CRASH
Colorado Review of Anesthesia for Surgicenters And Hospitals
Guiding the future of patient care

ACLS
Anesthesiology Focused Review

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Anschutz

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Commercial Disclosures: none

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Outline

- Understand the broad survival epidemiology for perioperative cardiac arrests
- Review the 2025 ACLS cardiac arrest algorithm and key supporting evidence that translates to intraoperative codes
- Evaluate the role of additional resuscitation adjuncts (calcium chloride, sodium bicarbonate, mechanical compression devices, etc.)
- Review management for unique perioperative arrest circumstances (prone surgery, obstetric arrests, etc.)

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Epidemiology of Intraoperative Arrests

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Cardiac Arrest Epidemiology

	In-Hospital Arrest	Perioperative Arrest
Incidence	60-80 arrests per 10,000 admissions	**Intraoperative:** 3-5 arrests per 10,000 cases ***Anesthesia-related arrests:** 0.74 per 10,000 (medication/airway)
Rhythm	Non-shockable (75%)	Non-shockable (75%)
ROSC	~50%	58 – 69%
Survival to Discharge	~20%	**Intraoperative arrest:** 64.3% **Perioperative arrest:** 31.2%

Fielding-Singh V, Willingham MD, Fischer MA, Grogan T, Benharash P, Neelankavil JP. A Population-Based Analysis of Intraoperative Cardiac Arrest in the United States. Anesth Analg. 2020 Mar;130(3):627-634.
Sobreira-Fernandes D, Teixeira L, Lemos TS, Costa L, Pereira M, Costa AC, Couto PS. Perioperative cardiac arrests - A subanalysis of the anesthesia -related cardiac arrests and associated mortality. J Clin Anesth. 2018 Nov;50:78-90.
Ramachandran SK, Mhyre J, Kheterpal S, et al. Predictors of survival from perioperative cardiopulmonary arrests: a retrospective analysis of 2,524 events from the Get With The Guidelines-Resuscitation registry. *Anesthesiology*. Dec 2013;119(6):1322-39.

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Focus on *Intraoperative Arrests*

A&A Anesthesia & Analgesia

A Population-Based Analysis of Intraoperative Cardiac Arrest in the United States

Vikram Fielding-Singh, MD, JD,* Mark D. Willingham, MD, MS,* Matthew A. Fischer, MD, MS,* Tristan Grogan, MS,† Peyman Benharash, MD,‡ and Jacques P. Neelankavil, MD*

- National Inpatient Sample (NIS) database of community hospitals
- Utilized ICD-10 code for **intraoperative** arrest (not perioperative)
- Followed hospitalization metrics, including survival

64.3%

Survival to hospital discharge

Fielding-Singh V, Willingham MD, Fischer MA, Grogan T, Benharash P, Neelankavil JP. A Population-Based Analysis of Intraoperative Cardiac Arrest in the United States. Anesth Analg. 2020 Mar;130(3):627-634.

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Focus on *Perioperative Arrests*

Predictors of Survival from Perioperative Cardiopulmonary Arrests

A Retrospective Analysis of 2,524 Events from the Get With The Guidelines-Resuscitation Registry

Anesthesiology, V 119 • No 6

- Data from AHA prospective, multi-site, observational registry that include over 400 hospitals, published in *Anesthesiology*
- Tracked patients with **perioperative arrest** (intraoperative to first 24 hours after leaving PACU)
- Following perioperative arrest: **ROSC in 58%, 32% survived to hospital discharge, 20% survived neurologically intact.**
- Survival after arrest from **shockable rhythm** significantly higher versus asystole or PEA (OR 1.60, CI 1.16 – 2.20)

Ramachandran SK, Mhyre J, Kheterpal S, et al. Predictors of survival from perioperative cardiopulmonary arrests: a retrospective analysis of 2524 events from the Get With The Guidelines-Resuscitation registry. Anesthesiology. [illegible]

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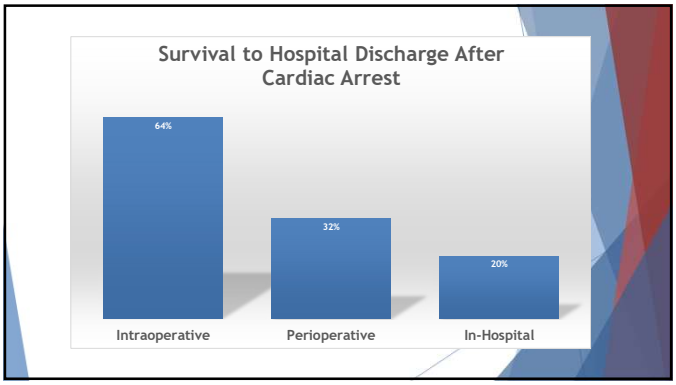

