PART 9

IMPELLA TROUBLESHOOTING AND RESUSCITATION

Tim Balthazar, M.D.
Departments of cardiology and intensive care,
University Hospital Brussels, Belgium

Christophe Vandenbriele, M.D, PhD.
Cardiology and critical care medicine,
Department of cardiovascular diseases,
University Hospitals Leuven, Belgium

Key messages

- Suction events can lead to insufficient support and haemolysis, calling for rapid intervention.

- Suction events are mostly due to abnormal device position or insufficient preload. A fluid challenge test can be useful in difficult cases.

- A culprit oriented approach should be used when troubleshooting the Impella supported patient with signs of persistent circulatory failure.

- Right ventricular failure is an important cause of insufficient preload during left ventricular Impella support.

- The Impella can dislodge during cardiopulmonary resuscitation and position should be evaluated at return of circulation.

Executive summary

This chapter provides an overview of common troubleshooting situations during Impella support, starting with suction alarms and haemolysis. We illustrate the importance of proper device position and show how the Impella Smart Assist® can differentiate between diastolic and continuous suction events. Furthermore, a systematic approach is offered to resolve these suction alarms. Also, a culprit-oriented approach to the patient with persistent circulatory failure is proposed, focusing on optimization of device performance. Finally console alarms and the purge system are discussed in brief.

1 - SUCTION EVENTS AND HAEMOLYSIS

Suction events are amongst the most common problems encountered during Impella management in the cardiac intensive care unit and should be avoided at any time. Longer standing suction events can lead to haemolysis and insufficient circulatory support.

1.1 - Causes and consequences

Figure 1 - Impella console showing suction alarm on the console of an Impella equipped with the Smart Assist® platform
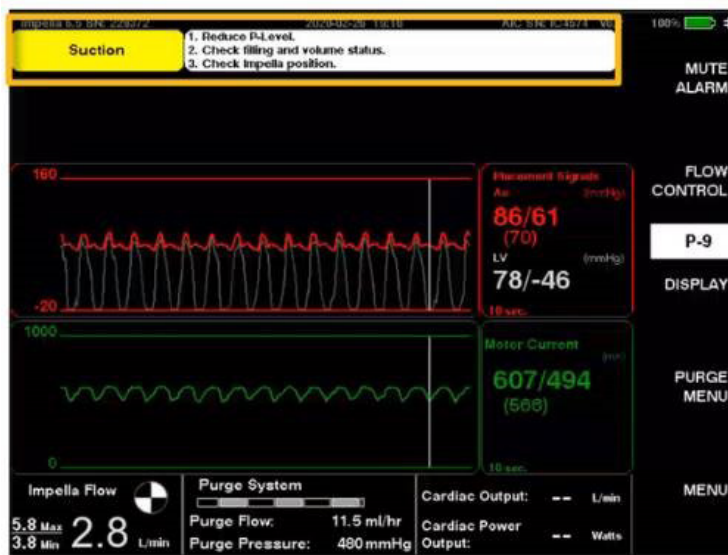
Suction alarms *(Figure 1, yellow box)* on the device console are the result of decreases in flow, leading to a reduction in motor current *(Figure 1, green waveform)*. The newer devices equipped with Smart Assist® *(Figure 1, white pressure tracing)* will show a decrease in the calculated ventricular pressure waveform during suction. Most common causes are:

- Contact of the Impella device inlet with a ventricular structure (mitral valve leaflet, chordal structure, ventricular wall,...).

- Abnormal / altered device positions.

- Insufficient preload.

- Device related thrombus formation.

- Excessive support to a recovering heart.

Suction events may:

- Decrease the level of support that is provided to the circulation, which may result in haemodynamic deterioration.

- Increase shear stress for red blood cells, resulting in haemolysis. It is also possible to encounter haemolysis without overt suction alarms in case of subtle abnormalities. The preferred test to quantify haemolysis is the plasma free haemoglobin (PfHb).

1.2 - Diagnostic steps

1.2.1 - Verify device position on echocardiography

- The end of the inlet cage (termed "teardrop" for the shape on imaging) is ideally located about 3.5 cm from the aortic valve *(Figure 2, left panel: normal device position)*. Avoid including the pigtail in the measurement of insertion depth. Colour Doppler (showing turbulence and flow convergence; *Figure 2, right panel*) can be helpful.

