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UK multisociety consensus statement on the emergency management and resuscitation of patients with left-sided Impella support

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ABSTRACT

The use of left-sided Impella microaxial flow pumps has expanded rapidly for the management of cardiogenic shock, left ventricular unloading and as a bridge to heart transplantation. However, standard life support and resuscitation algorithms are not directly applicable to patients receiving this therapy due to fundamental alterations in circulatory physiology. To address this gap, eleven UK Impella centres and eight national professional societies collaborated to develop a unified national consensus statement on the emergency management of patients with left-sided Impella support. Using a systematic review of the literature and a modified Delphi process guided by the European Society of Cardiology framework for grading recommendations, expert representatives achieved agreement on key priorities and structured actions to be undertaken in the first few minutes of resuscitation. The consensus outlines early recognition of circulatory inadequacy (mean arterial pressure <30 mm Hg or end-tidal CO_2 <2 kPa), prompt activation of multidisciplinary responders, reduction of Impella power to P2 before initiating cardiopulmonary resuscitation and structured division of patient-focused and device-focused teams. Device-specific troubleshooting algorithms are presented for suction, malposition, purge-system failure and mechanical malfunction. This multisociety consensus represents the first national standard for emergency management and resuscitation of patients supported by a left-sided Impella device and is intended to inform structured clinical training and improve patient outcomes through rapid, coordinated and physiologically tailored interventions.

INTRODUCTION

The Impella is a microaxial flow pump that has seen increasing use and iterative development since its approval for use in 2008.[1] The two contemporary left-sided devices available are the Impella CP (figure 1), which can be inserted percutaneously and provide flows up to 4.3 L/min and the Impella 5.5, inserted surgically and can provide flows of up to 5.5 L/min.[2] There is also a right-sided device, Impella RP, inserted percutaneously that can provide flows greater than 4 L/min.

There has been limited advance in the management of cardiogenic shock over the past decades. Revascularisation has been the mainstay of evidence-based management[3 4] with a lack of support for intra-aortic balloon pump (IABP) or venous-arterial extracorporeal membrane oxygenation (VA-ECMO).[5 6] Recently, the first positive randomised trial in cardiogenic shock and mechanical support was published in post ST elevation myocardial infarction using an Impella CP, showing a 12.7% absolute reduction in 6-month mortality.[7] This was a highly selected cohort, excluding comatose cardiac arrest and prolonged shock (>24 hours), with a number needed to treat of eight but a number needed to harm of six and fragility index of four. This exemplifies the tightrope in device support to improve cardiac output and unloading versus the acquisition of complications through its use. There is also an important health economic consideration for the wider healthcare system that is not yet clear.

In VA-ECMO unloading strategies for the left ventricle (LV) are sometimes needed and include adjustment of extracorporeal membrane oxygenation (ECMO) blood flow, inotropes, IABP and Impella. There is observational data suggesting Impella may improve outcomes by unloading the LV.[8] The larger Impella 5.0, now 5.5, has also been used to bridge directly to heart transplantation in predominant left ventricular failure leading to low cardiac output.[9] This area lacks randomised evidence, but clinically it can be useful to avoid sternotomy for placement for surgical mechanical support and allow early mobilisation postoperatively.

There are also important considerations around the technique used by interventional cardiologists to avoid the risk of myocardial perforation.[10] Echocardiography is key to ensuring correct initial positioning, in particular avoiding contact with mitral valve apparatus or septal wall that can induce future suction and haemolysis. Device removal can also be performed in the catheter lab with suture closure devices or with vascular surgery if needed.

