

Goal-Directed Resuscitation During Cardiac Arrest

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April 24th, 2017



Disclosures

- Co-Chair: International Liaison Committee on Resuscitation (ILCOR)
- President and Board Chair, SaveMiHeart
- Immediate Past Chair, American Heart Association Emergency Cardiovascular Care Committee (AHA-ECC)
- Past Chair, AHA-ECC ACLS Subcommittee
- NIH and AHA Research Funding
- PhysioControl: Equipment support for research

Outline

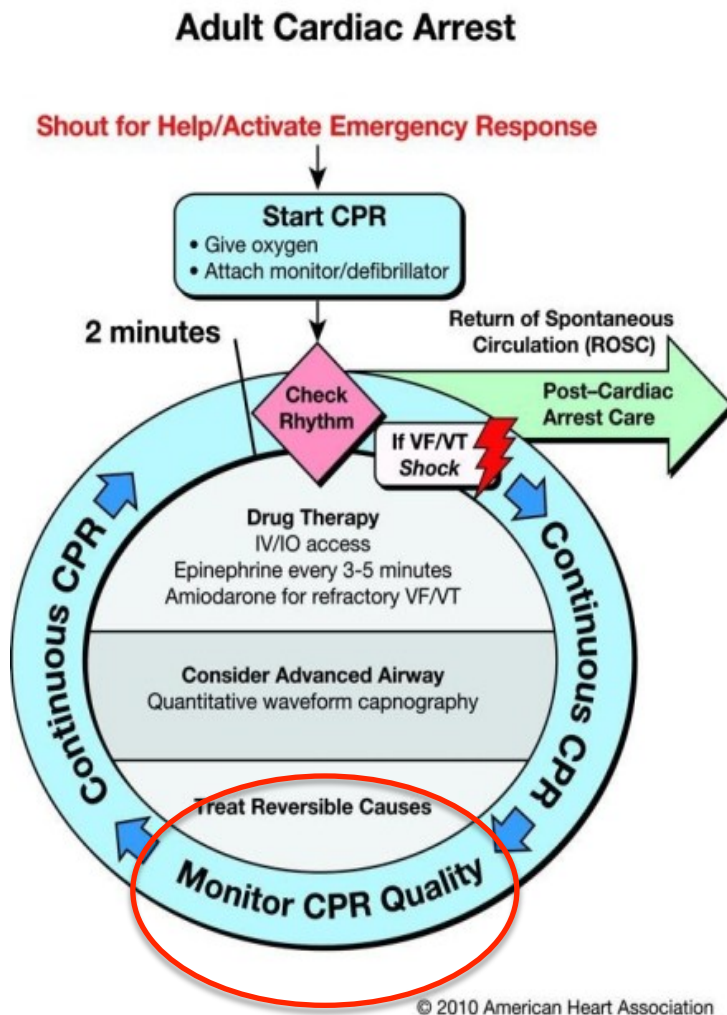
- CPR Quality
- Physiologic Monitoring and Goals During CPR
- Goal-Directed CPR in the Emergency Department

CPR Quality in the Emergency Department?



Is this effective CPR?

CPR Quality



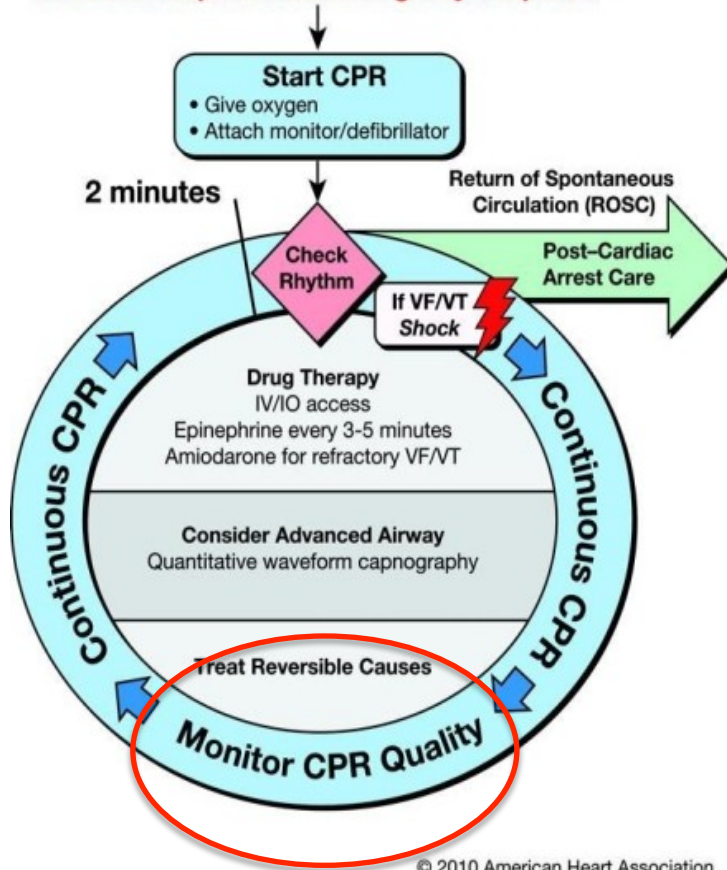
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- Chest Compression CCF >80%
- Compression rate of 100 to 120/min
- Compression depth of 5-6 cm
- No leaning on chest during relaxation
- Avoid excessive ventilation
 - Only minimal chest rise and a rate of 10 breaths/min

CPR Quality

Adult Cardiac Arrest

Shout for Help/Activate Emergency Response

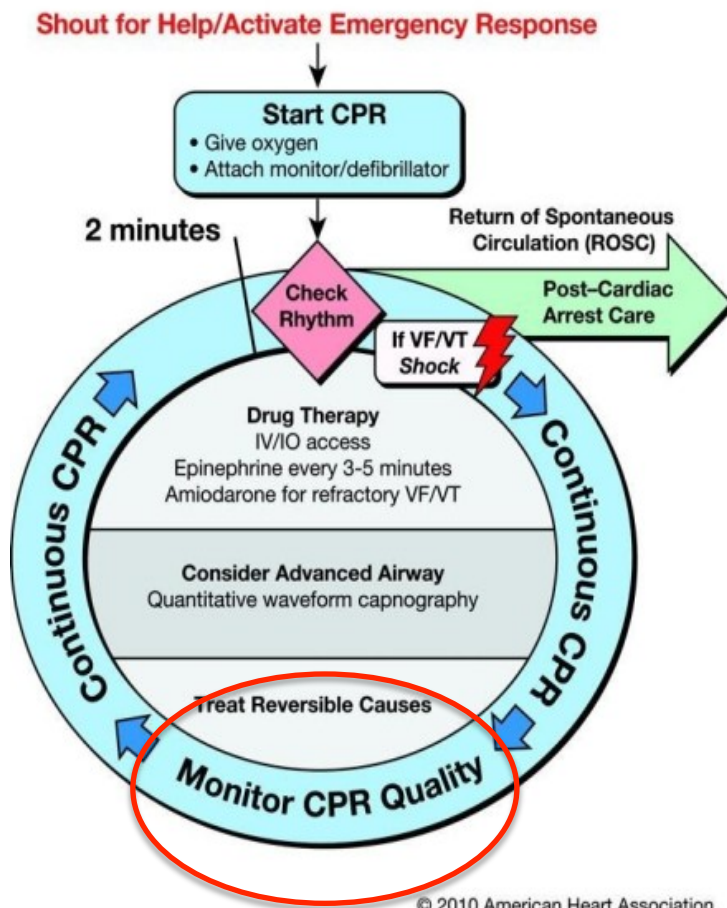


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CPR Quality

Adult Cardiac Arrest

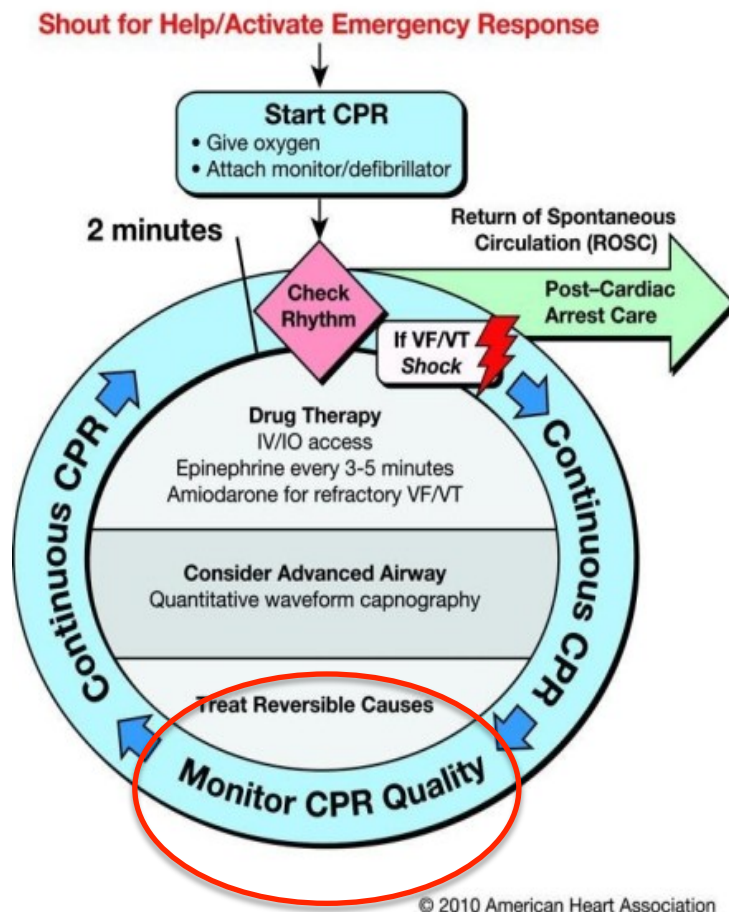


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CPR Quality

Adult Cardiac Arrest



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Although no clinical study has examined whether titrating resuscitative efforts to physiologic parameters during CPR improves outcome, it may be reasonable to **use physiologic parameters** (quantitative waveform capnography, arterial relaxation diastolic pressure, arterial pressure monitoring, and central venous oxygen saturation) when feasible **to monitor and optimize CPR quality, guide vasopressor therapy,** and detect ROSC. [\(Class IIb, LOE C-EO\)](#)

CPR Quality in the Emergency Department?

