CPR

The Science Behind the Hands

Public Health
Seattle & King County

CITY OF SEATTLE FIRE DEPT.

KING COUNTY MEDIC ONE

KING COUNTY TRAINING

HARBORVIEW MEDICAL CENTER
UW Medicine

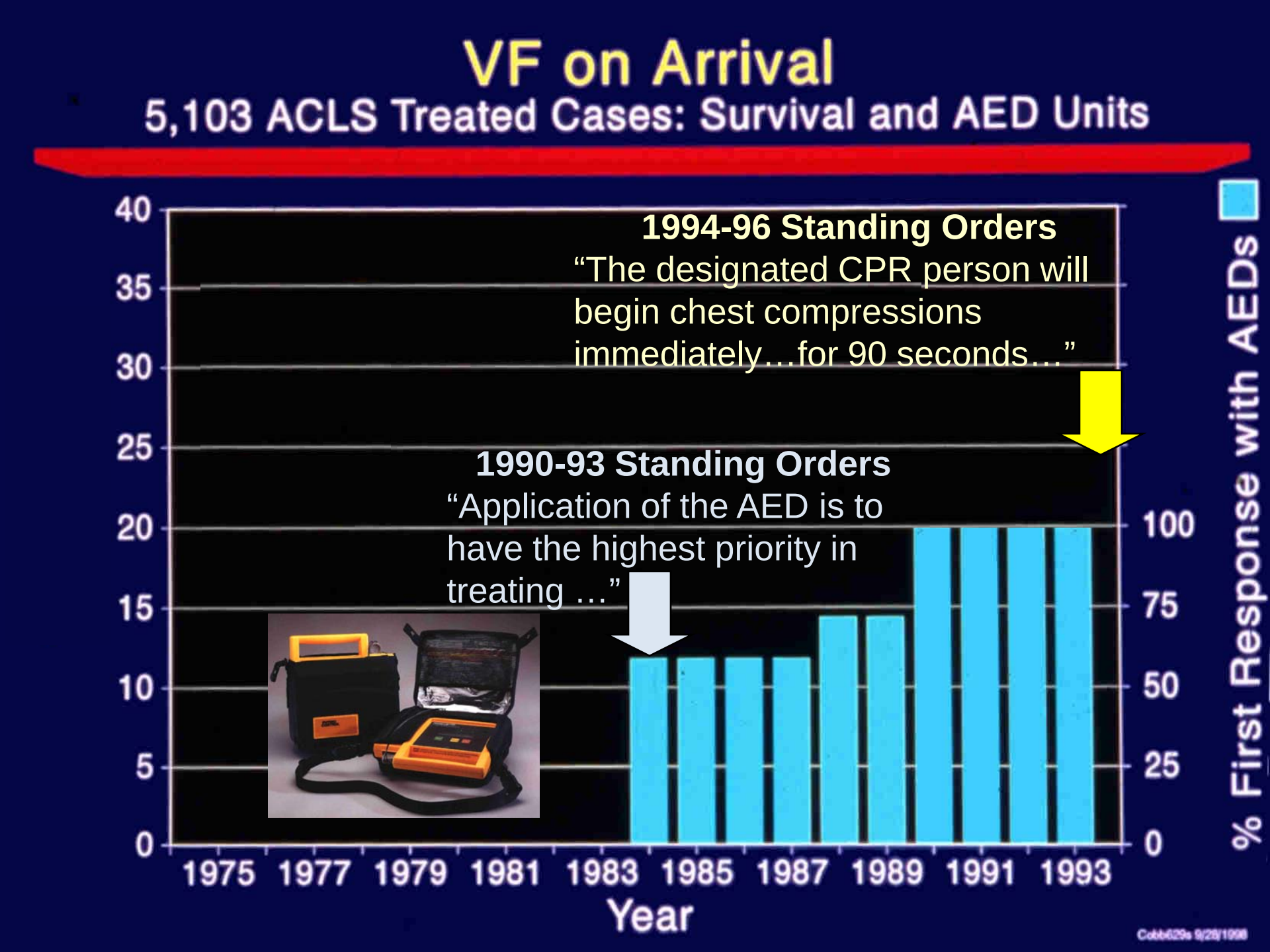
Life Sciences
DISCOVERY FUND

Resuscitation Arsenal

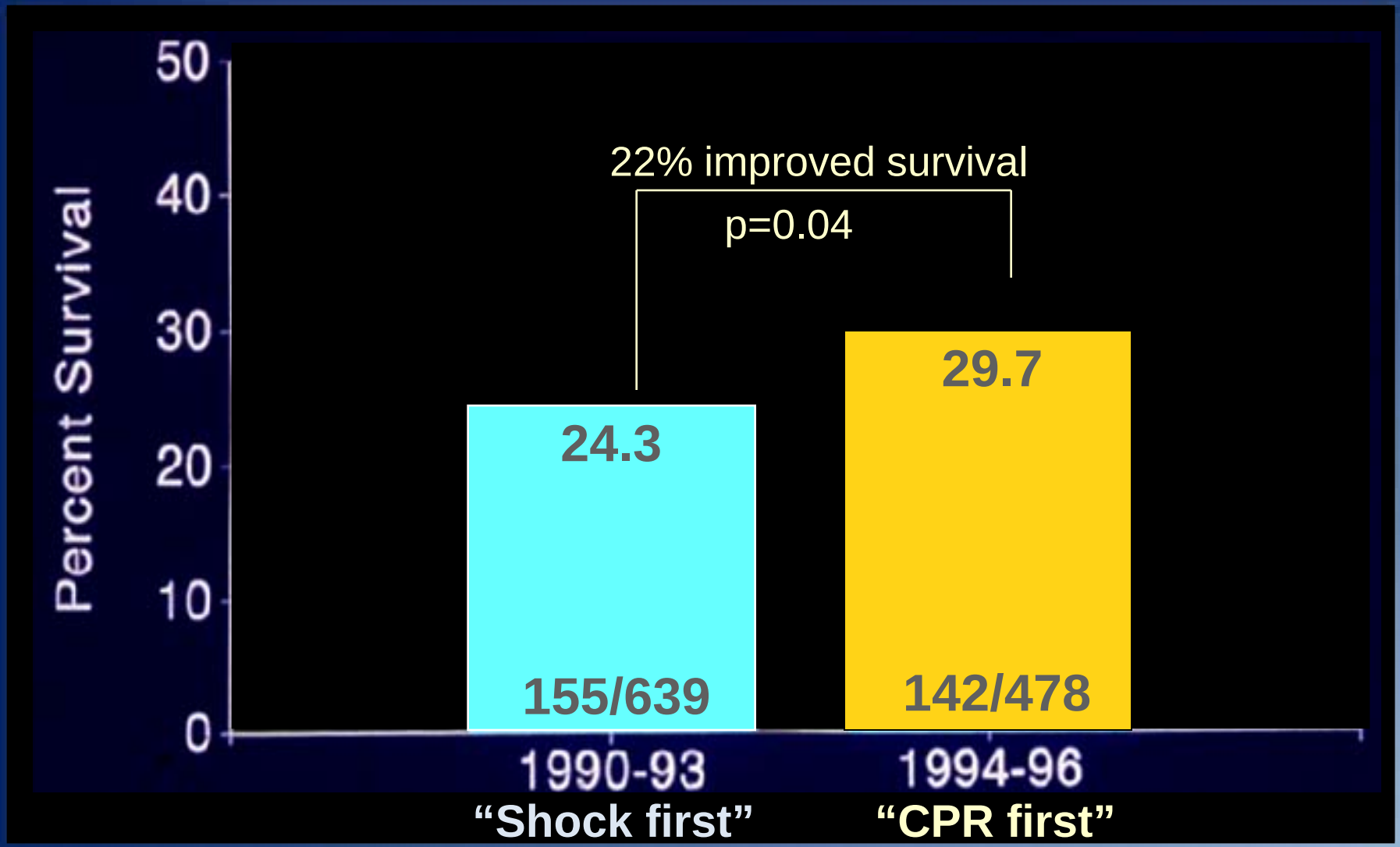
Therapeutic hypothermia
Transcutaneous pacing
Sodium bicarbonate Rx
Calcium, Magnesium
Fluids and Pressors
Antiarrhythmic Rx
Epi/Vasopressin
O_2/intubation
Shock
CPR

VF on Arrival

5,103 ACLS Treated Cases: Survival and AED Units



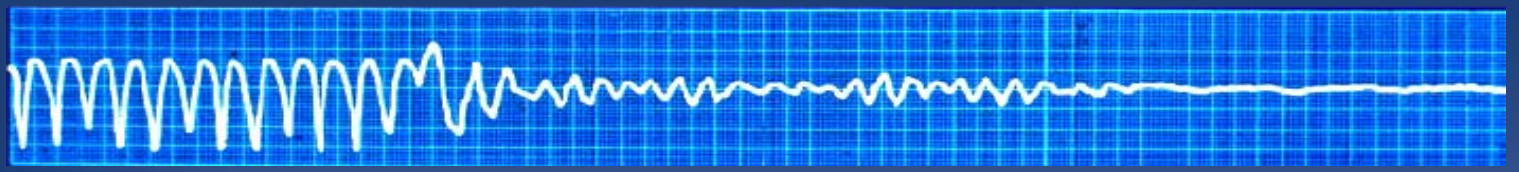
CPR Prior to Shock
Out-of-hospital VF Analysis of Survival n=1117

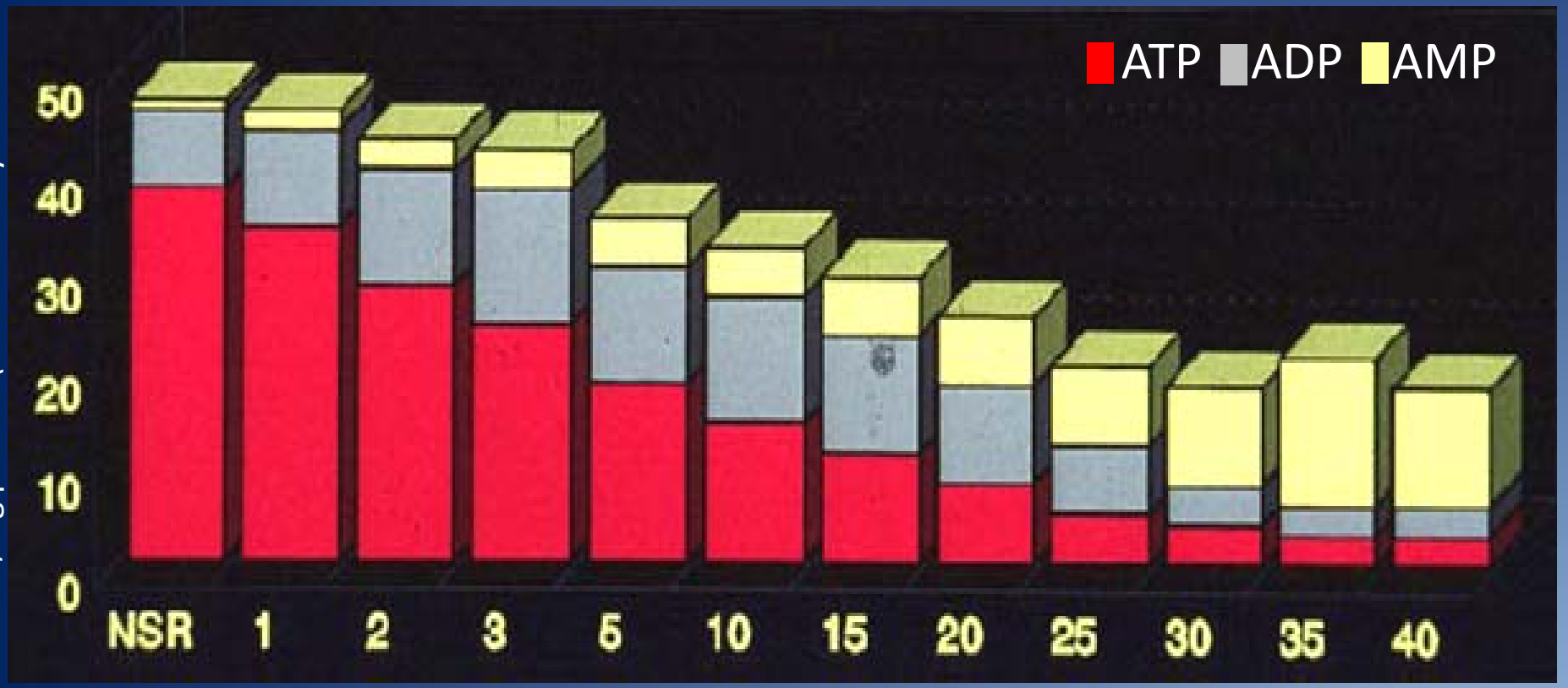


Cobb LA et al. JAMA 1999;281:1182-88

Adenosine Nucleotide Concentrations During VF

n = 10 swine (~10 samples/time period)





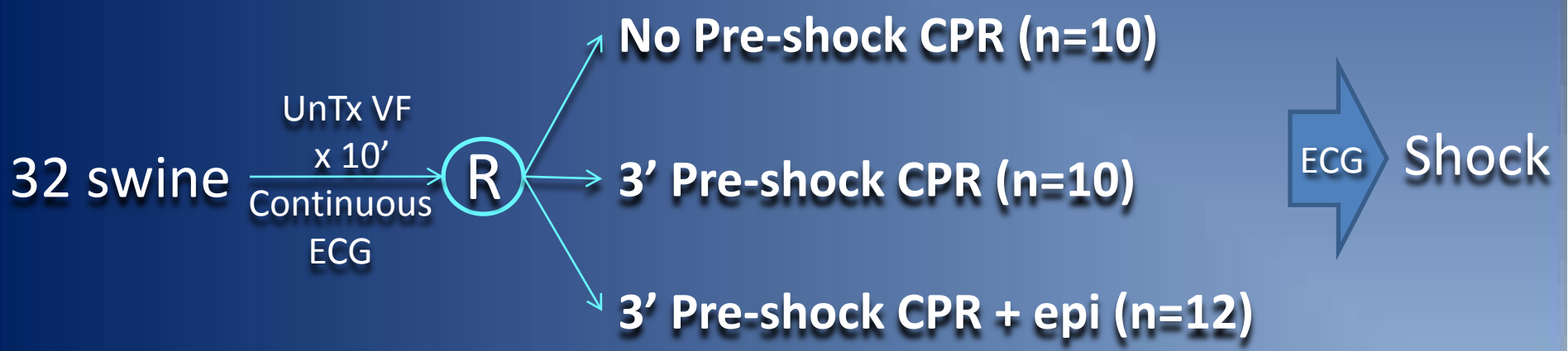
Neumar RW. Ann Emerg Med 1991;20:222-9

Precountershock Cardiopulmonary Resuscitation Improves Ventricular Fibrillation Median Frequency and Myocardial Readiness for Successful Defibrillation From Prolonged Ventricular Fibrillation: A Randomized, Controlled Swine Study

