

CARDIOPULMONARY RESUSCITATION (CPR) QUALITY GUIDELINE

NOTE: This guideline is intended to summarize recommendations related to CPR quality (chest compressions and ventilation) during pediatric cardiac arrest. It is not a comprehensive summary of all aspects of pediatric resuscitation.¹ Check here for PALS Guidelines ([Cardiac Arrest](#), [Bradycardia](#), [Tachycardia](#)).

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SUMMARY OF RECOMMENDATIONS

Monitor CPR quality using:

- Zoll™ Defibrillator
- EtCO₂ goal >20 mmHg
- Arterial DBP goal >30 mmHg for small infants and >35 mmHg for everyone else.

Targets:

- Chest compression rate 100-120
- Chest compression depth 4-5 cm for infants (or at least 1/3 of the chest thickness for very small infants) and 5-6 cm for everyone else
- Fully recoil after each compression
- Avoid any pauses, or at least minimize them as much as possible
- If intubated or LMA in place, ventilate at a rate of 10/minute with tidal volumes to see visible but minimal chest rise. If not intubated then use 15:2 ratio for infants/children and 30:2 for adults

Technique:

- Lower height of bed if necessary to ensure good angle for compressor
- Activate "CPR Release" on mattress if available & use a backboard
- Use "one-hand" or "two-hand" technique. Two thumb technique in infants may cause thumb fatigue
- Stand on a stool
- Compress over middle of puck of Zoll™ pad
- Two compressors stand on same side of bed as each other and across from Zoll™

BACKGROUND

During cardiac arrest, a lack of blood flow and oxygen delivery causes very rapid tissue ischemia then death. The underlying cause of cardiac arrest must be identified and reversed if possible; but in the meantime, it is essential that good quality chest compressions (CC) is delivered to the patient in order to maintain blood flow and oxygen delivery. It is well-known that survival from cardiac arrest is associated with time to initiation of CC,² adequate rate,³ depth,⁴ full recoil⁵ and minimizing pauses.⁶ It is also associated with avoidance of excess ventilation.⁷

Chest compressions should be initiated when:

- Pulses are absent
OR
- Patient has severe bradycardia, hypotension on arterial line combined with EtCO₂ <20, indicating very low cardiac output

MONITORING QUALITY OF CPR DURING CARDIAC ARREST

It has been shown that the visual impressions of team members regarding quality of CC are inaccurate.⁸ Similarly, it has never been demonstrated that "finger on the pulse" is an accurate measure of quality of CC. Therefore, we must use objective measures to determine that we are delivering quality CC to a patient during cardiac arrest. We recommend using 3 measures to follow CPR quality:

- Zoll™ Defibrillator output
- End tidal carbon dioxide (EtCO₂)
- Arterial diastolic blood pressure (DBP)

Zoll™ Defibrillator:

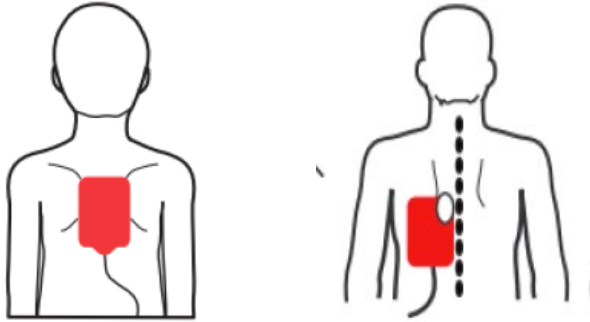
For full details about this equipment, refer to the Zoll™ R Series User Manual [here](#).

Before using, ensure that there is a green ✓ in the top right window. If in the rare event that neither Zoll™ defibrillator is functional and you think you might need to defibrillate/cardiovert a patient, then the old LifePak is still available, kept on the crash cart by the service elevators.