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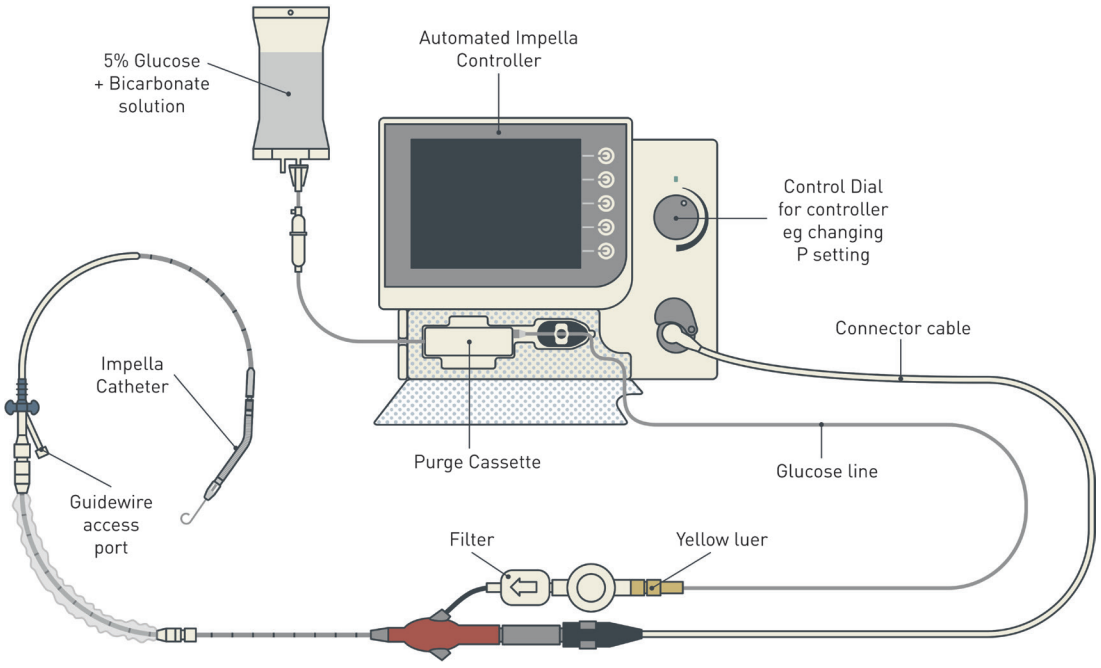

Figure 1 Impella CP components.

However, outcomes will also be dependent on the daily care of the patient delivered by and reliant on the experience of the whole frontline multidisciplinary team. This is even more relevant considering that high complication rates (bleeding, limb ischaemia, haemolysis, acute kidney injury, etc) have been reported during Impella therapy.[11] Over the last decades, standardised resuscitation algorithms have been established to provide a clear prioritised structure to managing emergency medical situations. There is also manufacturer guidance for the management of critical alarms with Impella therapy.[12] However, there is limited guidance in format that aligns patients' resuscitation and device troubleshooting in Impella therapy.[13] In this consensus statement, we have sought to produce an emergency algorithm in a format similar to standard advanced life support algorithms that combines patients and device focus in the first few minutes of resuscitation.

SCOPE AND METHODS

This consensus statement is designed for staff managing left-sided Impella support. It is focused on cardiac arrest; however, many of the same principles apply to all emergencies while on Impella support.

We developed this statement by convening a national Impella Emergency Algorithm Working Group comprising eleven UK centres managing Impella: Barts Health NHS Trust, London; Bristol Royal Infirmary, Bristol; Freeman Hospital, Newcastle; Golden Jubilee National Hospital, Clydebank; Guy's & St Thomas' NHS Foundation Trust, London; Harefield Hospital, Harefield; King's College Hospital NHS Foundation Trust, London; Royal Brompton Hospital, London; Royal Papworth Hospital NHS Foundation Trust, Cambridge; St George's University Hospitals NHS Foundation Trust, London; University Hospitals Birmingham NHS Foundation Trust, Birmingham. The process was supported by eight national organisations: Association of Cardiothoracic Anaesthesia and Critical Care, British Association of Critical Care Nurses, British Cardiovascular Society, British Society of Heart Failure, Intensive Care Society, Faculty of Intensive Care Medicine, Resuscitation Council UK and the Society for Cardiothoracic Surgery in Great Britain & Ireland. A patient representative from the Faculty of Intensive Care Medicine was a core member throughout the process.

Terms of reference were developed during the initial online meeting and agreed by consensus. Multidisciplinary and multispecialty input was mandated along with oversight from a patient representative. All conflicts of interest (COI) were identified and declared; the chair was required to have no direct COI. Any member with a direct financial COI was not eligible to decide on recommendations relating to the COI.