Robert Allen Berg, MD
Ronald Willard Hilwig, DVM, PhD
Karl B. Kern, MD
Gordon Allen Ewy, MD

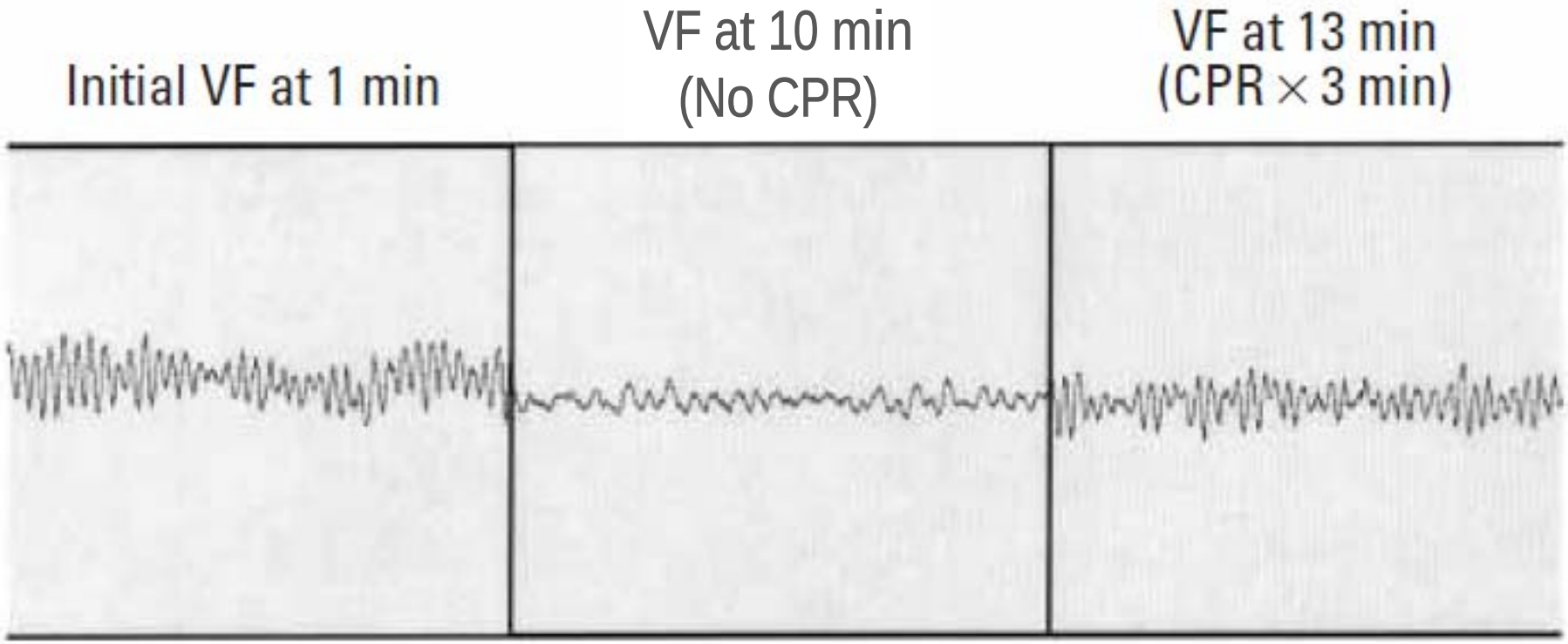
See related article, p. 553, and editorial, p. 571.

Study objective: After prolonged ventricular fibrillation (VF), precountershock cardiopulmonary resuscitation (CPR) will improve myocardial "readiness" for defibrillation compared with immediate defibrillation.



Berg RA. Ann Emerg Med 2002;40:563-70

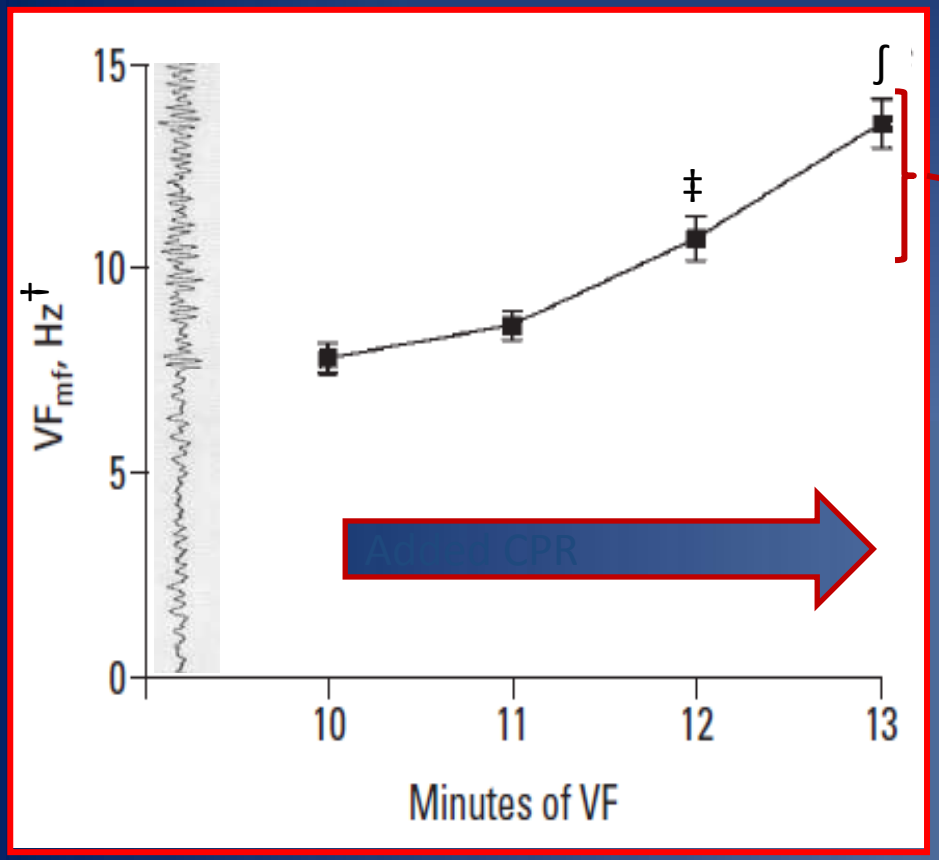
Changes in VF Waveform With and Without 3 Minutes of Pre-shock CPR



MF = VF median frequency in Hz; AMP = VF amplitude in mV

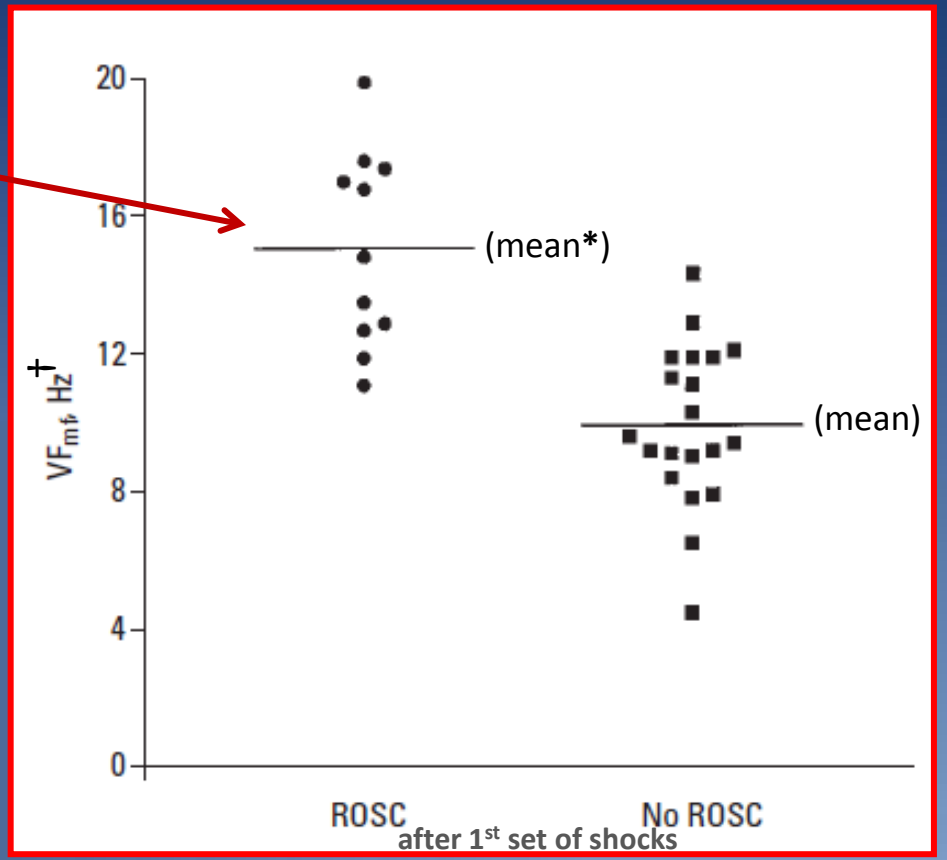
Berg RA. Ann Emerg Med 2002;40:563-70

Changes in VF Median Frequency With/Without Pre-shock CPR and Shock Outcome



‡ p<0.01 vs 10 and 11 minutes of VF

∫ p<0.001 vs 10, 11 and 12 minutes of VF



* p<0.001

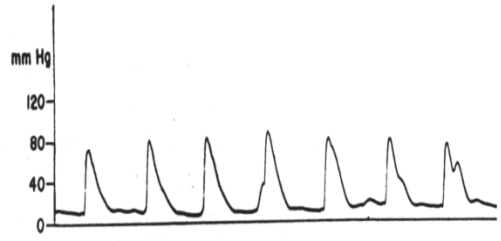
† VF median frequency by fast Fourier transformation

Berg RA. Ann Emerg Med 2002;40:563-70

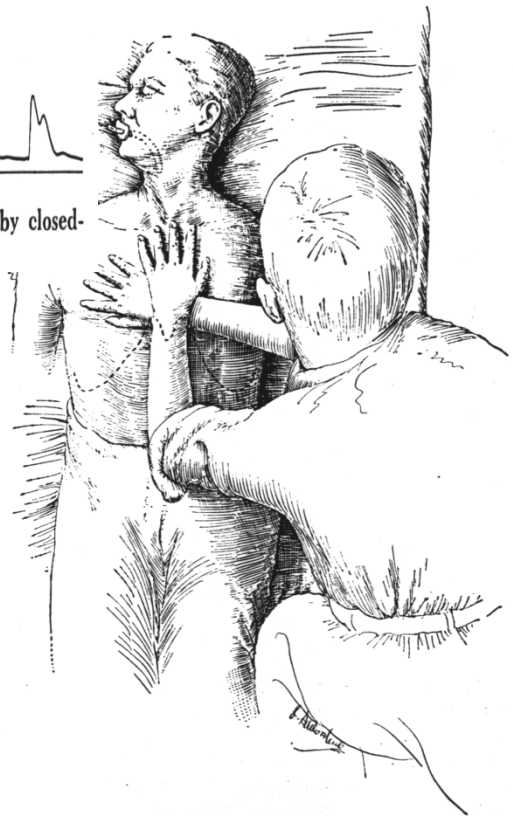
J.A.M.A., July 9, 1960

CLOSED-CHEST CARDIAC MASSAGE

W. B. Kouwenhoven, Dr. Ing., James R. Jude, M.D.
and
G. Guy Knickerbocker, M.S.E., Baltimore



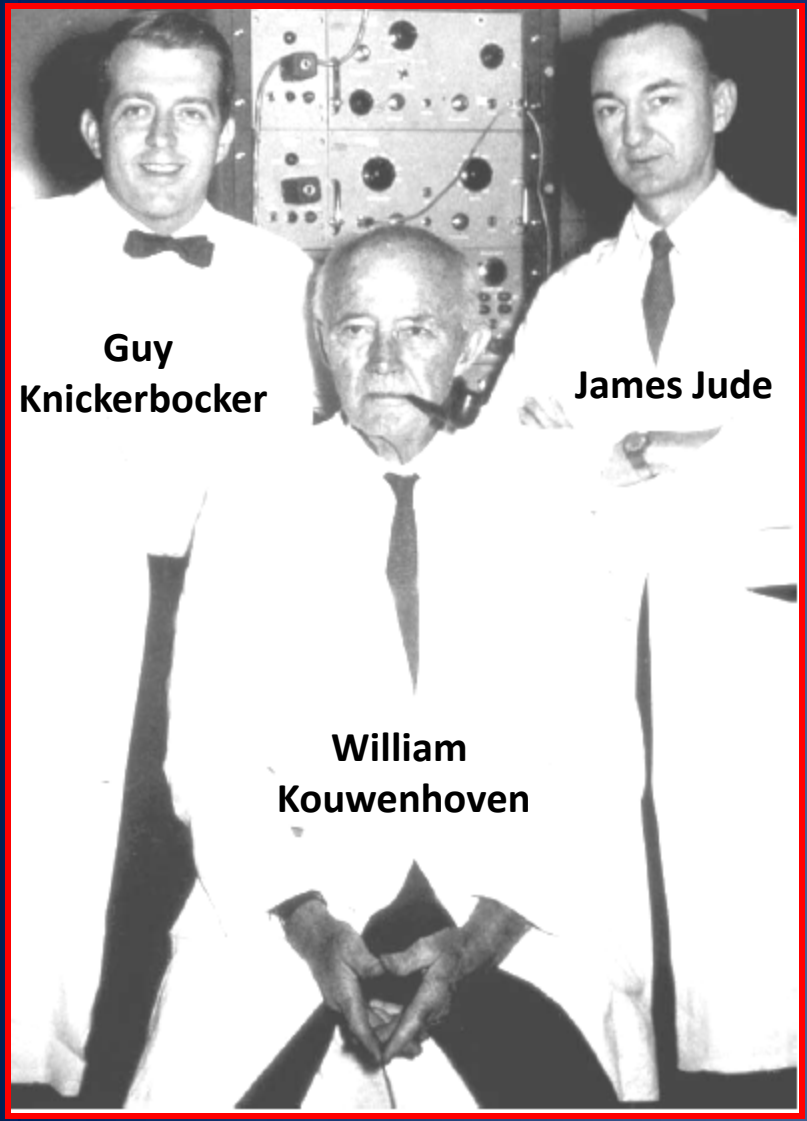
Blood pressure produced in an adult by closed-chest cardiac massage.

