Temporary Mechanical Circulatory Support

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Introduction

Temporary Mechanical Circulatory Support (MCS) plays a vital role in the management of patients with acute cardiogenic shock. Cardiogenic shock is defined by hemodynamic parameters, including systolic blood pressure less than 80 mmHg or mean arterial pressure 30 mmHg less than baseline; severe reduction of the cardiac index (CI) to less than 1.8 L/min/m^2 without support or less than 2.0–2.2 L/min/m^2 with support with LV end diastolic pressure greater than or equal to 18 mmHg or RV end-diastolic pressure greater than or equal to 10–15 mmHg [1]. Clinical signs of cardiogenic shock include signs of hypoperfusion and end-organ dysfunction such as cool extremities, decreased urine output, renal failure, liver dysfunction, and altered mental status. With widespread availability of temporary MCS, these devices can be utilized to stabilize these patients during an acute decompensation in an attempt to recover end-organ function while determining the next steps of care.

The original version of the chapter has been revised. A correction to this chapter can be found at https://doi.org/10.1007/978-3-031-05713-7_22

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S. Stewart, P. Blood (eds.), *A Guide to Mechanical Circulatory Support*,
https://doi.org/10.1007/978-3-031-05713-7_16

Table 1 Common temporary MCS devices

	Left heart support	Right heart support	Oxygenation
IABP	Yes	No	No
Impella	Yes	Yes	No
Tandem	Yes	Yes	No
ECMO	Yes	Yes	Yes

Temporary MCS devices span from minimally invasive, percutaneous devices that can be placed at bedside or in the catheterization lab to more robust devices that require surgical implantation. With proper timing and appropriate patient selection, the use of temporary MCS can improve survival of this very sick patient population. Here, we will discuss the most commonly used temporary MCS devices, outlining indications, management techniques, and potential complications. Table 1 describes characteristics of the most common devices used.

Intra-Aortic Balloon Pump (IABP)

The intra-aortic balloon pump (IABP) is a commonly utilized method for acute support given its ease of implantation and widespread availability in smaller community hospitals. Since its initial implant in the 1960s, it has been the main form of temporary MCS for patients with cardiogenic shock. The IABP augments hemodynamics by allowing for left ventricular unloading and increased coronary perfusion.

Configuration and Mechanism of Action

The IABP catheter is comprised of a long 20–50 mL closed polyurethane balloon distally mounted on a flexible catheter with dual lumens. One lumen allows for aspiration and flushing of the distal tip, as well as pressure monitoring, ultimately impacting the timing of the device, while the other lumen shuttles gas to and from the balloon. The therapeutic cycle of the balloon is controlled by a mobile console containing helium which allows computer control of the synchronized inflation/deflation circuit (Fig. 1).

The IABP catheter is placed percutaneously under fluoroscopy guidance most commonly in the common femoral artery, though the axillary or subclavian artery can also be used for placement. The catheter is advanced over a guidewire with the distal tip positioned in the proximal descending aorta, 1–2 cm below the left subclavian artery, and the proximal end of the balloon above the renal arteries so as to not impair renal blood flow.

The hemodynamic effects of IABP counter-pulsation are increased coronary artery blood flow and decreased left ventricular end-diastolic pressure (LVEDP) which in turn result in left ventricular (LV) afterload reduction, decreased preload, and a modest increase in cardiac output.

The inflation of the balloon should coincide with the onset of diastole, which is when the aortic valve closes. The inflated balloon then displaces blood back to the