Evidence was collected from Pubmed and Google Scholar from 2000 onwards. We searched for articles and guidelines exploring initial cardiac arrest, responder teams, Impella troubleshooting, initiating cardiopulmonary resuscitation (CPR), device adjustments and Impella algorithms. Exact search terms included "Impella" and "microaxial flow pump" and "cardiac arrest", "resuscitation", "CPR", "emergencies", "algorithm", "alarm", "ventricular arrhythmia", "bleeding", "signs of life" and "capnography". There were 1056 articles identified in total. After cross-referencing, 35 studies were assessed for quality and certainty.[14 15] The summary of the evidence was tabulated and made available for the expert panel (see online supplemental appendix 1). The European Society of Cardiology framework for guidelines was used to determine the class of recommendation and level of evidence.[16] This details a standard process for membership formation and declaration of conflict of interests. A quorate 75% agreement was required for a level of recommendation. The class of recommendation is as follows; I is 'recommended', IIa is 'should be considered', IIb is 'may be considered' and III is 'not recommended'. The level of evidence is as follows: A refers to multiple randomised trials, B to a single randomised trial and C to observational data and expert consensus.

The working group employed a modified Delphi process to reach consensus, defined as at least 75% agreement among voting members. Each Impella centre and national society was allocated one vote, with the consortium chair casting the deciding vote in the event of a tie. A quorum was established as participation by more than 50% of voting members. The consultation process was initiated in April 2024 with the formation of the working group in June 2024. Through electronic communications, virtual meetings and after five modified Delphi rounds (online supplemental appendix 2), the following consensus statement was finalised in May 2025.

UK IMPELLA EMERGENCY ALGORITHM DEVELOPMENT

The following sections outline key issues identified in the resuscitation of patients with left-sided Impella support and key recommendations. These have been distilled into an Impella emergency algorithm (figure 2).

A regular clinical familiarity with Impella is essential, and the consensus statement is intended to be complementary and implemented through the provision of structured training.[13]

Recommendation	Class	Level
Emergency responders to patients deteriorating and in cardiac arrest with Impella are recommended to have dedicated resuscitation training using a structured algorithm.	I	C

Initial response

Identifying cardiac arrest in a patient supported with an Impella device can be challenging. We recommend using the standard advanced life support assessment for a patient who is unresponsive and/or not breathing normally, alongside one of two key physiological indicators. The first is a mean arterial pressure (MAP) of <30 mm Hg which was determined through expert consensus to be a pressure below which any adult patient would have inadequate circulation. This would need to be confirmed with correct transducer position and function. The second is an endotracheal end-tidal carbon dioxide ($ETCO_2$) of <2 kPa. There is some, though limited, evidence of prognostic relevance of $ETCO_2$[17] in cardiac arrest.

On recognition of cardiac arrest using these parameters, the first priority is to call for help and activate hospital-specific response teams. In UK hospitals, all emergency activations occur through '2222' with standardised cardiac arrest response teams, so this was standardised in the algorithm. However, each institution will need to amend this to hospital-specific response teams for troubleshooting the Impella. These will need to be available 24/7 with appropriately trained healthcare professionals who have expertise in troubleshooting of Impella position and access as well as ability to perform transthoracic or transoesophageal echocardiography. There is also currently a 24/7 helpline and remote monitoring service provided by the manufacturer for assistance in troubleshooting the Impella.

Once help has been called for, the first responder should proceed to reduce the power (P) setting to P2 and start CPR. The reduction in P is important as movement of the thoracic organs during CPR can lead to the Impella inflow being displaced towards the aortic valve. This carries the risk of entraining and damaging the aortic valve if the Impella is at high flow, which could lead to severe aortic regurgitation. This will not only add to the perilous haemodynamic state of the patient but render the Impella and other forms of mechanical support significantly less effective.

Recommendation	Class	Level
In the event of a patient who is unresponsive or not breathing normally, a mean arterial pressure <30 mm Hg and/or endotracheal end tidal carbon dioxide of <2 kPa should be an indication to initiate CPR. The P setting should be reduced to P2 prior to starting CPR.	IIa	C

Initial and secondary responder

The recommended team structure after CPR has been initiated is to split into a team that will focus on the patient and one that will focus on the Impella. This should be overseen by a team leader who maintains oversight over the resuscitation and can work through the algorithm. In a patient who has required and is dependent on Impella support, the priority should be to restore circulation by resolving device dysfunction caused by mechanical failure or physiological problems.

The 'patient team' should follow standard advanced life support algorithms and look to address any reversible causes of cardiac arrest. A quarter of patients has been reported to suffer major bleeding on Impella therapy,[11] and this should be assessed as a priority and the patient adequately resuscitated. The team leader can coordinate with the Impella team with regards to fluid resuscitation, need for vascular repair and anticoagulation reversal.

The 'Impella team' will constitute appropriately trained healthcare professionals. As a first step, they should expose the patient and inspect the Impella from the insertion site to the console. Indications of the cause of arrest can be identified such as catheter movement, unsecured sheath and catheters, access site bleeding and cable disconnections or damage.

