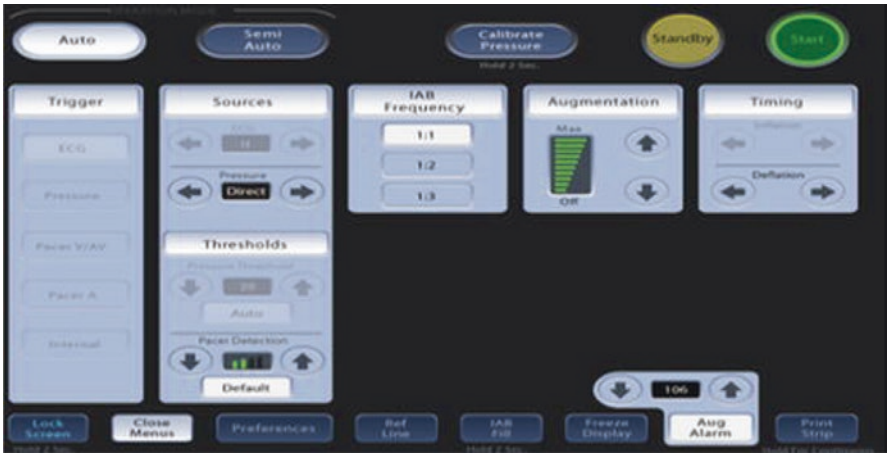


Fig. 27.10 Press "start button," select mode, and set the frequency at 1:1

Fig. 27.11 IABP frequency confirmed on the console

  - Auto Mode: Automatically selects the most appropriate lead and trigger and sets the inflation and deflation timing.
  - Asynchronous: Rate of 80/min and only used when a patient has no cardiac output
  - Select frequency: at 1:1 (Fig. 27.10).
- Confirm fluoroscopic balloon inflation and balloon waveforms on the console (Fig. 27.11).

Troubleshooting

- Inflation occurs at the dicrotic notch as a sharp "V" and ideally, diastolic augmentation rises above systole (Fig. 27.12). Deflation occurs just before systolic ejection and results in a reduction in assisted end-diastolic and end-systolic pressure (Fig. 27.12).
- See Fig. 27.13 for variations with heart rate and rhythm.

Timing Errors: Adjust the Onset of Inflation/Deflation

- Early inflation before aortic valve closure or dicrotic notch.
- Diastolic augmentation encroaches onto systole and causes AI and an increase in LVEDP and MVO_2 demand (Fig. 27.14).
- Early deflation during the diastolic phase.
- Deflation is seen as a sharp drop following diastolic augmentation (Fig. 27.15) and causes suboptimal coronary perfusion, retrograde coronary and carotid blood flow, and increased MVO_2 demand.
- Late inflation markedly after the dicrotic notch.
- This causes suboptimal diastolic augmentation and coronary artery perfusion (Fig. 27.16).

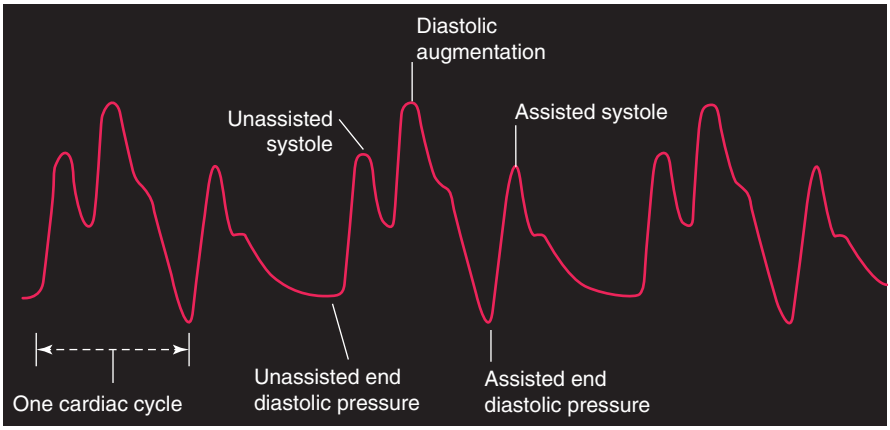


Fig. 27.12 Inflation of the IABP occurs at the dicrotic notch and deflation occurs just before systolic ejection

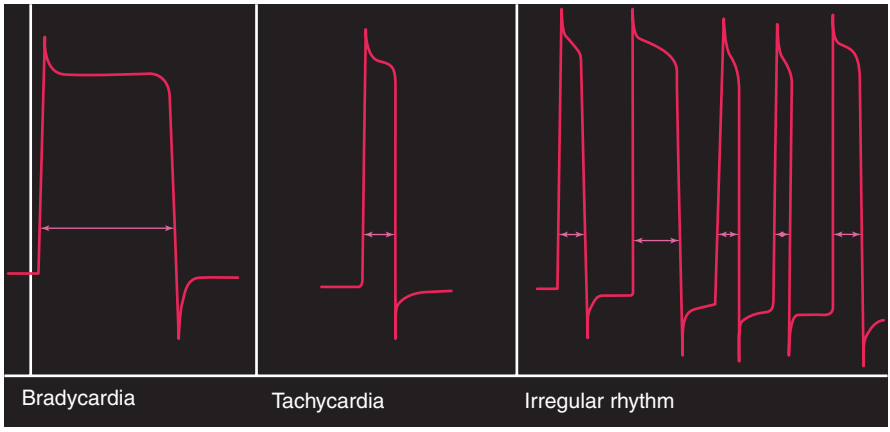


Fig. 27.13 Normal variations in balloon pressure waveform

- Late deflation after the aortic valve has opened.
- Afterload reduction is essentially absent (Fig. 27.17) and MVO_2 consumption is increased can impede left ventricular ejection.

Gas Loss

- If blood observed:
  - Stop pumping and remove IABP.
- If blood not observed
  - Check if connections are tight, perform an autofill, and press start.
- Fig. 27.18 shows the hemodynamic changes in the setting of gas loss.

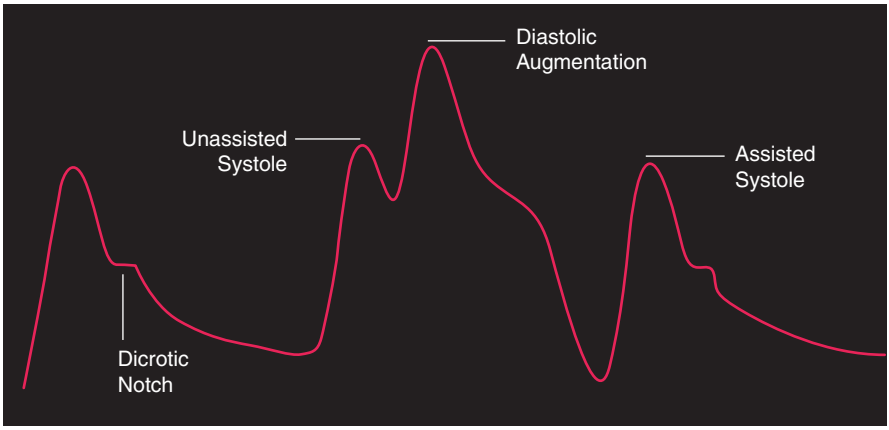


Fig. 27.14 Early IABP inflation before aortic valve closure or the dicrotic notch