- Verify the angle between the pump and the mitral valve apparatus *(Figure 3)* and check for subtle sucking of chordal material into the inlet.

- Check for microbubbles in the left ventricle, which often indicates significant haemolysis.

Figure 2 - Left ventricular Impella position on transthoracic echocardiography in the parasternal long axis view

Left panel showing correct Impella position with the inlet at 3.5 cm from the aortic valve, free from ventricular structures. **Right panel** showing colour Doppler artefact with flow converging to the inlet and turbulent flow with an emerging "colour mosaic" at the level of the outlet in the ascending aorta.
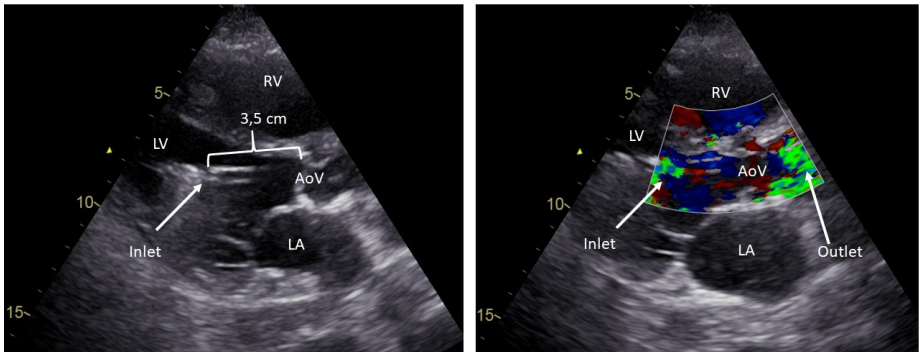

Figure 3 - Illustrating the importance of the angle (in purple) between the pump and the horizontal plane of the mitral valve (both in dotted green lines)

A wide angle (> 126.5 degrees; **left panel**) reduces the risk of suction events and subsequently haemolysis as compared to a narrower angle **(right panel)**.
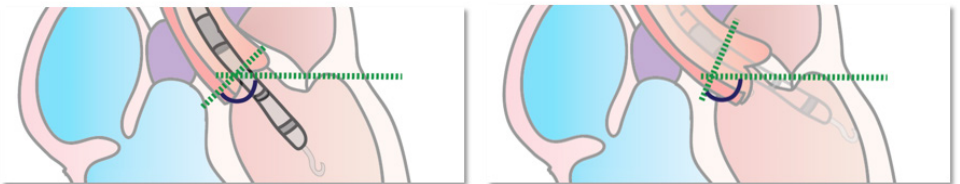

after Nakamura et al., Organs 2020

Figure 4 - Impella console with Smart Assist® with continuous ventricular pressure waveform

The **upper left-hand panel** illustrates continuous suction that leads to a continuous decrease in motor current which results in continuous lowering of the calculated ventricular pressure waveform. The **lower left-hand panel** illustrates diastolic suction leading to a decrease of the calculated ventricular pressure waveform, but only during diastole.
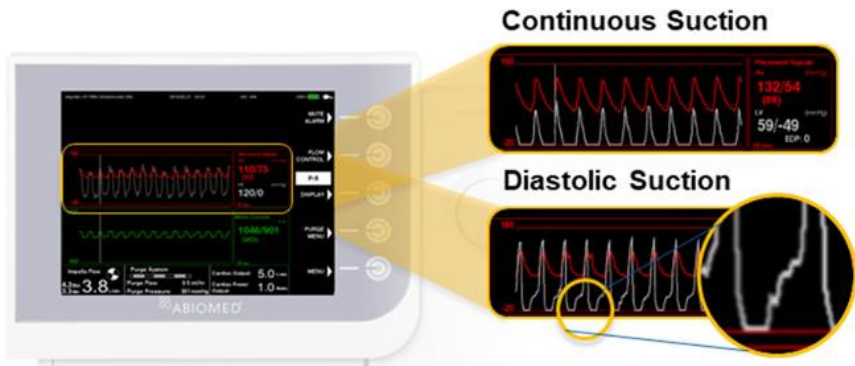
1.2.2 - Smart Assist®

Impella devices equipped with Smart Assist® can differentiate suction events during the diastole from continuous suction events (*Figure 4*; discussed further as well):

- Continuous suction events are mostly related to device position or thrombus formation.