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IHCA versus Intraoperative Arrest

- OR arrests typically recognized immediately
- Full resuscitation equipment available in OR (airway, rescue medications)
- Anesthesia provider familiar with patient's medical history
- Frequently reversible precipitants to intraoperative arrests

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Perioperative Arrest Epidemiology: Key Points

- Intraoperative arrests exceedingly rare: ~5 per 10,000 cases*
- Outcomes are considerably improved in intraoperative and perioperative arrests as compared to in-hospital arrests
- Patients arresting due to shockable rhythms demonstrate higher survival as compared non-shockable rhythms

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2025 ACLS Review

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American Society of Anesthesiologists

ANESTHESIOLOGY

Perioperative Resuscitation and Life Support (PeRLS): An Update

American Heart Association.

Part 9: Adult Advanced Life Support: 2025 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Jane G. Wigginton, MD, MSCS, Vice Chair; Sachin Agarwal, MD, MPH; Jason A Bartos, MD, PhD; Ryan A. Coute, DO; Ian R. Drennan, ACP, PhD; Ameera Hasmid, MD; Peter J. Kudenchuk, MD; Mark S. Link, MD; Ashish R. Panchal, MD, PhD; Michele M. Pelter, RN, PhD; Marina Del Rios, MD, MS; Amber J Rodriguez, PhD; Sarah M. Perman, MD, MSCE; Stephen Sanko, MD; Pavitra Kotini-Shah, MD; Michael C. Kurz, MD, MS, Chair

Review major updates to 2025 ACLS cardiac arrest guidelines & accompanying evidence for high quality resuscitation

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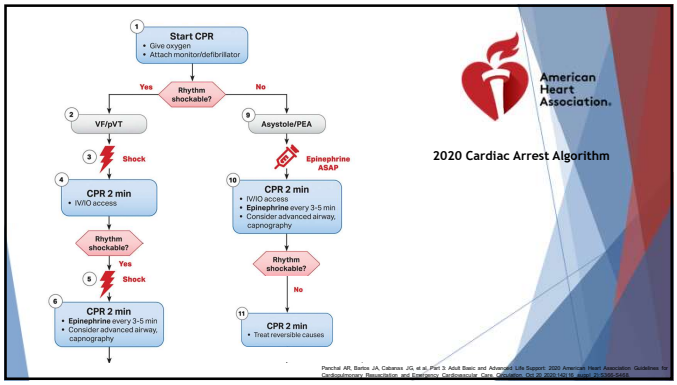

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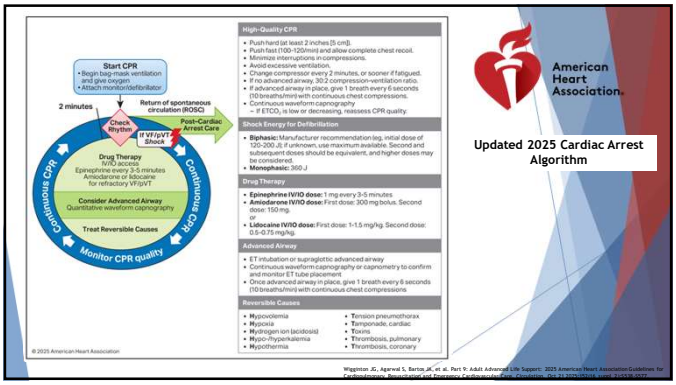

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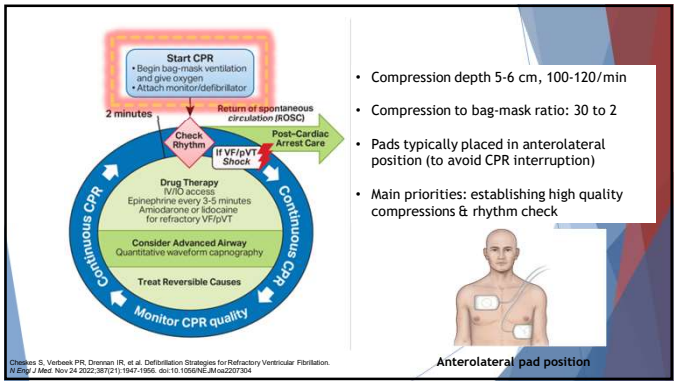