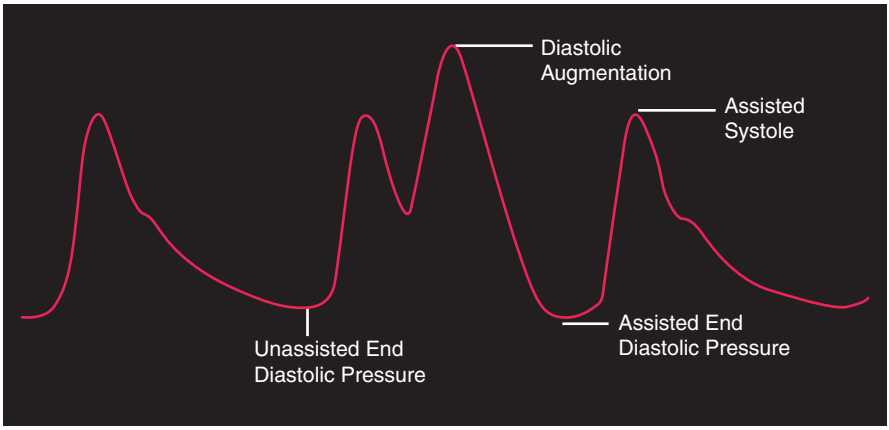


Fig. 27.15 Early IABP deflation during the diastolic phase

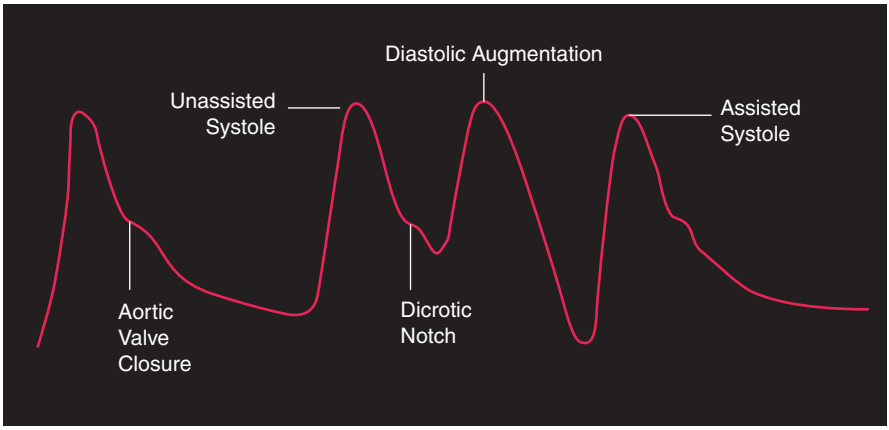


Fig. 27.16 Late inflation markedly after dicrotic notch

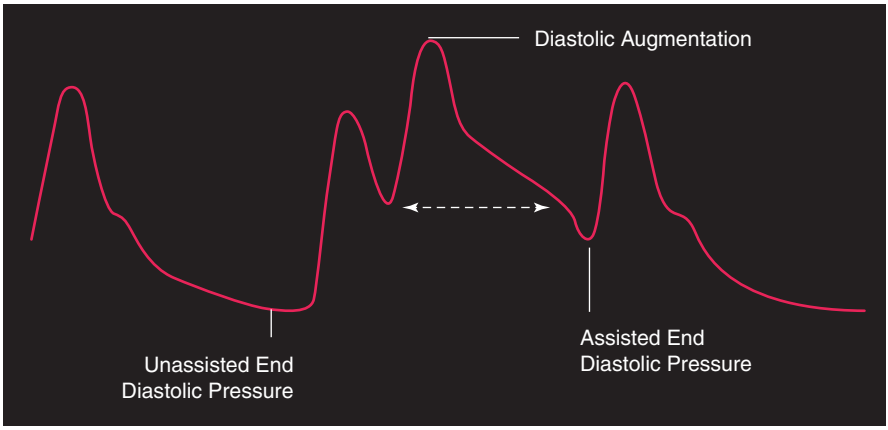


Fig. 27.17 Late deflation after the aortic valve has opened

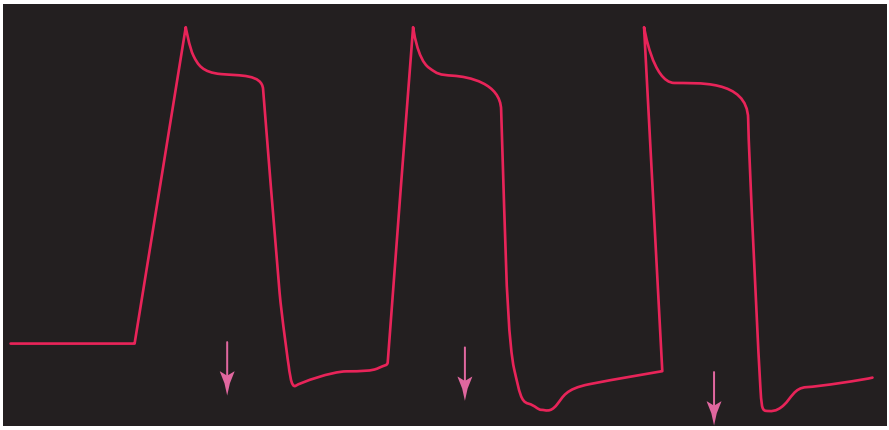


Fig. 27.18 Gas loss

Catheter Restriction

- Restriction in IABP or tubing
  - Relieve restriction.
- Membrane not unfolded
  - Try to manually inflate/deflate.
- IABP remains in the sheath
  - Make sure IABP is in position.
- Figure 27.19 shows the hemodynamic changes in the setting of catheter restriction.

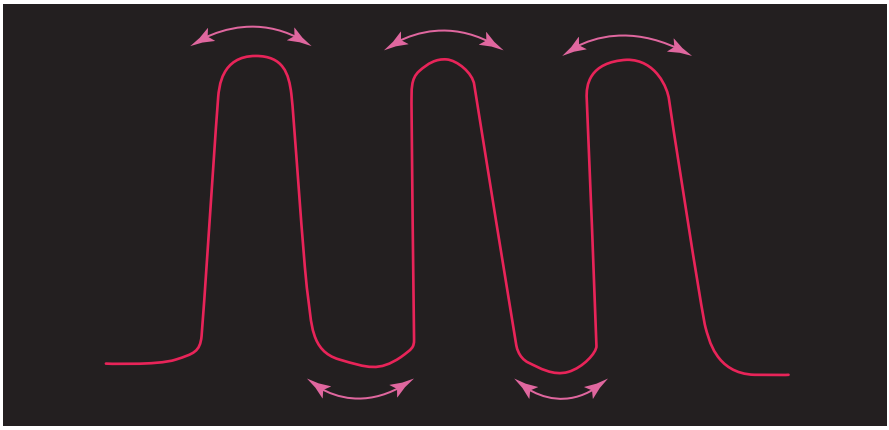


Fig. 27.19 Catheter restriction

Impella

Catheter-based, impeller-driven, axial flow pump which pumps blood directly from the left ventricle into the ascending aorta, contributing a cardiac output of up to 2.5 L/min for Impella 2.5 and 4 L/min for Impella CP.

Contraindications

- Mural thrombus in the left ventricle.
- Mechanical aortic valve or severe aortic stenosis (aortic valve area ≤ 1.5 cm^2 in PROTECT I and II trials; ≤ 0.6 cm^2 as per ABIOMED) [9–11].
- Moderate to severe aortic insufficiency (echocardiographic grade > 2+).
- Severe peripheral arterial disease or extreme tortuosity.
- Blood dyscrasia or coagulopathy predisposing to increased bleeding risk ($\leq$ 75000/mm^3 or INR ≥ 2.0 or fibrinogen ≤ 1.5 g/L).

Preimplantation

- Iliofemoral angiography to rule out severe PVD.
- Deploy two preclose sutures (see vascular closure devices).
- Press the power side button of the console for 3 sec. The console automatically performs a system check (Fig. 27.20).
- Open the Impella kit under sterile conditions (Fig. 27.21).
- Press "menu" and "start case."
- Auto prime (performed by the nonsterile technician).

Fig. 27.20 Press power button for 3 s

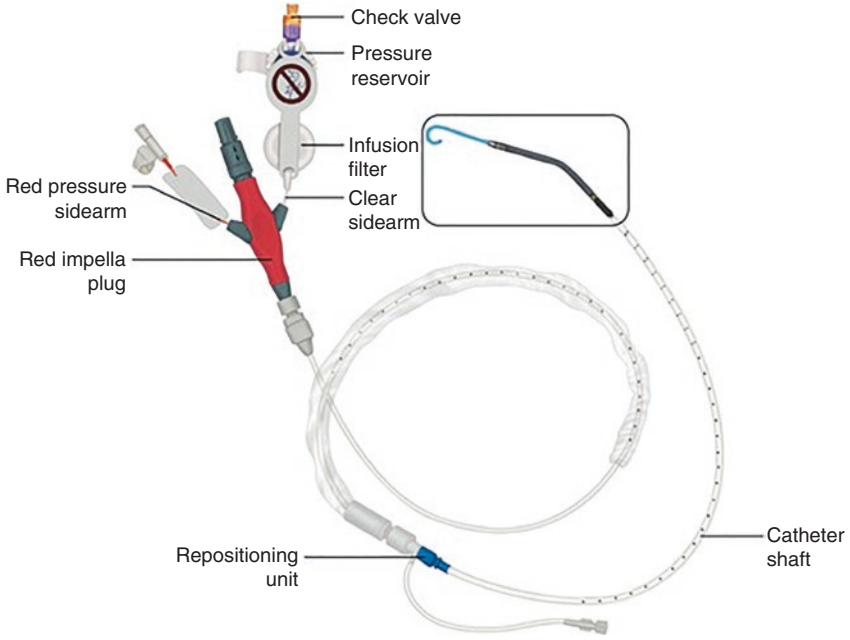


Fig. 27.21 Open Impella kit

- Connect the purge fluid spike of the purge cassette to the purge fluid bag (500 ml of 20% dextrose + heparin 50 U/ml) (Fig. 27.22).
- Press open the purge cassette door on the left side of the console, and snap the purge cassette into the slot, then slide the purge pressure transmitter to the right till you hear a snap (Fig. 27.23).
- The controller automatically starts to prime the purge cassette.