Recommendation	Class	Level
The recommended priority in an Impella cardiac arrest is to restore circulation by resolving device dysfunction caused by mechanical failure or physiological problems.	I	C

Impella troubleshooting

The Impella team should then focus on key interventions and troubleshooting that can be performed to resolve device dysfunction. These have been structured on the most likely alarms to appear on the Impella controller screen (also termed Automated Impella Controller).

Suction

A suction alarm on the Impella controller can indicate insufficient preload to the pump and can also be identified with dropping flows on the Impella despite unchanged P setting. It is important to understand that the Impella flow is calculated by the device by measuring the power consumption for the set revolutions per minute (RPM) and therefore is not a true measure of flow. Suction of heart muscle can also lead to significant ventricular arrhythmias which may not resolve without addressing the suction itself despite attempts at defibrillation.

In a patient not in cardiac arrest, the first action would be to reduce the RPMs on the device either by 1–2 levels to a minimum of P2 to reduce negative pressure on the inflow. In a cardiac arrest situation, the P setting will have been reduced to P2 on initiation of CPR and should not be

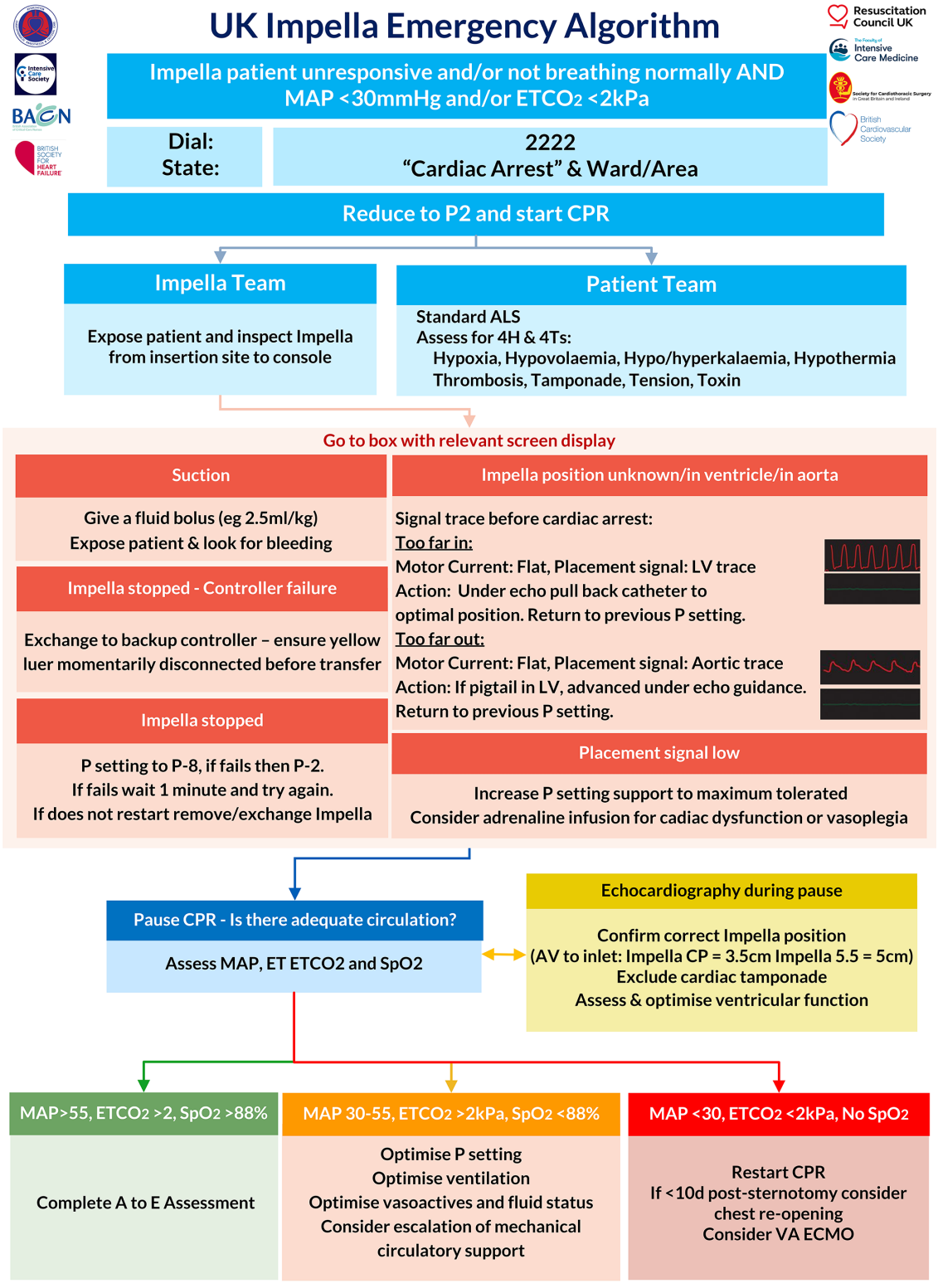

Figure 2 UK Impella emergency algorithm. ALS, advanced life support; AV, aortic valve; CPR, cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; ET ETCO2, endotracheal end tidal carbon dioxide; LV, left ventricle; MAP, mean arterial pressure; P, power; SpO_2, peripheral oxygen saturations; VA ECMO, venous-arterial ECMO.

reduced further to prevent backflow through the Impella. The next step is to administer a fluid bolus for preload such as 2.5 mL/kg and further boluses if needed. In the interim, it is important to assess and treat for causes of suction such as bleeding. There will also be cases where lack of LV preload is due to right ventricle (RV) dysfunction and where fluid could be detrimental to achieving better forward RV flow. Patient history and echocardiography will be key and are highlighted in the next section.

The smart assist Impella also produces left ventricular waveforms which are calculated from the aortic pressure sensor and pressure gradient which is inversely related to the

motor current. These can produce differing patterns such as aortic-LV uncoupling of the waveforms in suction due to device position (such as abutting the septal wall) rather than low preload alone. These should be interpreted with caution as they are calculated, manually adjusted to baseline, absent at certain P settings (P3 and below) and affected by a number of physiological and mechanical confounders.

Mechanical failure