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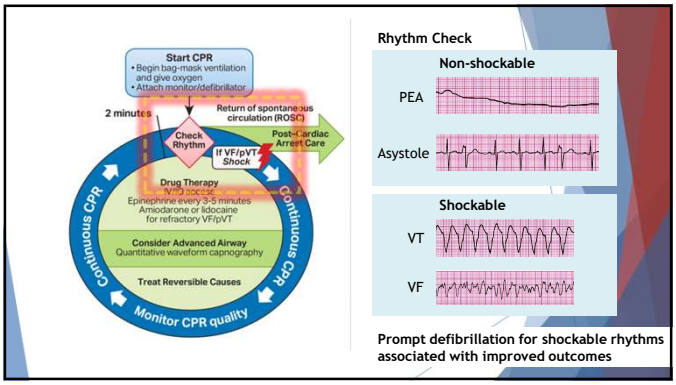

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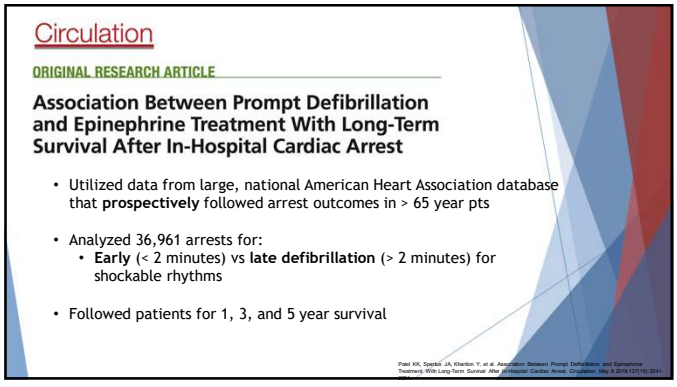

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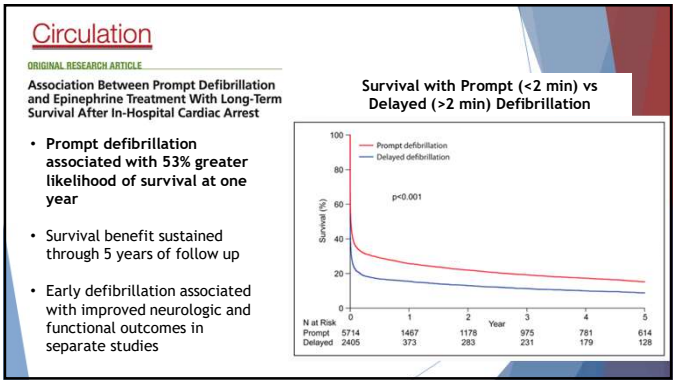

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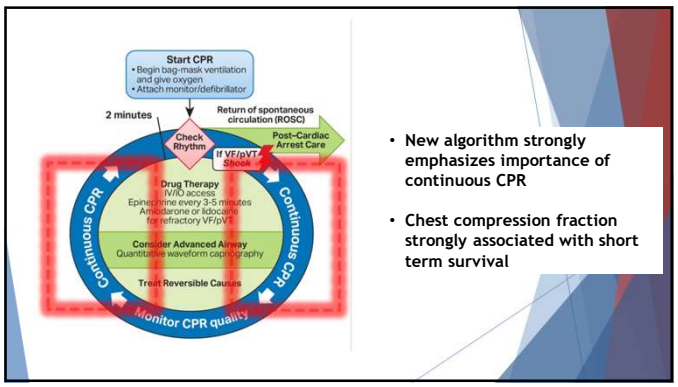

- **New algorithm strongly emphasizes importance of continuous CPR**
- **Chest compression fraction strongly associated with short term survival**

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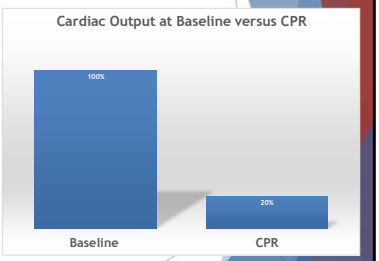
CPR: Poor Substitute for the Heart

- High quality CPR provides:
  - 10-30% of normal blood flow to the heart
  - 30-40% of normal blood flow to the brain
- Significant decrement in cerebral and coronary blood flow with poor quality CPR



Meaney, P. A., et al. "CPR quality: improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association." Circulation 128.4 (2013): 417-435.

Duggal C, et al. J Appl Physiol. 1997; 74(1):147-153.