• Auto-detect
- Connect the black end of the connector cable to the red Impella catheter (Fig. 27.24).
- Snap the clear plastic clip on the sidearm to the connector cable (Fig.27.25).
- Hand the white end of the white connector cable to the technician to connect to the console with a click as shown. The controller automatically recognizes the catheter type (Fig. 27.26).

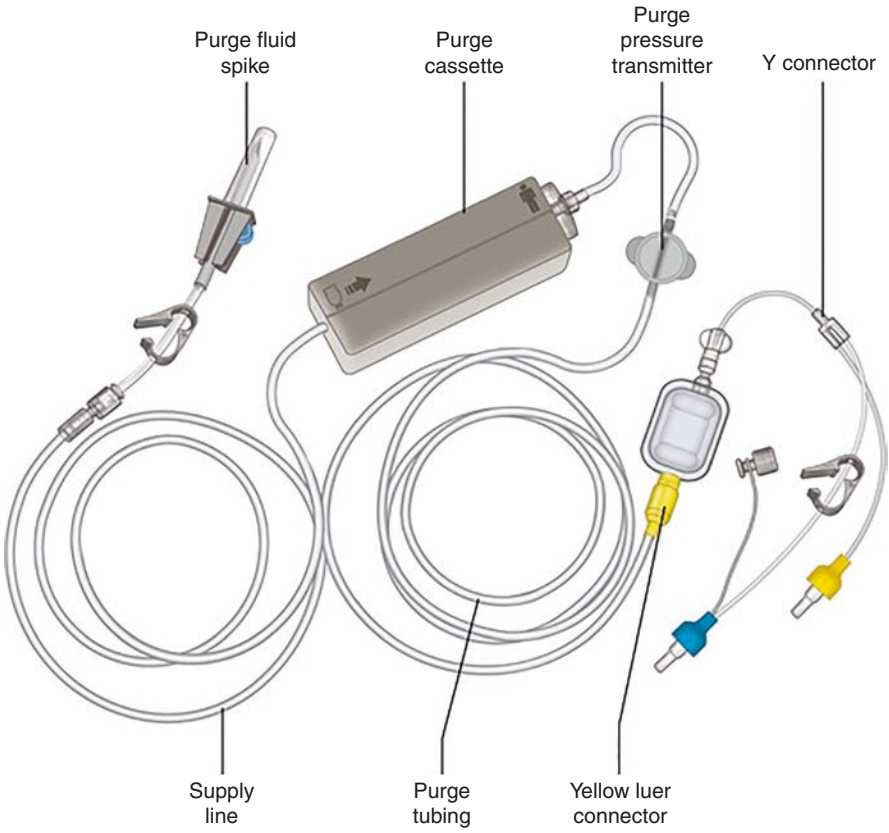


Fig. 27.22 Connect purge fluid spike to the fluid

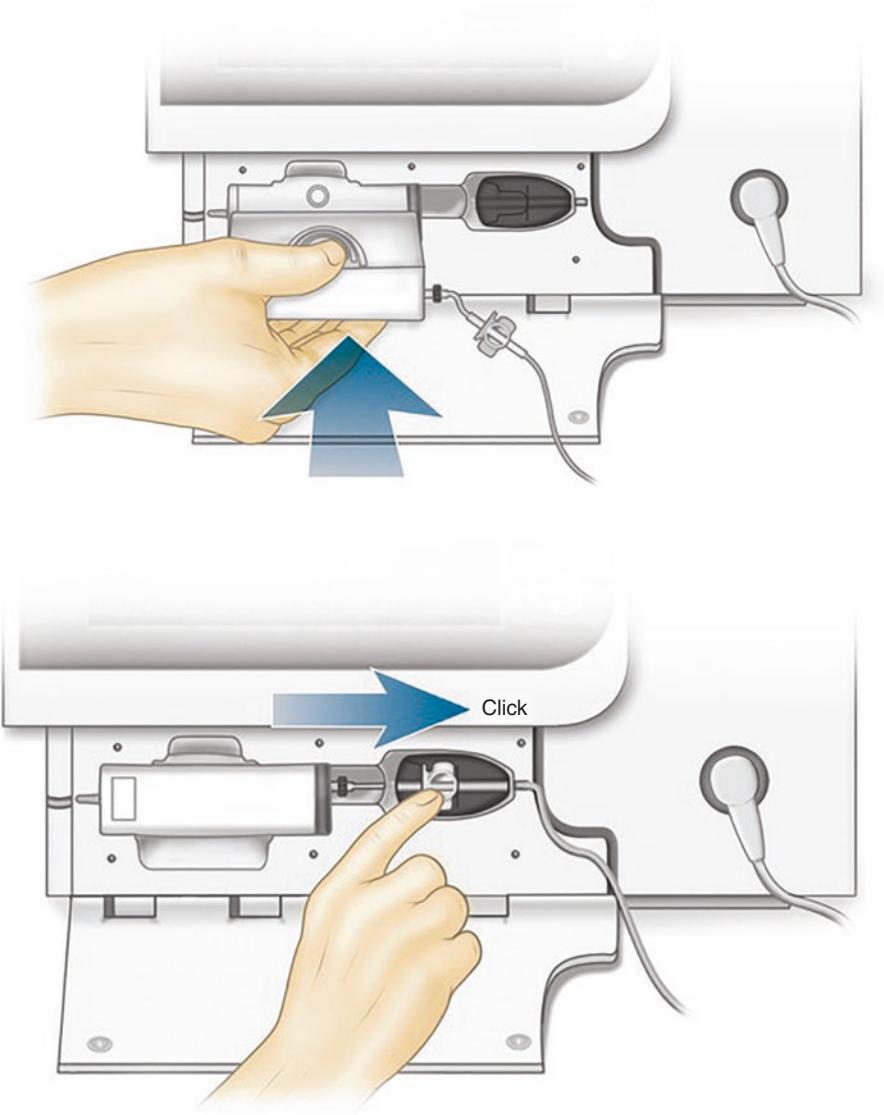


Fig. 27.23 Snap purge cassette into the slot

Fig. 27.24 Connect connector cable to Impella

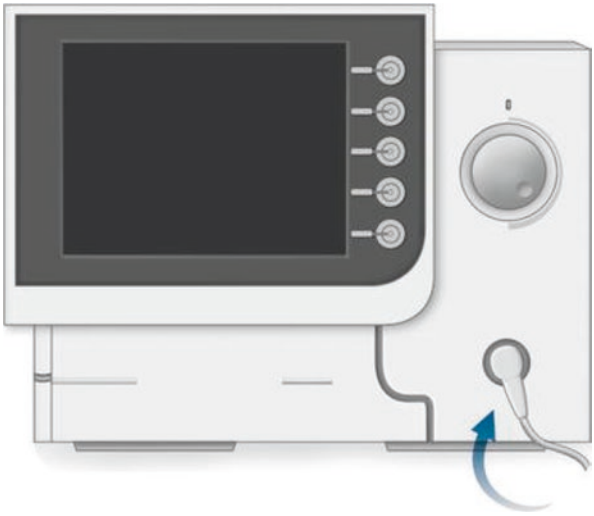


Fig. 27.25 Snap clear plastic clip on the sidearm

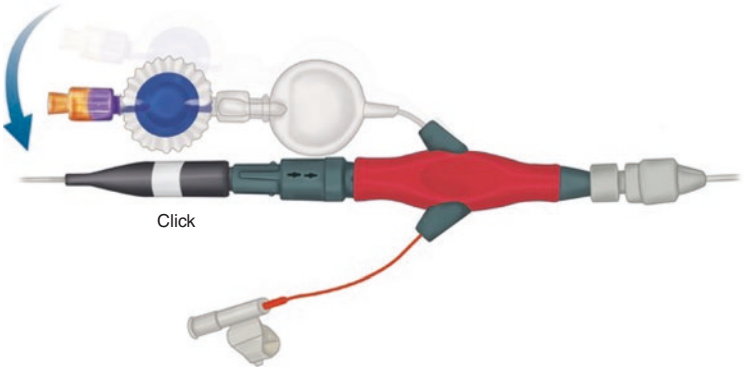


Fig. 27.26 Connect cable to console

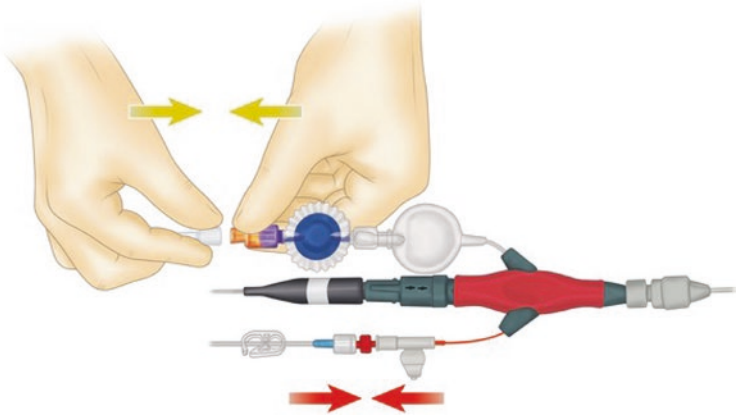


Fig. 27.27 Connect Impella to purge system

- Auto de-air
  - Connect the red port of the purge system to the red port of the Impella catheter and the yellow port of the system to the yellow port of the Impella catheter (Fig. 27.27). Ensure connections are tight.
  - Squeeze the white flush valve for 10 s until the controller beeps and fluid exits the Impella catheter (Fig. 27.28). The screen will show "Catheter is ready to insert." Select "default" for purge fluid values.

Implantation

