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Automated CPR and Defibrillation: The Future of Cardiac Arrest Management

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Cardiac Arrest

- Cessation of normal circulation of blood due to failure of the heart to contract effectively during systole
- Sudden (non-traumatic) cardiac arrest affects 40,000 Canadians per year
- 70% occur outside of hospital
  - 5% of this group survive

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Cardiac Arrest

- Extremely high morbidity and mortality
- The presenting rhythm is shockable < 50% of the time in both hospital and EMS environments
- Potential for significant improvement of CPR and defibrillation
- Defibrillation is most effective during the first few minutes after cardiac arrest

Cardiopulmonary Resuscitation (CPR)

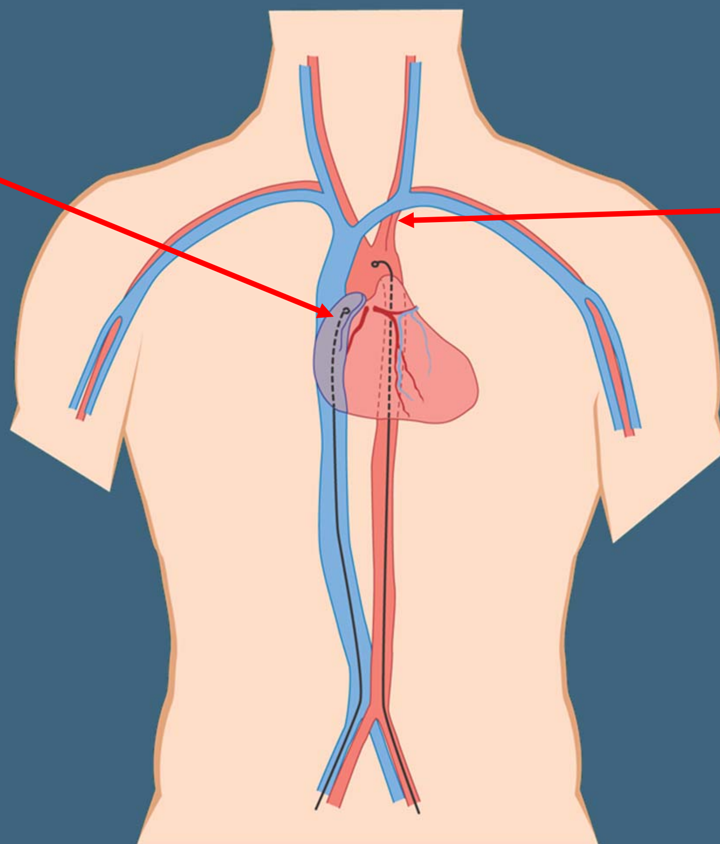
- Irreversible ischemic brain injury thought to occur >5 min of normothermic cardiac arrest
- Only clinical interventions shown to improve survival from cardiac arrest are <u>early CPR</u>, <u>early defibrillation</u>, and prolonged hypothermia after ROSC

CPR

- Effectiveness of CPR dependent on provider administering compressions at consistent rate and depth
- Successful resuscitation of arrested heart depends on generating adequate coronary perfusion pressure (CPP) during CPR
  - Minimum CPP of 15 mmHg is necessary to achieve ROSC if initial defibrillation attempts have failed

Coronary Perfusion Pressure

Right Atrial
Diastolic Pressure
(RA–DP)