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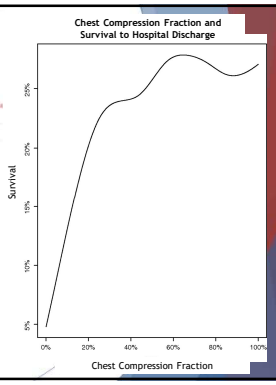
Chest Compression Fraction Determines Survival in Patients With Out-of-Hospital Ventricular Fibrillation

RESEARCH ARTICLE · Originally Published 14 September 2009

Jim Christenson, MD, Douglas Andrusiek, MSc, Siobhan Everson-Stewart, MS, Peter Kudenchuk, MD, David Hostler, PhD, Judy Powell Clifton W. Callaway, MD, PhD, ... SHOW ALL ... the Resuscitation Outcomes Consortium Investigators AUTHOR INFO & AFFILIATIONS

Circulation • Volume 120, Number 13 • https://doi.org/10.1161/CIRCULATIONAHA.109.852202

- Prospective data collected from 11 geographically distinct centers in North America, 506 arrests
- Compression fraction measured via thoracic impedance or accelerometer
- Patients followed through hospital discharge
- **Strong association between chest compression fraction and survival to hospital discharge**



Christenson J, Andrusiek D, Everson-Stewart S, et al. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. Circulation. Sep 29 2009;120(13):1241-7.

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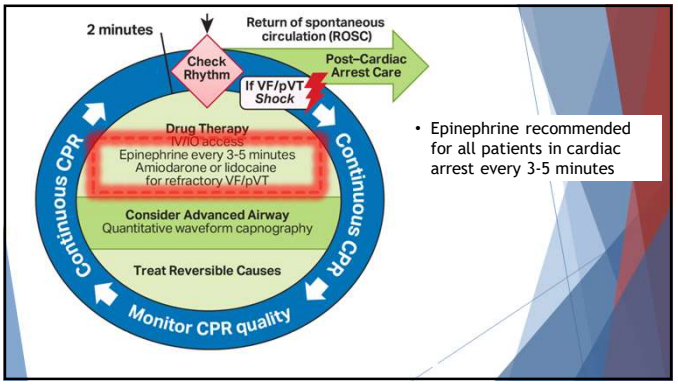

- Epinephrine recommended for all patients in cardiac arrest every 3-5 minutes

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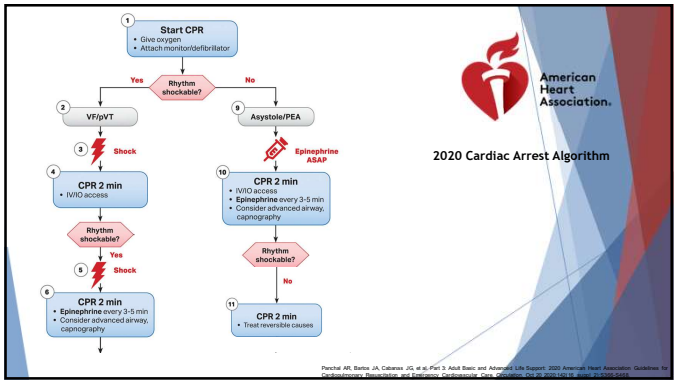

Panchal AR, Bartos JA, Cabañas JG, et al. Part 3: Adult Basic and Advanced Life Support: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. Oct 20 2020;142(16_suppl_2):S366-S468.

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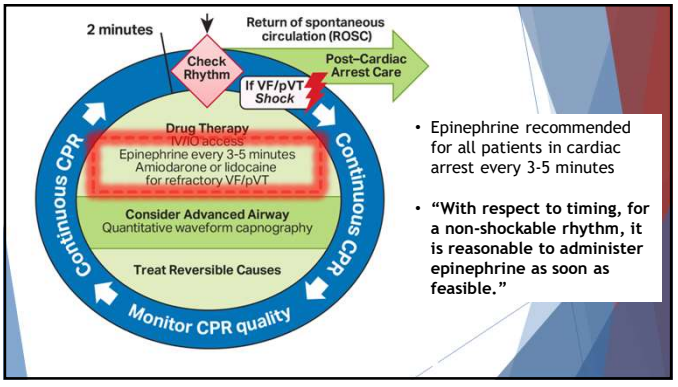

- Epinephrine recommended for all patients in cardiac arrest every 3-5 minutes
- **"With respect to timing, for a non-shockable rhythm, it is reasonable to administer epinephrine as soon as feasible."**

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The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 AUGUST 23, 2018 VOL. 379 NO. 8

A Randomized Trial of Epinephrine in Out-of-Hospital Cardiac Arrest

- Adult patients with **OHCA** (traumatic arrests excluded)
- Following unsuccessful defibrillation or CPR, randomized to 1 mg **epinephrine versus placebo**
- Outcome: survival at 30 days, survival with a favorable neurologic outcome