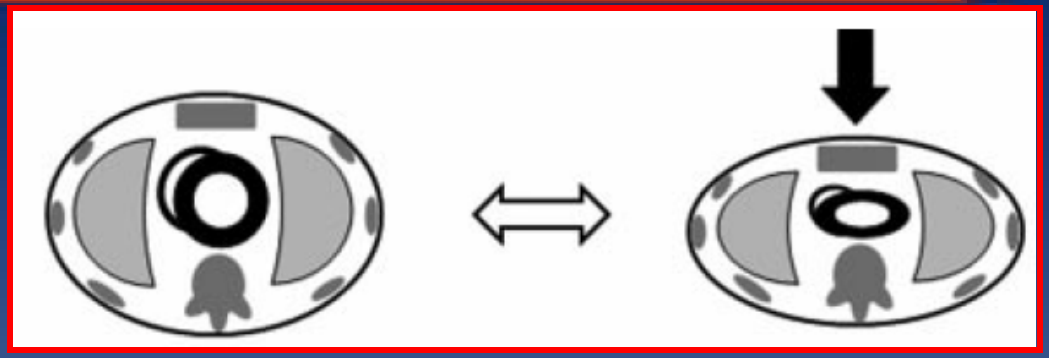


Cardiac resuscitation after cardiac arrest or ventricular fibrillation has been limited by the need for open thoracotomy and direct cardiac massage. As a result of exhaustive animal experimentation a method of external transthoracic cardiac massage has been developed. Immediate resuscitative measures can now be initiated to give not only mouth-to-nose artificial respiration but also adequate cardiac massage without thoracotomy. The use of this technique on 20 patients has given an over-all permanent survival rate of 70%. Anyone, anywhere, can now initiate cardiac resuscitative procedures. All that is needed are two hands.

Kouwenhoven WB. JAMA 1960;173:1064-7

Heart Pump Mechanism of CPR





Relaxation Compression

Observation

- Brief ↑arterial BP when heavy defibrillation electrode applied to chest wall

Explanation

- Heart sits in confined space (sternum, spine, pericardium)
- CC → Heart compressed between sternum & spine → blood ejected
- Relaxation → heart refilling

Kouwenhoven WB. JAMA 1960;173:1064-7

Thoracic Pump Mechanism of CPR

Pressure-synchronized Cineangiography During Experimental Cardiopulmonary Resuscitation

James T. Niemann, M.D., John P. Rosborough, Ph.D., Mark Hausknecht, M.D. Daniel Garner, M.S., and J. Michael Criley, M.D.

Visualization of Cardiac Valve Motion in Man During External Chest Compression Using Two-dimensional Echocardiography

Implications Regarding the Mechanism of Blood Flow

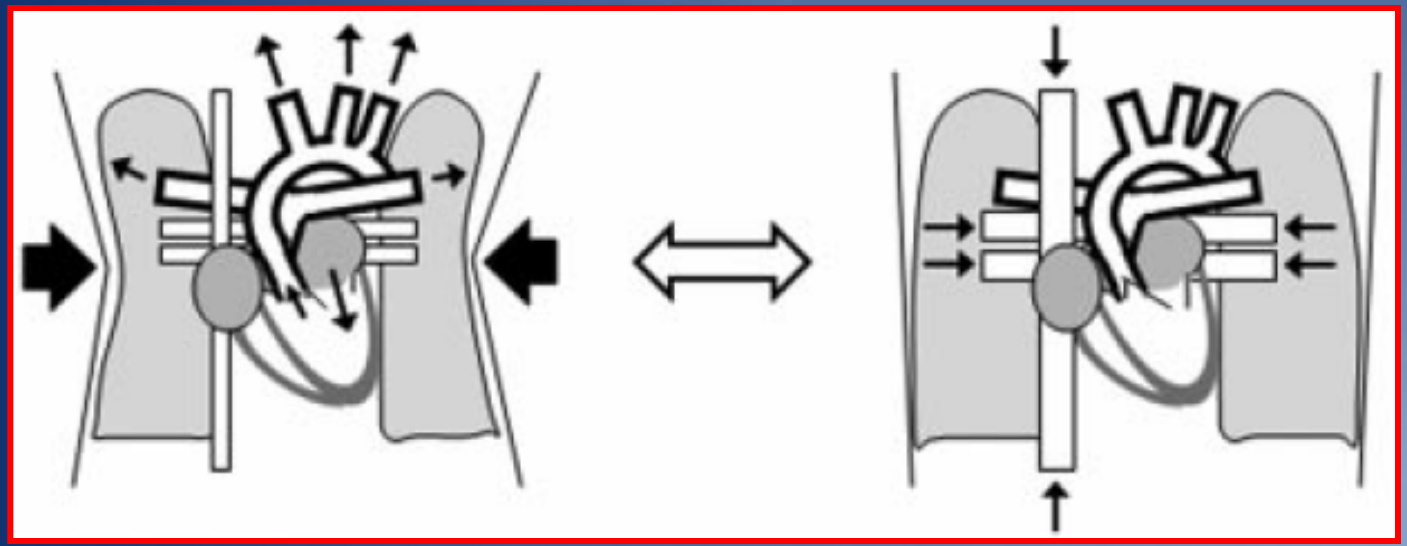
Jeffrey A. Werner, M.D., H. Leon Greene, M.D., Carolyn L. Janko and Leonard A. Cobb, M.D.

Two-dimensional echocardiography during CPR in man: implications regarding the mechanism of blood flow

JEFFREY A. WERNER, MD, FACC; H. LEON GREENE, MD, FACC; C. L. JANKO; LEONARD A. COBB, MD, FACC

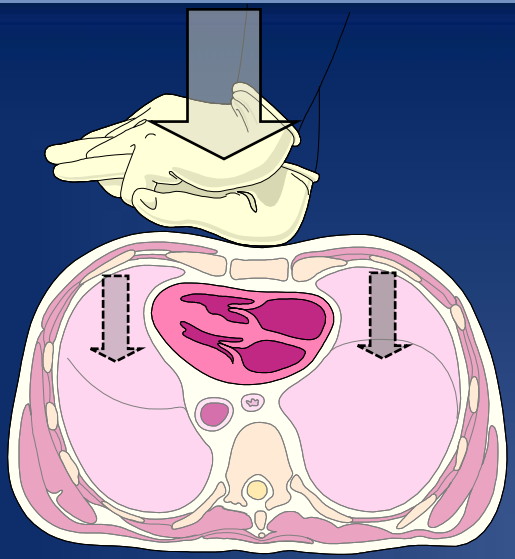
Mechanisms of Blood Flow During Cardiopulmonary Resuscitation

Michael T. Rudikoff, M.D., W. Lowell Maughan, M.D., Mark Effron, M.D., Paul Freund, and Myron L. Weisfeldt, M.D.



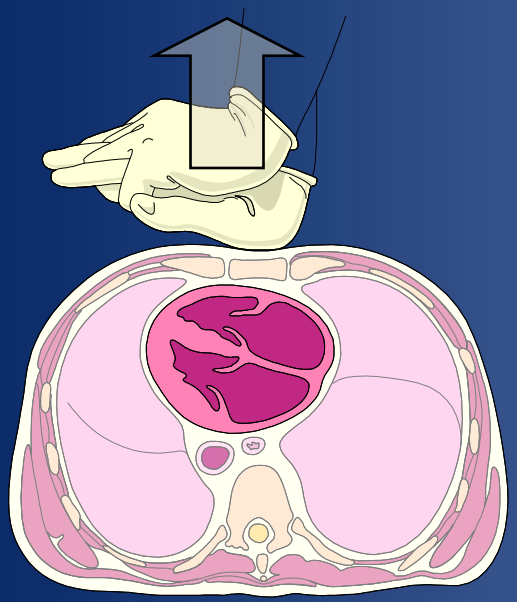
Compression **Relaxation**

Niemann JT Circulation 1981;64:985-91 Werner JA. Circulation 1981;64:1417-21; Crit Care Med 1981;9:375-6 Rudikoff MT, Circulation 1980;61:345-52



Compression

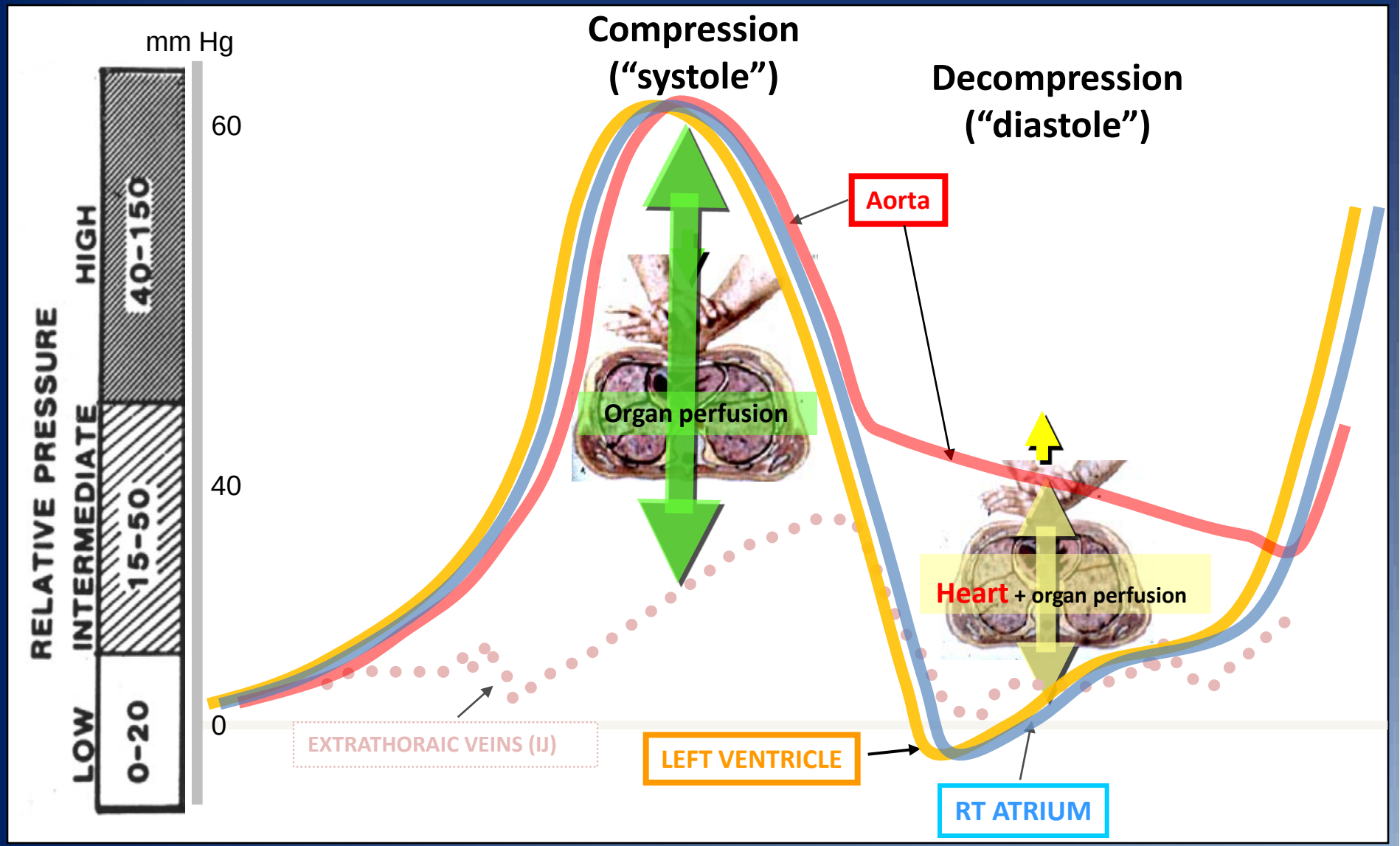
- Increased intrathoracic pressure
- Ejects blood from heart and lungs
- "Good" compression increases forward output and BP