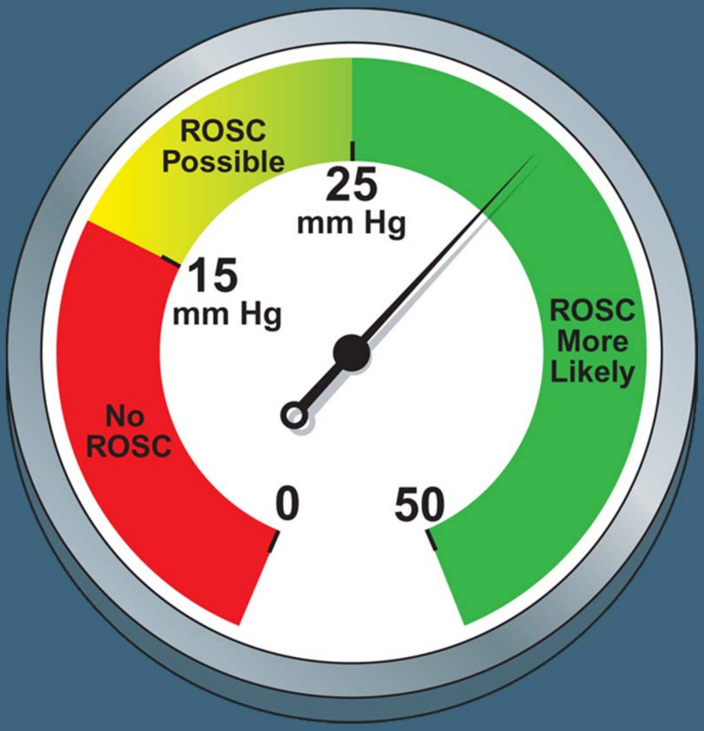


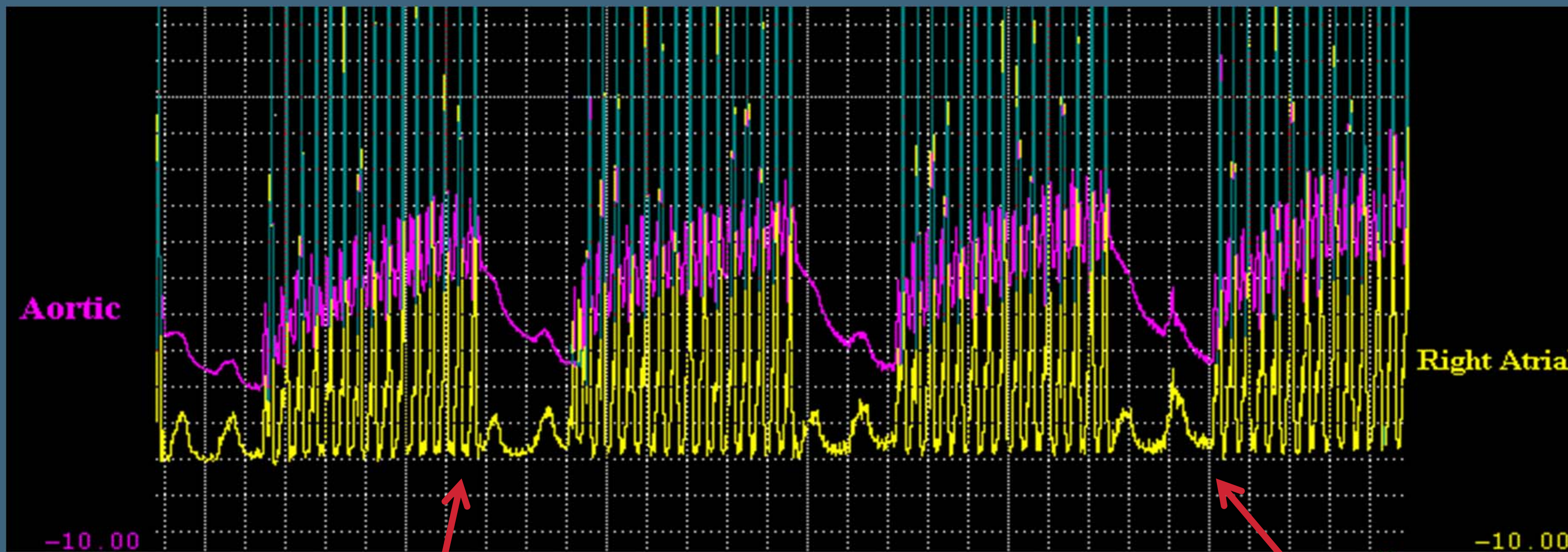
Aortic
Diastolic
Pressure
(A–DP)

CPP = ADP minus RADDP
[pressure driving coronary blood flow (ADP) – resistance (RADP)]

Myocardial Perfusion and ROSC

- ROSC more likely in a well perfused myocardium
- 2 basic reasons:
  - Profound ischemia prevents ROSC
  - Decreased preload means less squeeze (RA = RV pressure, Aortic = LV pressure)