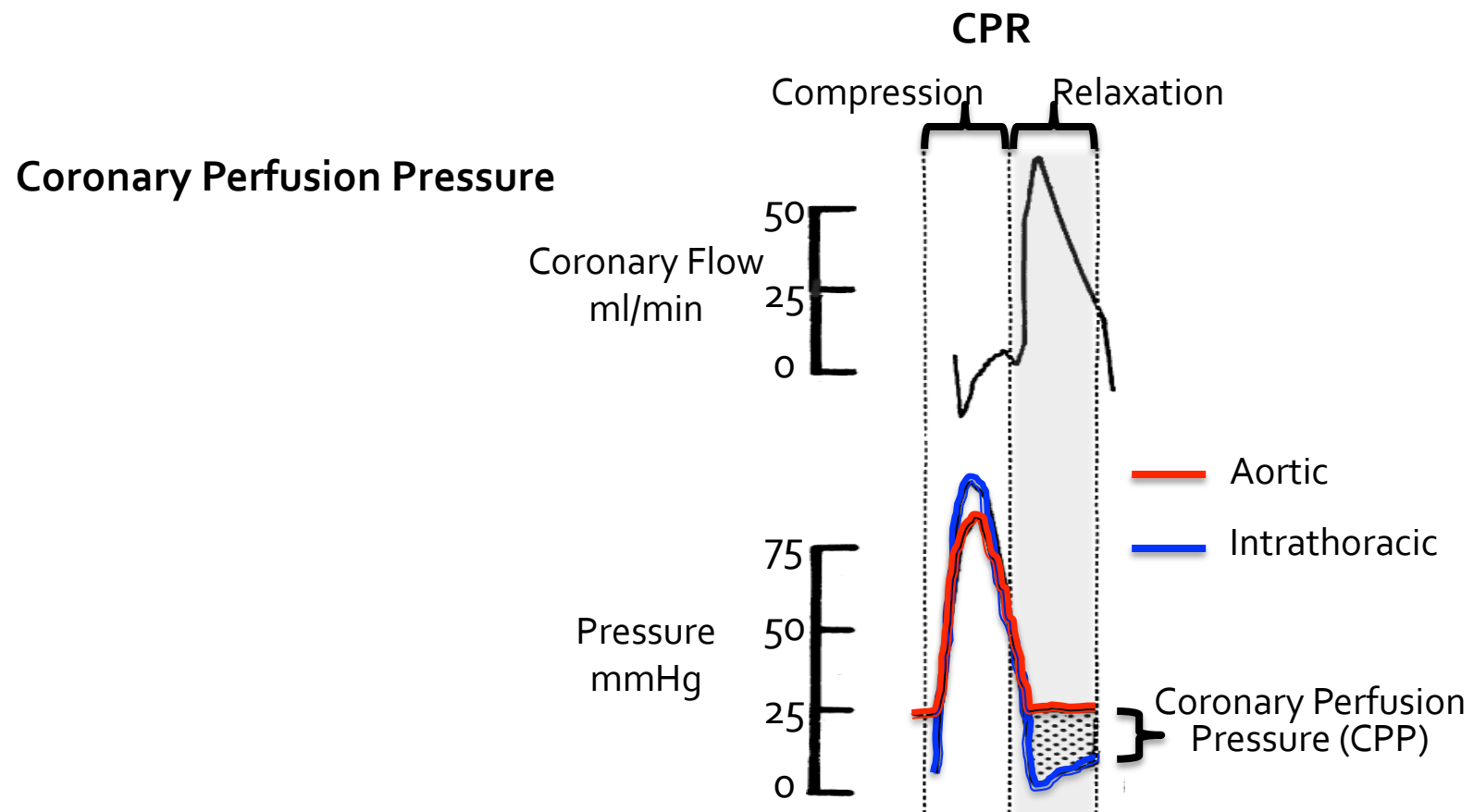


How would you improve CPR effectiveness?

CPR Physiologic Monitoring

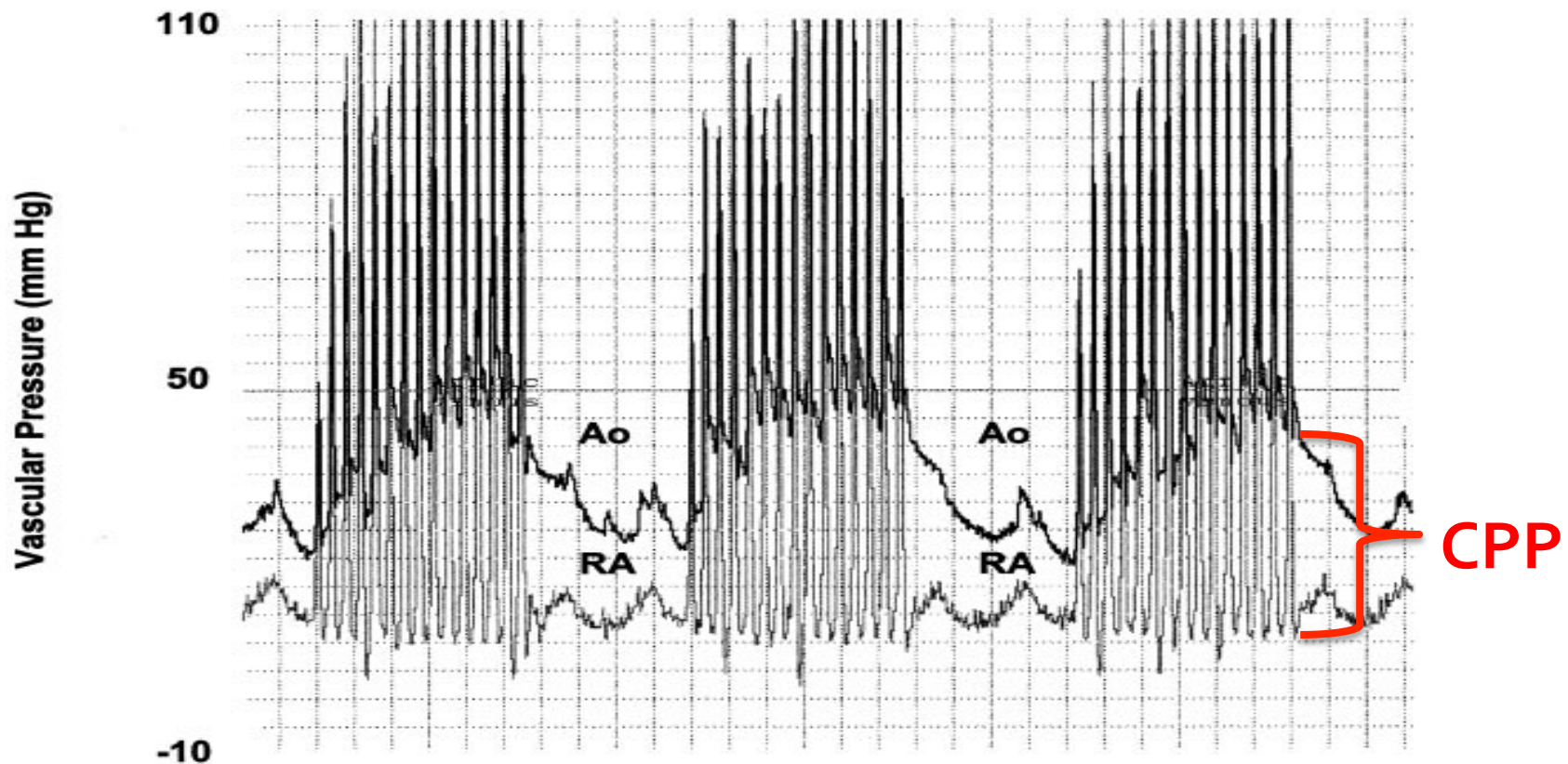
- Coronary Perfusion Pressure
- Arterial Relaxation Pressure
- End-Tidal CO₂
- Central Venous Oxygen Saturation
- Cerebral Near Infra-Red Spectroscopy