- Insert a 7 F introducer/catheter and remove the introducer. Administer heparin to achieve an ACT of 250–300 s or bivalirudin to achieve an ACT of >300 s.
- After successive dilations with 8 Fr, 10 Fr, and 12 Fr dilators (Fig. 27.29), upgrade to a 13 Fr (Impella 2.5) or 14 Fr (Impella CP) peel away catheter/dilator by supporting the shaft of the introducer (Fig. 27.30).

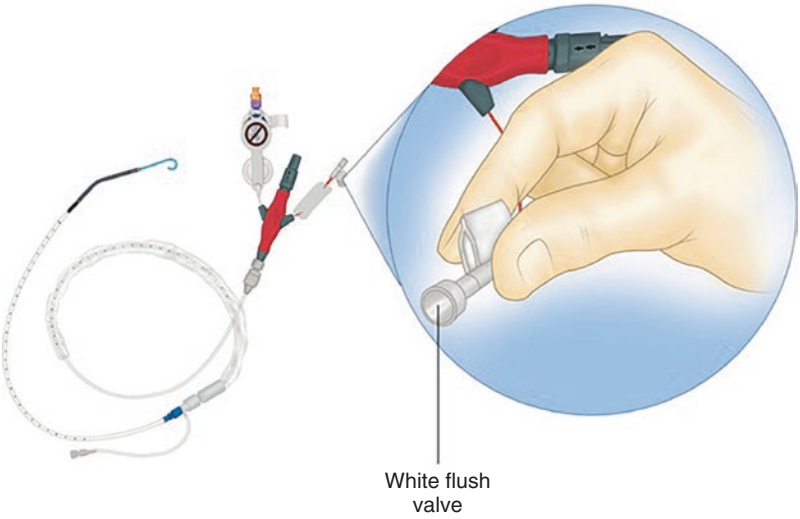


Fig. 27.28 Squeeze white valve for 10 s until controller beeps and fluid exits the Impella

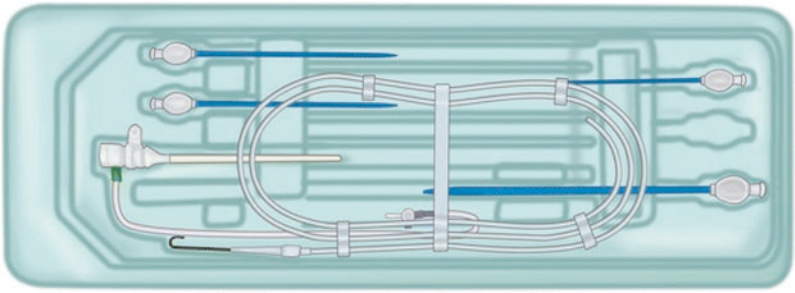
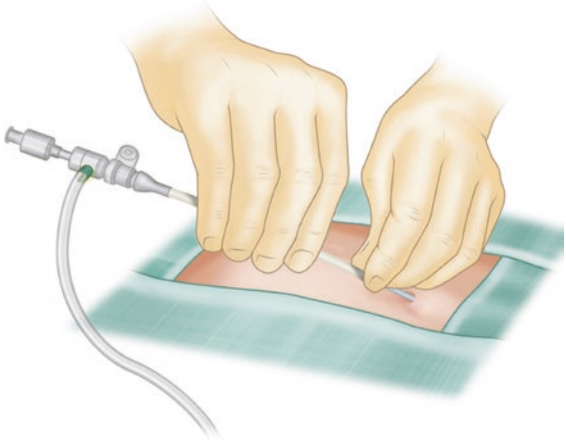


Fig. 27.29 Successively dilate to 12 Fr

Fig. 27.30 Upgrade to a 13Fr catheter/dilator



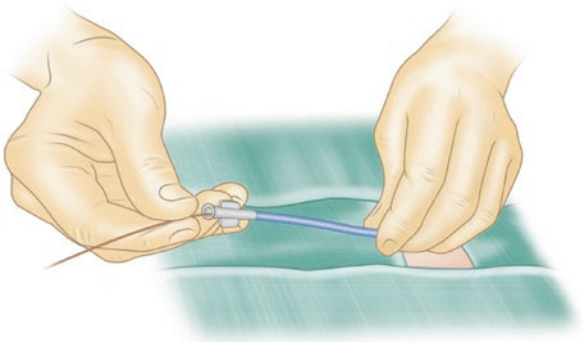


Fig. 27.31 Insert 0.035″ guidewire into LV

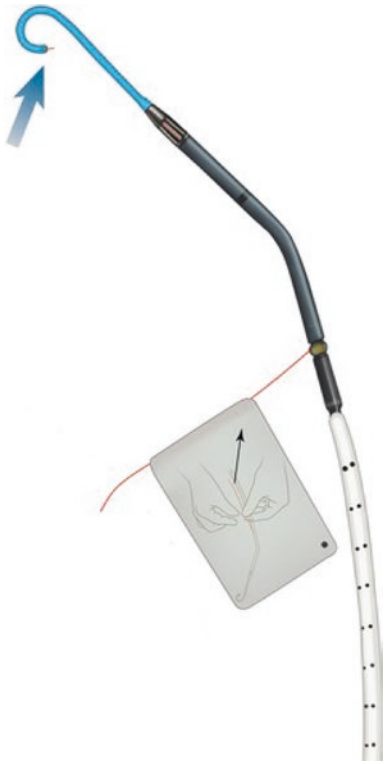


Fig. 27.32 EasyGuide Red lumen

- Remove the 13 or 14 Fr dilator and insert a 6 Fr diagnostic catheter (Judkins Right or Multipurpose with no side holes) over a 0.035″ guidewire into the left ventricle (Fig. 27.31).
- Exchange the 0.035 wire for a 0.018 guidewire and advance it until the floppy end and 3–4 cm of the stiffer part are visible in the left ventricle. Remove the 6 Fr diagnostic catheter.
- Backload the blue pigtail section on a 0.018 guidewire using preassembled EasyGuide Red lumen until it exits near the label (Fig. 27.32).