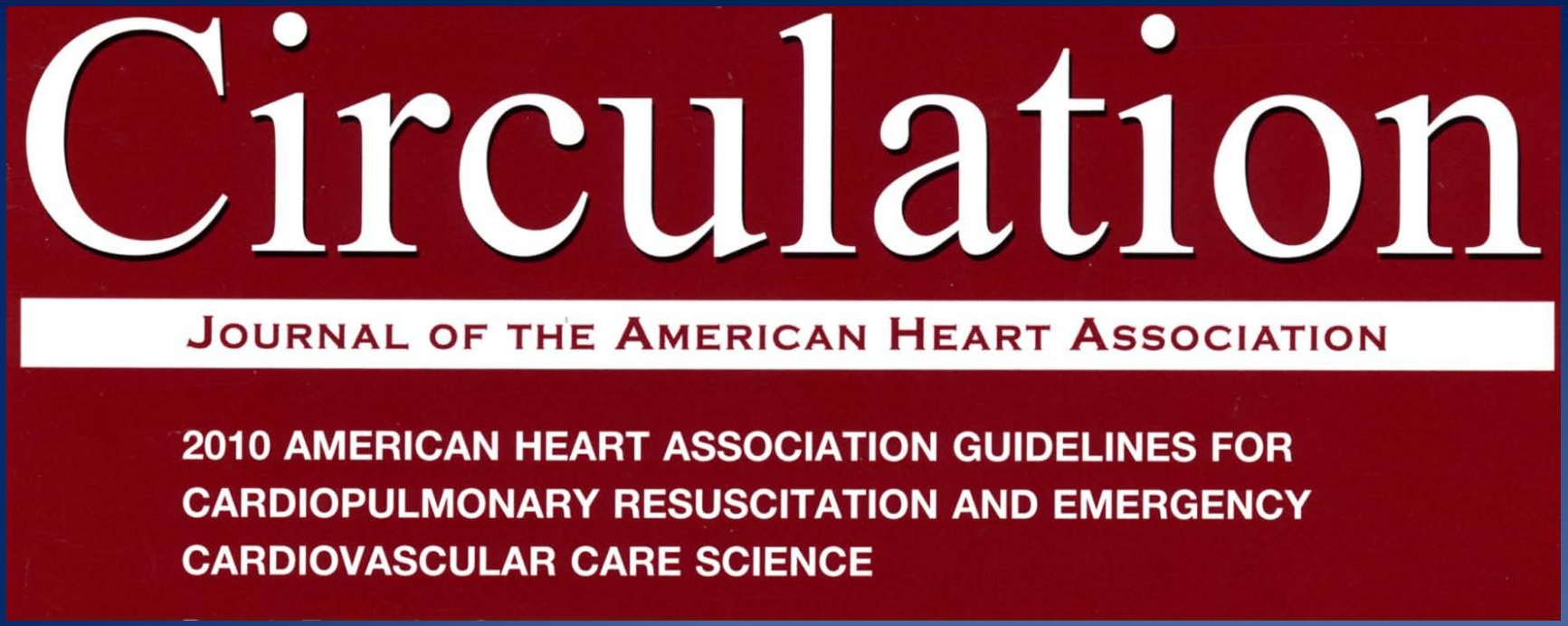
Decompression (recoil)

- Decreased intrathoracic pressure
- Refilling of heart and lungs
- "Good" recoil → ↑vacuum → ↑refilling → ↑forward output

Hemodynamics of CPR



Criley JM et al. Circulation 1986;74(IV):42-50 (modified).



"The adult sternum should be depressed at least **2 inches** (5 cm) with chest compression and chest recoil/relaxation times approximately equal (…duty cycle of **50%**) … at a rate of at least **100** compressions/minute."

Berg RA et al. Circulation 2010; 122 (suppl): S685-S705

Cardiac output during cardiopulmonary resuscitation at various compression rates and durations

KEVIN R. FITZGERALD, CHARLES F. BABBS, HENRY A. FRISSORA, ROBERT W. DAVIS, AND DOUGLAS I. SILVER
Biomedical Engineering Center, Purdue University, West Lafayette, Indiana 47907

Relationship of Blood Pressure and Flow During CPR to Chest Compression Amplitude: Evidence for an Effective Compression Threshold

C. F. Babbs, MD, PhD
W. D. Voorhees, PhD
K. R. Fitzgerald
H. R. Holmes, MS
L. A. Geddes, ME, PhD

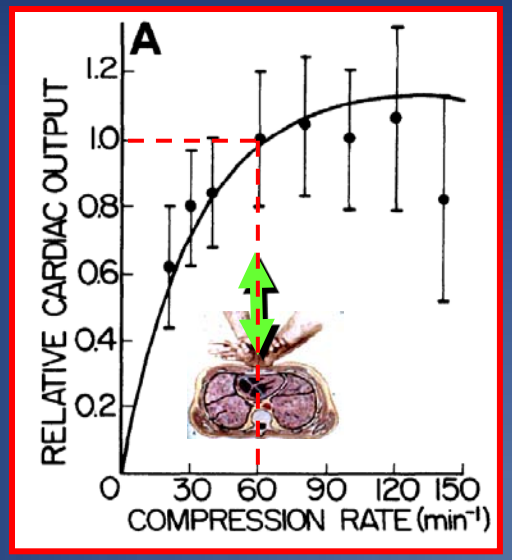
Instrumented dogs

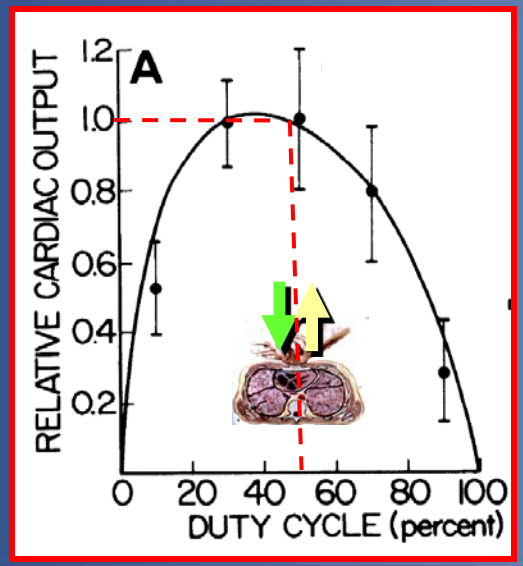
Thumper to randomly targeted compression rates & duty cycles; intrathoracic pressures

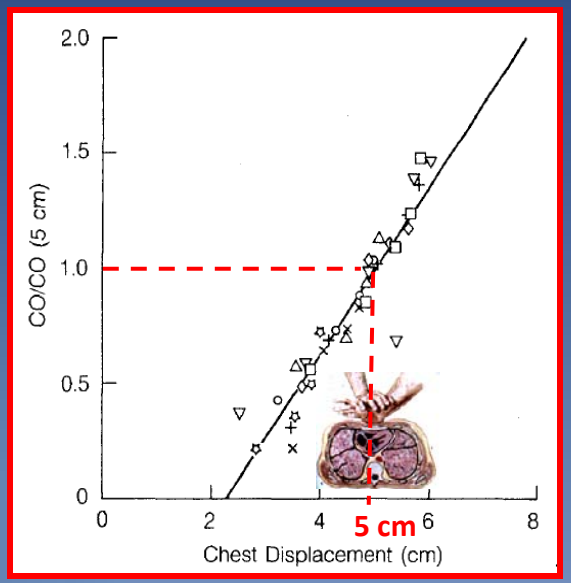
VF

Measure

- **Chest displacement***
- **Cardiac output****
- **Stroke volume**
- **Blood pressure**







Fitzgerald KR. Am J Physiol 1981;141:H442-8.
Babbs CF. Ann Emerg Med 1983;17:527-532.

*Normalized to 5 cm chest displacement
**Normalized to 60/min; 50/50 duty cycle

Clinical and hemodynamic comparison of 15:2 and 30:2 compression-to-ventilation ratios for cardiopulmonary resuscitation*

Demetris Yannopoulos, MD; Tom P. Aufderheide, MD; Andrea Gabrielli, MD; David G. Beiser, MD; Scott H. McKnite, BS; Ronald G. Pirrallo, MD, MHSA; Jane Wigginton, MD; Lance Becker, MD; Terry Vanden Hoek, MD; Wanchun Tang, MD; Vinay M. Nadkarni, MD; John P. Klein, PhD; Ahamed H. Idris, MD; Keith G. Lurie, MD

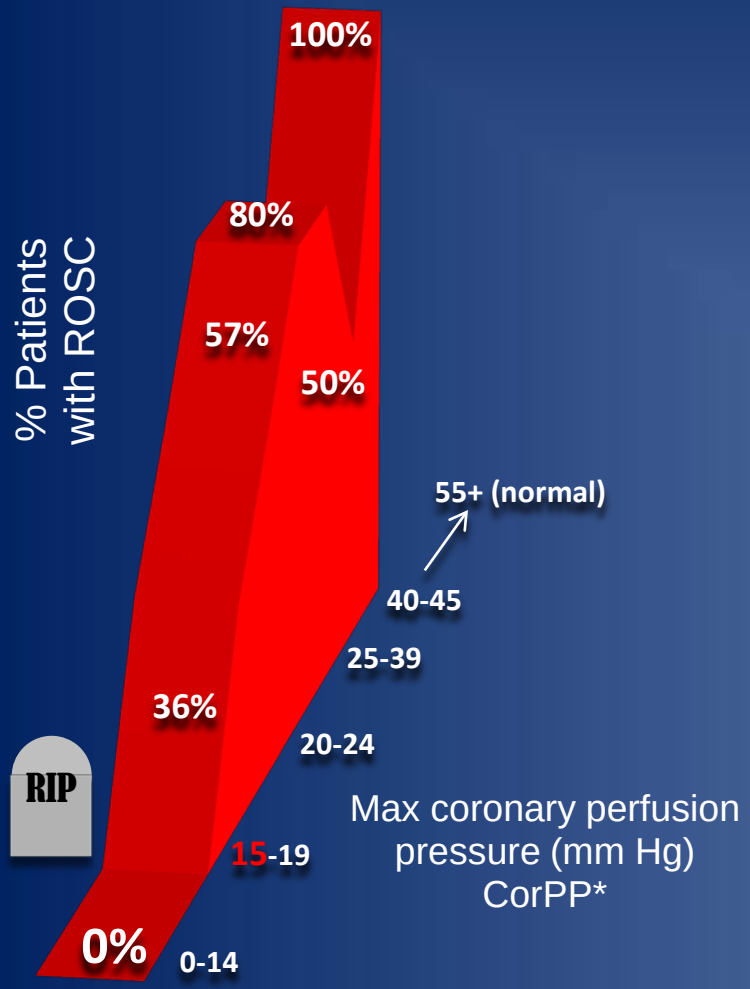
Increasing C:V ratio to 30:2 . . .

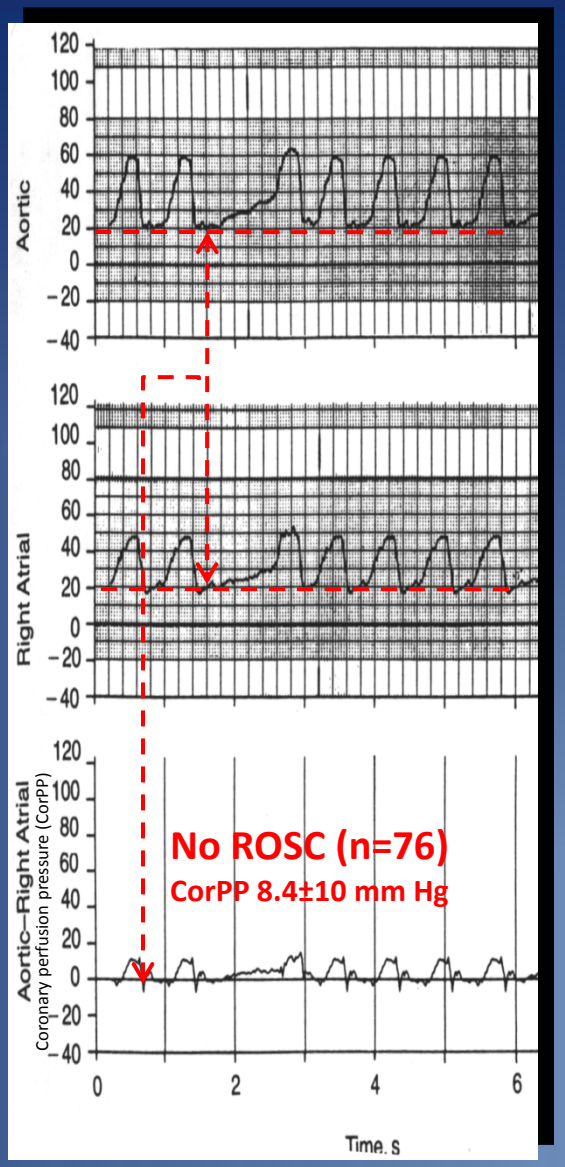
- Increased CO 35%
- Doubled common carotid artery blood flow
- No negative effects on oxygenation/pH balance
- No worsening of CPR quality
- No difference in rescuer fatigue or discomfort

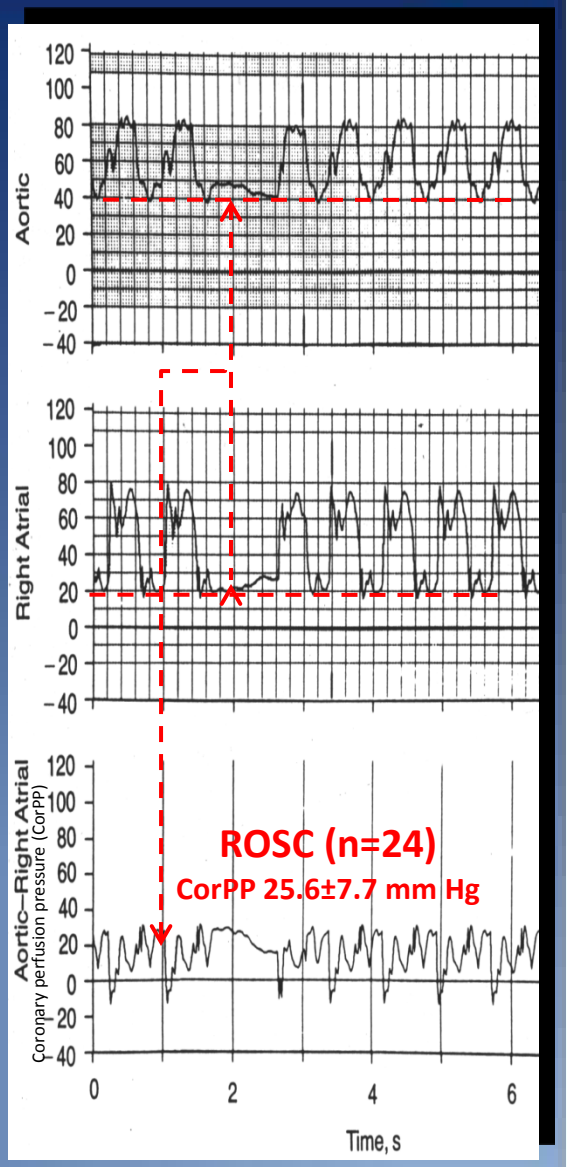
Yannopoulos D Cric Care Med 2006;34:1444-49