CPR Hemodynamics



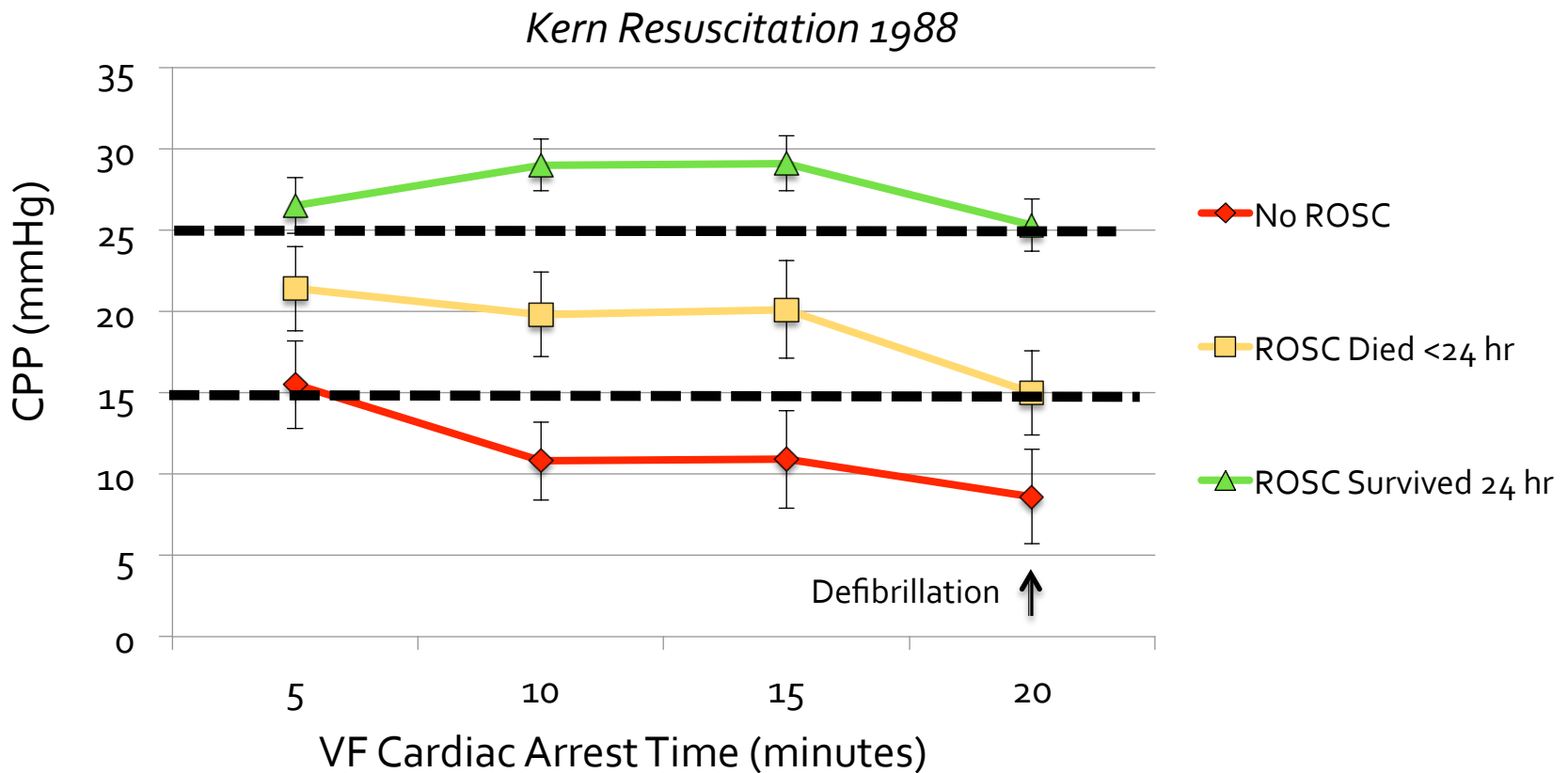
Bellamy Circulation 1984

Coronary Perfusion Pressure (CPP) During CPR



Berg Circulation 2001

Coronary Perfusion Pressure During CPR Predicts and Cardiac Arrest Outcome



Coronary Perfusion Pressure During CPR in Humans

Clinical Investigation

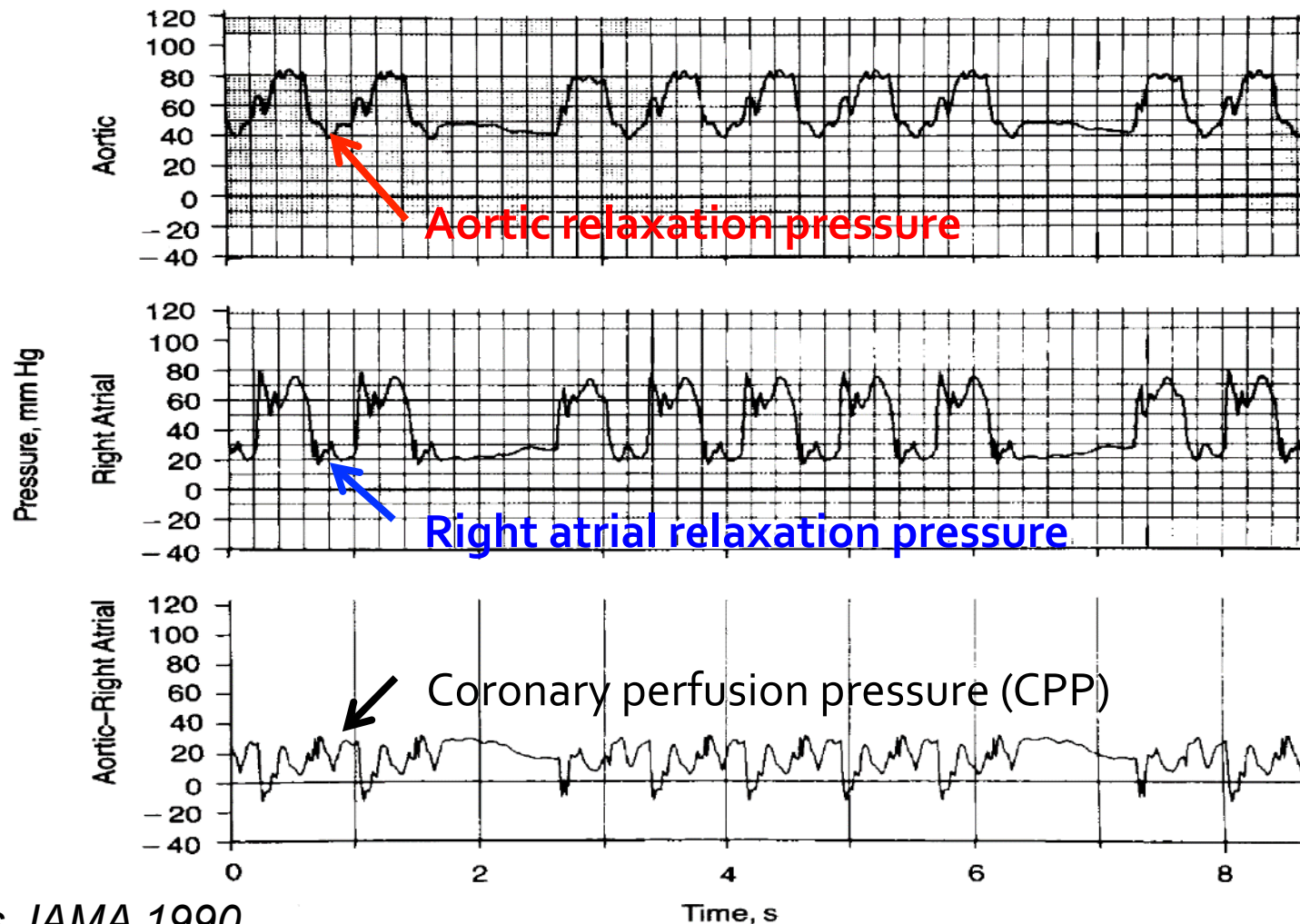
Coronary Perfusion Pressure and the Return of Spontaneous Circulation in Human Cardiopulmonary Resuscitation

Norman A. Paradis, MD; Gerard B. Martin, MD; Emanuel P. Rivers, MD; Mark G. Goetting, MD; Timothy J. Appleton;
Marcia Feingold, PhD; Richard M. Nowak, MD

Coronary perfusion pressure (CPP), the aortic-to-right atrial pressure gradient during the relaxation phase of cardiopulmonary resuscitation, was measured in 100 patients with cardiac arrest. Coronary perfusion pressure and other variables were compared in patients with and without return of spontaneous circulation (ROSC). Twenty-four patients had ROSC. Initial CPP (mean \pm SD) was 1.6 ± 8.5 mm Hg in patients without ROSC and 13.4 ± 8.5 mm Hg in those with ROSC. The maximal CPP measured was 8.4 ± 10.0 mm Hg in those without ROSC and 25.6 ± 7.7 mm Hg in those with ROSC. Differences were also found for the maximal aortic relaxation pressure, the compression-phase aortic-to-right atrial gradient, and the arterial PO_2 . No patient with an initial CPP less than

pressure monitoring catheters. *Down time* was defined as the time from collapse to initiation of basic life support. *Prehospital time* was the time from collapse to arrival at the hospital. *Total arrest time* equaled prehospital time plus catheterization time. Time data were used only if the arrest was witnessed. Cardiac arrest was diagnosed initially by absence of palpable pulses. On-duty physicians performed clinical

Coronary Perfusion Pressure During CPR in Humans



Relationship of Coronary Perfusion Pressure and ROSC

Paradis JAMA 1990

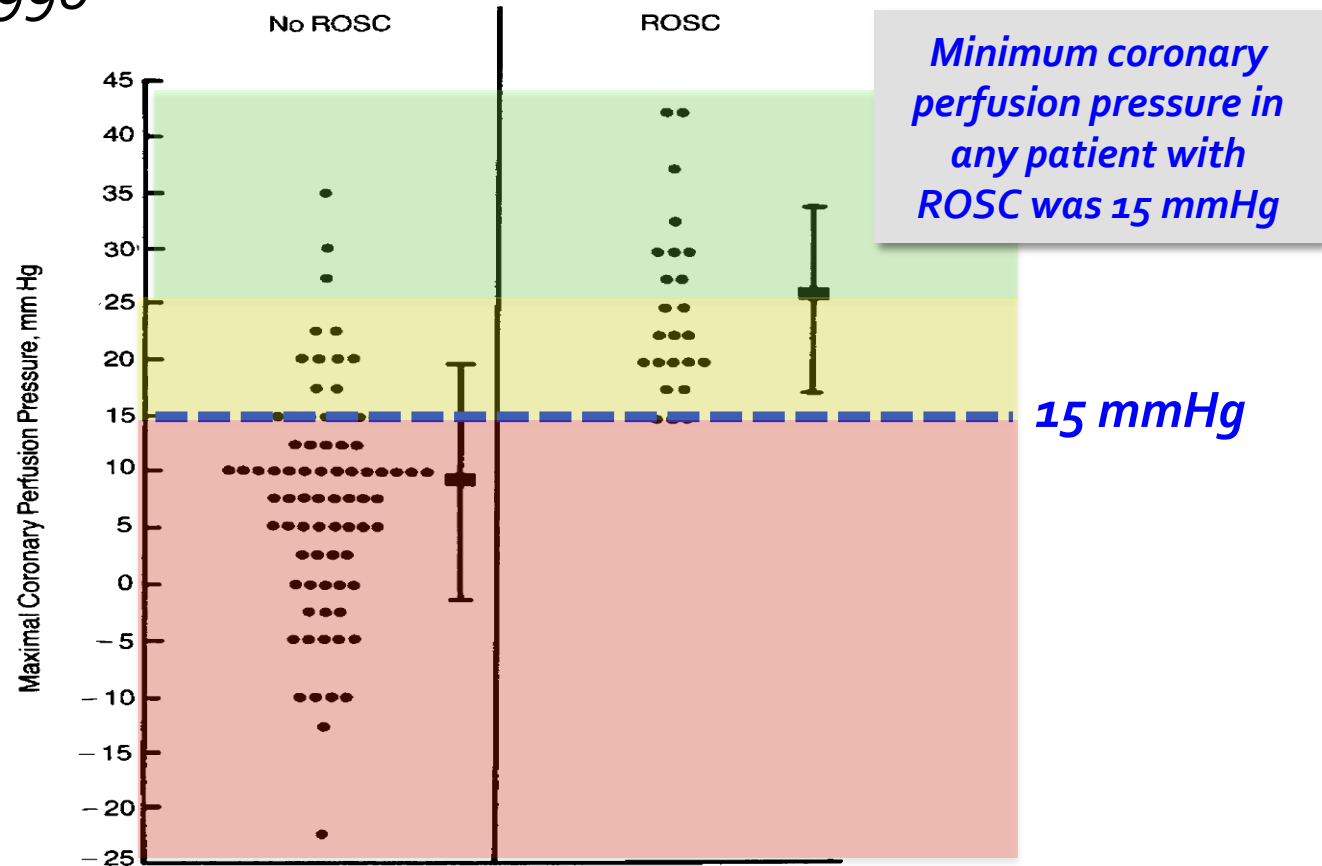
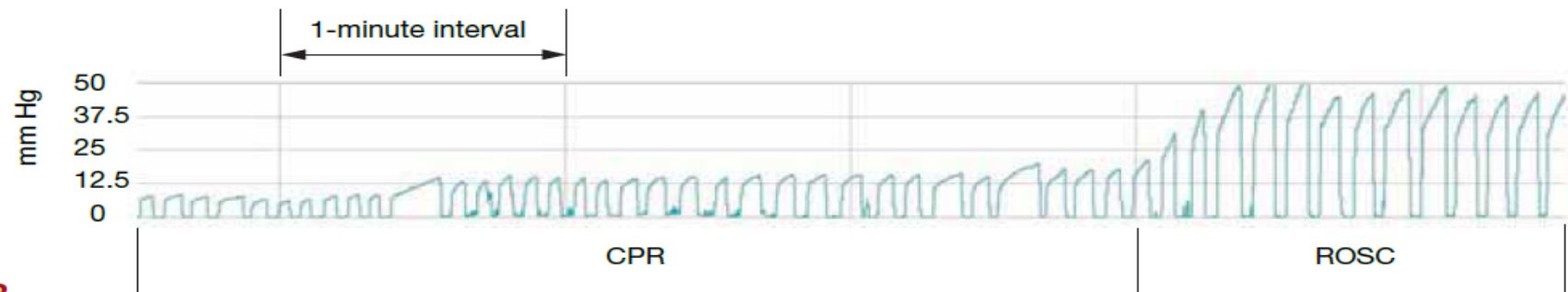


Fig 2.—Distribution of maximal coronary perfusion pressures among patients without and with return of spontaneous circulation (ROSC). Each dot represents a patient. The bar is the mean \pm SD.