- Diastolic suction events are mostly related to insufficient preload.

The actions to be taken depend on the underlying aetiology:

- Bed-side repositioning (always under real-time imaging).

- Optimizing left ventricular preload (see next topic).

- Increase anticoagulation targets.

- Consider weaning attempt.

2 - THE PATIENT WITH PERSISTENT CIRCULATORY FAILURE

The scenario that needs the most comprehensive approach is that of a patient with persistent signs of circulatory failure (persistent lactate acidosis, biochemical signs of end-organ failure) despite MCS.

2.1 - Possible causes

The three main causes of persistent circulatory failure are:

- Insufficient device capacity (not enough support despite maximal device flow) considering patient body surface area, temperature and other parameters that reflect the expected needs for oxygen delivery. Also, residual cardiac function (e.g., left ventricular outflow tract velocity time integral) and global haemodynamics (low mixed venous oxygen saturation and persistently elevated filling pressures) are needed in the decision to escalate.

- Vasoplegia and microcirculatory failure as a consequence of SIRS.

- Suboptimal device performance (not reaching its maximal flow) which is often associated with suction events and sometimes also with ventriculo-arterial uncoupling.

Figure 5 - The three main causes of persistent circulatory failure: insufficient device capacity, suboptimal device performance and vasoplegia
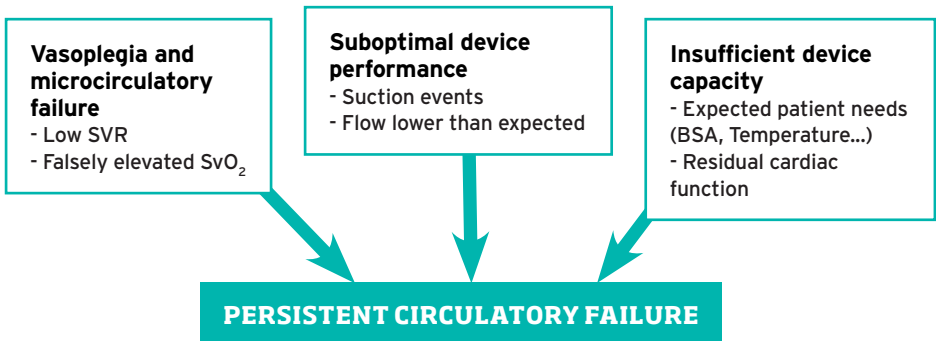

Vasoplegia and microcirculatory failure
- Low SVR
- Falsely elevated SvO_2

Suboptimal device performance
- Suction events
- Flow lower than expected

Insufficient device capacity
- Expected patient needs (BSA, Temperature...)
- Residual cardiac function
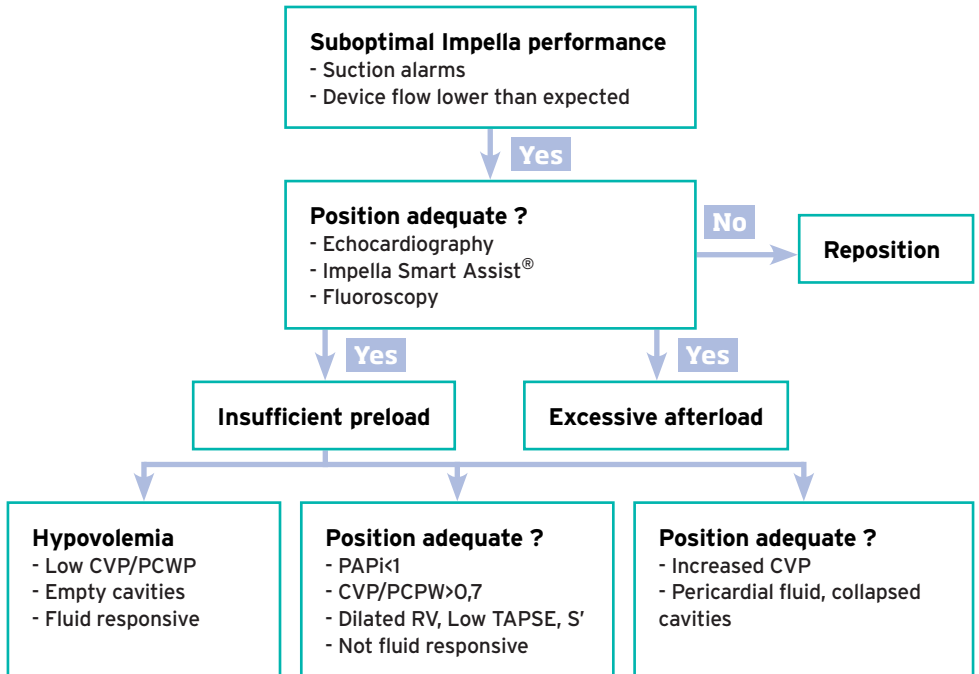
PERSISTENT CIRCULATORY FAILURE