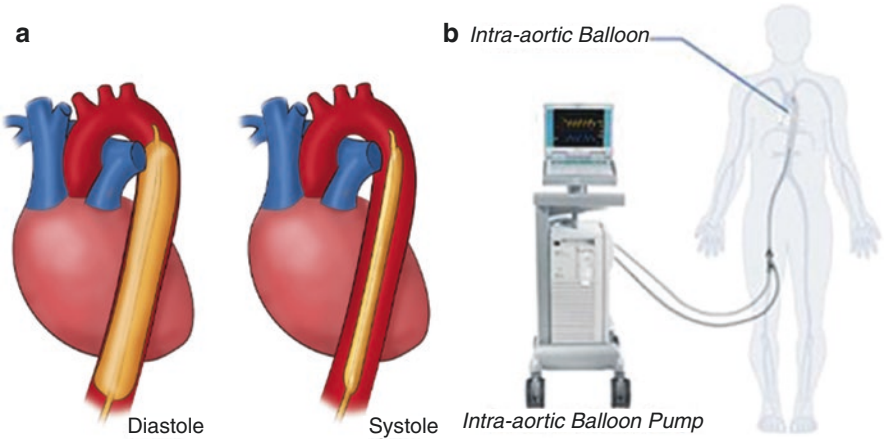

Fig. 1 (**a**) Inflation/deflation of the IABP and (**b**) exterior components

aortic root which increases the diastolic pressure. The coronary arteries also fill during diastole, so this displaced blood results in increased coronary blood flow to the myocardial tissue. With proper timing of the inflation/deflation cycle, an increase in cardiac output of 10–20% may be noted [2]. The rapid deflation of the balloon should occur just ahead of the aortic valve opening, which identifies systole causing a suction effect within the aorta, propelling the blood volume forward, thus decreasing afterload, preload, and myocardial workload. Augmentation can be set to change as the patient has recovery of their native heart function. Most patients are placed on a 1:1 augmentation as the starting setting, meaning the balloon inflates and deflates with every valve opening. As there is recovery of native heart function, and contributing underlying cardiac output improves the augmentation on the pump may be changed to either 2:1 (inflating and deflating with every other opening) or 3:1 (inflating of deflating with every third opening) before removal of the pump 3.

Indications and Contraindications

IABP therapy is considered beneficial for a multitude of cardiac indications and common uses in practice. Indications for placement include cardiogenic shock, intractable angina, or myocardial ischemia. This is especially useful in severe left main coronary artery disease awaiting further therapy or surgical bypass. An IABP can be placed as precautionary therapy during high-risk percutaneous coronary intervention or as temporary treatment of refractory ventricular arrhythmias and acute mitral valve regurgitation. Often an IABP can be used for low cardiac output patients while weaning from cardiopulmonary bypass or as a bridge to advanced heart failure therapies such as durable VAD or transplant. It is considered the simplest and most cost-effective therapy to implement in the treatment of cardiogenic shock, and therefore it is still one of the most commonly used, especially in many

smaller hospital settings [3]. An IABP can also be used in conjunction with VA ECMO to serve as an "vent" to allow for left ventricular unloading while receiving ECMO support.

The IABP should not be used in cases of aortic dissection, abdominal aortic aneurysm, complex aortic valve stenosis, or aortic insufficiency. Caution should be used in cases of severe vasodilatory or septic shock and severe peripheral artery disease as the risks may outweigh any benefits of support. The balloon's counterpulsation will worsen an incompetent aortic valve by displacing blood volume through the valve during diastole increasing the preload of the left ventricle and minimizing the potential additional blood flow to the coronaries.

Complications

Potential adverse events related to insertion include bleeding, hematoma, infection, thrombocytopenia, limb ischemia, vascular injury, or arterial perforation and should be vigilantly monitored for occurrence. Observe for any excessive bleeding and drainage at cannulation site and frequently assess limb perfusion by checking relevant pulses, appropriate capillary refill, temperature, and color.

In respect of the mechanical action of the balloon, potential complications may include aortic dissection or an embolic event related to helium, plaque, or thrombus. Of note, errors in timing of the balloon inflations and deflations may also cause complications subtherapeutic effects of the IABP therapy. Monitoring timing of the balloon inflation with waveforms is imperative to avoid complications. Early balloon inflations can cause an increase in afterload, an increase in myocardial oxygen consumption, and a decrease in stroke volume. Both early inflations and late deflations can be a very dangerous error due to the acute increase in afterload, resulting in a potential range of complications from a marked decrease of cardiac output to cardiac arrest. If the balloon deflates too early, there will be minimal or no decrease in the afterload. Early balloon deflations and/or late inflations will result in less time for the diastolic filling of the coronaries thus minimizing additional coronary flow [4].

Impella (Abiomed)

Engineering and Function

The Impella pump (Amiomed, Danvers MA) is the culmination of a series of innovations which has revolutionized temporary ventricular assist devices. Its design is largely based on the Archimedes' screw in using rotational force to generate the power necessary to eject blood forward (Fig. 2).

The Impella is a micro axial blood pump that supports circulation and provides between 2.5 and 6 L/min of flow, depending on the cannula being used. The Impella motor spins creating a negative pressure that pulls blood from the inflow area through the cannula and unloads into the outflow area. The impella is controlled by the Automated Impella Controller (AIC) which provides the interface for