Perkins GD, Ji C, Deakin CD, et al. A Randomized Trial of Epinephrine in Out-of-Hospital Cardiac Arrest. *N Engl J Med*. Aug 23, 2018;379(8):711-721. doi:10.1056/NEJMoa1806842

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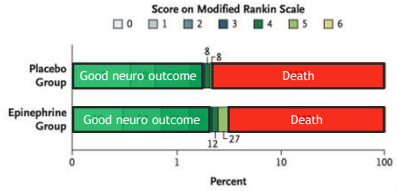
Table 3. Primary and Secondary Outcomes.*

Outcome	Epinephrine	Placebo	Odds Ratio (95% CI)†	
			Unadjusted	Adjusted
Primary outcome				
Survival at 30 days — no./total no. (%)‡	130/4012 (3.2)	94/3995 (2.4)	1.39 (1.06–1.82)	1.47 (1.09–1.97)



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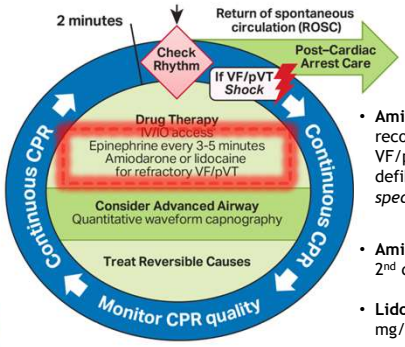

- **Amiodarone** or **lidocaine** recommended for refractory VF/pVT that is unresponsive to defibrillation (*unresponsive not specifically defined*)
- **Amiodarone:** 1st dose 300 mg, 2nd dose 150 mg
- **Lidocaine:** 1st dose 1-1.5 mg/kg, 2nd dose 0.5-0.75 mg/kg

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The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 MAY 5, 2016 VOL. 374 NO. 18

Amiodarone, Lidocaine, or Placebo in Out-of-Hospital Cardiac Arrest

- Enrolled patients with OHCA with refractory VF/VT from 10 North American sites
- Patients randomized to IV amiodarone, lidocaine, or placebo after first unsuccessful shock
- Outcomes: survival to hospital discharge, favorable neurologic outcome at discharge
- 3,026 patients enrolled

Kudenchuk PJ, Brown SP, Daya M, et al. Amiodarone, Lidocaine, or Placebo in Out-of-Hospital Cardiac Arrest. *N Engl J Med*. May 5, 2016;374(18):1711-22.

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Table 3. Outcomes According to Trial Group in the Per-Protocol Population.*

Outcome	Amiodarone (N=974)	Lidocaine (N=993)	Placebo (N=1059)	Amiodarone vs. Placebo Difference (95% CI) percentage points	P Value	Lidocaine vs. Placebo Difference (95% CI) percentage points	P Value	Amiodarone vs. Lidocaine Difference (95% CI) percentage points	P Value
Primary outcome: survival to discharge — no./total no. (%)†	237/970 (24.4)	233/985 (23.7)	222/1056 (21.0)	3.2 (−0.4 to 7.0)	0.08	2.6 (−1.0 to 6.3)	0.16	0.7 (−3.2 to 4.7)	0.70
Secondary outcome: modified Rankin score ≤3 — no./total no. (%)‡	182/967 (18.8)	172/984 (17.5)	175/1055 (16.6)	2.2 (−1.1 to 5.6)	0.19	0.9 (−2.4 to 4.2)	0.59	1.3 (−2.1 to 4.8)	0.44
Mechanistic (exploratory) outcomes									
Return of spontaneous circulation at ED arrival — no./total no. (%)	350/974 (35.9)	396/992 (39.9)	366/1059 (34.6)	1.4 (−2.8 to 5.5)	0.52	5.4 (1.2 to 9.5)	0.01	−4.0 (−8.3 to 0.3)	0.07
Admitted to hospital — no. (%)	445 (45.7)	467 (47.0)	420 (39.7)	6.0 (1.7 to 10.3)	0.01	7.4 (3.1 to 11.6)	<0.001	−1.3 (−5.7 to 3.1)	0.55
Modified Rankin score in all patients‡	5.0±1.9	5.1±1.8	5.2±1.8	−0.14 (−0.30 to 0.02)	0.09	−0.06 (−0.22 to 0.10)	0.45	−0.08 (−0.24 to 0.08)	0.34

2b	B-R	1. Amiodarone or lidocaine may be considered for VF/pVT that is unresponsive to defibrillation.