A purely mechanical issue may have arisen with a controller failure. There is a clear step-by-step process to follow to exchange to a backup controller.[12] However, if the screen is non-functioning, turn on the backup controller and change over the white connector cable. Transfer the purge system and ensure depressurisation on transfer by disconnecting momentarily the yellow luer lock connection. Confirm the message on the backup controller to restart the Impella, or if no message appears within 30 s then increase the P setting manually.

An 'Impella stopped' alarm could have occurred for several mechanical reasons. The first step is to adjust the P setting to P8. If the Impella fails to restart, then adjust to P2. If this fails, attempt the procedure again one further time. The next step would be to consider urgent removal of the Impella to prevent aortic insufficiency or replacement.

Malposition

Impella malposition is a serious concern, particularly for femoral inserted Impella CP catheters which can be prone to displacement when the patient may change position shortening or lengthening the aortic distance. All devices are at risk if not appropriately secured to the body and locked at the Tuohy-Borst valve. The Impella controller will alert to a 'position unknown' or 'in ventricle' or 'in aorta"' when abnormal readings are detected. The position identified by the controller can be incorrect and manual interpretation of waveforms and imaging is essential. Prior to cardiac arrest, there may have been abnormalities in the displayed waveforms that can be of use (figure 3). During cardiac arrest, the waveforms will be difficult to interpret, and echocardiography will be even more key.

The displayed waveforms consist of an arterial waveform in mmHg which is transduced at a sensor near the outflow portion of the Impella catheter. This should therefore normally display an aortic arterial trace. The motor current displays P use by the Impella in mA, which is affected by a number of physiological and mechanical parameters. The most important of which to recognise is a motor current fluctuation should always occur in systole and diastole due to differing pressures in the LV and aortic chambers. If both the inflow and outflow of the Impella are within the same cavity, there will be a flat trace. This will also be the case where there is no cardiac contraction such as in cardiac arrest or in some severely impaired LV function (eg, fulminant myocarditis) in patients on ECMO support.

If the catheter migrates into the LV sufficiently, the arterial waveform will change to a left ventricular trace and the motor current will become flat. In this case, echocardiography should be performed and the catheter pulled back into an optimal position at P2 level of P. The catheter can be withdrawn in exceptional emergencies if echocardiography is not available but there is significant risk of damage, such as entrapment and damage of mitral valve apparatus. In an Impella CP, the catheter should be withdrawn to the point where the waveform changes from LV to aortic and then a further 3 cm. The optimal position of the Impella will be measured on echocardiography as described below. On confirmation of adequate position, the Impella should be setback to the pre-arrest P setting.