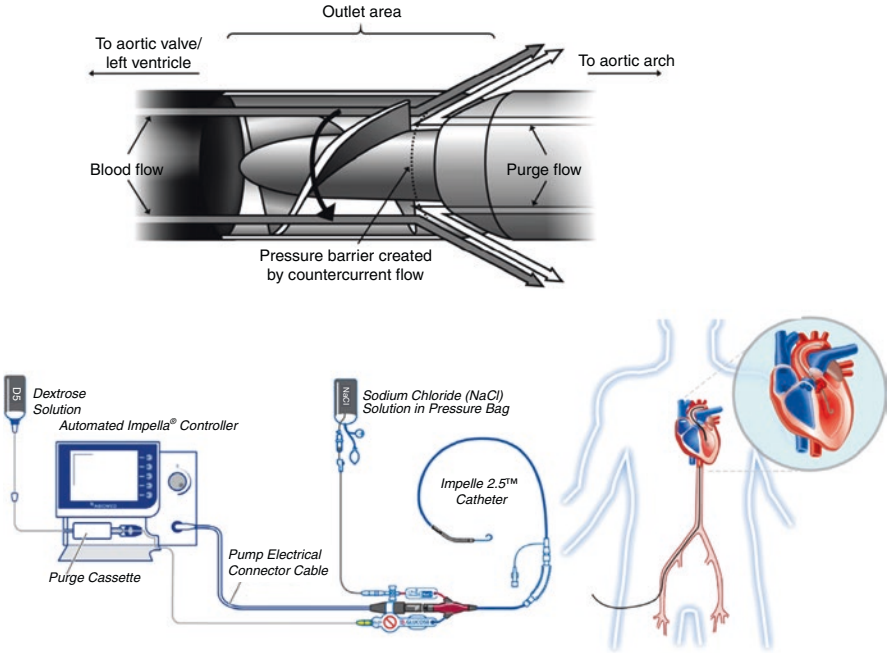

Fig. 2 Impella pump design. (Used with permission from [5])

monitoring and controlling the speed. The speed of the impeller rotation is adjusted by Performance Level, or commonly referred to as P-Level. P-Levels 0–9 correlate to expected flow ranges on a scale of RPMs, with P9 being the highest speed or RPMs (Impella 2.5 only goes as high as P8). The amount of mechanical ventricular unloading can directly be controlled by titrating P-level, as long as the impella positioning is adequate.

A correctly positioned cannula places the inflow area in the middle of the left ventricle and the center of the cannula sits across the aortic valve, while the outflow is in the ascending aorta. Cannulas come equipped with sensors in the distal tips that provide waveforms on the console. These waveforms help determine how the cannula is positioned in relation to the aortic valve. The Ao Placement Signal indicates if the outlet area of the cannula is in the ventricle or aorta by a sensor reading current pressures. In cases where there is little cardiac function, a flat Ao or placement signal may be present. Pulsatility on the waveform may return as cardiac function improves. The motor current measures the energy intake and fluctuates with speed and pressure changes throughout the cardiac cycle. When the cannula is positioned correctly across the aortic valve, the motor current will produce a pulsatile waveform. Since the inlet and outlet areas are on opposing sides of the aortic valve, the device detects the different pressure readings from either end of the cannula as the valve opens and closes. This produces the pulsatile motor current waveform. If the cannula slides out of correct position and the inlet and outlet are both in the ventricle or aorta, the motor current will become flat, as there is no longer change in the

pressure between the two ends. In cannulas equipped with SmartAssist, an additional LV waveform is present when set P-4 or higher. The LV placement signal is calculated from the Ao Placement signal and the gradient of the motor current.

Waveforms should be monitored on the placement screen which displays real-time operating data for the impella. Questionable waveforms should be evaluated by echo to view the positioning across the aortic valve, to ensure the cannula is appropriately positioned or make necessary adjustments. Abiomed also offers a remote monitoring option, Impella Connect, in which one can log into the AIC and view the device status, waveforms, and alarms. Table 2 reviews potential waveform expectations.

In addition to close monitoring of waveforms for proper placement, frequent assessment of external cannula length and exit site should be evaluated for marking changes, bleeding, or signs of infection. It is also important to monitor volume status to prevent suction or hemolysis. If suction occurs, the P-level should be reduced and the cause of suction evaluated and treated.

The catheter uses a purge system which both cools the motor and prevents clot formation. The solution is a combination of heparin and 5% dextrose. The console automatically adjusts the purge flow and provides a purge pressure value to monitor. Attention should be paid to the purge flow and purge pressure as raising values can be an indicator of clot formation and/or impending pump dysfunction.

While the heparin within the purge solution has a systemic effect, it may be necessary to start a heparin drip in order to maintain adequate anticoagulation. Most studies report a target aPTT range from 55 to 80 s. Abiomed recommends use of ACT goal during patient support of 160–180 s. Table 3 represents all the available impella devices currently approved.

Table 2 Expected impella waveforms by cannula type

	2.5	CP with SA	LD	5.0	5.5 with SA	RP
Sensor type	Open pressure port	Fiber optic sensor	Differential pressure sensor	Differential pressure sensor	Fiber optic sensor	Differential pressure sensor
Placement waveform	Aortic (ventricular indicates in the wrong position)	Aortic (ventricular indicates in the wrong position)	Pulsitile (may look like ventricular waveform, but incorrect position would produce a flat waveform)	Pulsitile (may look like ventricular waveform, but incorrect position would produce a flat waveform)	Aortic (ventricular indicates in the wrong position)	Pulsitile (may look like PA waveform, but incorrect position would produce a flat waveform)
LV waveform	Not available	Present P4 or higher	Not available	Not available	Present P4 or higher	Not available
Motor current	Pulsitile (if flat, indicates in the wrong position)	Pulsitile (if flat, indicates in the wrong position)	Pulsitile (if flat, indicates in the wrong position)	Pulsitile (if flat, indicates in the wrong position)	Pulsitile (if flat, indicates in the wrong position)	Pulsitile (if flat, indicates in the wrong position)