Our Zoll™ defibrillator has technology embedded in the pads to measure CC technique. There is a sensor in both the anterior and posterior pads that allows for accurate depth measurements to be made (to account for patient movement with mattress deflection). There are 2 sizes of pads. The adult pads should be used for patients ≥ 25 kg (approx. 8 years of age) and the pediatric pads should be used for patients < 25 kg. The pediatric pads will always be connected to the cable of the defibrillator on the crash cart, so if a patient is ≥ 25 kg, the adult pads must be connected to the cable.

It is important to place the pads in the correct position on the patient to achieve accurate measurements. The anterior pad has a puck with a red cross on it. The **horizontal line must line up about 1 cm above the bottom of the sternum** and the **vertical line must line up with the middle of the sternum**. The pediatric posterior pad (which has no separate puck) should be placed **over the spine between the scapulae**. The adult posterior pad

should be placed so that the **puck is just to the left of the patients' spine below the left scapula**, as highlighted in the diagrams directly on the pads.



Pediatric Posterior Pad Adult Posterior Pad

The type of feedback shown on the Zoll™ depends on whether the adult pads or the pediatric pads are being used. This is because the depth guidelines for pediatrics vary based on the size of the patient, so the machine doesn't know if the patient is an infant requiring 4 cm depth, or an older child/adult requiring 5-6 cm depth (see below for more description of CC depth).

Zoll™ output from adult pads:



Zoll™ output from pediatric pads:



The adult pad set-up gives verbal feedback such as "Push harder" which is not available with the pediatric pads.

The metronome is configured to activate shortly after CC are detected. The metronome rate is pre-programmed to 100.

There are 2 timers:

1. "Idle time" which counts pauses in compressions
2. Total time, which counts the total duration of the event that is captured on the Zoll™.

Note: The pads obscure images on X-rays so they must be removed prior to taking the image.

End Tidal CO₂:

EtCO₂ generally reflects pulmonary blood flow, so is a good indicator of overall blood flow during CPR. The level of EtCO₂ has been shown to be associated with survival and the current recommendations are to attempt to **improve CC quality if EtCO₂ < 20 mmHg.**⁹ EtCO₂ is also valuable in determining whether return of spontaneous circulation (ROSC) has occurred. Therefore, we recommend **no longer routinely pausing CC to do a pulse check** but rather continue until you see an abrupt increase of EtCO₂ to >35 mmHg.

Arterial Diastolic Blood Pressure (DBP):

As coronary perfusion occurs during diastole, it is important that adequate diastolic pressure be maintained to increase chances of ROSC. Current recommendations are to keep DBP > 25 mmHg⁹ but we recommend trying to achieve closer to normal if possible. Therefore we recommend **goals of DBP > 30 mmHg for small infants and > 35 mmHg for everyone else**. Non-invasive blood pressure readings are not accurate during CC so cannot be targeted if an arterial line is not *in situ*.

RECOMMENDATIONS ABOUT PERFORMING CPR

Height of Bed:

In order for staff to adequately perform CC by achieving full recoil, to avoid leaning on the chest and to achieve adequate depth, we recommend that the height of the bed be as low as possible. This means that the bed height will likely **have to be lowered** at the beginning of a cardiac arrest event, since bed height is often raised to allow comfort of the staff for day-to-day bedside skills and assessments.

Mattress / Backboard:

Compressibility of a mattress has been shown to affect the abilities of staff to be able to adequately perform CC^{10 11} we recommend that the **CPR Release** on the bed be used to firm up the mattress as much as possible and that a **backboard be placed under a patient as soon as possible** after CC are started. In order to maintain skin integrity, it is not recommended to keep a patient on a backboard for a prolonged period of time *just in case* an event may occur, and should be removed once the event is complete. Backboards are located on the sides of each crash cart.