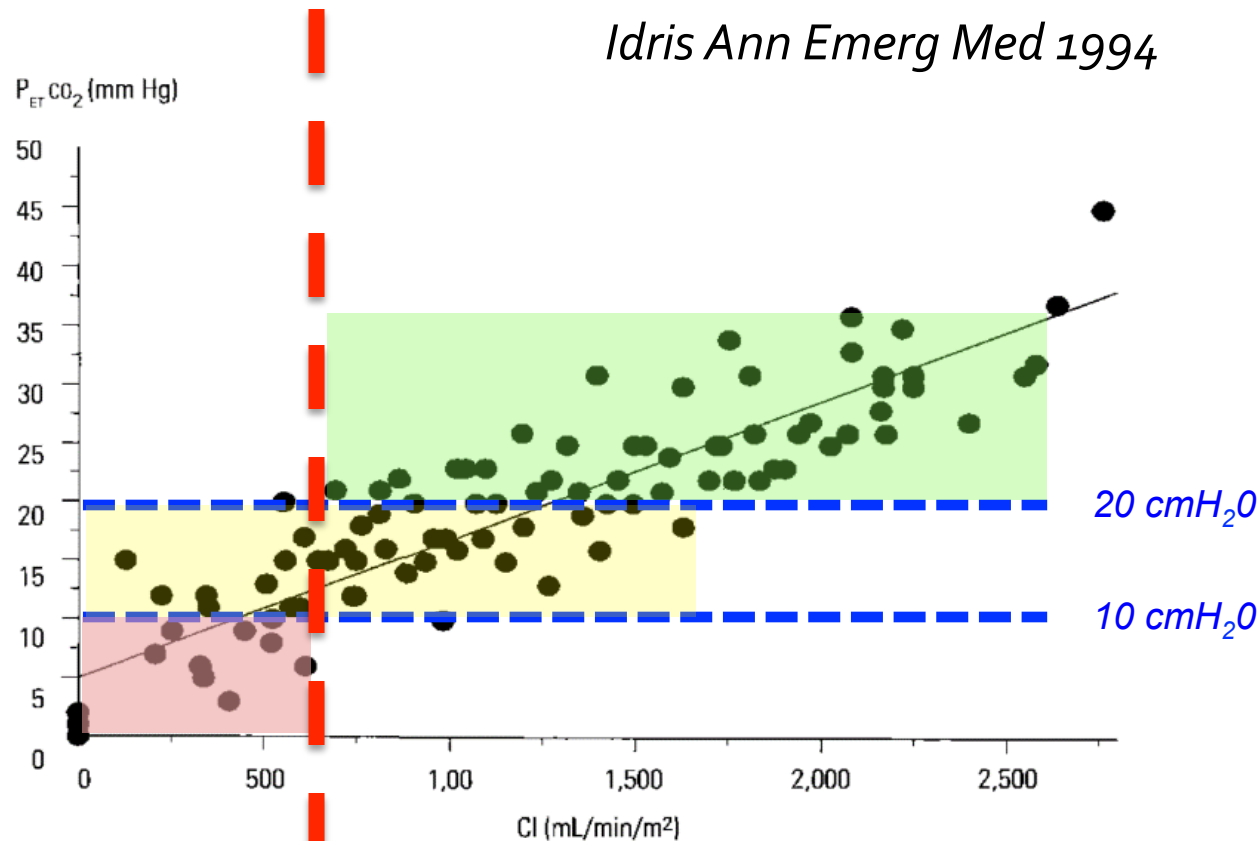
Waveform Capnography During CPR



B.

Capnography to monitor effectiveness of resuscitation efforts. This second capnography tracing displays the PETCO₂ in mm Hg on the vertical axis over time. This patient is intubated and receiving CPR. Note that the ventilation rate is approximately 8 to 10 breaths per minute. Chest compressions are given continuously at a rate of slightly faster than 100/min but are not visible with this tracing. The initial PETCO₂ is less than 12.5 mm Hg during the first minute, indicating very low blood flow. The PETCO₂ increases to between 12.5 and 25 mm Hg during the second and third minutes, consistent with the increase in blood flow with ongoing resuscitation. Return of spontaneous circulation (ROSC) occurs during the fourth minute. ROSC is recognized by the abrupt increase in the PETCO₂ (visible just after the fourth vertical line) to over 40 mm Hg, which is consistent with a substantial improvement in blood flow.

End-Tidal CO₂ is Proportional to Cardiac Output During CPR



Limitations

- ↕ Variable Ventilation
- ↑ Sodium Bicarbonate
- ↓ Epinephrine

Normal Cardiac Index 2.6-4.2 ml/min/m²

END-TIDAL CARBON DIOXIDE AND OUTCOME OF OUT-OF-HOSPITAL CARDIAC ARREST

ROBERT L. LEVINE, M.D., MARVIN A. WAYNE, M.D., AND CHARLES C. MILLER, PH.D.

ABSTRACT

Background Survival after cardiac arrest occurring outside the hospital averages less than 3 percent. Unfortunately, the outcome of prolonged resuscitative attempts cannot be predicted. End-tidal carbon dioxide levels reflect cardiac output during cardiopulmonary resuscitation. We prospectively determined whether death could be predicted by monitoring end-tidal carbon dioxide during resuscitation after cardiac arrest.

Methods We performed a prospective observational study in 150 consecutive victims of cardiac arrest outside the hospital who had electrical activity but no pulse. The patients were intubated and evaluated by mainstream end-tidal carbon dioxide monitoring. Our hypothesis was that an end-tidal carbon dioxide level of 10 mm Hg or less after 20 minutes of standard advanced cardiac life support would predict death.

Newer studies reemphasize the importance of these variables but underscore that these factors do not reliably predict survival or death.⁵⁻⁷ In addition, only a fraction of patients who are initially resuscitated progress to long-term survival. A method of predicting the outcome of cardiac arrest is needed. The end-tidal carbon dioxide level may be a marker that can reliably identify irreversible cardiac arrest.

Normally, levels of alveolar carbon dioxide and therefore end-tidal carbon dioxide are determined by carbon dioxide production, alveolar ventilation, and pulmonary blood flow.^{8,9} During low-flow states, end-tidal carbon dioxide levels reflect predominantly pulmonary blood flow; in cardiac arrest, the level is determined entirely by the cardiac output generated by cardiopulmonary resuscitation.¹⁰⁻¹⁸ Therefore, as an indirect measure of cardiac output, end-tidal carbon dioxide represents a potential predictor of sur-

End-Tidal CO₂ Prognostication during CPR

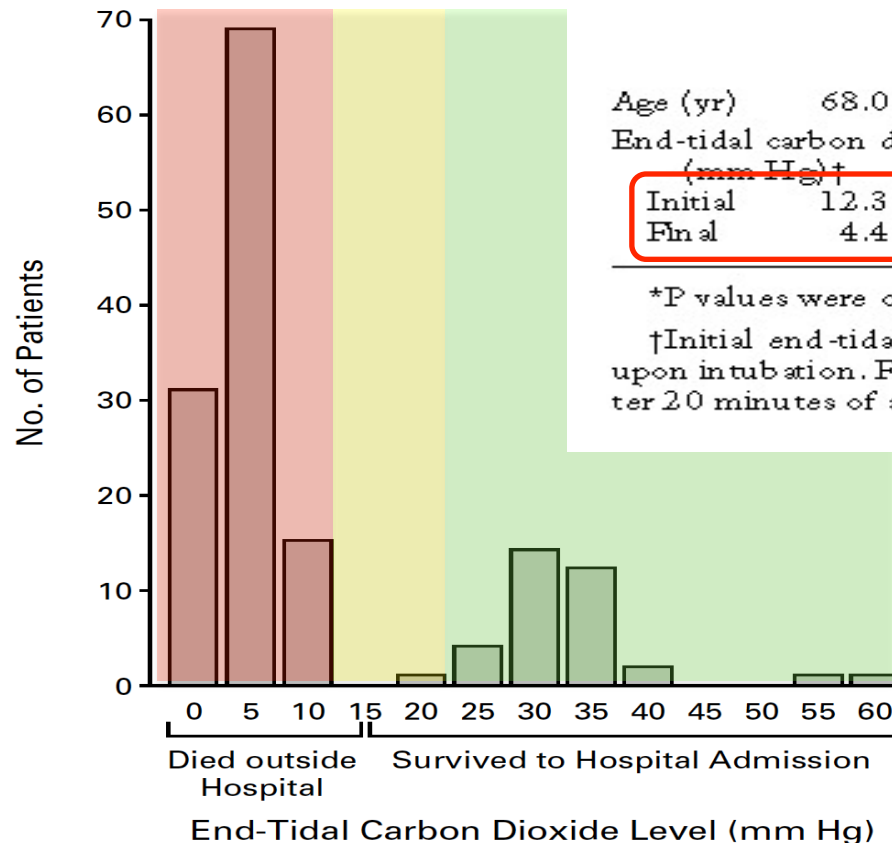
TABLE 1. END-TIDAL CARBON DIOXIDE VALUES IN PATIENTS WHO SURVIVED TO HOSPITAL ADMISSION AND IN THOSE WHO DID NOT.

VARIABLE	NONSURVIVORS (N=115)	SURVIVORS (N=35)	P VALUE*
	mean ±SD (range)		
Age (yr)	68.0±13.8 (31-95)	71.5±13.0 (27-90)	0.19
End-tidal carbon dioxide (mm Hg)†			
Initial	12.3±6.9 (2-50)	12.2±4.6 (5-22)	0.93
Final	4.4±2.9 (0-10)	32.8±7.4 (18-58)	<0.001

*P values were calculated with the Wilcoxon rank-sum statistic.

†Initial end-tidal carbon dioxide levels were determined immediately upon intubation. Final end-tidal carbon dioxide levels were determined after 20 minutes of advanced cardiac life support.