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Important Insights from Non-OR Arrests

- **Early defibrillation** (for shockable rhythm arrests) and a **high compression fraction** associated with improved survival
- For OHCA, epinephrine improves survival, without convincing benefit of long-term survival or neurologic recovery (still recommended)
- For OHCA, no difference in survival or degree of disability between patients receiving amiodarone, lidocaine, and placebo (*may be considered*)

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Additional Resuscitation Adjuncts

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Calcium Chloride

- Increased extracellular Ca+ increases myocardial contractility and systemic vascular resistance
- Prior small randomized trials have not shown any aggregate benefit of calcium administration during non-OR arrests
- **COCA** trial, published in 2020, further questioned benefit of calcium chloride

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JAMA | Original Investigation 2020

Effect of Intravenous or Intraosseous Calcium vs Saline on Return of Spontaneous Circulation in Adults With Out-of-Hospital Cardiac Arrest
A Randomized Clinical Trial

- Danish trial that enrolled 383 patients with OHCA (~80% non-shockable rhythm)
- Patients received 1-2 doses of 750 mg CaCl with median time to administration **18 minutes**
- Trial stopped early due to signal of harm for calcium chloride group

Vallentin MF, Granfeldt A, Meilandt C, et al. Effect of Intravenous or Intraosseous Calcium vs Saline on Return of Spontaneous Circulation in Adults With Out-of-Hospital Cardiac Arrest: A Randomized Clinical Trial. JAMA. Dec 14 2021;326(22):2268-2276. doi:10.1001/jama.2021.20903

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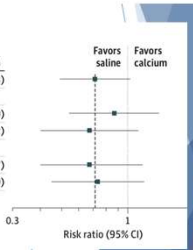
JAMA | Original Investigation 2020

Effect of Intravenous or Intraosseous Calcium vs Saline on Return of Spontaneous Circulation in Adults With Out-of-Hospital Cardiac Arrest
A Randomized Clinical Trial

	Return of spontaneous circulation, No./total (%)		
	Calcium	Saline	Risk ratio (95% CI)
Overall	37/193 (19)	53/198 (27)	0.72 (0.49 to 1.03)
Initial rhythm			
Shockable	17/43 (40)	24/53 (45)	0.87 (0.54 to 1.39)
Nonshockable	20/150 (13)	29/145 (20)	0.67 (0.40 to 1.12)
Time to trial drug, min			
≥18	15/91 (16)	26/106 (25)	0.67 (0.38 to 1.17)
<18	22/102 (22)	27/92 (29)	0.73 (0.45 to 1.19)



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Calcium Chloride

- No appreciable benefit of protocolized, **late** calcium chloride in OHCA cardiac arrest
- CaCl has numerous indications in perioperative arrest settings (hyperkalemia, massive transfusion)

3: No Benefit **B-R**

4. For adults in cardiac arrest, routine administration of calcium is not recommended.

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Sodium Bicarbonate

- Expands circulating volume (8.4% sodium-bicarbonate) and corrects acidosis
- Animal studies from the 70 and 80's demonstrated physiologic benefit in resuscitation (correction of metabolic acidosis)
- Few studies demonstrated improved ROSC, the remaining majority showing minimal benefit or possible harm
- **Removed** from AHA resuscitation guidelines in 2010 (barring hyperkalemic arrest, TCA overdose), with no compelling subsequent evidence of benefit

3: No Benefit **B-R**

5. For adults in cardiac arrest, routine administration of sodium bicarbonate is not recommended.

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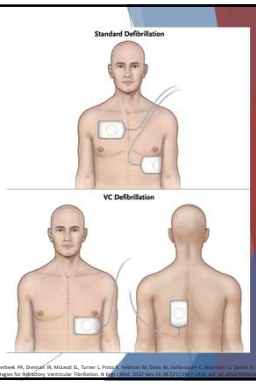
Vector Change

- Defibrillation can be unsuccessful due to inadequate transfer of energy to the heart
- Changing defibrillator pad orientation from anterolateral to anterior-posterior can allow better ventricular capture



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ORIGINAL ARTICLE

Defibrillation Strategies for Refractory Ventricular Fibrillation

- Cluster-randomized trial of OHCA in six Canadian health systems
- 405 patients enrolled with **refractory VF** (persistent despite 3 shocks)
- Clustered treatment: standard defibrillation versus **vector change** after third shock

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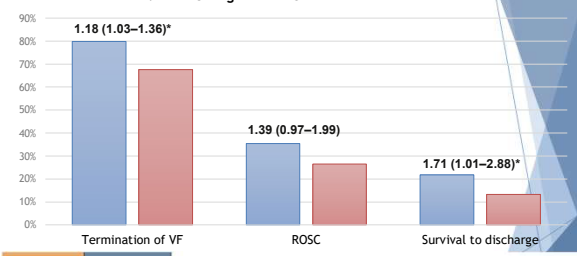
Vector Change versus Standard Defibrillation



2b | B-R

1. The usefulness of vector change for adults in cardiac arrest with persisting VF/pVT after ≥3 consecutive shocks has not been established.

