EM CASES SUMMARY

Episode 169 Cardiac Arrest Controversies Part 1: CPR, Defib, Medications, Airway

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Maximizing high quality chest compressions in cardiac arrest

Perhaps the most important aspect of cardiac arrest care is providing high quality chest compressions with a depth of at least 5 cm (but no more than 6 cm), a rate of between 100 and 120 compressions per minute, allowing full chest recoil between compressions and minimizing interruptions. The goal is near continuous compressions that pause only for defibrillation and brief pulse checks. Good neurologic outcomes after out-of-hospital cardiac arrest (OHCA) correlates well with target ranges of chest compression rate and depth.

Strategies to ensure high quality chest compressions and minimize pauses in chest compressions

- Feedback monitor devices for rate, depth and recoil of compressions
- Metronome for rate of compressions (smartphone metronome is a "poor person's" feedback monitor device)
- Dedicated chest compression coach (note that chest recoil is difficult for the coach to assess)
- Changing chest compressors every 2 minutes (even fit chest compressors tire after 45 seconds of constant high quality chest compressions, tend to slow down and have poor chest recoil)
- Pre-charge the defibrillator before pausing chest compressions (reduces perishock pause)
- Countdown from 10 before pausing chest compressions so that every team member is ready to immediately defibrillate or perform a pulse check
- Transesophageal ultrasound may help to locate the optimum location on the chest to maximize compression of the heart with each chest compression
- PoCUS pulse checks
  - The PoCUS pulse is more accurate and as rapid compared to the palpation technique at determining whether or not a patient has a pulse
  - Ensure that the PoCUS probe is optimally placed on the patient with adequate gel well *before* any pause in chest compressions
- Arterial line (to assess for the presence of a pulse generated from chest compressions/guide resuscitation)
- Mechanical chest compression devices (see below)

Are mechanical chest compression devices better than manual compressions?

Advantages of mechanical CPR

- Ensures high quality chest compressions performed consistently

- Cognitive offloading so team can concentrate on other aspects of resuscitation
- Decreases interruptions to compressions
- Allows defibrillation while chest compressions are ongoing (eliminates perishock pause)
- Allows for consistent prolonged CPR in patients with prolonged extrication time at the scene, being transferred long distances and in hypothermia victims

The studies comparing mechanical CPR vs manual CPR suggest that outcomes are better with mechanical CPR for in-hospital cardiac arrest while for out of hospital cardiac arrest the evidence is mixed. For highly skilled resuscitation teams, mechanical CPR does not seem to have any advantage over manual CPR. Training teams on placing and initiating mechanical CPR machines rapidly without pause in chest compressions is a prerequisite for using these devices, as inexperience with this will likely lead to a prolonged pause in chest compressions.

Bottom line: For patients who require time consuming extrication at the scene, for those with hypothermia related arrest, for those who require long transports with ongoing CPR, and when skilled resuscitation teams are not present, mechanical CPR may be preferred over manual chest compressions.

Defibrillation: Pad position/contact and dual sequential defibrillation for refractory ventricular fibrillation

Pad placement for defibrillation

The key concept when it comes to pad placement is that as long as the heart is in between the pads so that the vector of energy goes through the heart, the precise location of the the pads does not matter. Nonetheless, our experts prefer the sternum/apex or right anterior/left lateral placement of pads over the anterior/posterior "sandwich" placement of pads in cardiac arrest because it minimizes pauses in chest compressions (the patient needs to be rolled over in order to place the posterior pad for anterior/posterior pad placement).

Skin contact for defibrillation

Perhaps more important than the pad placement is ensuring adequate contact on the skin. In patients who are hirsute and/or sweating profusely, consider handheld defibrillation paddles to ensure adequate contact with the skin.

Dual sequential defibrillation for refractory VF vs changing pad position

Refractory VF is defined as VF that does not respond to three or more standard defibrillation attempts. Case series have suggested that **dual sequential defibrillation (DSD)** may improve ROSC rates by adding a second set of defibrillator pads using a separate defibrillator (ensuring that pads are not touching each other) and defibrillating both machines within a second of each other.

The 2020 DOVE-VF was a pilot study of 152 out of hospital cardiac arrests which compared standard care with either DSD or changing pad position (switching from anterior/lateral to anterior/posterior). ROSC was obtained in 25% of the standard care group, 39% of the vector change group, and 40% of the DSD group. It was unclear whether this will translate to improved neurological survival. This study suggests that **changing pad position is as effective as dual sequential defibrillation**.

It is important to understand that DSD should *not* be employed for *recurrent* VF, a separate entity from *refractory* VF.