Saving the Heart: CPP and ROSC in Human CPR

n=100 patients with cardiac arrest



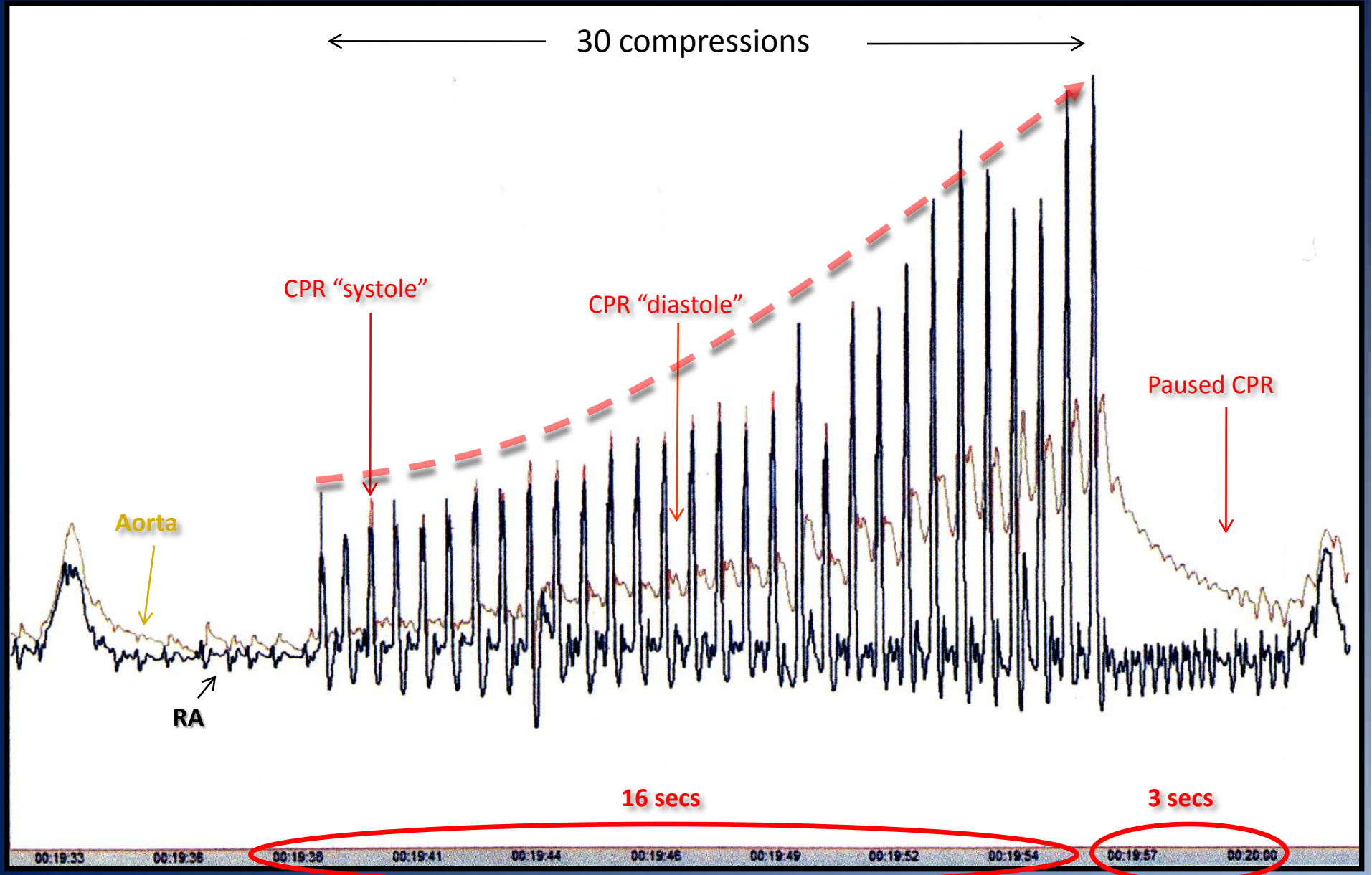




*CorPP = Aorta – RA pressure gradient during relaxation (diastolic) phase of precordial compression

Paradis NA., et al. JAMA 1990;263:1106-1113

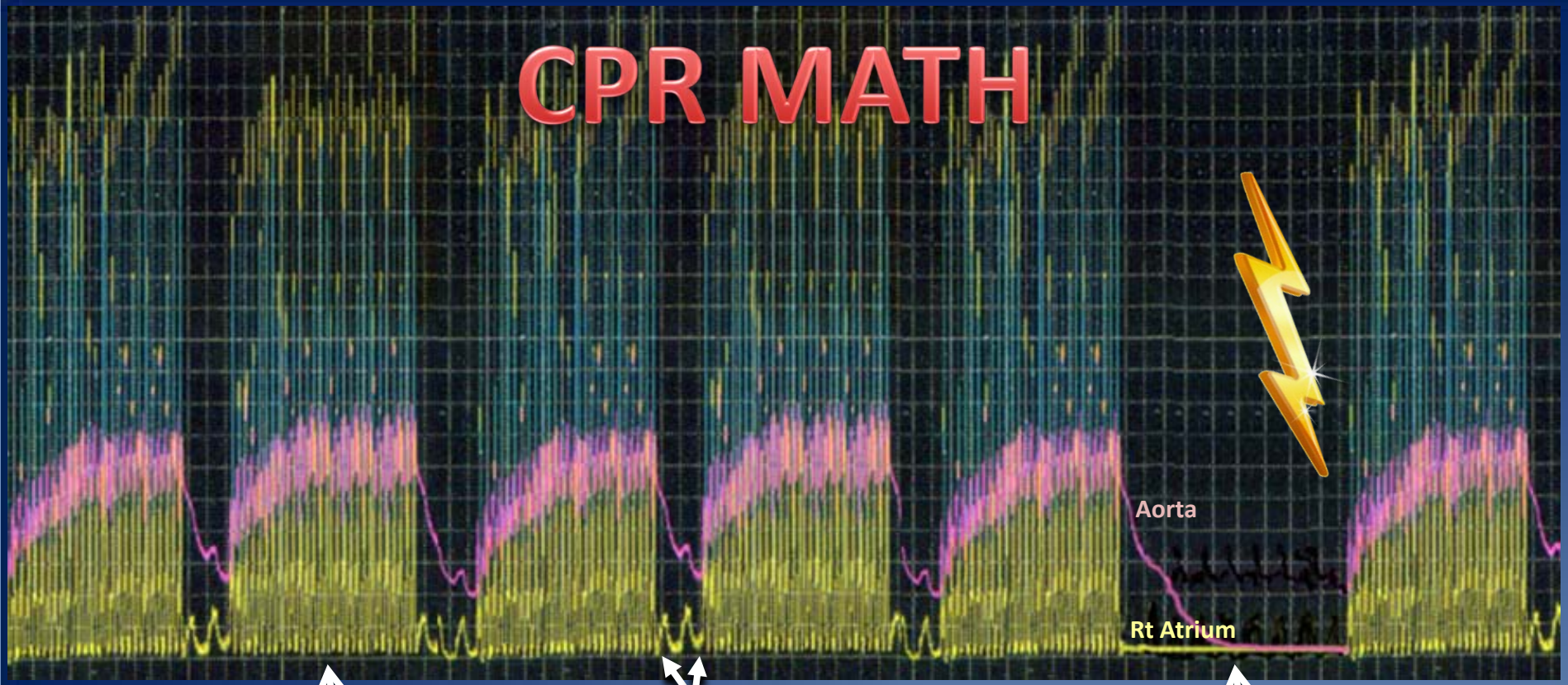
The Price of CPR Pauses



Causes of CPR Pauses

- Ventilation
- Defibrillation
- Intubation
- Line placement (central)
- Chaos

CPR MATH



30 cc @ 100 cc/min

2 breaths

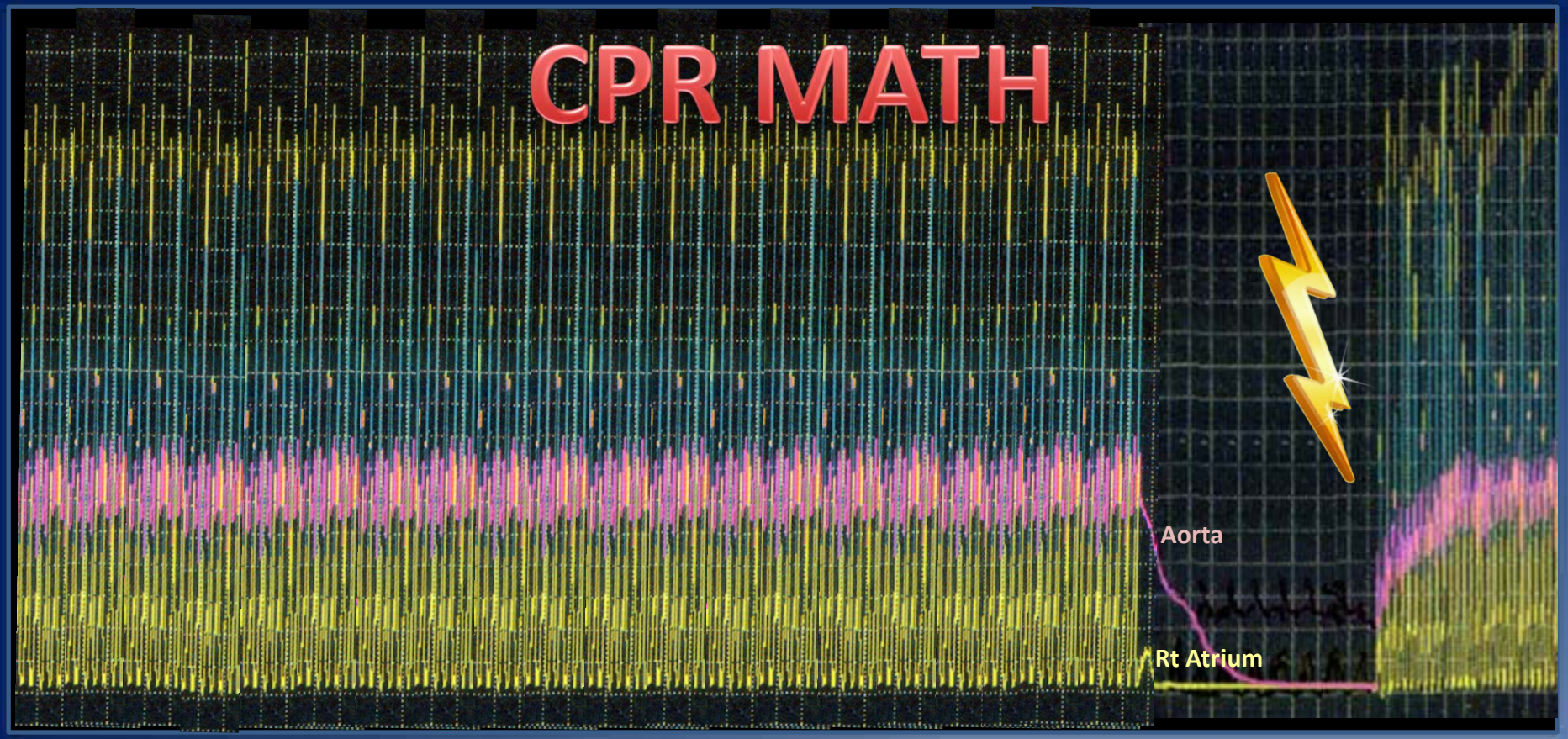
Rhythm/vitals analysis/shock
~10 secs

150 compressions (90 secs)/2 min
Avg compression rate = 75/min
CPR fraction* = 90 secs/120 secs (75%)

150 compressions (90 secs) /~130 secs
Avg compression rate = 69/min
CPR fraction = 90 secs/130 secs (69%)

*Proportion of resuscitation time devoted to chest compressions in absence of spontaneous circulation