Stool and Kneeling on the Bed:

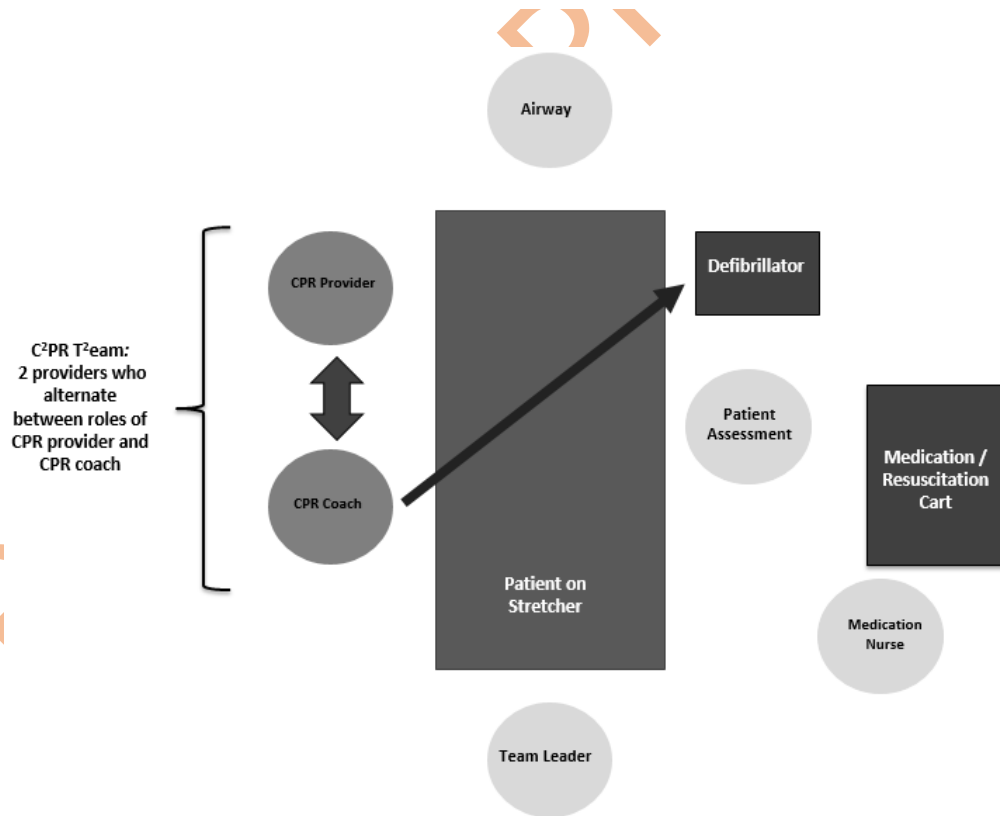
In order for staff to adequately perform CC by achieving full recoil, avoiding leaning on the chest and achieving adequate depth, we recommend that **those performing CC stand on a stool** at all times. Only the very few very tall staff may not have to do this to achieve quality CPR. Stools are found on the top of the crash carts. If the patient's bed is in motion (i.e. being transported to PICU from elsewhere in the hospital) then the staff member performing CC will have to **kneel on the bed** to adequately perform CC. As soon as the bed is no longer in motion, however, the staff member performing CC should come off the bed and stand on a stool.

Where to Stand and Where to Place the Crash Cart / Defibrillator:

Those performing CC on a patient should **stand on the opposite side** of the bed to the Zoll™ defibrillator so that he/she can see the output at all times. In a non-ECLS situation, the crash cart with the Zoll™ defibrillator on top should be located on the same side of the bed as the patient's monitor, so the team leader can easily view both screens. In an ECLS situation, the defibrillator must be taken off the crash cart and placed at the foot of the bed (next to the wall with the patient turned head out). See 2 suggested room schematics below.



Door (PICU room 20)



Recommended Chest Compression Techniques:

CC should be performed directly over top the puck on the pad of the Zoll™ defibrillator. See above for discussion of puck placement on the patient's chest. If the Zoll™ output is demonstrating either consistently low depth or even showing an "idle time" message in an infant, the compressor should move his/her hand to

re-centre it on the puck. Even small changes in hand position off-centre causes the sensors on the Zoll™ to underestimate depth.