Table 3 Current impella devices available for use

	Impella 2.5	Impella CP with SmartAssist	Impella LD	Impella 5.0	Impella 5.5 with SmartAssist	Impella RP
Flow	2.1–2.5 L/min	3.1–4.3 L/min	4.2–5.2 L/min	4.2–5.2 L/min	~6.0 L/min	3.9–4.4 L/min
Insertion	Percutaneous 12 Fr sheath	Percutaneous 14 Fr sheath	Surgical-open	Surgical-axillary cut down	Surgical-axillary cut down or open	Percutaneous
Length of time	<1 week	<1 week	<2 weeks	<2 weeks	<1 month	<2 weeks
Pros	– Speed – Accessibility	– Speed – Accessibility	– Shorter catheter – Ease of direct insertion	– Pt can ambulate	– Maximal support – Pt can ambulate – Smart assist	– Percutaneous insertion vs. central cannulation for surgical RVAD
Cons	– Pt immobility – Catheter migration – Less support than a surgical impella	– Pt immobility – Catheter migration – Less support than a surgical impella	– Open chest insertion and explant	– No smart assist – Less flow than 5.5	– Surgical implant	– Need for fluoroscopy – Pt immobility
						

Indications/Contraindications

The impella line of devices have several indications. The left-sided percutaneous impella, namely the impella CP, is currently used for hemodynamic support during high-risk percutaneous coronary intervention (PCI) and may be the first line of support in the management of acute coronary syndrome complicated by shock. The surgical impellas are often used to manage progressive cardiogenic shock from pre-existing advanced heart failure and may also be used in cases of post cardiotomy shock. Impella is more frequency being used as a vent for VA ECMO patients to unload the left ventricle and help lower mortality rates. The impella RP can be used to provide right-sided support in complicated right ventricular infarction as well as in the support of right ventricular failure post durable left ventricular device implantation. The impella CP is currently being investigated for offloading prior to PCI in Anterior wall MI and high-risk cardiac surgery.

The use of the impella in AMI complicated by cardiogenic shock increased after the SHOCK II trial failed to show mortality benefit with the use of intra-aortic balloon pump [6]. While there have been many trials to investigate the mortality benefit of impella, most have been either poorly randomized or underpowered. With advancements in both catheter engineering and operator experience, more recent trials have demonstrated a decrease in hospital length of stay and 30-day mortality with early impella support [7].

Contraindications to impella support include known iliofemoral arterial occlusion (percutaneous catheters), severe aortic stenosis, LV thrombus, mechanical aortic valve, and contraindication to systemic anticoagulation.

Complications

Percutaneous impella support can be complicated by issues related to insertion, vessel occlusion leading to limb ischemia, and bleeding. The PROTECT I trial sited an insertion site hematoma in 8 out of 20 patients, although none necessitated transfusion or vascular intervention [8]. The risk of retroperitoneal hemorrhage is 0–2.2% when extrapolated from TAVR data [9]. The risk of pseudoaneurysm as extrapolated from cardiac catheterization is 0.4% and up to 3.4% in large bore access [10]. The rate of acute limb ischemia has been reported as high as 12% and often results in increase morbidity and mortality [11].

Hemolysis remains a challenging complication of Impella catheters. Hemolysis is breakdown of the red blood cell caused by sheering forces which disrupt membrane integrity. VAD hemolysis is discussed in a similar context in chapter "Ventricular Assist Device Complications."

Hemolysis is evidenced by hemoglobinuria either occult (laboratory analysis) or apparent (tea-colored urine, as in Fig. 3), anemia, indirect hyperglobinemia, and/or abnormal pump function. Rates of hemolysis have been reported to be approximately (or as high as) 10.3% [12]. Failure to recognize and treat hemolysis can lead to acute renal failure, platelet aggregation, and thrombosis with increased morbidity and mortality. Investigation in impella-related hemolysis begins with a transthoracic

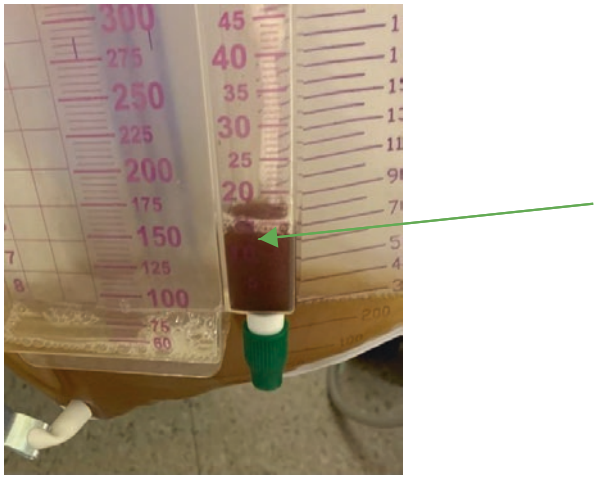

Fig. 3 Urine color during episodes of hemolysis

echocardiogram evaluating appropriate positioning of the catheter and ventricular volume status. Treatment should be directed toward the inciting cause and include catheter repositioning, adequate anticoagulation, administration of volume, or augmentation of RV function.