CPR MATH



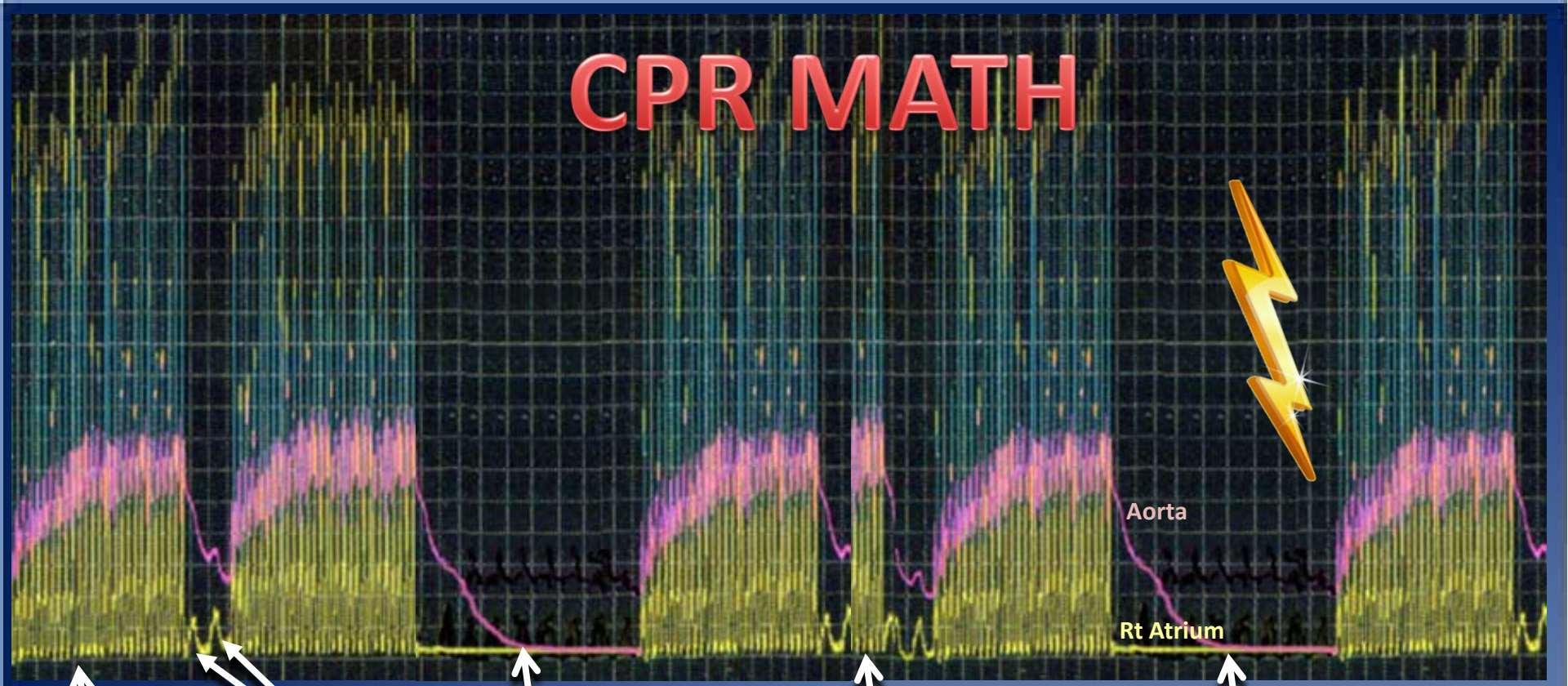
200 cc @100/min Asynchronous 1 breath/10 cc Rhythm/vitals analysis/shock ~7 secs

200 compressions (120 secs)/2 min
Avg compression rate = 100/min
CPR fraction* = 120 secs/120 secs (100%)

200 compressions (120 secs)/~127 secs
Avg compression rate = 94/min
CPR fraction = 120 secs/127 secs (94%)

*Proportion of resuscitation time devoted to chest compressions in absence of spontaneous circulation

CPR MATH



30 cc @ 100/min

2 breaths @ 1/sec

Unexplained pause

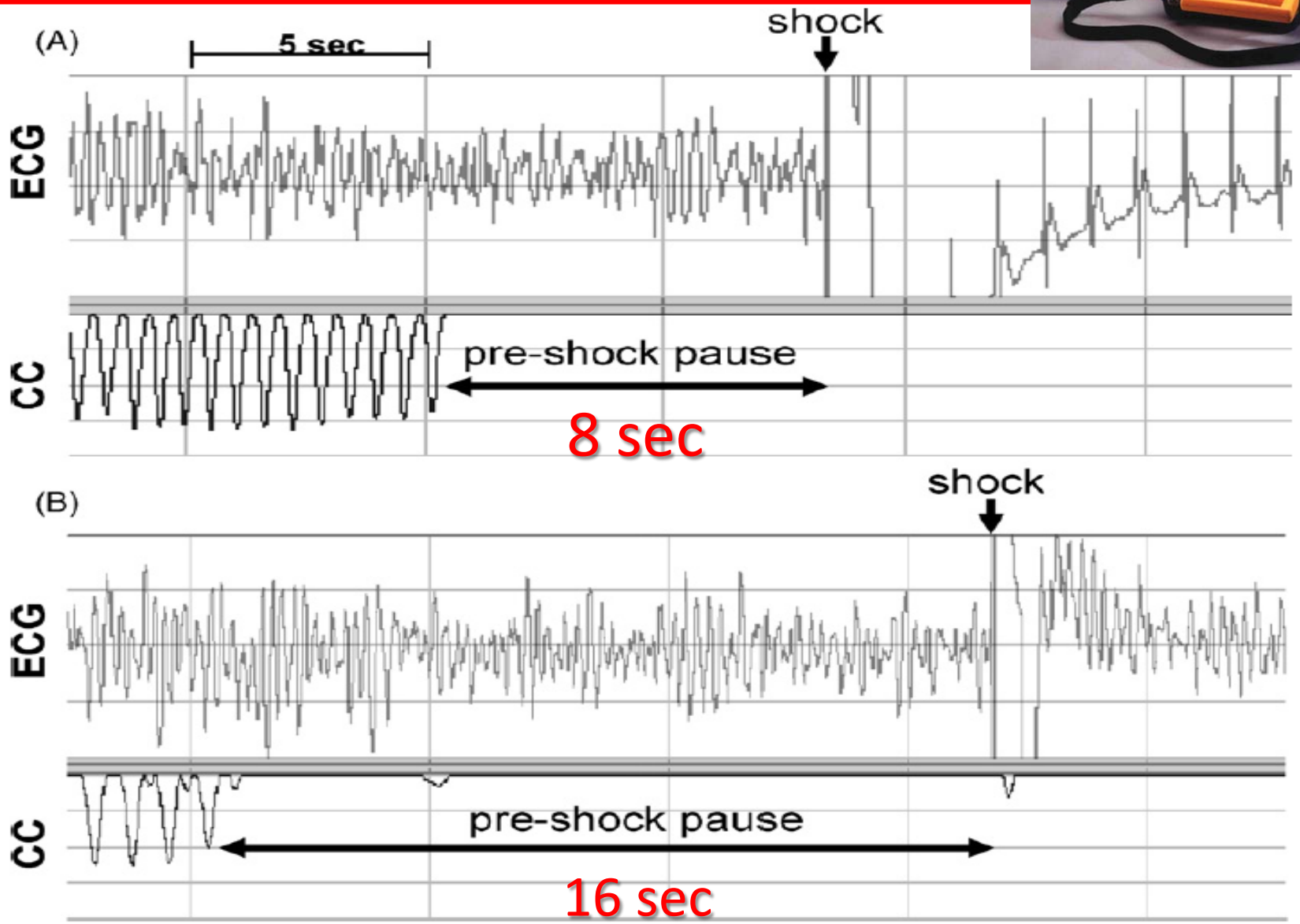
5 cc @ 100/min

Rhythm/vitals analysis/shock
~15 secs

125 compressions (75 secs)/2 min
Avg compression rate = 62/min
CPR fraction* = 75 secs/120 secs (62%)

125 compressions (75 secs)/~135 secs
Avg compression rate = 55/min
CPR fraction = 75 secs/135 secs (55%)

*Proportion of resuscitation time devoted to chest compressions in absence of spontaneous circulation


(A)
5 sec
shock
ECG
CC
pre-shock pause
8 sec
(B)
shock
ECG
CC
pre-shock pause
16 sec

Adverse Outcomes of Interrupted Precordial Compression During Automated Defibrillation

Ting Yu, MD; Max Harry Weil, MD, PhD; Wanchun Tang, MD; Shijie Sun, MD; Kada Klouche, MD; Heitor Povoas, MD; Joe Bisera, MSEE

- 20 instrumented swine
- 7 minutes of unsupported VF

↓ CPR + AED

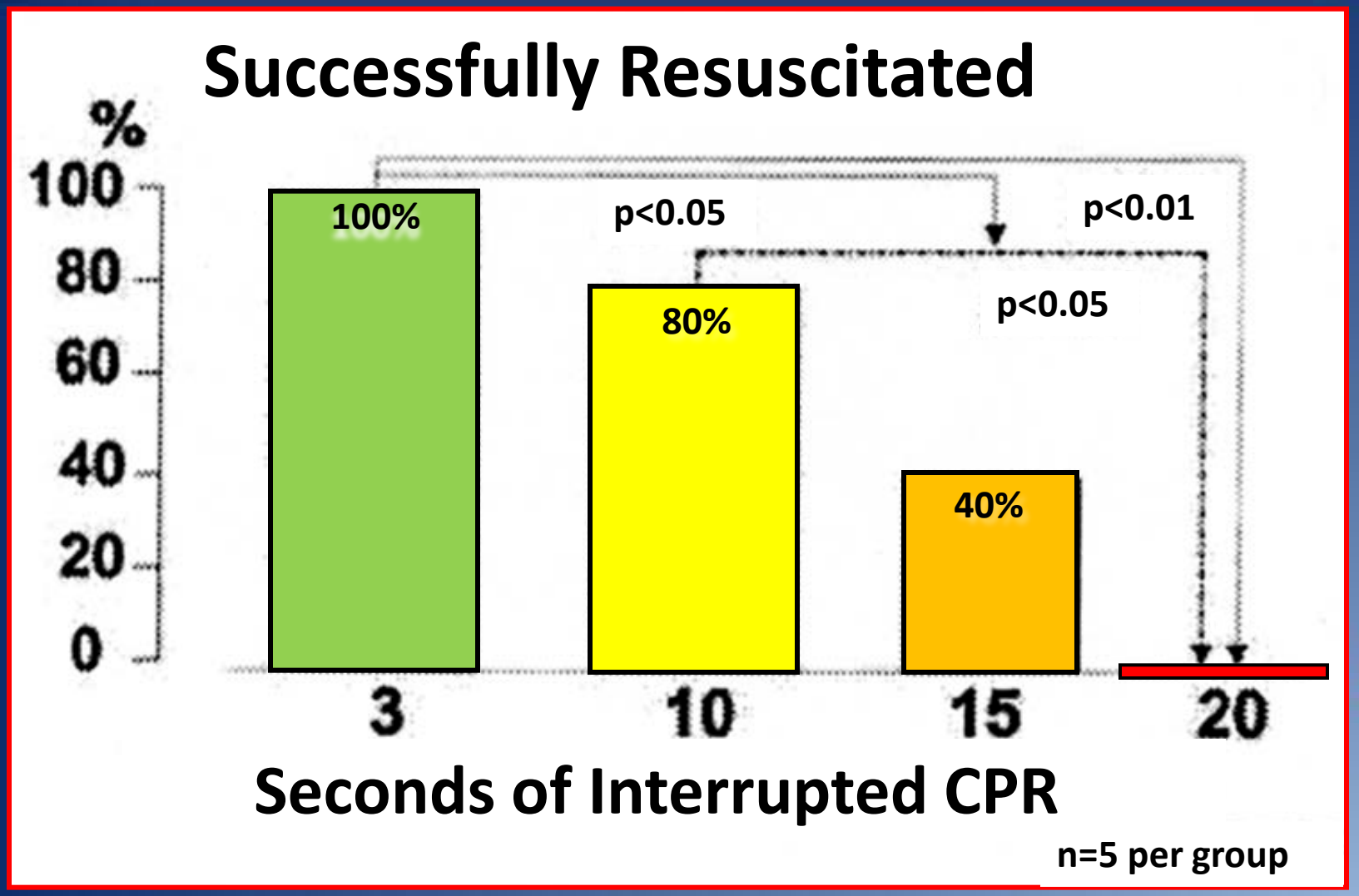
"Hands-off" interval prior to each shock

(mimicking analysis and charge interval of AEDs (10-19secs))

3 secs | 10 secs | 15 secs | 20 secs

Yu T et al. Circulation 2002;106:368-372

Effect of Interrupted Precordial Compression on Resuscitation Outcome

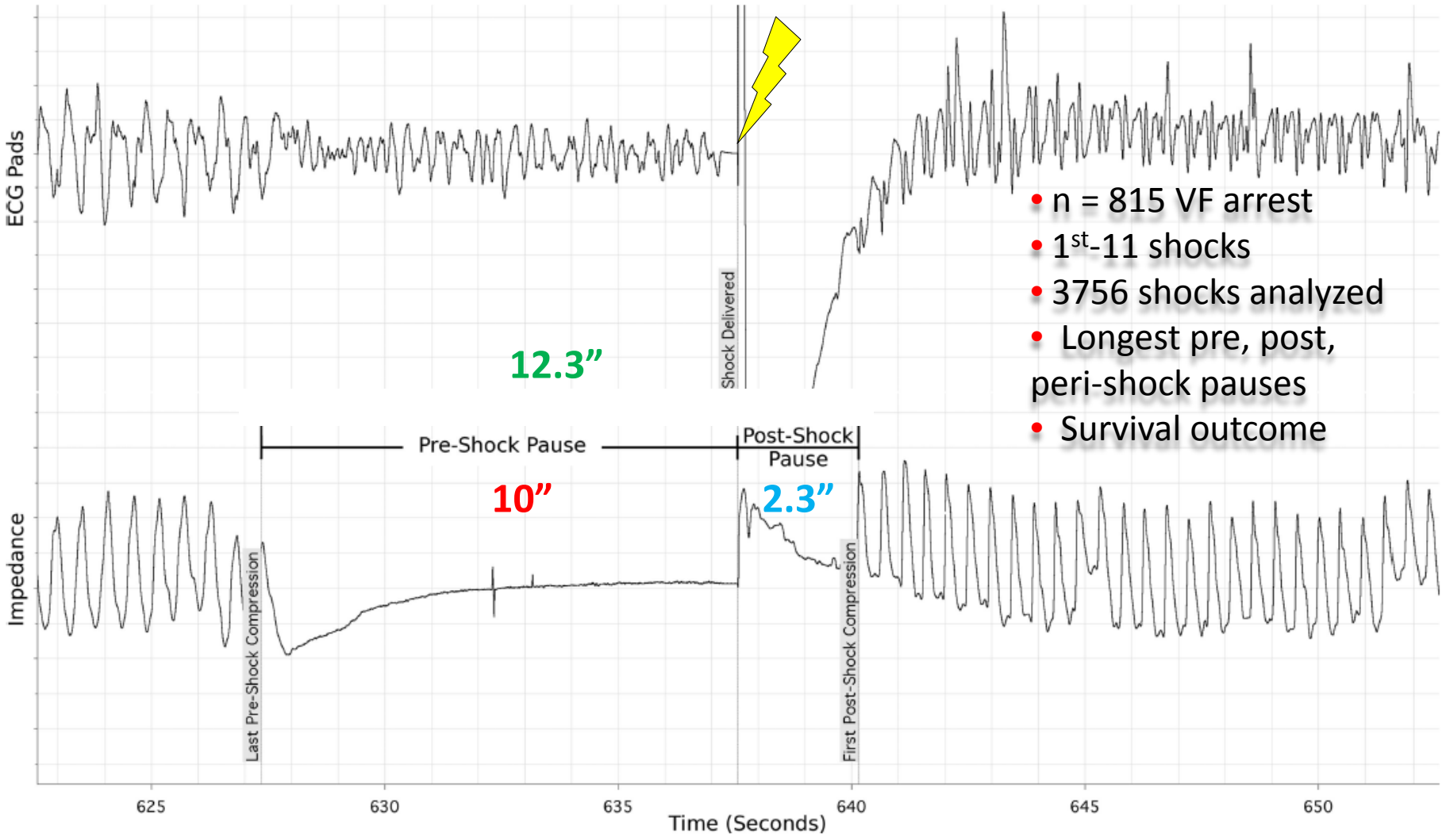


Yu T et al. Circulation 2002;106:368-372

Perishock Pause

An Independent Predictor of Survival From Out-of-Hospital Shockable Cardiac Arrest