- Remove EasyGuide by gently pulling the label while holding the Impella® catheter (Fig. 27.33).
- Keep the wire parallel to the cannula and advance the catheter in small increments to avoid bending the cannula (Fig. 27.34).
- Advance the catheter into the middle of LV, without coiling the guidewire, under fluoroscopy to 4 cm below the AV annulus free from mitral valve chordae. Ensure that the Impella is positioned across the aortic valve with the pigtail and inlet portion in the left ventricle and the outlet and motor portion in the aorta. Align catheter against the lesser curvature of the aorta (Fig. 27.35).

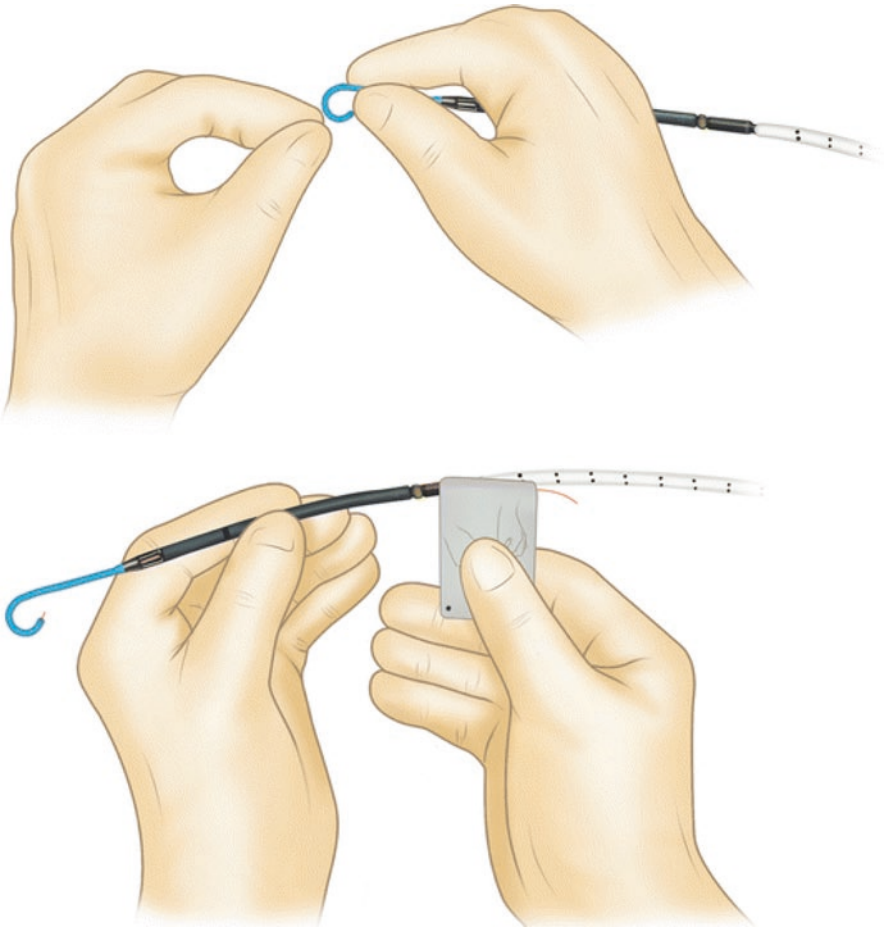


Fig. 27.33 Remove EasyGuide by gently pulling the label while holding the Impella

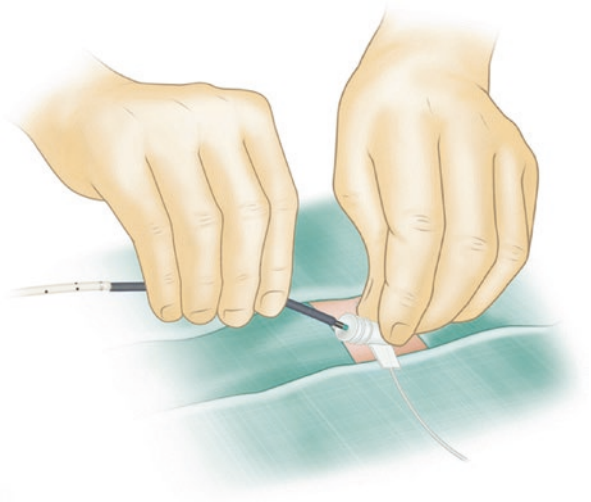


Fig. 27.34 Advance the catheter in small increments to avoid bending the cannula

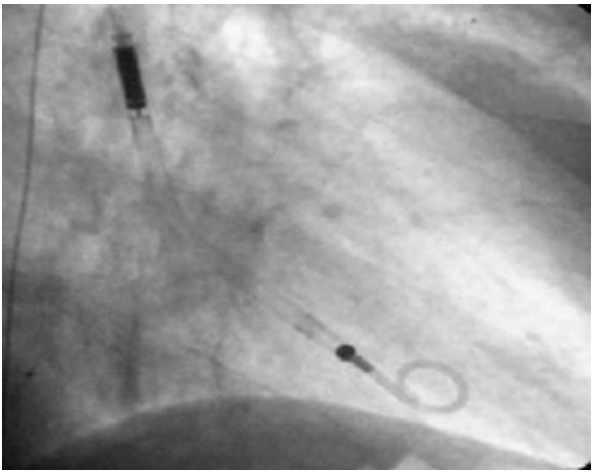


Fig. 27.35 Advance the catheter into the middle of the LV

- Remove any excess slack. Confirm that an aortic waveform is displayed on the Impella Console (Fig. 27.36).
- At the end of the procedure, the Impella catheter can be safely removed from the LV.

Troubleshooting

- If the Impella® catheter advances too far into the LV and the controller displays a ventricular waveform (Fig. 27.37), pull the catheter back until an aortic waveform is present. As soon as the aortic waveform appears, pull the catheter back

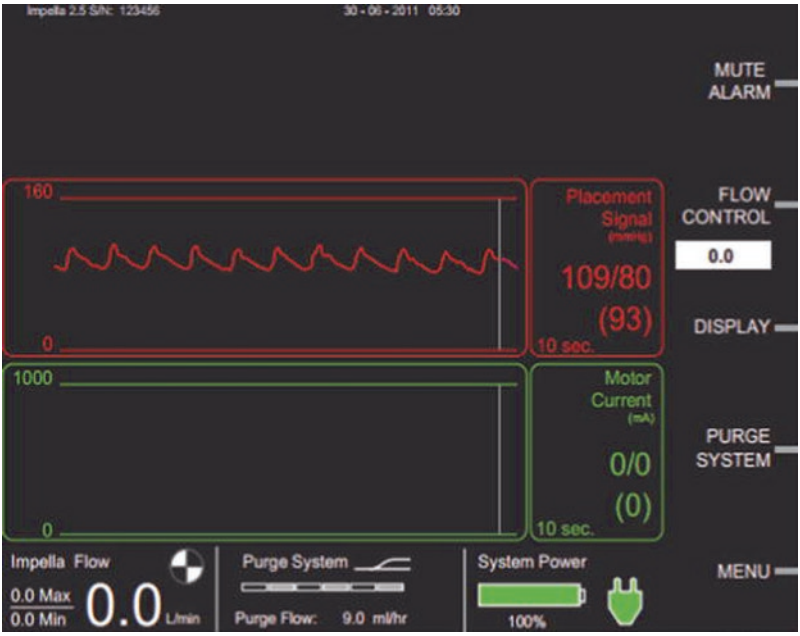


Fig. 27.36 An Aortic waveform is displayed on the Impella Console

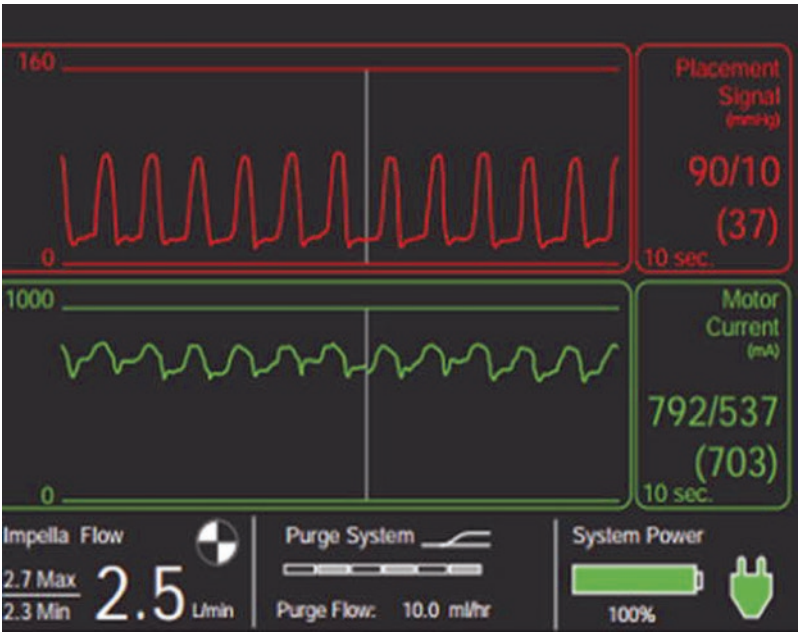


Fig. 27.37 If the Impella advances too far into the LV, the controller will display a ventricular waveform