Indications for Surgical Impella/Escalation

In the setting of cardiogenic shock with or without existing MCS, the presence of persistent shock symptoms should prompt consideration of escalation of support. Hemodynamic and serologic findings consistent with shock include:

- Need for vasopressor support to keep the SBP >90
- Cardiac index <2.2 L/m^2
- PCWP greater than 15 mmHg
- Lactate level >2.0
- Urine output <0.5 mL/kg/h

The surgically implanted impella (5.0 or 5.5) allows for increased support, increased patient mobility including ambulation due to its axillary artery approach, and the ability to provide longer duration of temporary support. In a study of 58 surgically implanted impellas implanted at three centers, 33% expired on support and 67% were bridged to other therapy. Of those bridged to other therapy, 51% were bridged to LVAD, 39% received transplant, and 10% were weaned off support [13].

Weaning

Proper weaning of the impella device is key in determining the next step of care for the supported patients. Failure to wean off the impella may result in the need for

bridging to durable LVAD or heart transplantation. Weaning should be considered once there is evidence of end-organ recovery, minimal rhythm disturbances, particularly ventricular arrhythmias, minimal need for vasoactive drugs, and signs of native left ventricular recovery, including echo evidence of improved function, minimal mitral regurgitation, increase arterial line pulsatility, and improved invasive hemodynamics (low CVP and wedge pressure, stable cardiac index greater than 2.2). The impella can be weaned by gradual reduction of the P-level, resulting in more native contribution of the heart. SmartAssist technology on the CP and 5.5 catheters allows for monitoring specific to weaning with the LVEDP trends screen. Information displayed should verified with patient's hemodynamics, but as the P-levels are being reduced, you can view MAP, native cardiac output, Impella flow, and LVEDP trends over specific time frames. As percutaneous support is reduced, cardiac output and native heart function should remain stable. If the patient has adequate hemodynamics (i.e., CVP <12, CI >2, no escalation in vasopressor agents) at P2, the catheter can be removed. If the patient cannot tolerate weaning, long-term support options, such as durable VAD, heart transplantation, or inotropic infusion, should be explored.

Left Atrial to Femoral Arterial Bypass

Left atrial to femoral arterial bypass (LA to FA bypass), more commonly known by its typical trade name of Tandem Heart (LivaNova LifeSPARC, London, UK), is a method of mechanical cardiopulmonary support which allows oxygenated blood to be delivered from the left atrium to the femoral artery, bypassing the ailing left ventricle. This device may be considered as an acute form of support in the rapidly deteriorating patient as a bridge to another form of support, such as a durable left ventricular assist device (LVAD) or a heart transplant, or when the cause may be reversible. The advantage of LA to FA bypass is that it can be rapidly deployed anywhere fluoroscopy or echocardiography is available.

Highly specialized care is needed for these patients once they are supported with this device and should only be undertaken by staff who have been trained extensively. Cannula securement is of utmost importance. When cannulated with transsepetal approach, even very small movements can dislodge the catheter so anchoring the cannulas with additional external holders and monitoring cm markings on cannulas help ensure cannulas remain in the appropriate place. Due to the size of the cannulas and their placement in the groin, frequent neurovascular checks are required to ensure adequate blood flow continues to circulate to extremities. Distal perfusion catheters can also be used to prevent limb ischemia.

Configuration

An LA to FA bypass device circuit is typically comprised of a long cannula (21 Fr 62 cm or 72 cm) that is placed via the right femoral vein and introduced into the left atrium using a transseptal puncture from the right atrial side of the heart (Fig. 4).