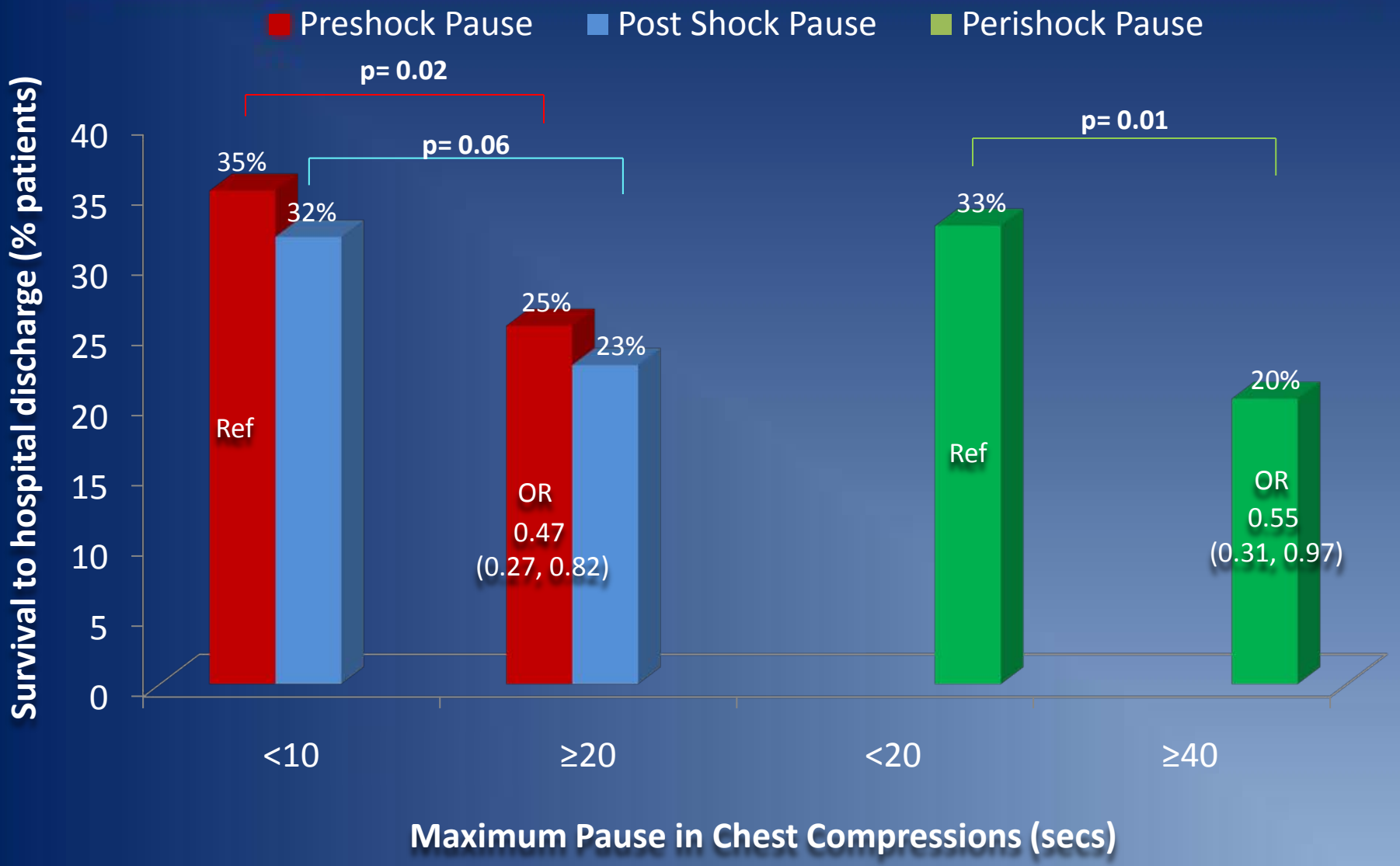
on behalf of the Resuscitation Outcomes Consortium (ROC) Investigators



- n = 815 VF arrest
- 1st-11 shocks
- 3756 shocks analyzed
- Longest pre, post, peri-shock pauses
- Survival outcome

Cheskes S et al. Circulation 2011;124:58-66

Shock Pauses and Cardiac Arrest Survival



Cheskes S et al. Circulation 2011;124:58-66

ORIGINAL CONTRIBUTION

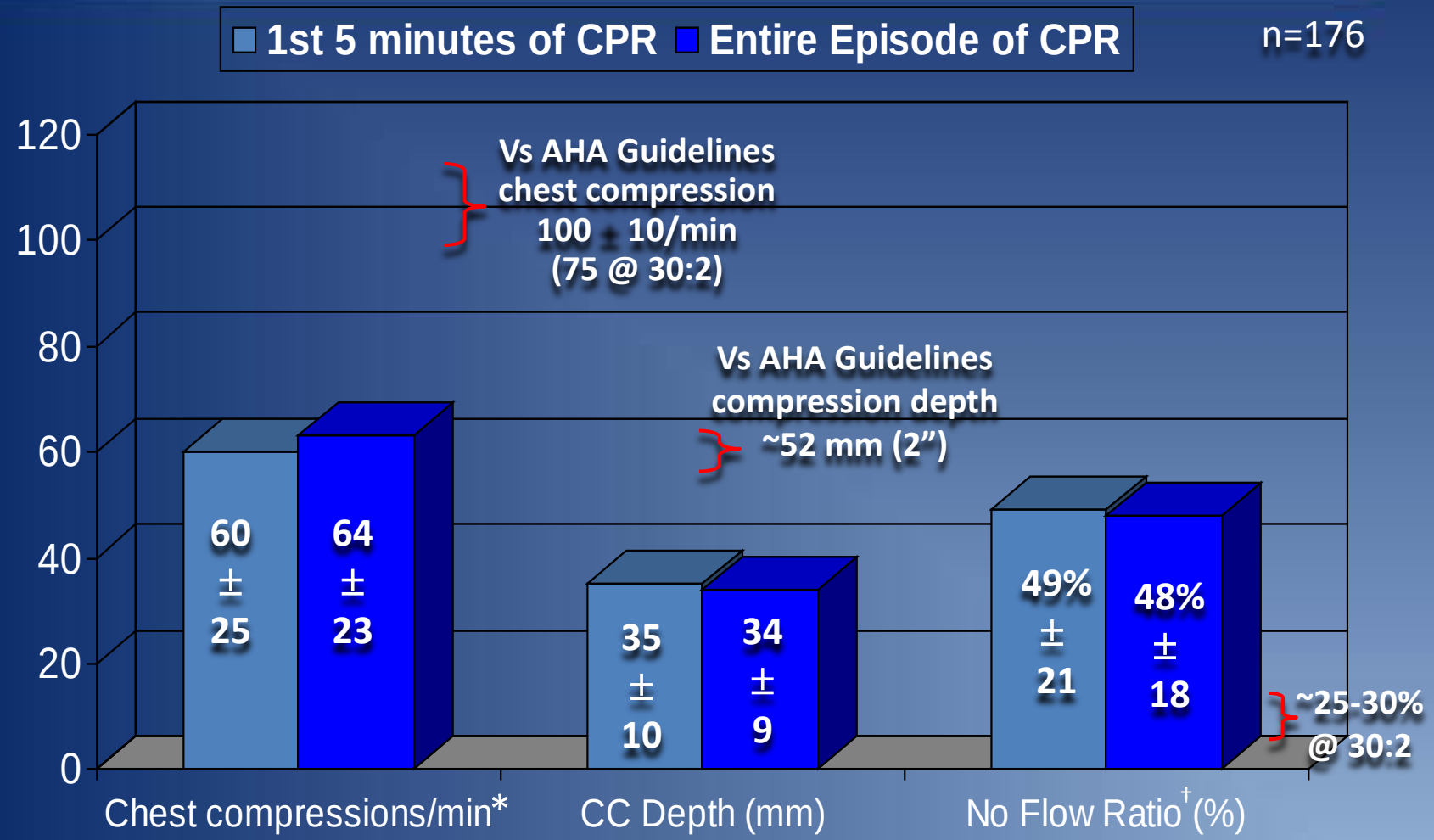
Quality of Cardiopulmonary Resuscitation During Out-of-Hospital Cardiac Arrest

Lars Wik, MD, PhD
Jo Kramer-Johansen, MD
Helge Myklebust, BEng
Hallstein Sørebø, MD
Leif Svensson, MD
Bob Fellows, MD
Petter Andreas Steen, MD, PhD

- n=176 adults with out-of-hospital cardiac arrest
- Automated resuscitation monitoring
  - Compression rate, depth, "hands off" time
  - Ventilation rate
  - ECG
  - Events

Wik L et al JAMA 2005;293:299-304

Quality of CPR During Out-of-Hospital Cardiac Arrest



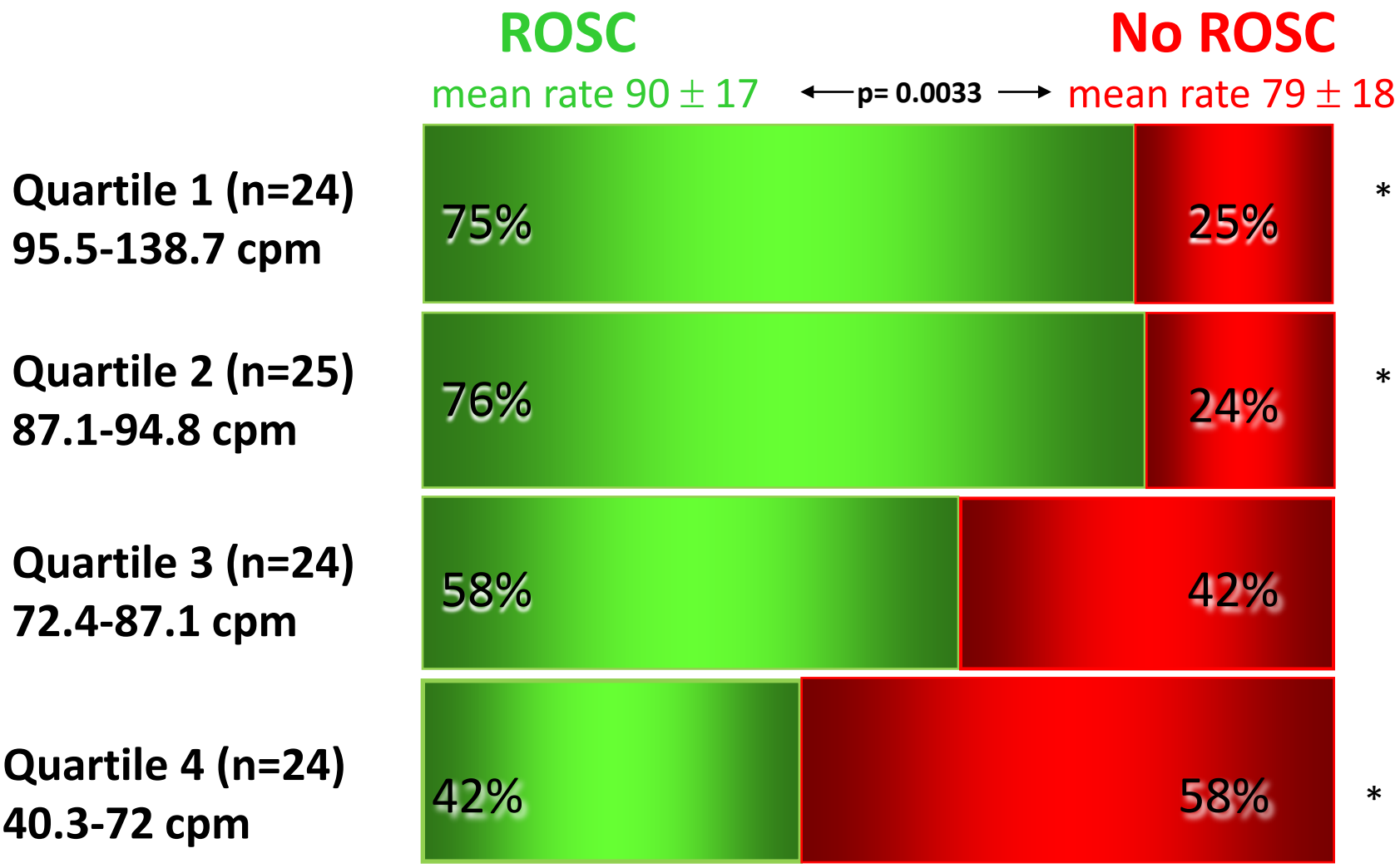
*Average # compressions given per minute vs instantaneous rate at which compressions, when given, were administered (120 ± 20)