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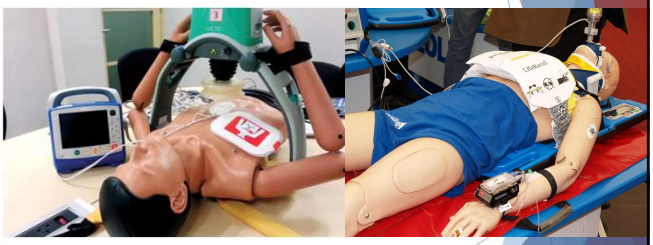
Mechanical CPR Devices



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Mechanical CPR Devices

Table 3 Summary of systematic reviews in the UR

	ROSC	Survival to hospital admission	Survival to hospital discharge OR 30 days	Neurological recovery
Sheraton et al. [17]	No[a]	NA	NA	NA
Liu et al. [18]	No	No	No	NA
Li et al. [19]	No	No	No	No
Khan et al. [20]	No	No	No	No
Couper et al. [21]	Improved[b]	NA	Improved	NA
Gates et al. [22]	No	No	No	No
Bonnes et al. [23]	Partially[c]	Partially	No	No
Zhu et al. [24]	No	No	No	No
Tang et al. [25]	No	Negative effect[e]	No	No
Wang et al. [26]	NA[d]	NA	Negative effect	Negative effect
Chiang et al. [27]	Partially	Partially	No	No

El-Menyar A, Nadvilekandy M, Ricci S, et al. Mechanical versus manual cardiopulmonary resuscitation (CPR): an umbrella review of contemporary systematic reviews and more. Crit Care. Jul 30 2024;28(1):259.

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ACLS Adjunct Summary

- No compelling evidence for benefit for protocolized **calcium** or **sodium bicarbonate** in non OR-arrests; neither recommended in 2025 AHA guidelines.
- **Vector change** offers promise for refractory (>3 shock) VF; no firm recommendation (or disapproval) in 2025 AHA guidelines
- Compressions performed by medical staff result in similar outcomes as **mechanical compression devices**

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Monitoring CPR Quality

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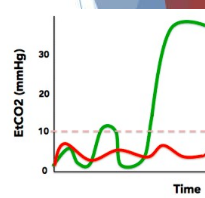
End-Tidal CO_2

- End tidal CO_2 correlates with pulmonary blood flow & cardiac output
- Higher end tidal CO_2 levels correlate with appropriate compression **depth** and **recoil**
  - CPR **goal end tidal > 10 mm Hg** (ideally > 20 mm Hg) – associated with ↑ ROSC
  - Allows for feedback to chest compressors
  - Abrupt increase > 10 mm Hg, or to 35 – 40 mm Hg, typically indicates ROSC



Rabjohns, Jennifer. End-Tidal CO2 in Cardiopulmonary Resuscitation. Academic Life in Emergency Medicine. Feb 6, 2019.

Sutton RM, French B, Meaney PA, et al. Physiologic monitoring of CPR quality during adult cardiac arrest: A propensity-matched cohort study. *Resuscitation*. Sep 2016;106:76-82.

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Arterial Blood Pressure Monitoring

- Diastolic blood pressure drives coronary perfusion pressure
- Improved ACLS diastolic BP associated with appropriate **depth** of compressions.
  - Diastolic blood pressure > 30 mm Hg associated with higher rates of survival to hospital discharge
  - **Goal diastolic blood pressure > 30-40 mm Hg** (limited data available on specific target)

Berg RA, Morgan RW, Reeder RW, et al. Diastolic Blood Pressure Threshold During Pediatric Cardiopulmonary Resuscitation and Survival Outcomes: A Multicenter Validation Study. *Crit Care Med*. 2023;51(1):91-102.