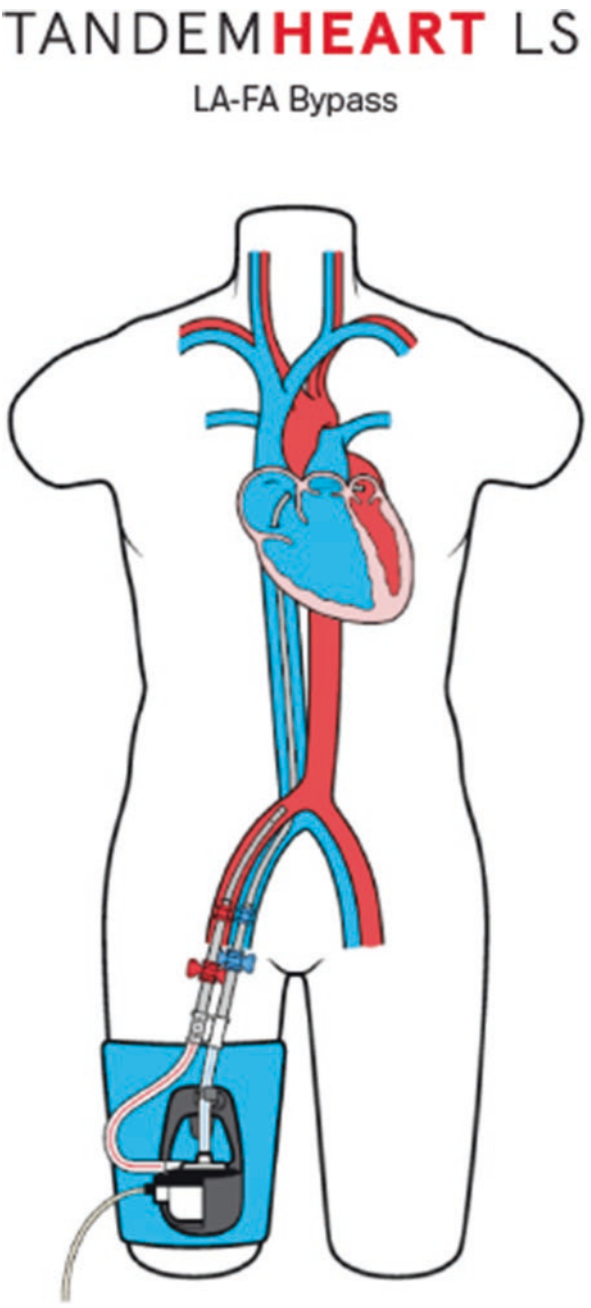

Fig. 4 Tandem configuration

The blood is pulled from the left atrium of the heart, sent through a centrifugal pump, and then placed back into the body via a short cannula (typically a 15 or 17 Fr) in an artery, usually femoral.

Indications and Contraindications

Indications for use include any form of left ventricular failure including but not limited to acute, chronic or acute-on-chronic heart failure, myocarditis, and acute myocardial infarction. This device may also be paired with a right ventricular support device to provide biventricular support to the patient. This support can be continued until a determination is made of myocardial recovery, until the patient can be bridged to durable support device or heart transplantation or terminal wean for palliative care [14].

Support is contraindicated for those patients with irreversible pre-existing conditions limiting survival such as those who are not candidates for transplant or durable VAD or non-recoverable disease such as advanced malignancy, unwitnessed cardiac arrest or prolonged CPR due to likelihood of severe anoxic brain injury, severe end organ dysfunction, severe coagulopathies, or recent or expanding hemorrhage, especially in the brain. Patients with a left atrial thrombus or very small peripheral vasculature are considered borderline candidates for therapy and must be considered carefully prior to selection.

Weaning of the device is done by slowly turning down the flow on the pump while monitoring the patient. If the patient cannot be weaned to recovery, advanced therapies such as durable VAD or transplant, or a terminal palliative wean would need to be considered.

Complications

Potential complications related to the insertion of LA to FA bypass include bleeding from cannulation sites, peripheral vessel perforation, distal ischemia, complications with the transseptal puncture such as puncture of the wall of the left atrium, or complications due to the cannula falling back into the right side of the atrium causing shunting of deoxygenated blood to the body. Other more generalized complications such as bleeding due to anticoagulation, thromboembolism, infection, neurological injury, and kidney failure can also occur [15].

Right Atrial to Pulmonary Artery Bypass

Right atrial to pulmonary artery bypass (RA to PA bypass), more commonly known by its typical trade name of Protek Duo (LivaNova, London, UK), is a method of mechanical cardiopulmonary support which was introduced in 2014. When a patient

has severe right ventricular failure that may rapidly progress to another form of support, such as a heart transplant, or when the cause may be reversible, this device may be considered for use. RA to PA bypass typically must be deployed with the availability of both fluoroscopy and pulmonary pressure monitoring capability by the trained physician.

Highly specialized care is needed for these patients once they are on this device and should only be undertaken by staff who have trained extensively for their management. Close attention needs to be paid to the fluid volume status as these pumps are preload-dependent. Frequent assessment of cannula kinks, chatter present, arrhythmias, intravascular volume, and filling pressures need to be evaluated. Similar to LA-FA bypass, cannula securement is very important with the Protek Duo. Because there is only one cannula site in neck, ambulation with this device is much easier. Tandem provides a vest to help secure the pump, but extra precaution should be taken whenever moving the patient.

Configuration

An RA to PA bypass device circuit is typically comprised of a long dual-stage cannula (29 or 31 Fr). Typical access site is the right jugular vein due to ease of placement via this approach, though other cannulation styles are possible. The cannula is positioned with one opening in the pulmonary artery and one opening in the right atrium. The blood is pulled from the right atrium, sent through a centrifugal pump, and then placed back into the pulmonary artery (Fig. 5).