***Pearl:** Successful ROSC with dual sequential defibrillation (DSD) may be time-dependent, with greater success early in the resuscitation. If using DSD, start it immediately after the failed third shock. Also, ensure that the two defibrillators are on the same side of the patient while the compressor is on the opposite side so that site lines are clear and team members do note trip on the defibrillator cables.*

Medications in cardiac arrest

In most cases cardiac arrest is a pump malfunction problem, and currently not one that medications appear to have a major role in reversing outside of certain discrete causes (hyperkalemia, hypocalcemia). Likewise, neurologic recovery is related to minimizing low flow to the brain and avoiding secondary insults. These goals currently appear to be best met with high-quality CPR and good ICU care. **In 2022 there remains no high quality evidence that any medication definitively improves long-term neurologic outcomes in cardiac arrest.**

Epinephrine in cardiac arrest – improved ROSC, but what about neurologic outcomes?

While epinephrine improves the rate ROSC in cardiac arrest, and may improve survival, it has never been shown to definitely improve survival with good neurologic outcome at hospital discharge. The PARAMEDIC2 trial is the most robust epinephrine in cardiac arrest RCT. It randomized 8014 adult out of hospital cardiac arrest patients to epinephrine 1mg every 3 minutes vs placebo. The 30-day survival was improved with epinephrine (3.2% vs 2.4%), but there was no difference in survival with good neurologic outcome. However, this may have been a power issue, especially looking at the longer-term outcomes. At 3 months there were not enough patients alive to provide the statistical power to reliably detect a difference between groups. It may be that it takes a long time for the brain to recover and if the study was powered for longer term outcomes, there may have been a significant difference in survival with good neurologic outcome.

Timing: 10 studies comparing "early" to "late" epinephrine uniformly found that earlier epinephrine was associated with better outcomes, particularly for patients with non-shockable rhythms

Dose: high dose epinephrine (≥0.2 mg/kg or 5 mg bolus dose) may improve the chances of ROSC but does not appear to improve survival and has shown a trend towards more harm. Our experts usually limit epinephrine to three 1 mg doses, especially in patients who have had VF or pulseless VT during their arrest. Infusion of epinephrine compared to bolus in experimental models suggests improved brain flow but has never been shown to improve survival or neurologic outcomes in cardiac arrest.

Is vasopressin better than epinephrine in cardiac arrest?

A 2001 RCT comparing vasopressin vs epinephrine failed to detect any survival advantage for vasopressin.

A 2013 study of vasopressin, steroids and epinephrine for *in hospital* cardiac arrest suggested that combined vasopressin-epinephrine and methylprednisolone during CPR and stress-dose hydrocortisone in post resuscitation shock, compared with epinephrine/saline placebo, resulted in improved survival to hospital discharge with favorable neurological status.

A 2019 Cochrane Review found that vasopressin compared to epinephrine in out of hospital cardiac arrest improved survival to admission but not ROSC rates.

The largest trial in 2021 is one of *in hospital* cardiac arrest patients comparing vasopressin and methylprednisolone vs placebo in patients who had received at least 1 dose of epinephrine. It found improved rates of ROSC. However, it found no significant effect in long term survival or survival with favorable neurologic outcome.

Bottom line: vasopressin may have an advantage over epinephrine to improve rates of ROSC and survival to hospital admission but has not been shown to have any advantage over epinephrine for long-term survival or neurologic outcome. Vasopressin should be considered in patients with true vasoplegia according to our experts.

Amiodarone or lidocaine for ventricular fibrillation and pulseless ventricular tachycardia?

Amiodarone and lidocaine are considered equivalent in the treatment of ventricular fibrillation or pulseless ventricular tachycardia according to the ACLS guidelines. However, a recent reanalysis of the ALPS trial suggests otherwise.

The ALPS RCT in 2016 compared amiodarone vs lidocaine vs placebo in OHCA patients with shock-resistant VF or pulseless VT. It found that neither amiodarone or lidocaine had a statistically significant benefit over placebo. However, there was a 3% difference in survival to discharge that was not statistically significant. In a subgroup analysis, amiodarone and lidocaine were better than placebo, however more patients who received amiodarone required temporary pacing.

In a 2022 Bayesian reanalysis of the ALPS trial treatment with amiodarone had high probabilities of improved survival and neurological outcome, while treatment with lidocaine had a more modest benefit. In another 2022 reanalysis of the ALPS data, the probability of ROSC decreased as time to drug administration increased. The effect of amiodarone but not lidocaine to restore ROSC declined with longer times to drug administration. They attributed this to amiodarone's adverse hemodynamic effects.

Bottom line: when given early in cardiac arrest amiodarone may be better than lidocaine and placebo to improve rates of ROSC, survival and neurologic outcome despite the ALPS trial failing to show a statistically significant benefit.