If the catheter migrates across the aortic valve into the aorta, the arterial waveform will remain aortic but the motor current will become flat. It is always essential to perform immediate echocardiography in this case and identify whether any of the Impella extends below the aortic valve. If there is no part of the device or its pigtail below the aortic valve, advancing the catheter will likely not be successful and a return to the catheter lab is needed. Moreover, there will be a serious risk of damage to the aortic valve with any catheter advancement. If a portion of the catheter extends through and below the aortic valve, advancement can be performed under echocardiography once again at P2 level. On confirmation of adequate position, the Impella should be set back to the prearrest P setting.

The smart assist LV waveform will become similar to the placement signal (ventricularised) in the case of migration into the or changing to an aortic waveform in migration out of the ventricle. This does not add significant benefit on top of noting the placement signal and motor current waveforms, so to avoid confusion, it is not considered within this emergency algorithm.

Placement signal low

If the aortic diastolic pressure measured by the sensor drops below 30 mm Hg, a placement signal low alarm will be triggered. This will likely represent poor cardiac function or severe vasoplegia but could also be the result of insufficient support from Impella such as inflow thrombus affecting flow. The first step should be to ensure the P setting has been adjusted to provide the maximum tolerated flow without causing other complications such as suction. An assessment should then be made to assess the cardiovascular system such as through echocardiography or any indwelling lines or cardiac output monitoring devices. There may be a need to increase inotropic support in case of worsening cardiogenic shock or need to address severe vasoplegia. In the case of a cardiac arrest, it may be pertinent to consider an adrenaline infusion or reduced bolus dosing instead of the 1 mg boluses given through advanced life support algorithm.

The placement signal low alarm can also indicate malposition with the device advanced too deeply and outlet sitting at the aortic valve level. This will require actions outlined in the malposition section.

Ventricular arrhythmias

Patients with left-sided mechanical support can maintain consciousness with ventricular fibrillation[18 19] despite no right-sided support. The Impella 5.5 can provide significantly more flow than the Impella CP, making ventricular arrhythmias more likely to be tolerated. Over time, this is likely to lead to significant RV failure if not rectified but reduces urgency for immediate intervention. Thus, if a patient displays any signs of consciousness, defibrillation should be delayed till sedation can be implemented. The causes of ventricular arrhythmias in acute heart failure are a complex interplay of electrophysiological and structural remodelling as well as neurohormonal mechanisms and