Levine NEJM 1998



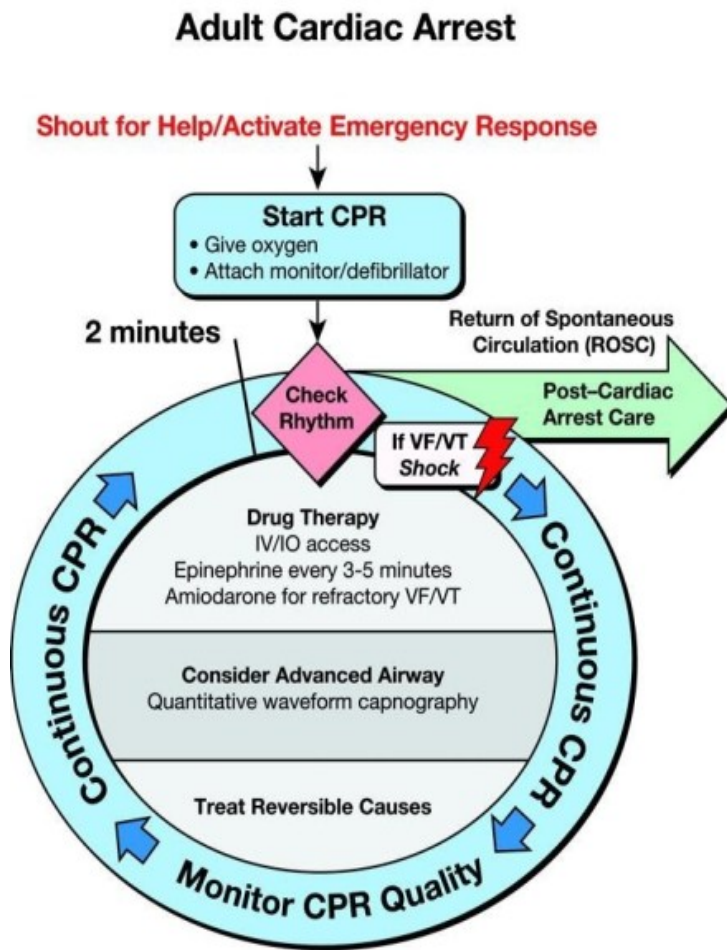
Physiologic Parameters of CPR Futility

Parameter	Futility	References
Coronary Perfusion Pressure	<15 mmHg	Paradis 1990 Kern 1988
Arterial Relaxation Pressure	<? mmHg	
End-Tidal CO ₂ (PetCO ₂)	<10 mmHg	Levine 1998

Physiologic Parameters of CPR Effectiveness

Parameter	Effectiveness	References
Coronary Perfusion Pressure	$\geq ?$ mmHg	N/A
Arterial Relaxation Pressure	$\geq ?$ mmHg	N/A
End-Tidal CO ₂ (PetCO ₂)	$\geq ?$ mmHg	N/A

Optimizing CPR Quality



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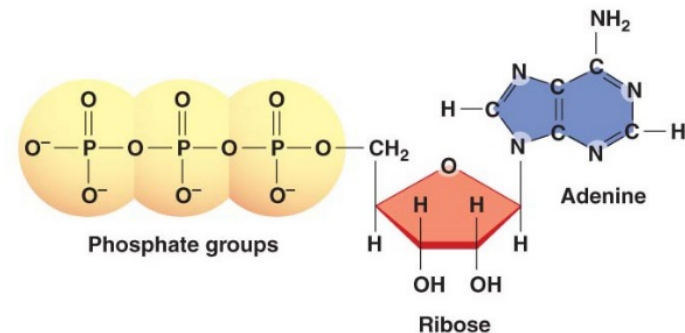
AHA ACLS 2015 Focused Update

Although no clinical study has examined whether titrating resuscitative efforts to physiologic parameters during CPR improves outcome, it may be reasonable to **use physiologic parameters** (quantitative waveform capnography, arterial relaxation diastolic pressure, arterial pressure monitoring, and central venous oxygen saturation) when feasible **to monitor and optimize CPR quality, guide vasopressor therapy**, and detect ROSC.

(Class IIb, LOE C-EO)

CPR Goals

- **Primary Goal:** Rapid return of spontaneous circulation (ROSC)
 - Organized electrical rhythm
 - Adequate mechanical function
- **Secondary Goal:** Minimize ischemic brain injury
- **Mechanistic Goal:** Maintain or restore adequate **ATP** for membrane polarization (neurons and myocytes) and mechanical function (myocytes)
- **Strategy:** Maximize oxygenated blood flow to the heart and brain



Myocardial and Cerebral Blood Flow Goals During CPR

Heart

Baseline: 60-70 ml/100g/min

Goal: **20-25 ml/100g/min**
(35% baseline)

Rationale: Estimated coronary blood flow required to meet the metabolic needs of the fibrillating heart .

Klocke et al., Control of coronary blood flow. Annu Rev Med 31: 489, 1980

Brain

Baseline 50 ml/100g/min

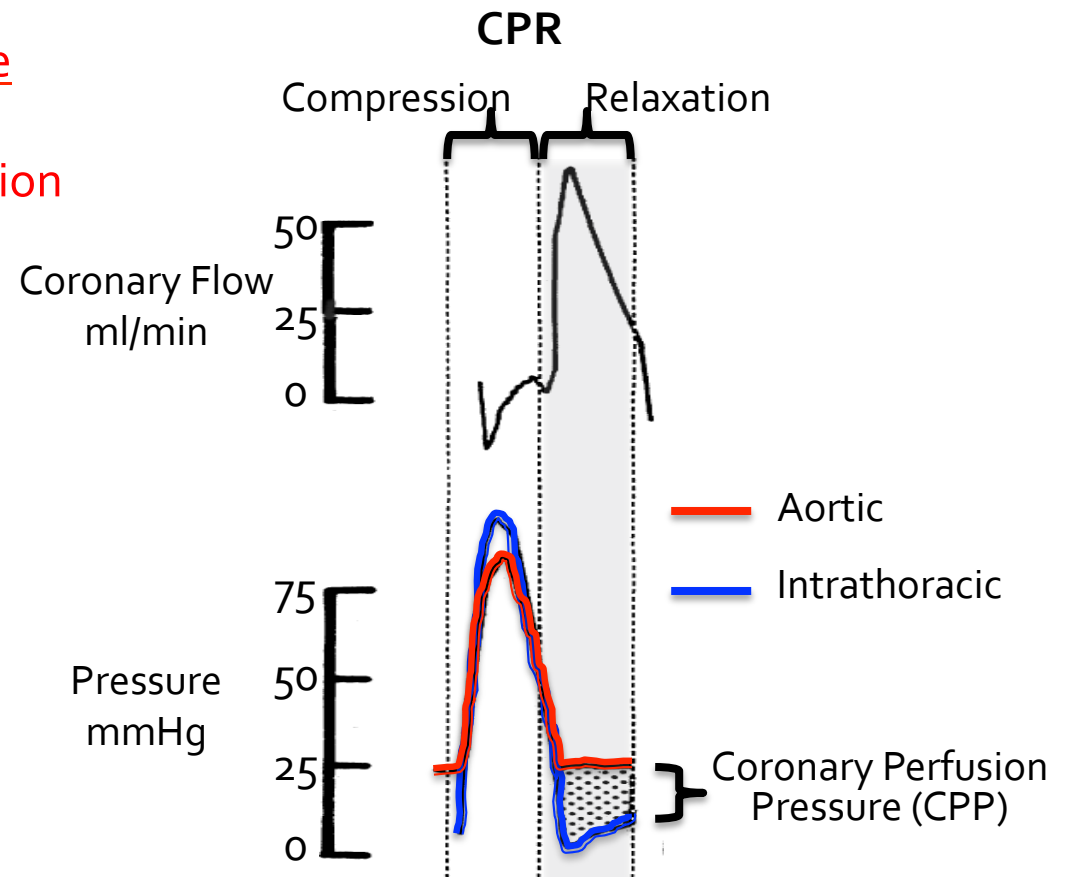
Goal: **10 ml/100g/min**
(20% baseline)

Rationale: Ischemic depolarization occurs in the cerebral cortex when blood flow falls below approximately 10 mL/100 g per minute.

Symon et al., Flow thresholds in brain ischemia and the effects of drugs. Br J Anaesth.1985;57:34-43.

Optimizing Myocardial and Cerebral Blood Flow During CPR

- Increase Aortic Relaxation Pressure
 - *Increase cardiac output*
 - Optimize chest compression rate, depth, duty cycle
 - *Increase arterial resistance*
 - Vasopressors