Best cardiac output is achieved by compressions on the lower third of the sternum.¹² For older children and adults, to achieve adequate depth, a **two-hand technique** should be used. For infants and young children, a two-thumb hand encircling technique may be used, although with the thick Zoll™ pads on the patient, this may cause thumb fatigue so it may not allow for maintenance of adequate compression depth over time. If that is the case, we recommend using a **one-hand technique**. Most importantly, hand location and technique **may have to be modified** if CPR quality metrics (Zoll™, EtCO₂, DBP) suggest that CPR quality is inadequate.

Two-Hand Technique:



One-Hand Technique:



Rate:

The recommended rate of CC for all ages is **100-120 per minute**.^{1 9} Rates that are too slow (inadequate output) and too fast (inadequate recoil and time to refill) are associated with decreased survival from cardiac arrest.³ We tend to compress too quickly when we're activated/stressed in events like these. Use the metronome on the Zoll™ or use the [CPR Tempo](#) or [CPR Timer](#) apps on a staff member's smart phone and ultimately look at the Zoll™ output to follow this rate.

Depth:

The recommended **depth of CC for infants is 4 cm**^{1 9} (or 1/3 chest thickness if 4 cm can't be achieved in the smallest infants). The recommended **depth for older children and adults is 5-6 cm**.^{1 9 13} Use the Zoll™ output to follow this depth. If inadequate depth is being seen and not fixed by the compressor pushing harder, then try these maneuvers:

- Reposition the compressor's hand to directly over the centre of the Zoll™ puck (see above)
- Change compression technique (one hand to two hands)
- Attend to whether full recoil is being achieved (see below)

If full recoil is not being achieved or there is excessive leaning, then depth will be underestimated.

Recoil / Leaning:

It is recommended that compressor's hands **completely recoil** before the next compression is done and that the compressor **not lean** on the patient.⁹ This ensures that adequate refilling of the heart can be achieved between compressions. When the Zoll™ adult pads are being used, feedback on this parameter can be viewed by the "Compression Release Bar". This feedback is not given when the Zoll™ pediatric pads are used. The pink release bar should come all the way up to the top, indicating total release between compressions.

Zoll™ CPR Feedback Output with Adult Pads:



Pauses:

Whenever CC are stopped during cardiac arrest, blood flow stops very quickly and takes a long time to build up again. Maintaining blood flow is especially important to the coronary arteries, which are delivering much needed oxygen to the myocardium. Therefore it is recommended to **avoid any pauses** in compressions,⁹ or at least minimize pauses as much as possible. The “idle time” timer on the Zoll™ will start as soon as it senses no CC are being performed. This can be used to track the duration of a pause. Common reasons for pauses:

- To place backboard under and posterior Zoll™ pad on the patient. A pause is inevitable but try to coordinate these 2 tasks to 1 patient turn.
- To intubate. Try to visualize the larynx without pausing compressions. If the intubator can get visualization, then a pause may not be necessary. If intubation cannot be achieved without a pause, consider inserting an LMA instead, or if intubation is necessary, then make the pause as brief as possible.
- To check if a pulse is present. This is **no longer recommended**. Instead, follow the EtCO₂. If the EtCO₂ < 35 mmHg then it is unlikely that ROSC has been achieved, so it is not necessary to check. If an abrupt rise in EtCO₂ is seen > 35 mmHg, then it is likely that ROSC has been achieved so it is reasonable to check for a pulse at that time.
- To check underlying rhythm. The Zoll™ defibrillator has “see through” technology that allows for the CC artifact on the rhythm to be cancelled out, leaving the underlying rhythm visible. Therefore, the rhythm on the Zoll™ defibrillator (not on the patient monitor which will likely have CC artifact) can be used to detect underlying rhythm. If the team does not trust this output or if the output is difficult to read, then a very brief pause can happen for this purpose.
- To defibrillate. It has been demonstrated that short pre- and post- shock pauses are associated with better survival⁶. Therefore, it is vital to discuss an upcoming defibrillation with the team so that all are aware when CC are to be stopped and quickly resumed.
- To cannulate during E-CPR. The surgeons may ask us to stop compressions while they are isolating and cannulating the vessels. We should keep these pauses to < 30 seconds each and to minimize the number of pauses. Use the “idle time” timer on the Zoll™ to keep track of how long the pauses are.