Figure 6 -. A systematic approach to the patient with suspected suboptimal device performance

After excluding incorrect position and excessive afterload, the main focus is on insufficient cardiac preload. Hypovolemia, right ventricular failure, and tamponade are the most frequent causes for insufficient preload that can be differentiated from another with right heart catheterization and echocardiography.

Suboptimal Impella performance
- Suction alarms
- Device flow lower than expected

Yes

Position adequate ?
- Echocardiography
- Impella Smart Assist®
- Fluoroscopy

No → **Reposition**

Yes

Yes

Insufficient preload

Excessive afterload

Hypovolemia
- Low CVP/PCWP
- Empty cavities
- Fluid responsive

Position adequate ?
- PAPi<1
- CVP/PCPW>0,7
- Dilated RV, Low TAPSE, S'
- Not fluid responsive

Position adequate ?
- Increased CVP
- Pericardial fluid, collapsed cavities

2.2 - Diagnosis

- Abnormal device position (Imaging and Impella Smart Assist® – continuous suction; *see previous paragraph*).

- Excessive afterload; this is easily identified (does not lead to suction events, presence of high blood pressure).

Insufficient preload is the most common cause. Here, the three most important underlying mechanisms are:

- Hypovolemia, which manifests as low filling pressures on RHC and empty cavities on echocardiography. In difficult cases a fluid challenge test is the best way to differentiate between hypovolemia and RV failure.

- RV-failure. This is identified during RHC based on PAPi (PAPi = $(PA_{systolic} - PA_{diastolic})/CVP$) <1 and CVP/PCWP > 0.6-0.8, although most of these data are based on patients receiving durable ventricular assist devices. The combination of elevated CVP and diastolic suction events is also highly suggestive of RV failure.

- Tamponade, mainly identified on echocardiography since invasive haemodynamics can be misleading during left ventricular unloading.

Figure 7 - Example of a positive fluid challenge test, showing an increase in cardiac output by echocardiography and invasive measurements, that resulted in a restoration of mixed venous oxygen saturation into the normal range

Also notice that right ventricular dimension increased relative to left ventricular dimension after fluids, which means the culprit is probably the right ventricle and careful monitoring of right ventricular function will be needed when further fluid loading in used to prevent an evolution to right ventricular failure
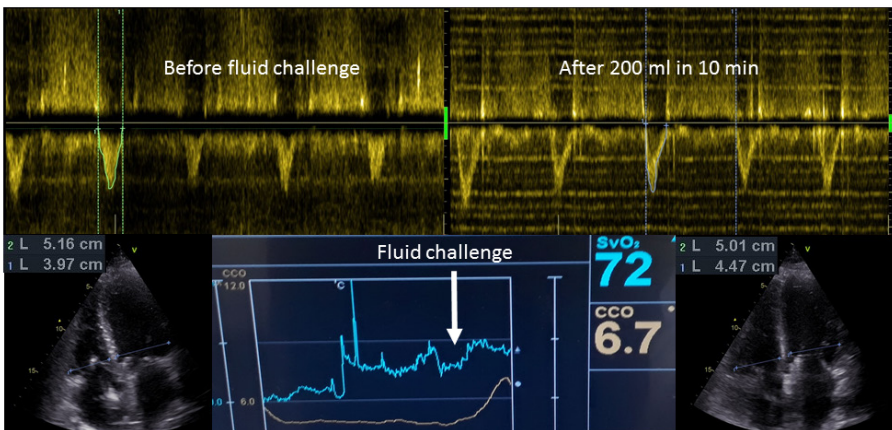
2.3 - Actions – depending on the underlying aetiology

- Bed-side repositioning (always under direct real-time imaging).