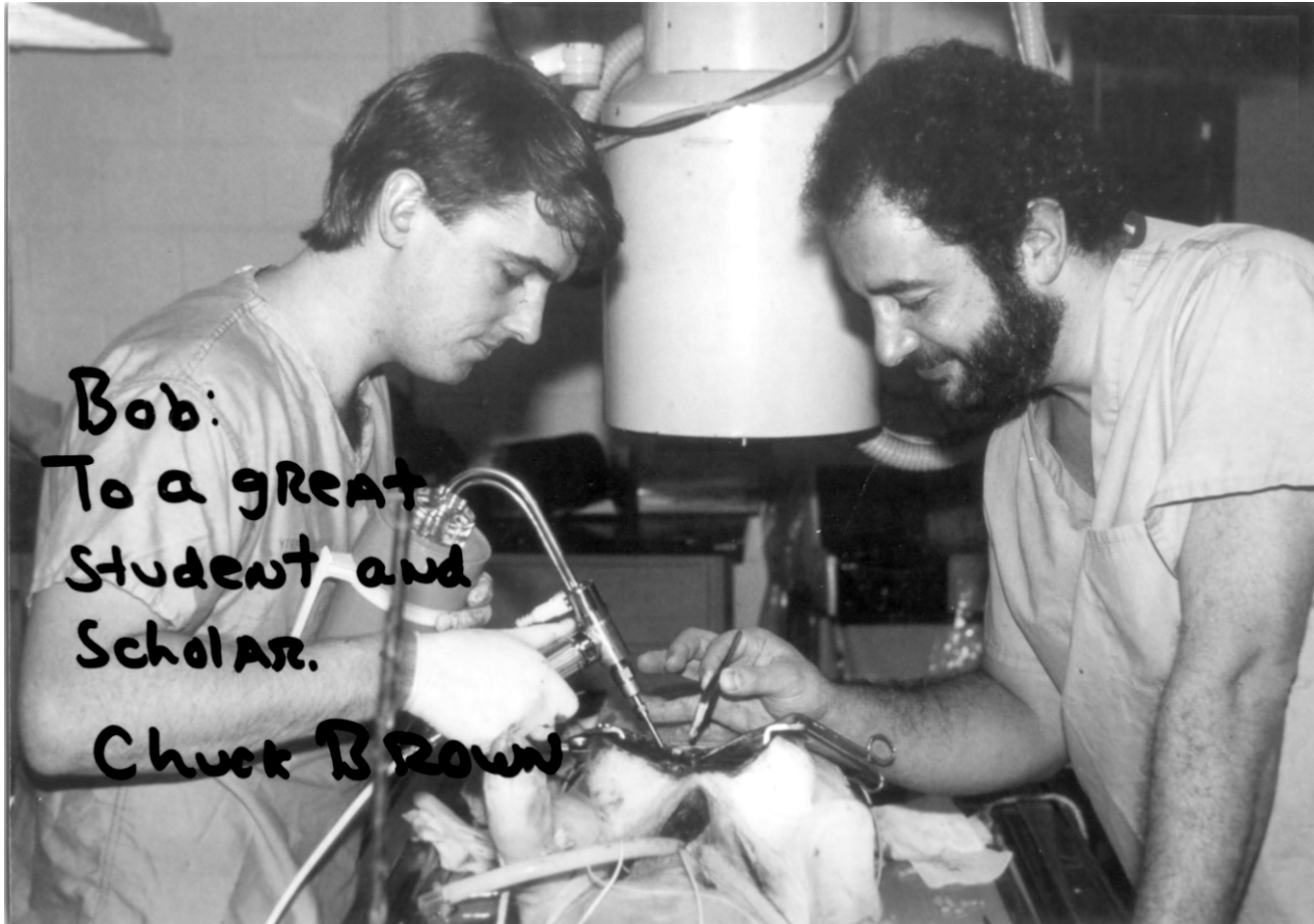


Bellamy Circulation 1984



Chuck Brown

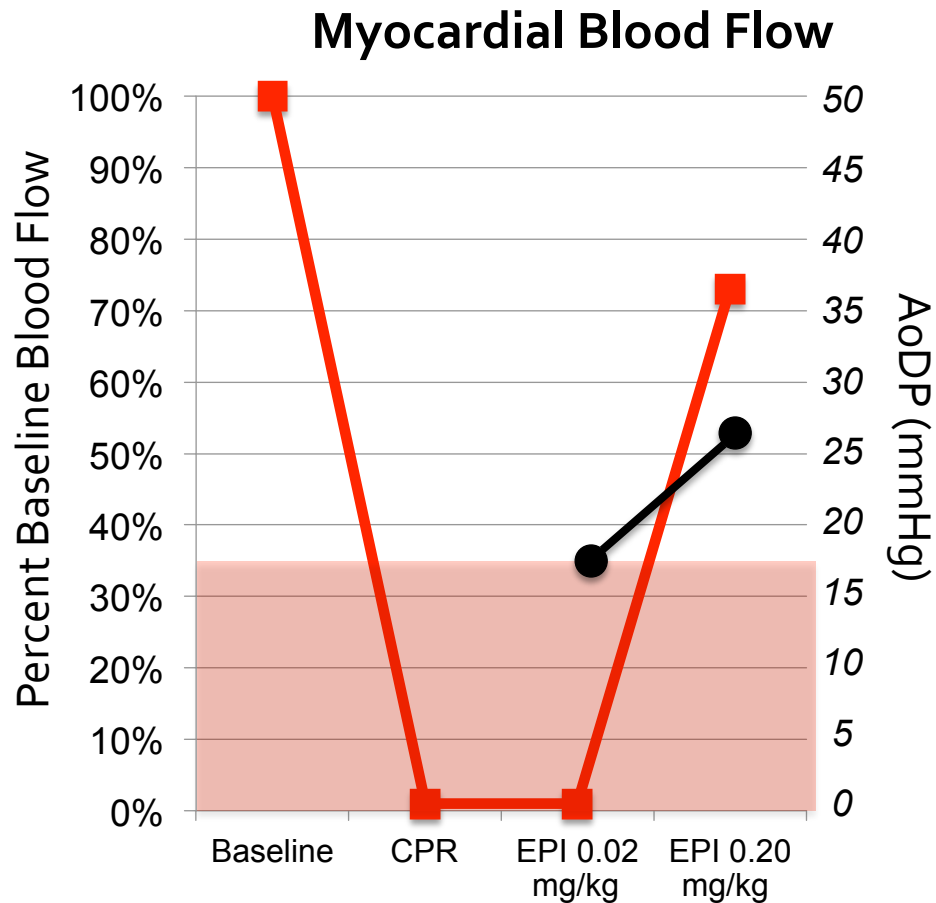
The Ohio State University



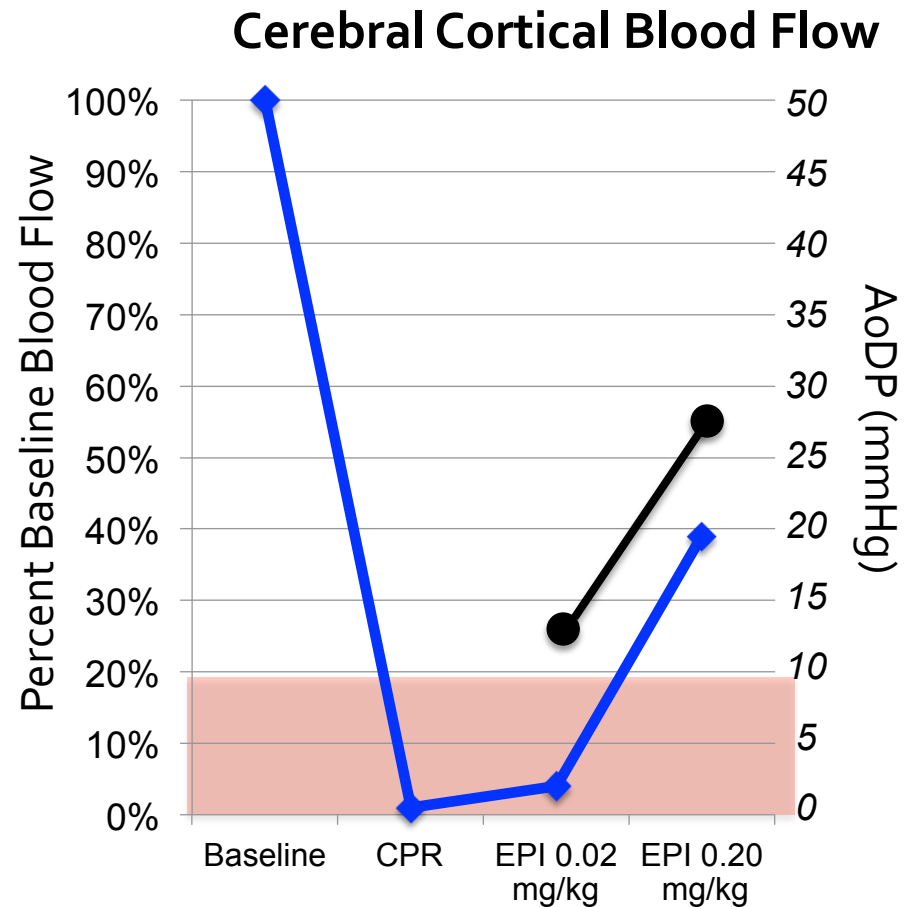
Bob:
To a great
Student and
Scholar.
Chuck Brown

1988

Dose-Dependent Effect of Epinephrine on Myocardial and Cerebral Blood Flow During CPR in Swine



Brown Circulation 1987



Brown Ann Emerg Med 1986

A COMPARISON OF STANDARD-DOSE AND HIGH-DOSE EPINEPHRINE IN CARDIAC ARREST OUTSIDE THE HOSPITAL

CHARLES G. BROWN, M.D., DANIEL R. MARTIN, M.D., PAUL E. PEPE, M.D., HARLAN STUEVEN, M.D.,
RICHARD O. CUMMINS, M.D., EDGAR GONZALEZ, PHARM.D., MICHAEL JASTREMSKI, M.D.,
AND THE MULTICENTER HIGH-DOSE EPINEPHRINE STUDY GROUP*

Table 2. Primary Outcome Measures.

VARIABLE	STANDARD-DOSE GROUP (N = 632)	HIGH-DOSE GROUP (N = 648)	99% CI*
	<i>no. (%)</i>		
Return of spontaneous circulation	190 (30)	217 (33)	−10 to 3
Successful resuscitation	139 (22)	147 (23)	−7 to 5
Admission to hospital	136 (22)	145 (22)	−7 to 5
Discharge from hospital	26 (4)	31 (5)	−4 to 2
Conscious at hospital discharge†	24 (92)	29 (94)	−20 to 16

*The confidence interval (CI) for the percent difference between the groups.

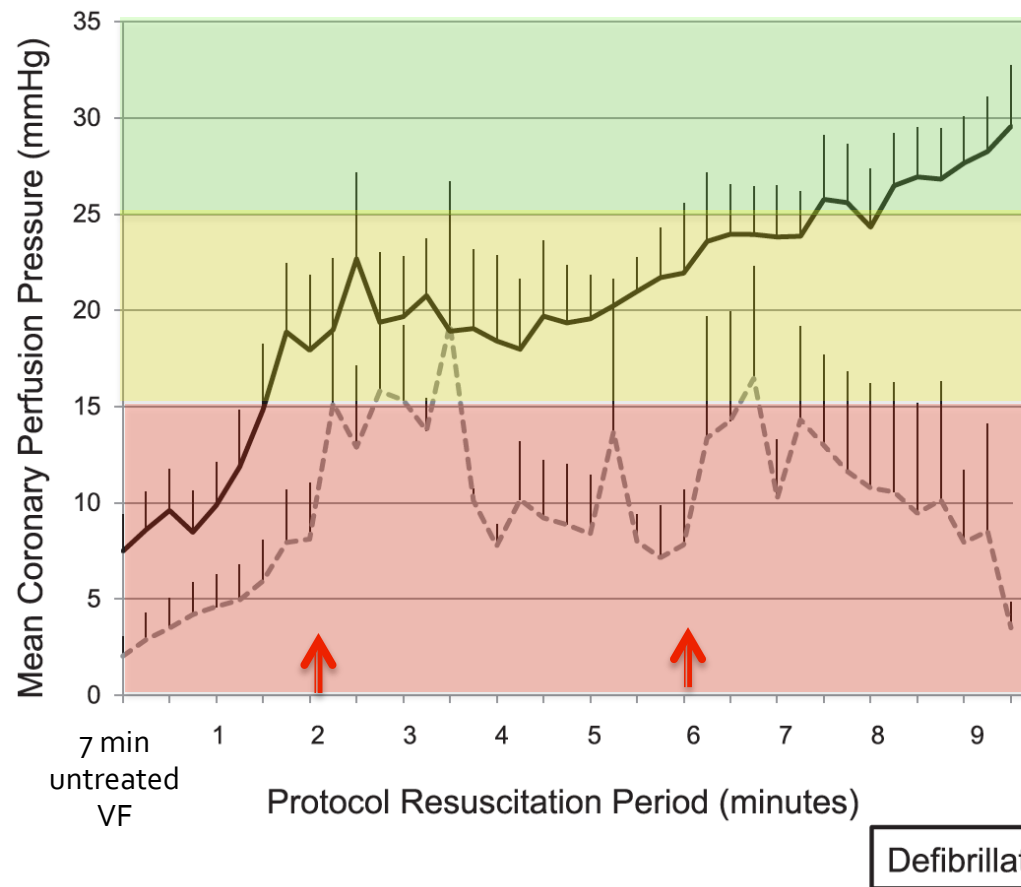
†Percentages shown are of the patients who survived to discharge.