Pitfall: given that the earlier vasopressors and amiodarone are given after cardiac arrest, the more likely they are to be beneficial; a pitfall is to delay the administration of these drugs.

Epinephrine or norepinephrine for post-ROSC shock?

Despite the limitations of observational data, evidence continues to suggest that norepinephrine infusion may be preferred over epinephrine after ROSC is achieved in cardiac arrest patients.

A 2021 retrospective review suggested that rates of ED refractory shock, re-arrest and mortality were higher in patients who received epinephrine compared to norepinephrine after ROSC was achieved.

A 2022 observational study in OHCA patients with post-resuscitative shock suggested that use of epinephrine was associated with higher all-cause and cardiovascular-specific mortality, compared with norepinephrine infusion.

These observational studies are difficult to interpret as it is likely that the sicker patients were more likely to receive epinephrine.

Bottom line: observational data suggest that norepinephrine is the preferred vasopressor for post ROSC shock

Pearl: Some experts recommend preparing a norepinephrine infusion, time permitting, before or during cardiac arrest resuscitation, so that as soon as post-ROSC shock is identified, the norepinephrine infusion can be initiated and titrated rapidly.

Is there a role for sodium bicarbonate in prolonged cardiac arrest?

Routine use of bicarb in cardiac arrest is not recommend in the ACLS guidelines but should be considered in specific cases of ASA overdose, Na-channel blockers with wide QRS complexes (TCA overdose, cocaine overdose) and hyperkalemia as potential causes of the cardiac arrest.

In theory, raising the serum pH in cardiac arrest patients may be beneficial. On the other hand, bicarbonate does not improve the ability to defibrillate or improve survival rates in animals; can compromise coronary perfusion pressure; may cause adverse effects due to extracellular alkalosis, including shifting the oxyhemoglobin saturation curve or inhibiting the release of oxygen; may induce hyperosmolarity and hypernatremia; produces carbon dioxide, which is freely diffusible into myocardial and cerebral cells paradoxically contributing to intracellular acidosis; and may inactivate simultaneously administered catecholamines. Some experts believe that bicarbonate has no role in a closed system such as cardiac arrest where excess CO_2 cannot be exhaled (because of venous-arterial dissociation).

A 2018 RCT suggested that bicarb in cardiac arrest with transient hyperventilation improves acid-base status without CO_2 elevation, but that it had no effect on the rate of ROSC or good neurologic survival.

A 2021 systematic review and meta-analysis of bicarb in out of hospital cardiac arrest which included 4 RCTs suggested that there was no benefit in survival at discharge or ROSC rate and pooled estimate of two studies showed that bicarb was associated with less sustained ROSC and good neurological outcomes at discharge.

There is some suggestion that in prolonged cardiac arrest sodium bicarbonate may have role, but there is no good RCT data to support this. A 2006 RCT of cardiac arrest patients given bicarb vs placebo found no difference in survival to ED admission but did show a trend toward improved survival in those patients with prolonged cardiac arrest > 15 minutes. A small 2018 RCT in patients in cardiac arrest >10 minutes there was a significant rise in pH but no improvement in survival to hospital admission or good neurologic outcome at 1 or 6 months.

Bottom line: while the use of bicarb in cardiac arrest may improve acid base status, it has never been shown to improve clinical outcomes and has many theoretical downsides; bicarb should be reserved for patients suspected of ASA overdose, Na channel blocker overdose or hyperkalemia, as a cause for their cardiac arrest, and it is still controversial for prolonged cardiac arrest >15 minutes based on weak evidence and physiologic rationale.

Is there a role for routine use of IV calcium in cardiac arrest?

While administration of IV calcium may have inotropic and vasopressor effects it does not appear to have a role for routine use in cardiac arrest. It may play a role when hyperkalemia, hypocalcemia (eg, after multiple blood transfusions), or calcium channel blocker toxicity is suspected as a contributor to the cardiac arrest.

The 2021 COCA RCT randomized 391 cardiac arrest patients to IV or IO calcium chloride vs normal saline immediately after the first dose of epinephrine and found that sustained ROSC was 19% in the calcium group vs 27% in the saline group, while survival at 30 days was 5.2% in the calcium group and 9.1% in the saline group, and favourable neurologic outcome was 3.6% in the calcium group vs 7.6% in the saline group. There was a trend towards more harm in the calcium group, but the trial was stopped early, so any definitive conclusion about benefit and harms are difficult to make.

Bottom line: there is no role for routine administration of calcium in cardiac arrest; it should be reserved for those patients suspected of hyperkalemia, hypocalcemia, massive blood transfusion or calcium channel blocker toxicity as a contributor to the arrest.