an additional 4 cm (the distance between adjacent markings on the catheter is 1 cm).

Potential Complications

- Access site complications.
- Bleeding complications.
- Displacement of the pump back into the aorta can also occur, but the addition of the pigtail catheter tip minimizes the displacement potential (see troubleshooting above).
- Hemolysis, as measured by free hemoglobin, resulting in higher rates of blood transfusion [12].

Extracorporeal Membrane Oxygenation (ECMO)

Extracorporeal membrane oxygenation (ECMO) can provide oxygenation, carbon dioxide removal, and perfusion support for days to weeks in patients needing cardiopulmonary support. The ECMO circuit requires vascular access, a blood pump, and an oxygenator. Vascular access may be veno-venous or veno-arterial depending on the nature of physiologic support. Veno-venous (VV) ECMO is used for respiratory support and provides no hemodynamic support. Veno-arterial (VA) ECMO is placed in patients who need cardiopulmonary support and provides both respiratory and hemodynamic support. It requires both arterial and venous cannulation, and blood is drained from the right atrium and returned to peripheral circulation using femoral or axillary arteries. Blood can be returned into central circulation using aortic cannulation [13–17].

Indications

- Cardiogenic shock.
- Bridge to transplant.
- Support for high-risk percutaneous coronary intervention.
- Severe cardiomyopathy.
- Respiratory failure.

Contraindications

- Severe aortic regurgitation.
- Malignancy.
- Prolonged CPR without adequate tissue perfusion.
- Unwitnessed cardiac arrest.

Complications

- Access site bleeding.
- Vascular injury.
- Central vein or intracardiac thrombosis.
- Cerebral hypoxia.
- Device thrombosis.

Cannula Size and Access Site Considerations

- Fem-Fem ECMO requires selection of one long cannula (50–55 cm) capable of reaching the right atrium and another 25 cm cannula capable of reaching the central circulation.
- A multistage cannula (multiple access points) vs a single-stage cannula (single access point) could be used. The single-stage cannula is preferred for the return limb of the circuit and the multistage cannula is preferred for the drainage line as it provides maximal emptying.
- When selecting cannula size, one method is to calculate the patient's full cardiac output based on body surface area and then select cannulas, which provide this flow using the information provided by the manufacturer.
- The other method is to estimate the largest French size cannula capable of being passed through the vessel by measuring the vessel diameter (D) and calculating circumference:
  - Circumference: $\pi D = 3.1 \times D$ = maximum size of a cannula that could be used. If $\geq 2/3$ of the vessel is occluded by the cannula, then venous stasis can lead to deep vein thrombosis, lower limb venous congestion, and ischemic injury [16].

Steps of Implantation

- V-V ECMO: Single access (Avalon catheter (13–31 Fr) is a dual lumen catheter that matches the body's flow by draining venous blood from superior and inferior vena cava and infusing blood in the right atrium (Figs. 27.38 and 27.39).
  - Obtain venous access and advance guidewires.
  - Administer heparin anticoagulation.
  - Place the dual-line catheter through venous access.
  - Back bleed the lines to eliminate air or clot.
  - Connect these lines "wet to wet" to a primed ECMO circuit.
  - Start flow through the ECMO circuit.
- V-V ECMO: dual access
  - Obtain dual venous access (femoral and right internal jugular veins) (Fig. 27.40).
  - The remaining steps are the same as V-V ECMO (as above).

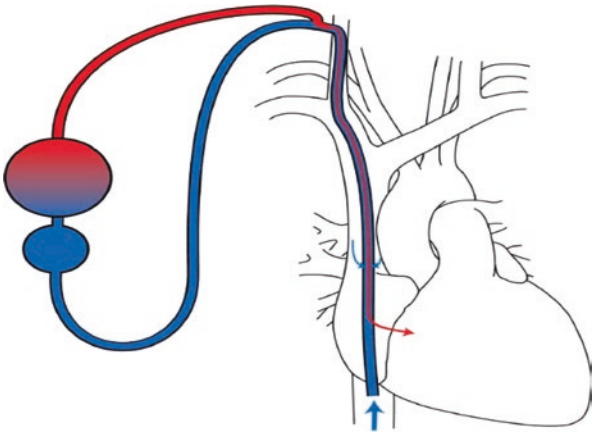


Fig. 27.38 V-V ECMO: single cannula approach [13]

Fig. 27.39 Avalon (Getinge, Gothenburg Sweden) catheter Bi-caval dual lumen catheter [17]

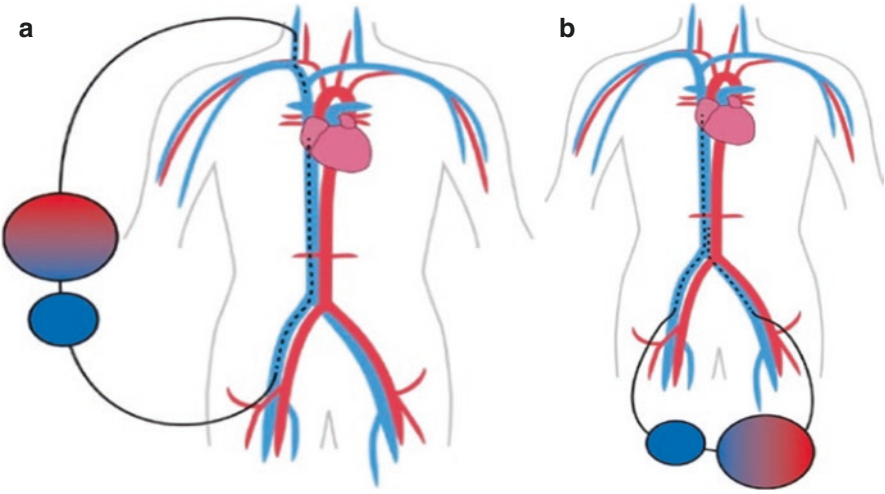


Fig. 27.40 V-V ECMO: two cannulation approach (**A**) femoral vein (for drainage) and right internal jugular for perfusion, (**B**) both femoral veins are used for drainage and perfusion [13]

- V-A ECMO:
  - Obtain femoral venous access and place a long cannula into the right atrium.
  - Obtain arterial access in the femoral, axillary, or internal jugular artery (Fig. 27.41).
  - The remaining steps are the same as V-A ECMO (as above).

RV Impella

The Impella RP (Abiomed Inc., Danvers, MA, USA) is an axial flow pump with a 22 F electric motor and outflow cannula, mounted on a thin and flexible 11 F catheter. Impella RP is designed to assist the right ventricle for up to 14 days in patients who develop acute right heart failure and can be used concurrently with other LVADs. Impella RP could provide flow up to 4 L/min at 33,000 rpm from the inferior vena cava to the pulmonary artery [18, 19].

Recently, the FDA issued a notification to healthcare providers that RV Impella post-approval study showed higher mortality than premarket clinical study, but the patients in the post-approval study were more likely to be in cardiogenic shock for > 48 hours, experienced a cardiac arrest, or suffered an ischemic neurologic event before getting Impella RP system [20].

Fig. 27.42 depicts the Impella RP placement and Fig. 27.43 depicts the Impella RP catheter.