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Intraoperative Arrest Differential Diagnosis

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Shockable	Non-Shockable	
Ventricular tachycardia	**Pulmonary**	**Anesthesia/Surgical**
Ventricular fibrillation	Auto-PEEP	Anesthetic Overdose
	Tension pneumothorax	LAST
	Bronchospasm	Gas/fat/amniotic fluid embolism
		Anaphylaxis
	Cardiac	Hemorrhage
		High spinal
	Tamponade	**Electrolyte**
	Pulmonary embolism	Hyperkalemia
	ACS / arrhythmia	Hypoglycemia

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Unique Perioperative Arrest Situations

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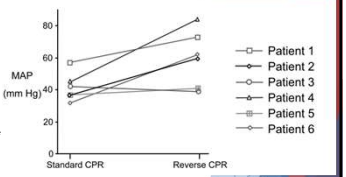
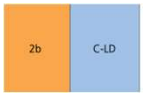
Prone CPR

- Data limited to case reports
- 14 prone arrests (93% neurosurgical cases)
- Arrest etiologies: hypovolemia, air embolism, arrhythmia
- ROSC achieved in all cases with **prone CPR***

Standard versus Reverse (Prone) CPR



2020 AHA ACLS Guideline



4. When the victim cannot be placed in the supine position, it may be reasonable for rescuers to provide CPR with the victim in the prone position, particularly in hospitalized patients with an advanced airway in place.

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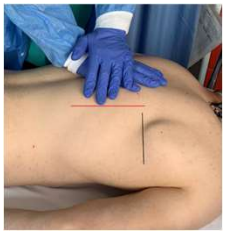
Prone CPR



- Perform compressions between T7 – T9 (just below inferior aspect of scapula)
- This compression location maximizes pressure over left ventricle
- Ensure rigid surface under sternum *(prone CPR pushes costovertebral joint against and AND heart against sternum)*

"Nevertheless, because most opportunities to perform prone CPR likely arise in an intraoperative or ICU context, we believe it reasonable to consider leaving patients prone for at least the first few minutes of CPR."

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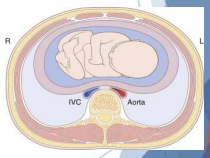
Cardiac Arrest in Pregnancy

- Cardiac arrest in 1 in 12,000 admissions for delivery
- Pertinent pregnancy physiology
  - Enlarged uterus (>12 wks) increases aortic afterload, compresses IVC
  - Decreased functional residual capacity & increased oxygen consumption



Jeejeebhoy FM, Zelop CM, Lipman S, et al. Cardiac Arrest in Pregnancy: A Scientific Statement From the American Heart Association. *Circulation*. Nov 3 2015;132(18):1747-73.

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Cardiac Arrest in Pregnancy

Unchanged Aspects of ACLS / Resuscitation

- Normal hand position for compressions (center of chest, lower portion sternum)
- Normal compression rate 100-120, 5-6 cm depth
- Defibrillation energy unchanged (200 J)
- All ACLS resuscitative medications recommended at typical doses

Jeejeebhoy FM, Zelop CM, Lipman S, et al. Cardiac Arrest in Pregnancy: A Scientific Statement From the American Heart Association. *Circulation*. Nov 3 2015;132(18):1747-73.

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Cardiac Arrest in Pregnancy

Important ACLS / Resuscitation Differences

Mitigate Uterine Aortocaval Compression

- Establish IV access **above diaphragm** for unstable patients
- **Manual left uterine displacement** when uterus at or above level of umbilicus (> 20 wks)

Jeejeebhoy FM, Zelop CM, Lipman S, et al. Cardiac Arrest in Pregnancy: A Scientific Statement From the American Heart Association. *Circulation*. Nov 3 2015;132(18):1747-73.

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Cardiac Arrest in Pregnancy

Important ACLS / Resuscitation Differences

Perimortem Cesarean Delivery

- Definitively relieves aortocaval compression and minimizes fetal neurologic injury
- Requires **early activation** of multidisciplinary maternal cardiac arrest team
- Generally, consider for > 20 week pregnancies

Peri-mortem C/S at 4 minutes

Delivery at 5 minutes*

Jeejeebhoy FM, Zelop CM, Lipman S, et al. Cardiac Arrest in Pregnancy: A Scientific Statement From the American Heart Association. *Circulation*. Nov 3 2015;132(18):1747-73.

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Summary

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- Approximately 64% of patients with intraoperative arrest survive to discharge (markedly higher survival than in-hospital arrests)
- Early defibrillation (for shockable rhythms) and high compression fraction are most impactful ACLS interventions
- $EtCO_2$ and diastolic blood pressure allow monitoring of CPR quality during code. Goal $EtCO_2$ > 10 and diastolic blood pressure > 35.
- Prone CPR physiologically effective; requires firm surface under sternum
- Pregnancy CPR: ACLS medications and dosing unchanged; main ACLS differences include manual uterine displacement and mobilization for peri-mortem cesarean section for > 20 weeks gestation.

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