No difference in outcome with standard vs. high-dose epinephrine

One size fits all design

Treatment not based on physiologic monitoring

Blood Pressure Guided CPR Improve Outcomes In Swine Cardiac Arrest Model



Pressure-Guided Care

Chest compression depth titrated to SBP > 100 mmHg
If CPP < 20 mmHg then Epi 0.02 mg/kg every min x 2
then vasopressin 0.4 U/kg. Repeat sequence after 2 min

5/8 (63%) good neurologic outcome

Median vasopressor doses: 3

Guideline Care

Standard chest compression depth
Epi 0.02 mg/kg every 4 minute

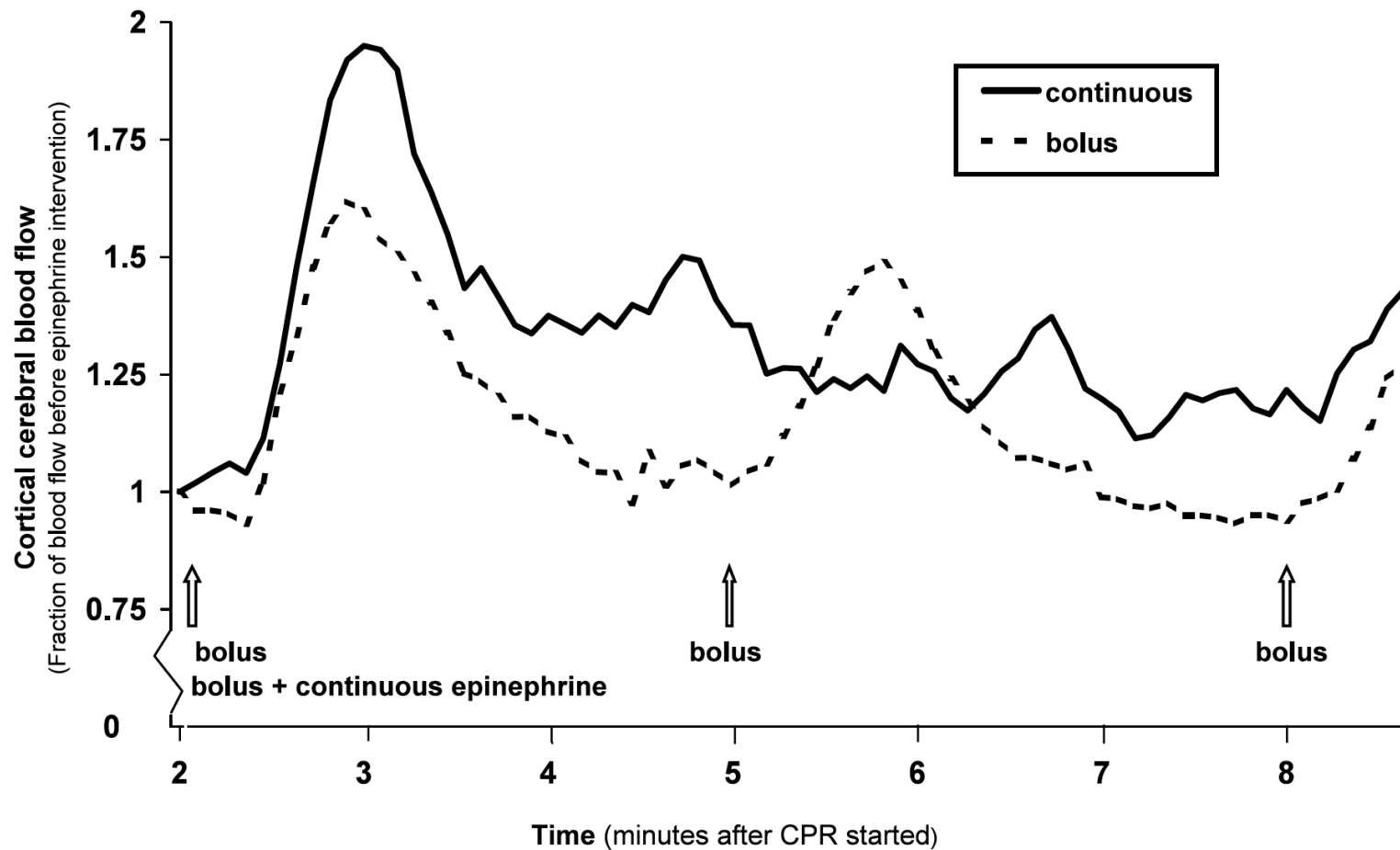
0/8 (0%) good neurologic outcome

Median vasopressor doses: 2

Defibrillation Attempt

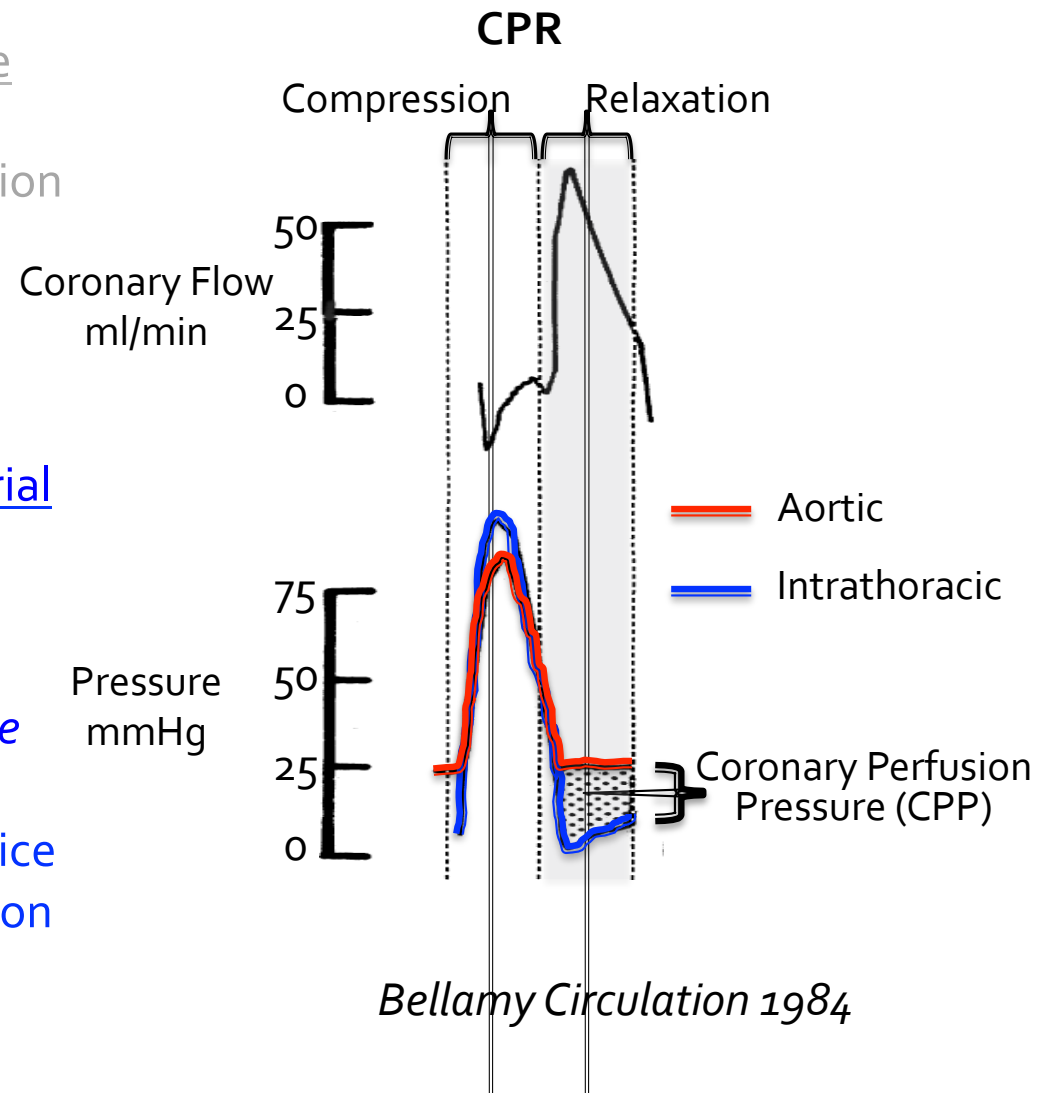
Bolus vs. Continuous Epinephrine During CPR

Johansson Resuscitation 2003

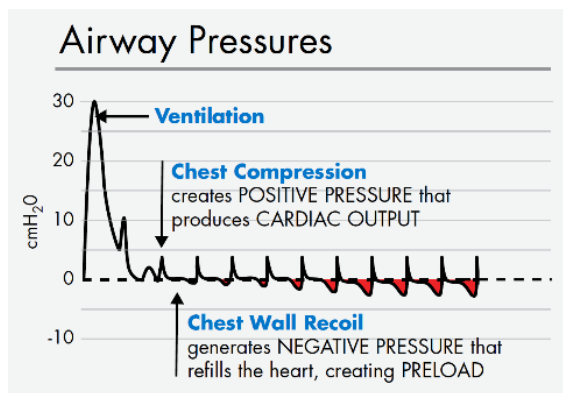


Optimizing CPR Hemodynamics

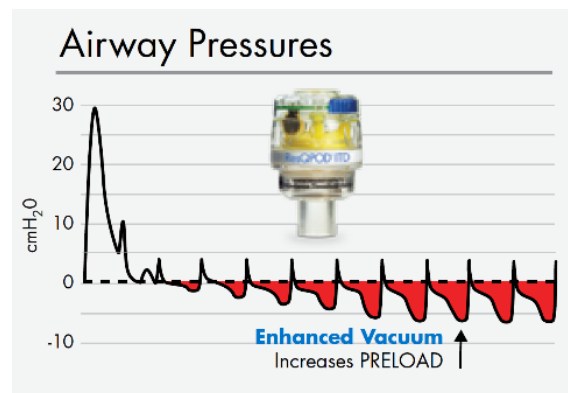
- Increase Aortic Relaxation Pressure
 - *Increase cardiac output*
 - Optimize chest compression rate, depth, duty cycle
 - *Increase arterial resistance*
 - Vasopressors
- Decrease Intrathoracic or Right Atrial Pressure
 - *No leaning on chest during relaxation*
 - *Negative intra-thoracic pressure during relaxation*
 - Impedance threshold device
 - Active chest decompression



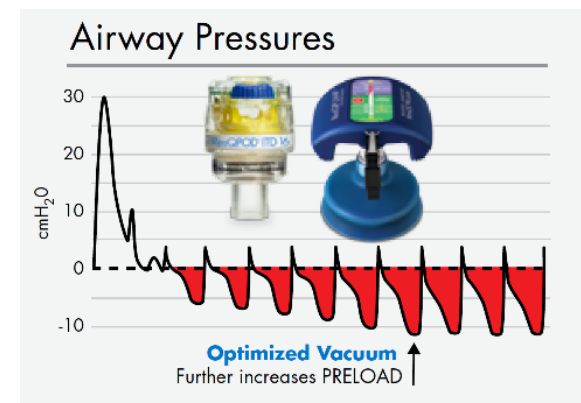
Active Compression-Decompression CPR + Impedance Threshold Device