Indications/Contraindications

Indications for use include any form of right ventricular failure including acute myocarditis, myocardial infarction, pulmonary embolism, etc. This device may also be paired with a left ventricular support device to provide biventricular support to the patient, including those with right ventricular failure following acute or durable LVAD placement, as well as other progressive myopathies. This support can be continued until evidence of recovery or as a bridge to heart transplantation, or palliation. Typically patient's requiring biventricular support without evidence of right ventricular recovery would not be considered for durable VAD, though there may be exceptions in rare cases.

Support is contraindicated for those patients with irreversible pre-existing conditions limiting survival such as those who are not candidates for transplant or non-recoverable disease such as advanced malignancy, unwitnessed cardiac arrest or prolonged CPR due to likelihood of severe anoxic brain injury, severe end-organ dysfunction, severe coagulopathies, or recent or expanding hemorrhage, especially in the brain.

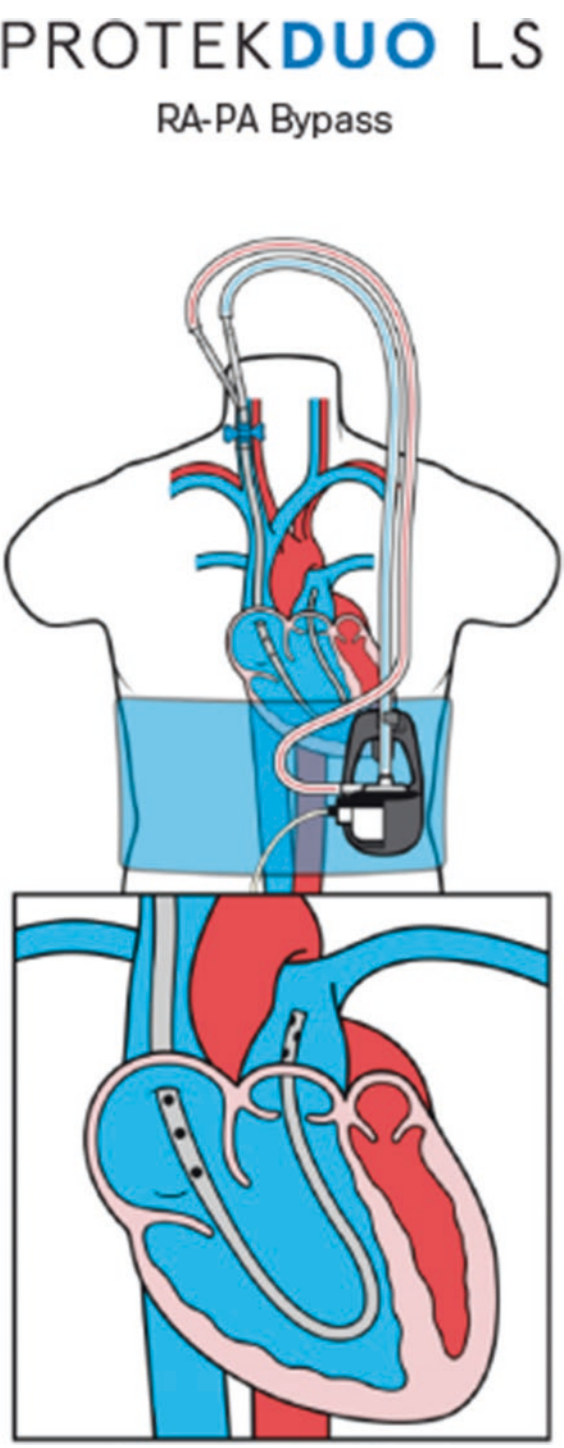

Fig. 5 Protek Duo cannulation

Complications

Potential complications of RA to PA bypass include procedure-related complications such as bleeding from the venous site or peripheral vessel perforation. Other more generalized complications such as bleeding due to anticoagulation, thromboembolism, infection, neurological injury, and kidney failure can also occur [16].

Extracorporeal Membrane Oxygenation (ECMO)

Extracorporeal membrane oxygenation, more commonly referred to as ECMO, is a method of mechanical cardiopulmonary support which was introduced in the 1970s but has become more frequently used over the past decade. ECMO may be utilized to manage severe biventricular failure (VA ECMO) or severe respiratory disease (VV ECMO) which is refractory to conventional treatment. ECMO deployment and management should only be performed by trained clinicians within prepared medical centers, and therefore transfer to an ECMO capable facility may be necessary for evaluation and care. Frequent blood draws from the ECMO machine are expected to monitor its function. Most programs require a perfusionist or ECMO Specialist to be at the bedside at all times to respond to emergent circuit issues like pump malfunctions, air in circuit, or clots in the circuit. In case of these emergencies, they are specially trained to exchange circuit and restore ECMO flow.