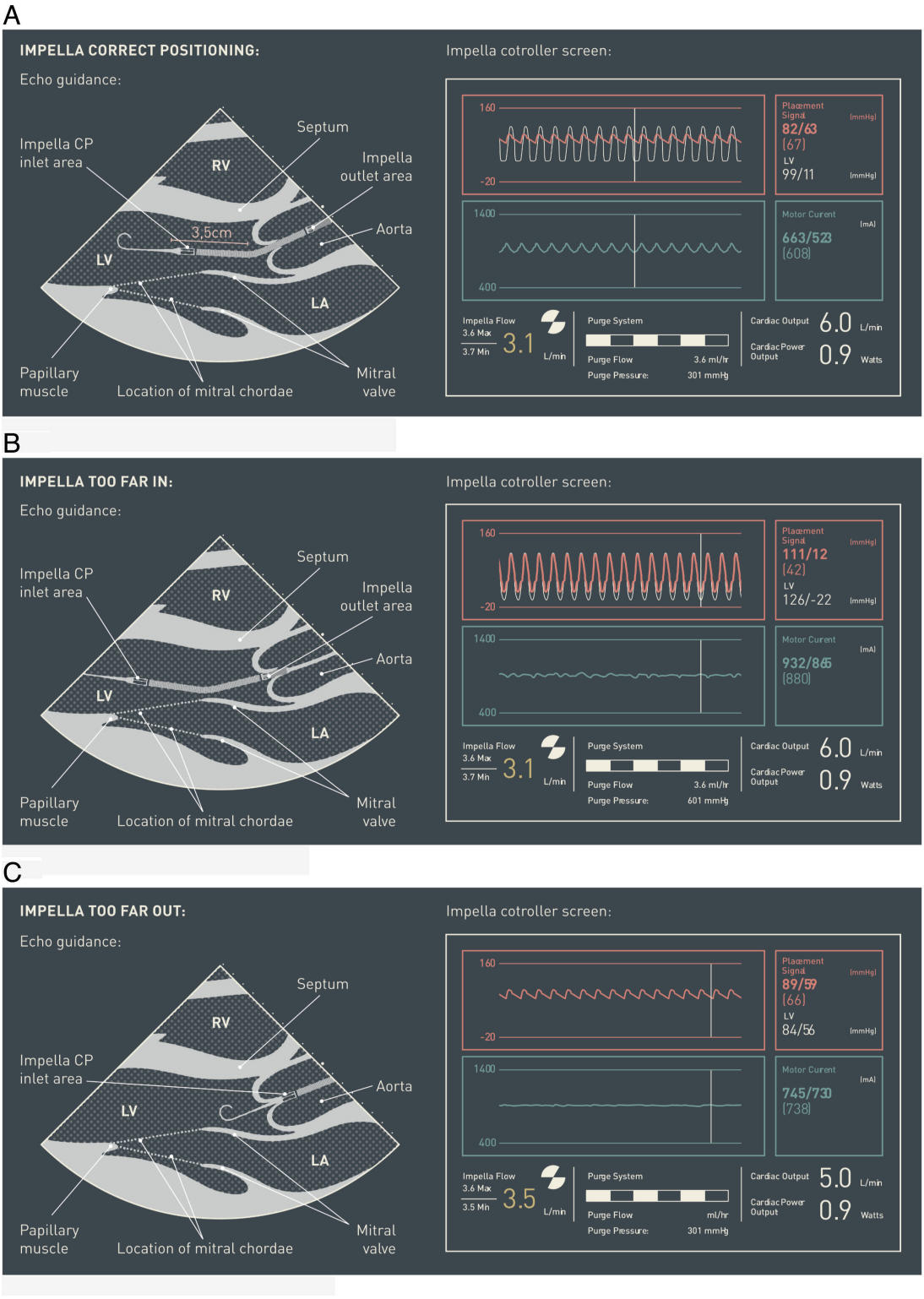

Figure 3 Impella CP Waveforms. (A) Impella correct position and waveforms. (B) Impella too far in and waveforms. (C) Impella too far out and waveforms. LA, left atrium; LV, left ventricle; RV, right ventricle.

drug interactions.[20] In addition, suction from the Impella should be managed if present as outlined above to prevent re-occurrence.

Purge system

The purge system provides a continuous high pressure fluid barrier to prevent blood from entering the motor housing and seizing motor function. The purge fluid is typically 5% dextrose and can contain bicarbonate and less often heparin. On failure of purge fluid delivery, the pump can seize up in the space of minutes to hours leading to an Impella stopped alarm. In this case, the Impella will likely need to be replaced or alternative mechanical support initiated if needed. There can be incomplete thrombosis of the Impella

pump indicated by rising purge pressure, reduced Impella flows and features of haemolysis. If, despite troubleshooting purge fluid delivery, this persists, there is also an option to deliver fibrinolytic therapy directly into the motor housing via the purge system.[21]

Recommendation	Class	Level
In an acutely unwell patient with a 'suction' alarm, reduce the P setting should be reduced by two levels down to a minimum level P2. Consider a fluid bolus of 2.5 mL/kg and assess for causes of hypovolaemia.	IIa	C
In ventricular fibrillation or ventricular tachycardia, defibrillation or cardioversion should be delayed if the patient is conscious until sedation can be implemented.	I	C
If a 'position unknown' or 'position in ventricle/aorta' alarm or abnormal placement and motor signals are present, echocardiography should be performed to assess for Impella malposition. When an expert is readjusting the Impella position, there should be continuous echocardiography, power (P) setting reduced to P2 and the Impella visible below the aortic valve.	IIa	C
In an acutely unwell patient if a purge system alarm is present, check the Impella purge system is functioning. If a device thrombosis is present, the need for intradevice thrombolysis may be considered.	IIb	C

Determination of adequacy of circulation

Once initial interventions have been attempted by the Impella team, a reassessment of the adequacy of circulation can be made by pausing CPR. This will be based on the MAP, $ETCO_2$ and peripheral oxygen saturations and split into three sets of actions listed below. There is a logical consideration to increasing the P setting during each pause in CPR; however, this was not included due to the complexity and delay it would add in delivery of quality continuous chest compressions.