Contraindications

- Mural thrombus in the right atrium.

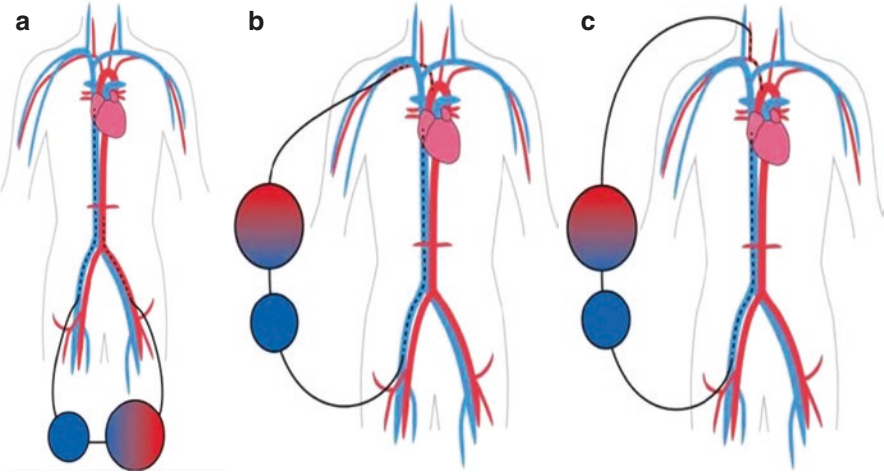


Fig. 27.41 Peripheral V-A ECMO cannulation approach: femoral vein (for drainage), (**A**) femoral, (**B**) axillary, (**C**) carotid, artery are used for perfusion [13]

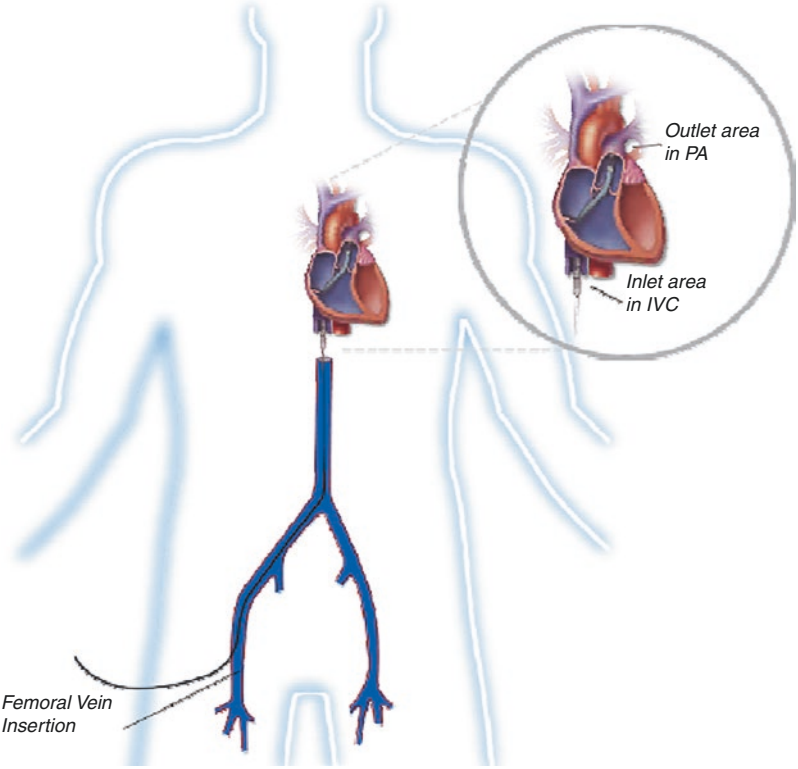


Fig. 27.42 RP Impella placement [20]

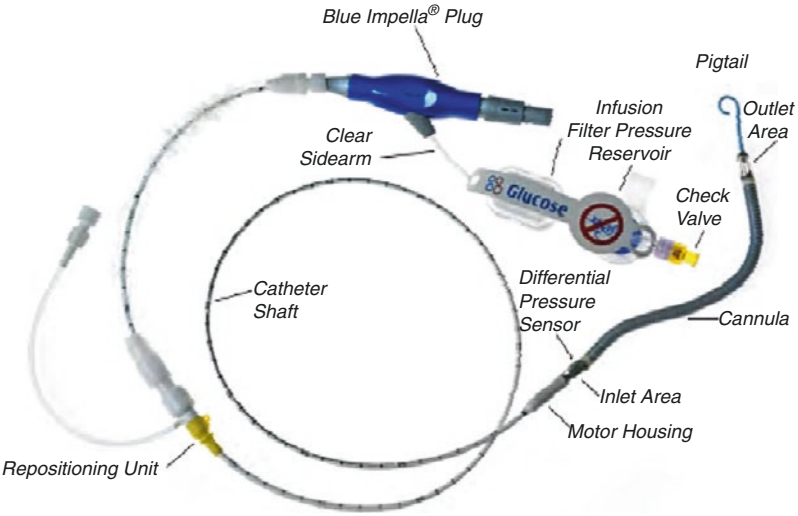


Fig. 27.43 Impella RP catheter [20]

- Mechanical valves, severe valvular stenosis or regurgitation.
- Presence of vena cava filter.
- Disorder of pulmonary artery that would preclude placement of Impella.

Steps of Implantation

- Obtain access in the femoral vein.
- Insert a 5–8 Fr introducer over the 0.035-inch guidewire to pre-dilate the vessel.
- Remove the 5–8 Fr introducer over the 0.035-inch guidewire. Insert the 8 Fr, 12 Fr, 16 Fr, and 20 Fr dilators sequentially, as needed. Remove the 20 Fr dilator and insert the 23 Fr introducer with a dilator. While inserting the 23 Fr introducer, hold the shaft of the introducer to advance it into the vein.
- Administer heparin. When ACT is at least 250 seconds, remove the 23 Fr dilator.
- Insert a 5–6 Fr diagnostic catheter or a flow-directed balloon-tipped catheter into the 23 Fr introducer and advance it over a guidewire into the left (preferred) or right pulmonary artery.
- Remove the 0.035-inch diagnostic guidewire, leaving the diagnostic or balloon-tipped catheter in the pulmonary artery. Form a curve or bend on the 0.025 inch Platinum Plus or similar stiff, 260 cm placement guidewire and then insert it.
- Advance the placement guidewire into the pulmonary artery, avoiding deep insertion into the most distal pulmonary artery.
- Remove the diagnostic or balloon-tipped catheter.
- Wet the cannula with sterile water and backload the catheter onto the placement guidewire. Advance the guidewire into the Impella RP Catheter and stabilize the cannula between the fingers. This prevents pinching of the outlet area. The guidewire must exit the inlet area on the inner radius of the cannula and align with the straight black line on the catheter. The guidewire must exit the inlet area on the inner radius of the cannula and align with the straight black line on the catheter. Advance the catheter through the hemostatic valve into the femoral vein and along the placement guidewire using a fixed-wire technique.
- Follow the catheter under fluoroscopy, and rotate the catheter as it enters the right ventricle to direct the cannula tip upward and across the pulmonary valve. Position the outlet area of the cannula approximately 4 cm past the pulmonary valve annulus.
- Remove the placement guidewire.
- Confirm position with fluoroscopy [18].

Complications

- Hemorrhage, valvular or vessel injury, perforation, arrhythmia.
- Arrhythmia.
- Insertion site infection.

TandemHeart

Tandem Heart (Cardiac Assist, Inc.), a percutaneous ventricular assist device is a left atrium to a femoral artery bypass system that provides hemodynamic support. The device reduces preload, augments cardiac output up to 4–5 L/min, and ultimately decreases myocardial work and oxygen demand. The device can be used as a bridge to transplant or surgical left ventricular assist device, left ventricular support in cardiogenic shock, and to maintain hemodynamic support in high-risk percutaneous coronary interventions (Fig. 27.44).

The system comprises of the following:

- 21 Fr venous "transseptal" inflow cannula with 14 side holes and an end hold.
  - Extracts oxygenated blood from the left atrium and delivers it into a continuous flow centrifugal blood pump.
  - The placement of the inflow cannula into the left atrium requires transseptal puncture under TEE guidance.