- Vasodilators (nitroprusside, nitrates, …).

  Culprit oriented intervention in case of insufficient preload:
  - Fluid boluses or transfusion
  - Pulmonary vasodilators, optimizing mechanical ventilation, inotropes, or RV MCS
  - Pericardiocentesis or surgical revision

3 - CPR DURING IMPELLA SUPPORT

CPR should be performed based on loss of perfusion pressure and/or flow, rather than on electrocardiogram or flattening of the arterial waveform, since the device can often maintain adequate perfusion pressures despite ventricular tachycardia.

3.1 - Possible causes

- Abnormal Impella position or suction events are possible triggers.

- Myocardial ischemia.

- Scar development after acute myocardial infarction.

- Drug induced.

- Metabolic derangements (pH or electrolyte abnormalities).

3.2 - Diagnosis and actions

- Consider reducing Impella P-level to P-2 during CPR to minimize potential damage to cardiac structures (especially when sunction alarm) and increase the level of support again at return of circulation. This also resolves the arrhythmia when it was induced by suction events. (Continuing support, however, can be considered for patients that have extremely poor native heart function).

- An Impella device is not a contraindication for electrical defibrillation.

- Thorough search for the reason of the arrest includes echocardiography in most cases.

- Also focus on Impella position after return of circulation, to ensure the Impella has not dislodged during CPR.

4 - PURGE SYSTEM ALARMS

The purge system is a unique property of the Impella device, designed to prevent blood entering the motor housing. The device controller will vary the infusion rate of this heparinized glucose solution to obtain purge pressures within a range (300-1100 mmHg) well above systolic blood pressure. The console will provide an alarm in case of excessive purge system pressure.

4.1 - Most common causes of purge pressure alarms

- Excessive purge system pressures; as a result of:
  - Kinked tubing
  - High viscosity of purge fluid
  - Obstruction of the purge system/outlet (e.g., thrombus)

- Low purge pressures; as a result of:
  - Leakage somewhere in the purge system
  - Low purge solution viscosity

4.2 - Actions – depending on the underlying aetiology

Excessive pressure:
- Check for kinked tubing
- Consider decreasing glucose viscosity if higher than 5%
- Consider replacing the purge cassette
- Local thrombolysis is used by some centrers with good results; but data remain scarce

Low purge pressures:
- Check for leakage in the system
- Consider replacing the purge cassette
- Consider increasing the glucose viscosity in the purge fluid if less than 20%

Table 1 - Overview of the most common alarms encountered in clinical practice (including purge system alarms)

Alarm	Cause	Action
Purge pressure low	⊘ Leakage in the tubing or system ⊘ Low purge viscosity	⊘ Check for leakage ⊘ Consider replacing purge cassette ⊘ Increase glucose % in purge fluid
Purge pressure high	⊘ Kinked tubing ⊘ High viscosity of purge fluid ⊘ Obstruction of the purge system/outlet (e.g., thrombus)	⊘ Check for kinked tubing. ⊘ Consider replacing purge cassette ⊘ Consider decreasing glucose % ⊘ Local thrombolysis?
Suction	⊘ Abnormal device position ⊘ Low device preload	⊘ Temporarily decrease P-level ⊘ Check device position ⊘ Hemodynamic assessment.

Alarm	Cause	Action
Position unknown	● Abnormal device position ● Low native heart pulsatility	● Check device position ● Check native heart output ● Check for excessive afterload
Placement signal lumen blocked	● Thrombus in lumen ● Kink in lumen ● Low native heart pulsatility	● Check for motor current pulsatility (excludes low native heart pulsatility) ● Try to aspirate on the line ● Can be accepted in some cases
Impella stop	● Clotting ● Extremely abnormal position with entangled cardiac structure	● Restart (first P-8, then P-2) ● Check position ● Re-implantation/exchange