If pauses have to happen, then discuss them ahead of time as a team to minimize their duration and to **coordinate as many activities as possible** during each pause.

Ventilation:

Adequate ventilation is important during cardiac arrest, however there is a danger to over-ventilating the patient.⁷ It is recommended to ventilate the patient at a rate of **10 breaths/minute^{1 9} (1 breath every 6 seconds)** and to use a **tidal volume necessary to achieve visible but minimal chest rise**. We tend to ventilate too quickly when we're activated/stressed during events like these. If the patient is intubated, then ventilations and CC do not need to be coordinated. If the patient is not intubated or has an LMA in place, then ventilations and CC should be coordinated using a ratio of 15:2 for children and 30:2 for adults. Once pulses return, decrease FiO₂ to maintain sats >94%.¹⁴

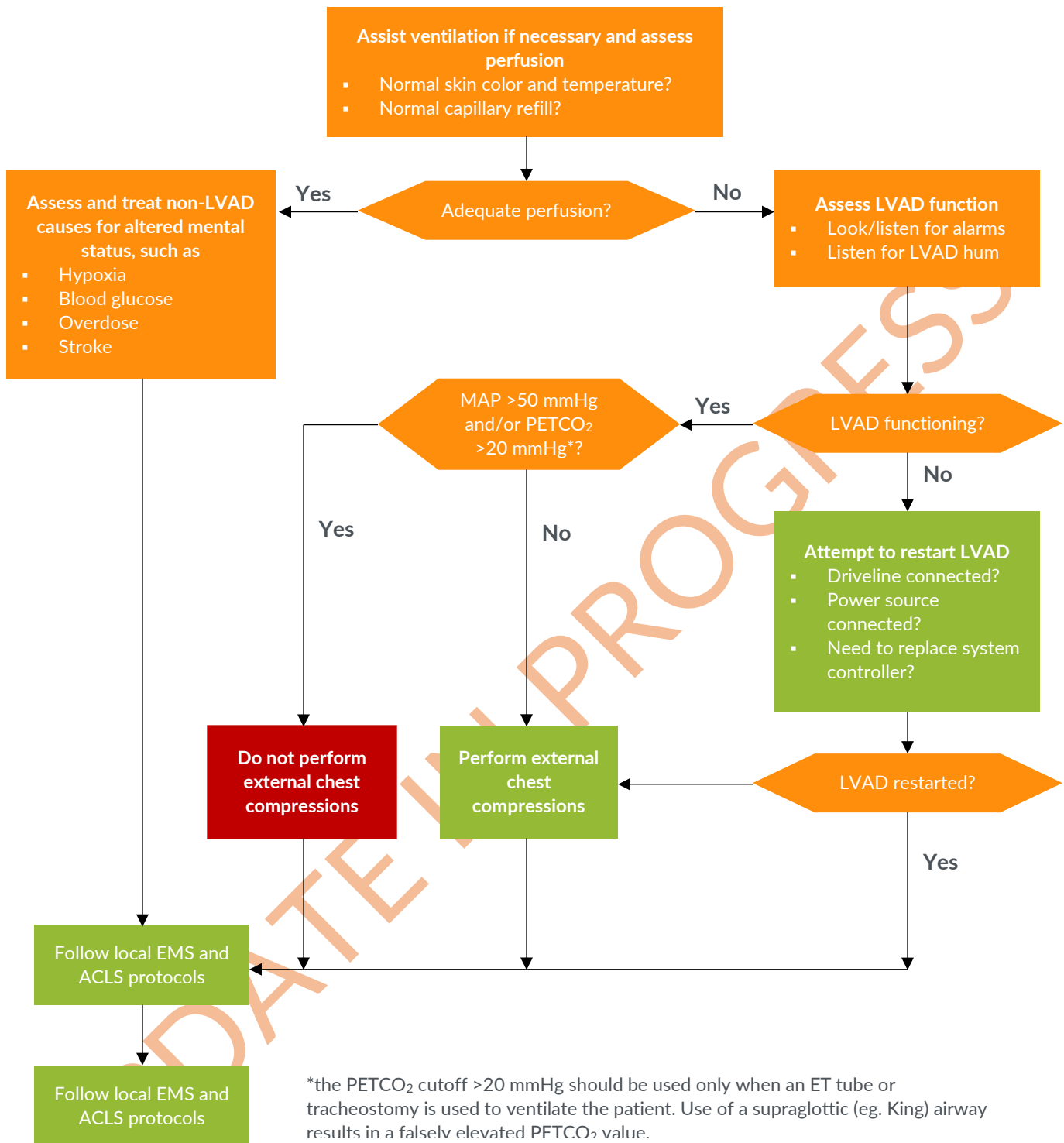
Performing CPR on Patients with a Ventricular Assist Device (VAD):