† % time without spontaneous circulation or chest compressions

Wik L et al JAMA 2005;293:299-304

Impact of Chest Compression Rate on Outcome

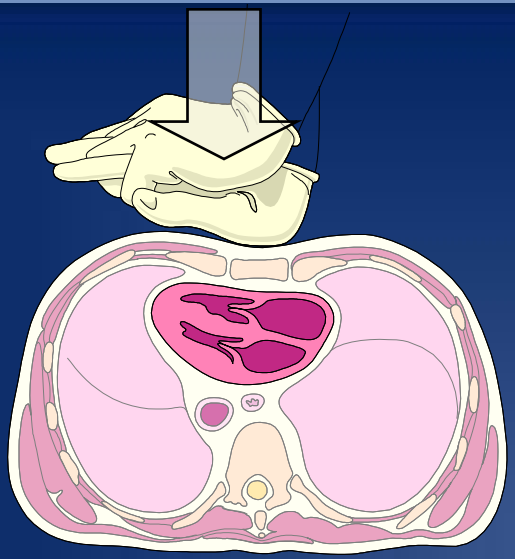
n= 97 patients in-hospital cardiac arrest



*ROSC = detectable pulse and perfusing rhythm for ≥ 5 min

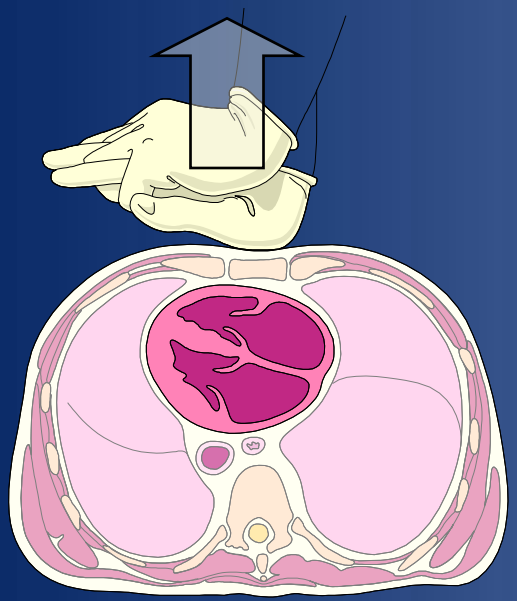
* p < 0.0083

Abella BS et al. Circulation 2005;111:428-434.



Compression

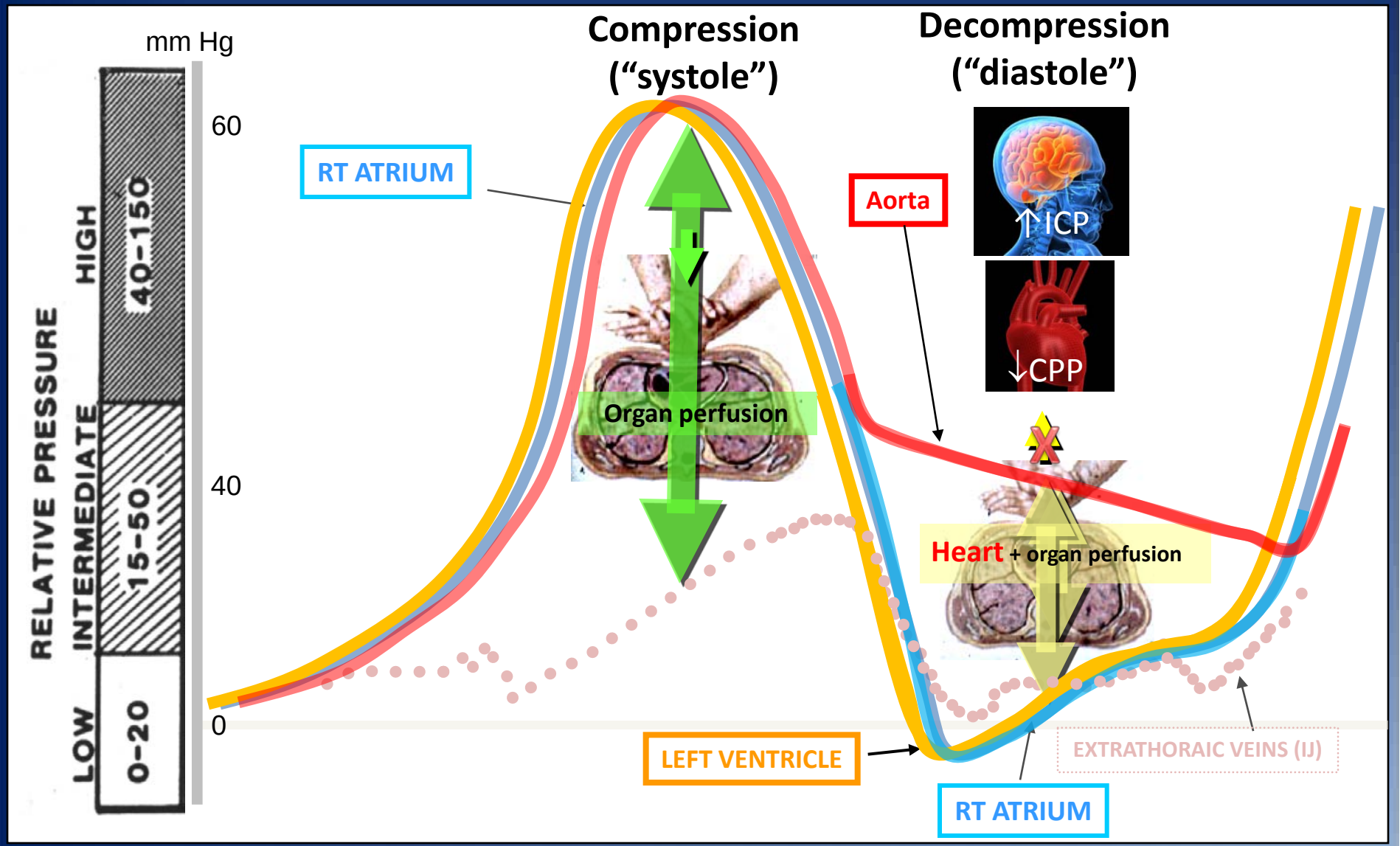
- Increased intrathoracic pressure
- Ejects blood from heart and lungs
- "Good" compression increases forward output and BP
- Tissue perfusion



Decompression (recoil)

- Decreased intrathoracic pressure
- Refilling of heart and lungs
- "Good" recoil → ↑vacuum → ↑refilling → ↑forward output
- Coronary and tissue perfusion

Hemodynamics of CPR



Criley JM et al. Circulation 1986;74(IV):42-50 (modified).

ELSEVIER

Resuscitation 64 (2005) 363–372

RESUSCITATION

www.elsevier.com/locate/resuscitation

Effects of incomplete chest wall decompression during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest☆

Demetris Yannopoulos[a,b], Scott McKnite[a,c], Tom P. Aufderheide[d], Gardar Sigurdsson[a], Ronald G. Pirrallo[d], David Benditt[b], Keith G. Lurie[a,b,c,*]

[a] *Minneapolis Medical Research Foundation, 914 South 8th St., 3rd Floor, Minneapolis, MN 55404, USA*
[b] *Cardiac Arrhythmia Center, University of Minnesota, Minneapolis, MN, USA*
[c] *Department of Emergency Medicine of Hennepin County Medical Center, Minneapolis, MN, USA*
[d] *Medical College of Wisconsin, Milwaukee, WI 53226, USA*

- n=9 instrumented swine

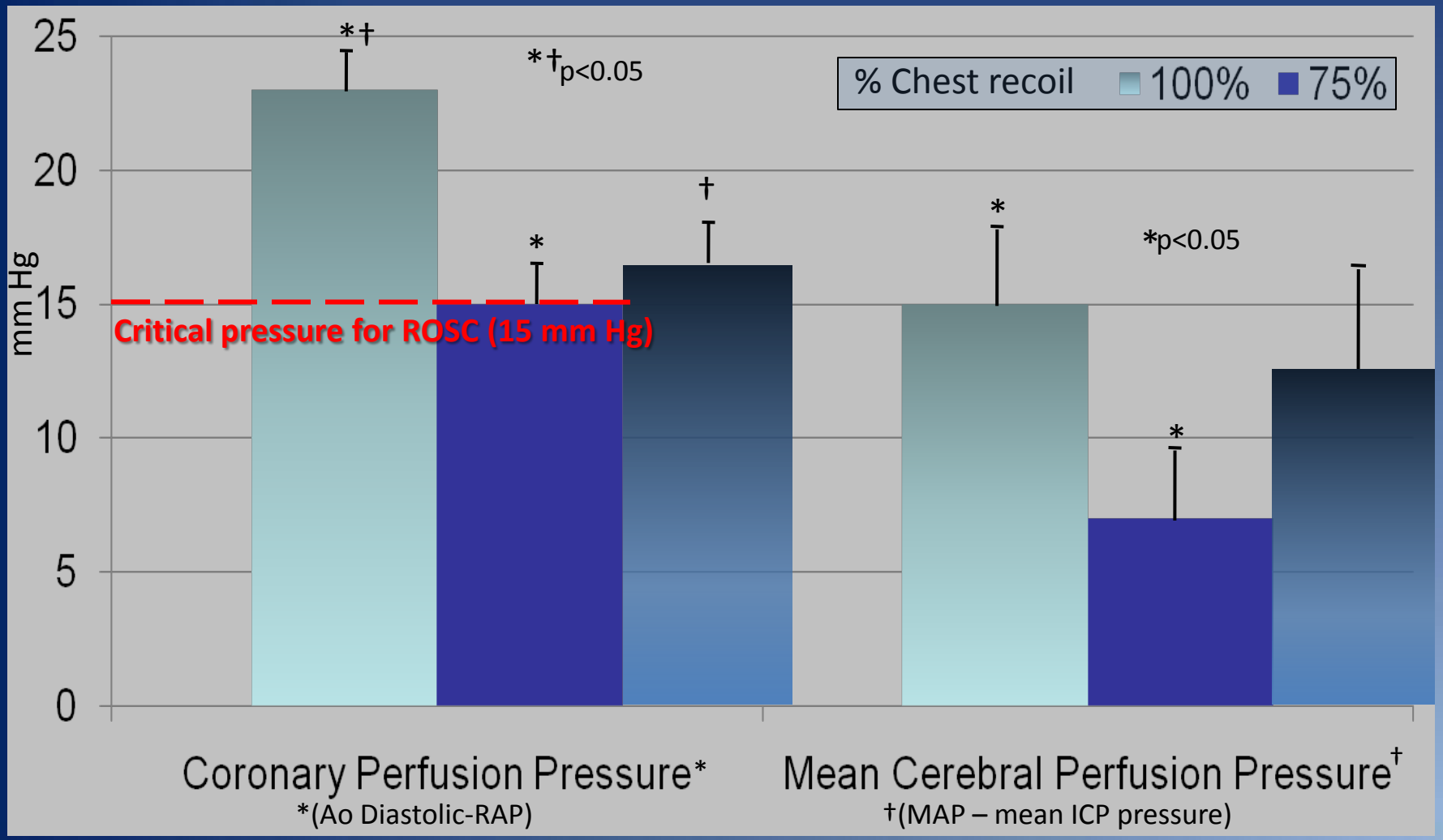
- 6 minutes untreated VF → standard CPR* x 3 min → CPR with 75% recoil (residual 1.2 cm sternal compression @ end decompression) x 1 min → standard CPR* x 1 min → defib x 3 → ACLS

*Standard CPR = CC @100/min, 50% duty cycle, 5 cm depth, full (100%) recoil, 15:2 ratio

Yannopoulos D et al. Resuscitation 2005;64:363-72

Effect of Incomplete Chest Decompression On Coronary and Cerebral Perfusion Pressures

n=9 instrumented swine → std CPR (100% recoil) x 3' → CPR (75% recoil) x 1'



Yannopoulos D et al. Resuscitation 2005;64:363-72; Paradis et al JAMA 1990;263:3257-8

"The striking observation [was] that there was little or no immediate recovery of … coronary *and cerebral* perfusion pressures after returning to 100% decompression.

[This] further demonstrates how important complete chest recoil is for effective CPR and how, even 1 minute of improper chest wall expansion, negatively influences these …variables."

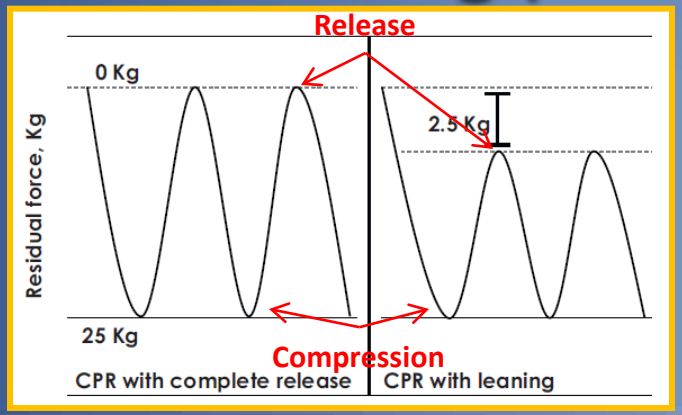
Yannopoulos D et al. Resuscitation 2005;64:363-72

Clinical paper

The prevalence of chest compression leaning during in-hospital cardiopulmonary resuscitation☆

David A. Fried[a], Marion Leary[a], Douglas A. Smith[a], Robert M. Sutton[b], Dana Niles[b], Daniel L. Herzberg[a], Lance B. Becker[a], Benjamin S. Abella[a,*]

- n= 108 in-hospital cardiac arrests 5/07-2/09
- Resuscitation performance evaluated with CPR-sensing/recording capable defibrillator (MRx-QCPR)
- 112,569 chest compressions analyzed
- "Leaning" = residual force ≥ 2.5 kg (~1 lb) between compressions (10%)



Fried DA. Resuscitation 2011;82:1019-24

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Lean (incomplete release) . . .

- Observed in most (91%) resuscitations
  - Seen >20% compressions in ~1 in 5 patients
- Not associated with CC depth, body mass, age, time of day; more common in men
- Frequency did not change over duration of resuscitation

Fried DA. Resuscitation 2011;82:1019-24