Is there a role for esmolol in refractory ventricular fibrillation?

In refractory VF there is a huge increase in sympathetic tone, at least partially due to the epinephrine given, which results in increased myocardial oxygen demand, exacerbation of myocardial ischemia, and depression of the VF threshold. Esmolol is an excellent sympatholytic and it increases the fibrillation threshold. It has the fastest onset and shortest half-life of any B-blocker.

There are no large RCTs for esmolol in refractory VF. A tiny 2014 study compared 6 patients who received esmolol after usual ACLS care with 19 controls who received usual ACLS care only. All 6 patients achieved ROSC after 500 mcg/kg IV bolus followed by a drip of a maximum of 100 mcg/kg/minute – with 4 of them achieving sustained ROSC. Survival to discharge with a good neurologic outcome was 50% in the esmolol group vs 11% in the control group.

A 2016 retrospective study compared 16 out of hospital cardiac arrest patients who received esmolol to 25 patients who did not and there were no improved rates of ROSC or survival to the ICU.

Bottom line: While esmolol is not ready for *routine* use in refractory VF, it can be considered as part of the "kitchen sink" when nothing else is working. More importantly, epinephrine should be discontinued in refractory VF. Esmolol should be considered for both refractory VF and recurrent VF.

Airway management in cardiac arrest

There has been a paradigm shift over the past 20 years from ABC to CAB for cardiac arrest resuscitation. High quality chest compressions and early defibrillation should take priority over securing the airway. Prehospital intubation does not improve outcomes in OHCA.

Once it has been established that defibrillation is not required and the first dose of epinephrine has been administered, it is a reasonable time to place a definitive airway during ongoing CPR. A pause in chest compressions should never occur to help facilitate placement of an ET tube. Providers should be skilled at placing an ET tube during ongoing chest compressions, and if not, a supraglottic airway should be considered.

Our experts believe that as long as end tidal CO2 monitoring is employed AND providers are experts at airway management, there is no convincing data to suggest a difference in outcomes between BVM, supraglottic airway or ET tube. The data that suggest otherwise were limited by high rates of multiple attempts at intubation.

- The AIRWAYS2 RCT suggested no difference in neurologically intact survival between supraglottic airway and ET tube. The supraglottic airway group was more likely to have successful ventilation after up to 2 attempts (87.4% vs 79.0%) but also had a higher rate of loss of previously established airway (11% vs 5%).

- An RCT out of France and Belgium showed no difference in 28-day survival between patients receiving BVM vs ET intubation. ROSC was higher with intubation (38.9% vs 34.2%, 95%CI -8.8% to -0.5%, p=0.03). Adverse events were more common in BVM group: airway management difficulty, airway failure (6.7% vs 2.1%), regurgitation was more common in the BVM group (15.2% vs 7.5%).
- The PART trial showed that placement of a supraglottic airway had better 72hr survival and neurological outcomes compared to ET intubation, however, intubation skill was a big confounder in this study: first pass success was only 56% and 20% of pts required 3 or more airway attempts. This study suggests that if intubation skills during ongoing chest compressions are limited, then a supraglottic airway may be preferable.
- A systematic review and meta-analysis comparing the effectiveness of different airway interventions during CPR in patients with OHCA suggested that supraglottic airway has better rates of ROSC compared to BVM or ET intubation however intubation success rates influenced the results.

If end tidal CO2 is not available a supraglottic airway or ET tube is recommended rather than BVM.

Disadvantages of ongoing BVM for the duration of the cardiac arrest is that it often requires two providers to do it effectively, needs to be monitored carefully by the team leader, and may not be the best use of provider utilization.

How to prevent hyperventilation during cardiac arrest

Many providers are adrenalinized and tend to hyperventilate during cardiac arrest, which has deleterious effects on the patient's physiology. One strategy to prevent hyperventilation is to have the bagger say "1-Mississippi, 2-Mississippi" etc. between each breath delivered. Another is to place the patient on a ventilator early in the resuscitation, whenever feasible.

Ketamine for sedation in cardiac arrest

Anecdotally, during CPR some patients appear to regain consciousness, chest compressions are stopped and then they lose their pulse again. Ideally, the patient should not be aware of chest compressions if there is a possibility that they are regaining consciousness. It has therefore been suggested that dissociative dose ketamine be administered to patients in cardiac arrest after other high priority tasks have been completed, so that they are not aware of chest compressions if/when they regain consciousness. Ketamine may also improve intubating conditions for patients who are going in and out of consciousness during the resuscitation. There is also a suggestion that ketamine may attenuate harmful cellular cascades after brain injury that result in permanent damage. Clinical trials are currently assessing whether ketamine sedation during cardiac arrest may improve neurologic outcomes.

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