Configuration

An ECMO circuit is comprised of the following components

- an oxygenator, which oxygenates blood and removes carbon dioxide,
- the blender, which provides a mixture of nitrogen and oxygen to the oxygenator,
- centrifugal pump to continuously move the blood,
- large bore cannulas for blood drainage and return,
- the controller to allow the operator to adjust the settings (typically RPMs and sweep speed).

There are two types of ECMO: venovenous (VV) and venoarterial (VA), both of which provide pulmonary support by oxygenating blood but only VA ECMO provides hemodynamic support. ECMO can be used in the acute setting with bedside peripheral cannulation of the femoral venous/arterial circulation or can be placed surgically with central cannulation of the great vessels or cardiac structures. The surgeon can alter inflow and outflow cannulation sites based on the need for support and the patient's clinical scenario.

In VV ECMO, deoxygenated blood is extracted from the right atrium or vena cava by direct cannulation or via a cannula in the femoral vein or right internal jugular vein. The blood is passed through an extracorporeal circuit to be oxygenated and

filtered of carbon dioxide, then returned to the right atrium by direct cannulation or via a second cannula accessed in either the femoral vein or right internal jugular. Typically the femoral vein access is used for drainage at the junction of the IVC/right atrium and the right internal jugular for return to SVC/right atrium to minimize recirculation. In the VV method, blood does not bypass the heart and tissue perfusion is dependent upon the patient's own cardiac output and pulsatility.

In VA ECMO, deoxygenated blood is extracted via the venous system and then after being cycled through the oxygenator it is recirculated to the systemic circulation via the aorta either by direct cannulation or via a cannula in the femoral or axillary artery, bypassing the heart and lungs. By flowing directly into the systemic circulation, VA ECMO results in an increase in afterload, which needs to be considered when managing acute cardiogenic shock, as this may result in increased LVEDP and worsen LV strain, ischemic and ventricular arrhythmias. Commonly, an LV vent is placed to actively reduce the LVEDP while relying on VA ECMO to provide sufficient hemodynamic support. The LV vent may be a surgical catheter placed via the pulmonary vein, LA or LV in the centrally cannulated patients or a percutaneous MCS device such as an Impella CP, TandemHeart, or IABP.

Indications/Contraindications

Indications for ECMO initiation include hypoxemic respiratory failure despite optimal ventilator settings, hypercapnic respiratory failure, massive pulmonary embolism, failure to wean from intraoperative cardiopulmonary bypass, scenarios of severe biventricular heart failure requiring support and may be needed as a bridge to lung or heart transplant or surgical ventricular assist device (VAD).

ECMO support is unsuitable, and therefore contraindicated, for irreversible preexisting conditions limiting survival such as those who are not candidates for transplant or durable VAD, non-recoverable respiratory disease, advanced malignancy, unwitnessed cardiac arrest or prolonged CPR due to likelihood of severe anoxic brain injury, severe organ dysfunction, coagulopathies, or recent or expanding hemorrhage.

Complications

Potential complications of ECMO include bleeding due to continuous anticoagulation and platelet dysfunction, thromboembolism since thrombus may form within the circuit, infection, neurological injury, kidney failure, heparin-induced thrombocytopenia (HIT). There are also cannula-related complications including distal ischemia, vessel perforation, and arterial dissection. Complications specific to venoarterial (VA) ECMO include cardiac thrombosis, pulmonary hemorrhage or edema, and cerebral hypoxia due to North-South (Harlequin) Syndrome (reference). North-South Syndrome may occur in cases of femoral cannulation of VA ECMO due to poorly oxygenated blood being distributed from the impaired lungs

to the ascending aorta to perfuse the upper body and brain while the ECMO circuit supplies well-oxygenated blood to the lower body. This causes a cyanosis of the upper body and hyperoxia of the lower body. A hybrid VVA ECMO configuration, i.e. the addition of a right internal jugular cannula integrated into the circuit, may improve this uneven perfusion issue.

As mentioned earlier, VA ECMO does not unload the left ventricle so due to stagnant LV blood and increased filling pressures, ECMO places the patient at risk for cardiac thrombosis, pulmonary edema, or pulmonary hemorrhage. In this instance, LV decompression via a surgical vent, IABP, or percutaneous left ventricular assist device (Impella) may be warranted.

Conclusion

Temporary MCS devices have been gaining in popularity and becoming more widely used as a means to bridge patients to transplant and to stabilize end-organ dysfunction prior to VAD implant. The various devices discussed in this chapter highlight their ability to support very complex hemodynamic needs. These pumps require skilled monitoring and in-depth understanding of device mechanism of action, placement of catheters, and potential complications to be successful in use. Each device is tailored for a specific purpose and is chosen based on the appropriate need for the patient's condition. With design changes over the years, it will be interesting to see what the future holds for temporary MCS use.

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