Standard CPR



ITD CPR

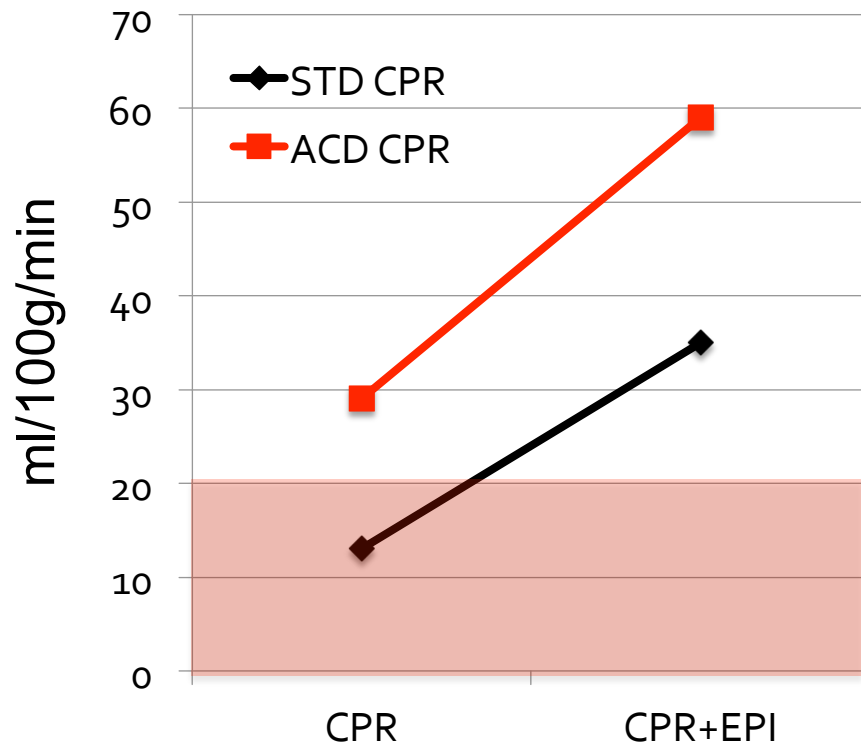


ITD+ACD CPR

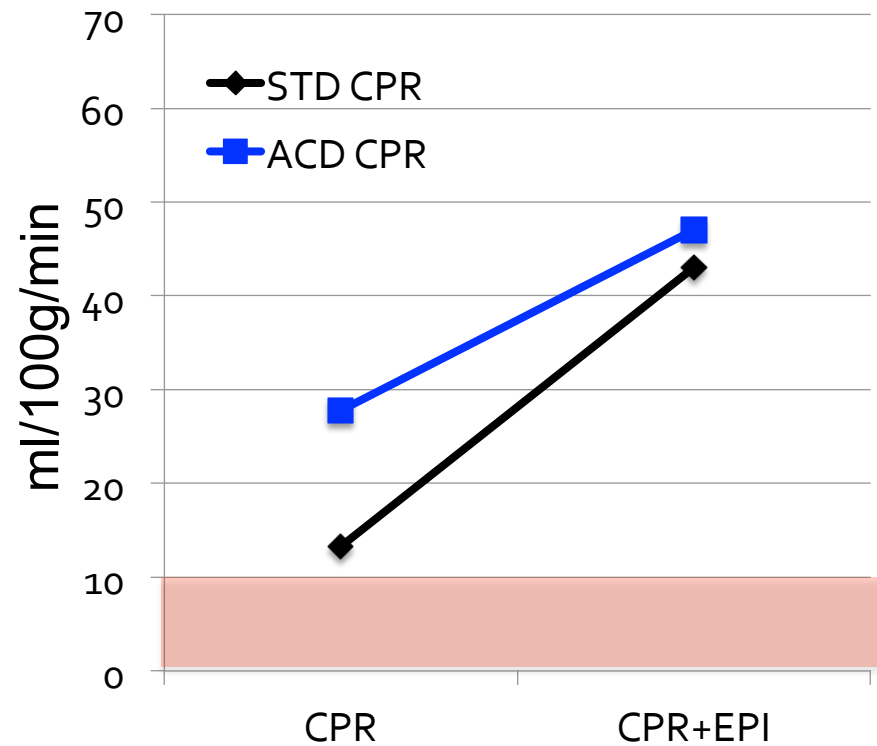
Effects of Active Compression-Decompression Resuscitation on Myocardial and Cerebral Blood Flow in Pigs

Karl H. Lindner, MD; Ernst G. Pfenninger, MD; Keith G. Lurie, MD;
Winfried Schürmann, MD; Ingrid M. Lindner, MD; Friedrich W. Ahnefeld, MD

Myocardial Blood Flow



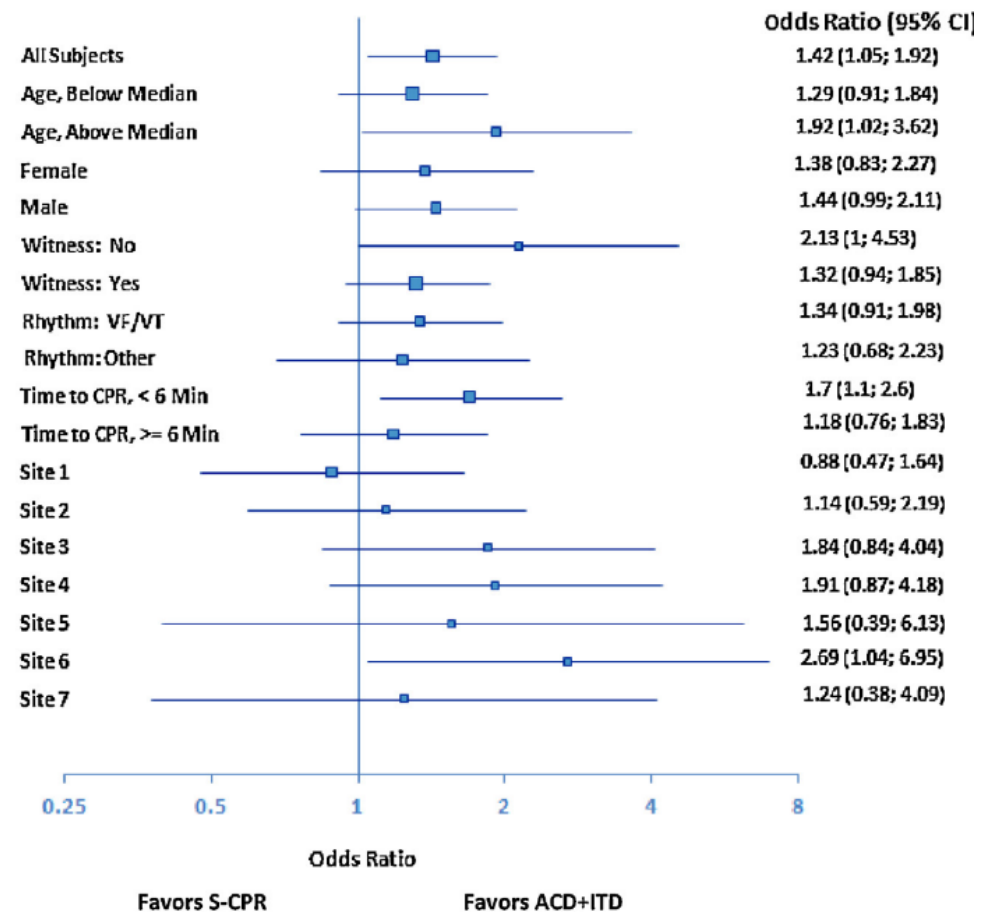
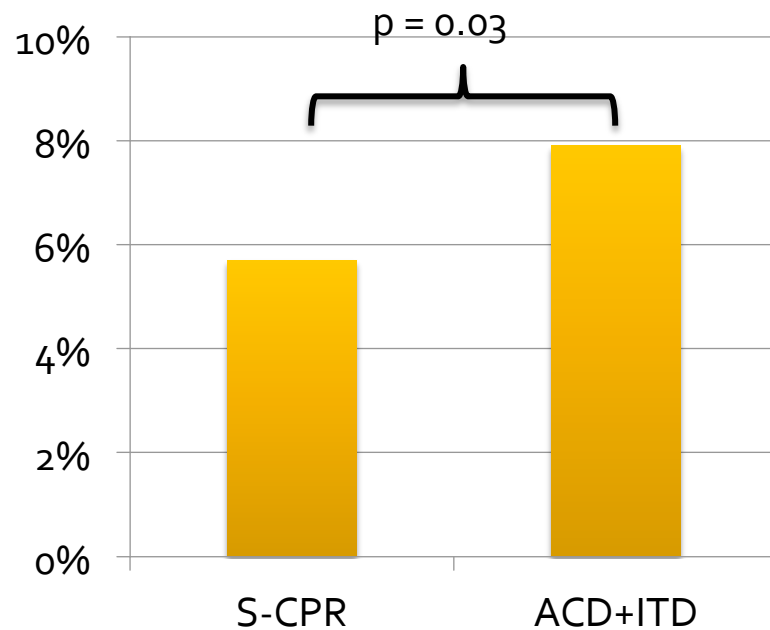
Cerebral Cortical I Blood Flow



Comparison of ACD+ITD and Standard CPR

Frascone Resuscitation 2013

Survival to Hospital Discharge
with MRS ≤ 3



CPR Quality in the Emergency Department?



How would you improve CPR effectiveness?

Adult Goal-Directed CPR Protocol

Univ. of Michigan Emergency Department

1. Standard ACLS (quality CPR, rhythm check, shock VF/VT, Epi 1mg IV/IO q5min)

2. Place Advanced Airway & Attach Waveform Capnography

**ENTER
PATHWAY**
If ETCO₂
<20mmHg

Optimize Chest Compressions

Switch to LUCAS-2^A

Add Res-Q Pod^B

Switch to CARDIO-PUMP

**EXIT
PATHWAY**
If ETCO₂
>20mmHg

A. May switch to LUCAS-2 regardless of ETCO₂

B. REMOVE Res-Q Pod after ROSC or ECPR started

3. Place Right Femoral Arterial + Venous 5Fr Catheters & transduce arterial BP

**ENTER
PATHWAY**
If DBP
<35mmHg

Start Epinephrine Infusion: 1 mcg/kg/min, continue until ROC

+

Epi 1mg q5min^C, until DBP>35 +/- Vasopressin 40u, x1 only^D

**EXIT
PATHWAY**
If DBP
>35mmHg

C. May titrate Epi pushes to achieve DBP>35

D. May substitute Vasopressin for one Epi dose

CPR Quality in the Emergency Department?



How would you improve CPR effectiveness?

Part 4: Advanced Life Support

2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations

Clifton W. Callaway, Co-Chair*; Jasmeet Soar, Co-Chair*; Mayuki Aibiki; Bernd W. Böttiger;
Steven C. Brooks; Charles D. Deakin; Michael W. Donnino; Saul Drajer; Walter Kloeck;
Peter T. Morley; Laurie J. Morrison; Robert W. Neumar; Tonia C. Nicholson; Jerry P. Nolan;
Kazuo Okada; Brian J. O'Neil; Edison F. Paiva; Michael J. Parr; Tzong-Luen Wang; Jonathan Witt;
on behalf of the Advanced Life Support Chapter Collaborators

KNOWLEDGE GAPS: *"Studies that measure the effect of physiological monitoring to guide resuscitation on ROSC and survival with good neurologic outcome are required."*