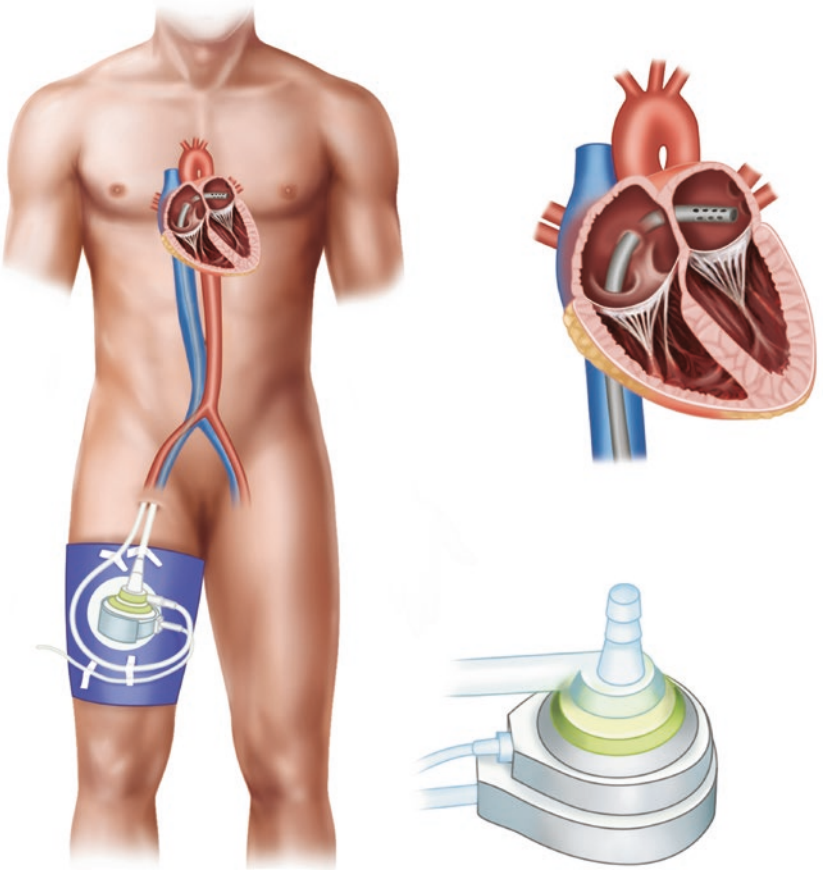


Fig. 27.44 Tandem heart device and centrifugal pump [23]

- Continuous flow centrifugal blood pump.
  - The pump is connected to a 15–17 F arterial infusion cannula.
- 15–17 Fr arterial infusion cannula.
  - Typically placed in the femoral artery and are required to pump blood from the LA to the right femoral artery.
  - Alternatively, two 12 Fr arterial perfusion catheters to pump blood into the right and left femoral arteries can be used instead of a single 15–17 Fr catheter in the right femoral artery.
- The Tandem heart pump comprises of a:
- Unique lubrication system, which feeds a nominal 10 cc/h of heparinized saline to cool the motor. The device requires systemic anticoagulation to prevent thrombosis and embolism [21–23].
- Pressure transducer that monitors the infusion pressure and identifies any disruption in the infusion line.
- In-line air bubble detector that monitors for the presence of air in the infusion line.

Contraindications

- Ventricular septal defect.
- Aortic insufficiency.
- Severe PVD.

Steps of Implantation

- Iliofemoral angiography to rule out severe PVD.
- Femoral artery access and preclosure with the Perclose™ device (see VCD Devices); upsize to a 15–17 Fr arterial sheath.
- Transseptal puncture via a femoral vein under fluoroscopic guidance using the Brockenbrough needle and a Mullins sheath is performed and its position in the LA is confirmed.
- Unfractionated heparin to achieve an ACT >400 s.
- Exchange Mullins sheath for the 21 Fr TH transseptal cannula with the 14 Fr obturator over the 0.038 in. J-tip 260 cm Amplatz Super Stiff guidewire and confirm its position (ensure all side holes of the TH are in the LA) by injecting dye and assessing the blood oxygen saturation level.
- The obturator and the wire are then removed and clamps applied for temporary homeostasis. Suture the peripheral end of the cannula to the skin of the patient's thigh and clamp it.
- Place the 15 Fr arterial perfusion cannula of the TH device with the distal end of the cannula lying above the aortic bifurcation. Suture the peripheral end to the patient's thigh and clamp it.
- De-air the extracorporeal system and attach the TH cannula to the inflow port of the centrifugal blood pump and femoral arterial cannula to the outflow conduit of the TH pump in the standard wet-to-wet fashion with Tygon tubing. Connect the power supply to the microprocessor-based controller.

- Connect the pump to the TH controller and adjust the speed to provide a cardiac output of 2.5–3.0 L/min.

Complications

- Puncture/rupture of the aortic root, coronary sinus, or posterior free wall of the right atrium.
- Thromboembolism—Unfractionated heparin to maintain an activated clotting time of 400 s during insertion and 250–300 s during support is mandatory.
- Hypothermia.
- Access site complications.

Protek Duo

Protek duo is a dual lumen cannula system that contains two lumens within a 29 or 31 F system. One lumen connects to an inflow cannula, with multiple holes, with access to the right atrium, whereas, the other lumen connects to an outflow cannula with access to the main pulmonary artery. The inflow cannula drains blood from the right atrium into a centrifugal pump, which delivers blood into the pulmonary artery bypassing the right ventricle. Hence, single venous access via an internal jugular approach is required for device placement (Fig. 27.45). Protek duo, in addition to providing right ventricular support, provides oxygenated blood directly into the pulmonary artery [24–26].

Contraindications

- Valvular stenosis (Table 27.4).
- Bleeding diathesis.

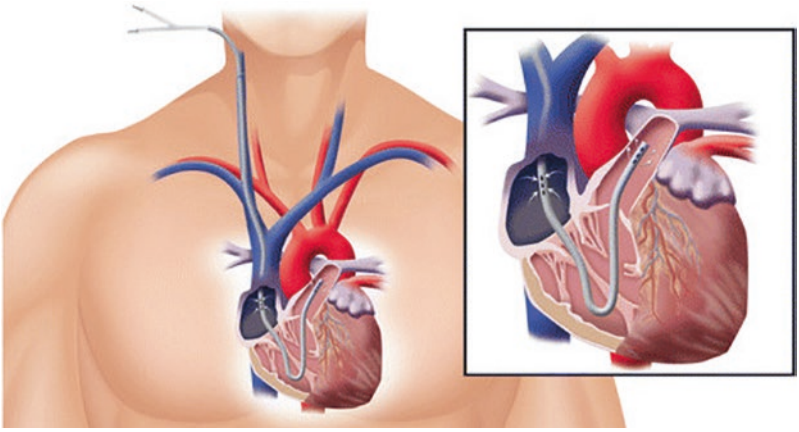


Fig. 27.45 Protek Duo dual lumen cannula. Published with permission from Kazui T et al [26]

Table 27.4 Summarizes an overview of the above hemodynamic support devices [27]

	IABP	Impella 2.5	Impella CP	RV Impella	V-A ECMO	V-V ECMO	Tandem Heart	Protek Duo
Vessel access	Arterial	Arterial	Arterial	Venous	Venous and arterial	Venous	Venous and Arterial	Venous
Fr Size	7–8	13	14	23	14 Arterial 21 Venous	21 Venous 21 Venous	15 Arterial 21 Venous	29
Support chamber	LV	LV	LV	RV	LV/RV	none	LV	RV
Oxygenation	No	No	No	No	Yes	Yes	No	Yes
Flow rate	< 0.5	< 2.5	<4	4	<7	<7	<5	<5
Preload	No change	Decreased	Decreases	No change	Decreases	Decreases	Decreases	No change
Afterload	Decreases	Decreases	Decreases	Decreases in RV	Increases	No change	Increases	Decreases in RV
Maximum implant duration	14 days	7–10 days	7–10 days	7–10 days	4 weeks	4 weeks	2–3 weeks	2–3 weeks
Coronary perfusion	Increases	Increases	Increases	No change	No change	No change	No change	No change
Affected by arrhythmias	Yes	No	No	No	No	No	No	No

Complications

- Bleeding and vascular injury.
- Right ventricular injury.
- Valvular injury.
- Thromboembolism.

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