During the pause in CPR, there is an opportunity to perform focused echocardiography if technically feasible. The Impella position should be confirmed, which should show the inflow free of obstruction (eg, from mitral valve apparatus or LV septum) and positioned an appropriate distance from the aortic valve. The measurement from the aortic valve to the inflow (appearing as echo-free space) should be 3.5 cm for an Impella CP and 5 cm for an Impella 5.5. There should also be an assessment to rule out reversible causes of arrest such as cardiac tamponade requiring drainage and to assess right ventricular function which may need further inotropic or mechanical support.

If a return of adequate circulation is confirmed by a MAP >55 mm Hg, $ETCO_2$ >2 kPA and oxygen saturations (sats)>88% then a standard Airway, Breathing, Circulation, Disability, Exposure (A–E) assessment should be made.

If an intermediate circulation is confirmed by a MAP 30–55 mm Hg, $ETCO_2$ >2 kpA and Sats <88% then further optimisation is needed. The P setting on the Impella should be optimised to provide sufficient forward flow without causing suction. The ventilation, vasoactive medications and fluid status should be optimised to improve oxygen delivery. There may also be a need to consider escalation of the support for further left-sided flow or additional right ventricular support based on echocardiographic and clinical assessment.

If an inadequate circulation remains confirmed by a MAP <30 mm Hg, $ETCO_2$ <2 kPa and Sats <88% then CPR should recommence. If the patient is less than 10 days post sternotomy with ongoing CPR, then emergency chest re-opening should be considered.[22] There should also be consideration of whether it is appropriate to perform extracorporeal CPR (ECPR) with insertion of peripheral veno-arterial ECMO if appropriate and available. In prolonged arrests and ECPR, there may be pragmatic use of mechanical cardiac compression devices; however, the safety of these devices is unknown in combination with Impella, and there may be a risk of myocardial perforation or injury.

Increasingly, patients are receiving a combination of Impella and ECMO therapy, termed 'ECPELLA'. In these patients the veno-arterial ECMO will be a more powerful biventricular support that should provide an adequate circulation. Thus, cardiac arrest in these patients should be managed using an ECMO guideline.[23]

Recommendation	Class	Level
Perform echocardiography to assess for Impella malposition requiring repositioning, right ventricular failure requiring inotropes or pericardial tamponade requiring drainage.	I	C
Assessment of adequate circulation is recommended to be made utilising a number of physiological parameters including mean arterial pressure, saturations and if present endotracheal end-tidal carbon dioxide.	I	C
The use of mechanical CPR devices in an Impella patient is lacking safety data and may be considered in refractory arrests and to facilitate emergency ECMO insertion.	IIb	C
In the presence of inadequate circulation in an Impella patient less than 10 days post cardiotomy, emergency chest re-opening should be considered.	IIa	C
In the presence of inadequate circulation, immediate escalation to temporary mechanical support such as ECMO should be considered.	IIa	C

Holistic care

It is essential to approach the patient's journey through a holistic lens, recognising not only the physiological aspects of disease but also the psychological, social and spiritual dimensions of care. A comprehensive understanding of the patient's values, preferences and lived experience allows clinicians to align treatment strategies with the individual's goals and priorities. This involves establishing an early, collaborative framework for discussions around goals of care, ensuring that the patient, their family and the multidisciplinary team are engaged in shared decision-making.

Though this algorithm is focused on an active resuscitation approach to patients who have deteriorated on Impella, it is important to recognise that this may not be the appropriate course of action for all patients. It is important that decision-making about the appropriateness of different resuscitative strategies is made early during a patient's journey and communicated effectively to the whole team.

During resuscitative efforts, consideration must be given to allowing relatives or significant companions to be present. An experienced member of staff who can explain what is going on should be delegated to stay with them and liaise with the team on their behalf.

Future

The rapidly developing field of mechanical circulatory support has understandably focused on the big questions around indications and survival. However, there is a need for further work on the management of complications and emergencies which can have significant impact on patient survival and quality of life. An example is the increasing recognition of the importance of device positioning and haemolysis which can precipitate renal failure.[24] Resuscitation in patients on mechanical support is particularly complex, but there is a need for foundational evidence to guide key decisions such as when CPR should, or should not, be initiated.

CONCLUSION

We present the UK Impella Emergency algorithm for use by healthcare professionals managing patients on left-sided Impella support. The consensus statement has been endorsed by eleven UK Impella centres and eight national societies. This document outlines key issues in the resuscitation of patients with Impella, including recognition of inadequate circulation and key timely interventions in the first few minutes of resuscitation.

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