See Peberdy *et al* for an excellent review of this topic.¹⁵ Recall that patients will not often have a palpable pulse or measureable systolic and diastolic blood pressure (you may be only to get a mean arterial pressure

reading given no pulsatile flow), so perfusion must be assessed by level of consciousness, capillary refill, skin temperature, colour. If a patient is intubated, the EtCO₂ can be a measure of blood flow as well, as described above.

Use MAP and EtCO₂ to determine if chest compressions should be started, as described in the decision tree below.¹⁵

UPDATE IN PROGRESS



Suggested decision tree for assessment of perfusion and need for chest compressions in a patient with a VAD.¹⁵

A priority for an unresponsive patient with a VAD is to establish whether there has been pump failure. A team member (with the help of trained family members) should be assigned to check the following:

- Looking and listening for alarms,
- Listening for a VAD hum over the left chest and left upper abdominal quadrant,
- Ensuring secure connections to the controller,

- Ensuring adequate power to the VAD.

All patients should have back up batteries and a controller with them at all times, so please ask a caregiver to provide the team with this backup equipment. If all above has been checked and there is no re-establishment of power, then consider replacing the controller unit. Family members should be engaged to change the controller unit, as they are trained to do this.

WHEN TO STOP COMPRESSIONS

Outside of a decision to terminate resuscitative events, chest compressions can stop when the following conditions are met:

- We have achieved adequate flows on ECLS
- There is a palpable pulse AND there is good pulsatility on arterial line (with diastolic blood pressures > 30 mmHg for infants and >35 mmHg for everyone else) OR EtCO₂ is consistently above 20 mmHg and rising, not falling

Considerations for termination of resuscitative efforts: No firm guidelines can be recommended for this complex topic, as every situation is different. The following factors to be considered **include, but are not limited to:**

- The outcomes of prior goals of care discussions with patient and/or family members
- Location of resuscitative efforts (i.e. in-hospital vs. out-of-hospital cardiac arrest) and presence of witness/monitoring at the time of the cardiac arrest
- Duration of resuscitative efforts
- Cause and reversibility of etiology of the cardiac arrest
- Presence of pre-existing conditions and long-term prognosis
- Eligibility for ECLS, which includes assessment for eligibility for bridging therapies such as surgery, transplant, VAD. See [ECLS documents](#) for a full description of our ECLS eligibility criteria
- Note: See other documents that relate to cardiac arrest in the setting of [hypothermia](#) as well as summarizing recommendations on [post-cardiac arrest care](#)

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- ¹³ Part 3: Adult Basic Life Support and Automated External Defibrillation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Travers AH, Perkins GD, Berg RA, et al. Circulation 2015;132:S51-83.
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