CPR stopped for breaths/rhythm analysis

CPR resumed

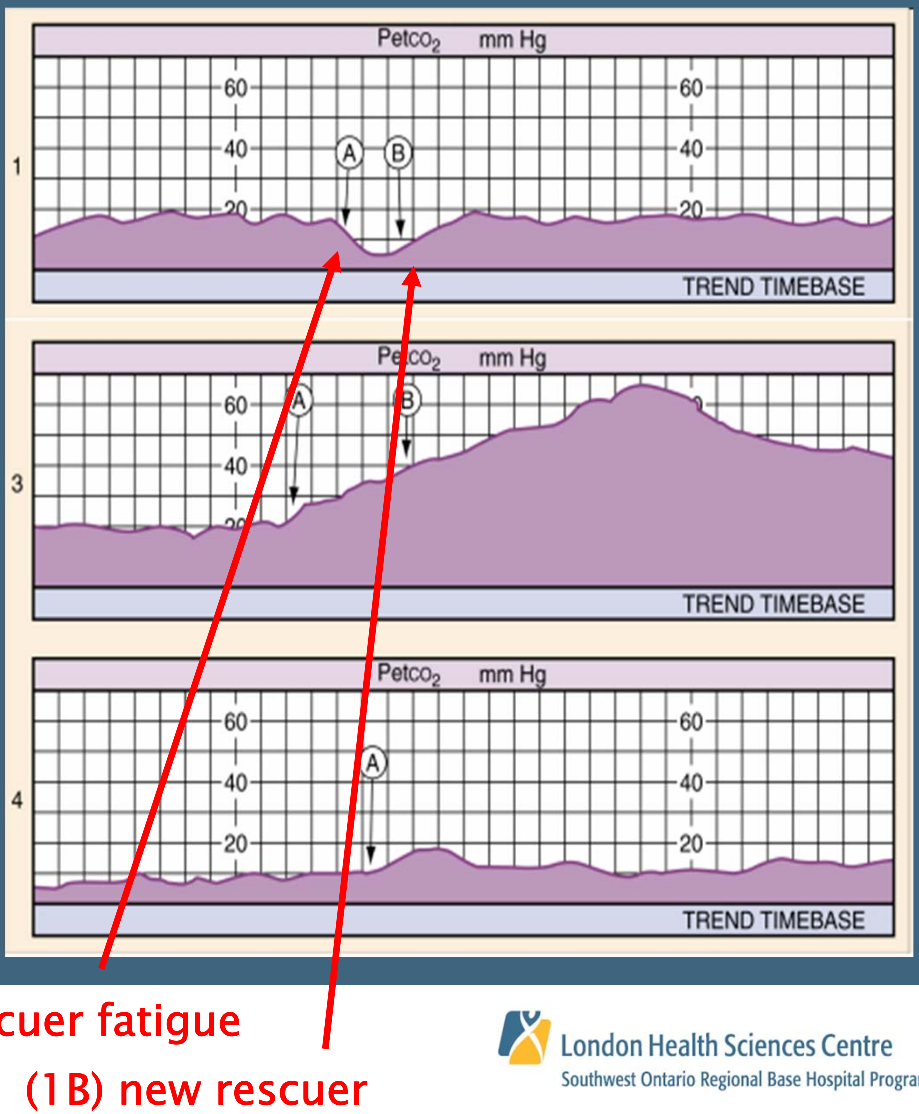
Periods of 2 minutes of chest compressions are necessary to generate CPP greater than 15 mmHg

Consequences of Pausing

- Decreased VF quality
- Decreased CPP/$ETCO_2$
- Decreased ROSC
- Decreased 24-hour survival

CPR

- $ETCO_2$ reliable indicator of cardiac output during CPR
  - correlates with coronary and cerebral perfusion pressures
- $ETCO_2$ depends on:
  - CO_2 production
  - alveolar ventilation
  - pulmonary blood flow (i.e. cardiac output)
- If minute ventilation held constant, only increased CO during CPR or ROSC significantly increases $ETCO_2$
- Resuscitation of cardiac arrest is likely to fail if $ETCO_2$ values are less than 10 mm Hg



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Limitations of Manual CPR

- Even when done properly, manual CPR does not adequately perfuse the brain or heart
- Additional limitations of manual CPR
  - Inconsistent compressions
  - Fatigue
  - Pausing to rotate rescuers or to move the patient
  - Cannot defibrillate if rescuer is in direct contact with the patient

The Potential Solution…

AutoPulse

- Portable compression device
- Back-board contains motor to retract load-distributing band
- Automatically adjusts to size/shape of each patient
- Consistent 20% reduction in AP-dimension of patient's chest
- Rate = 80 +/- 5 per min
- Continuous vs. 15:2 pause modes
- Cost $14,000 CAD per unit
  - Backboard
  - One (single use) life-band
  - 3 batteries
  - Instructional DVD

82.5cm x 46.2cm x 8.4cm, 12.3kg

Battery life = ~1 hour

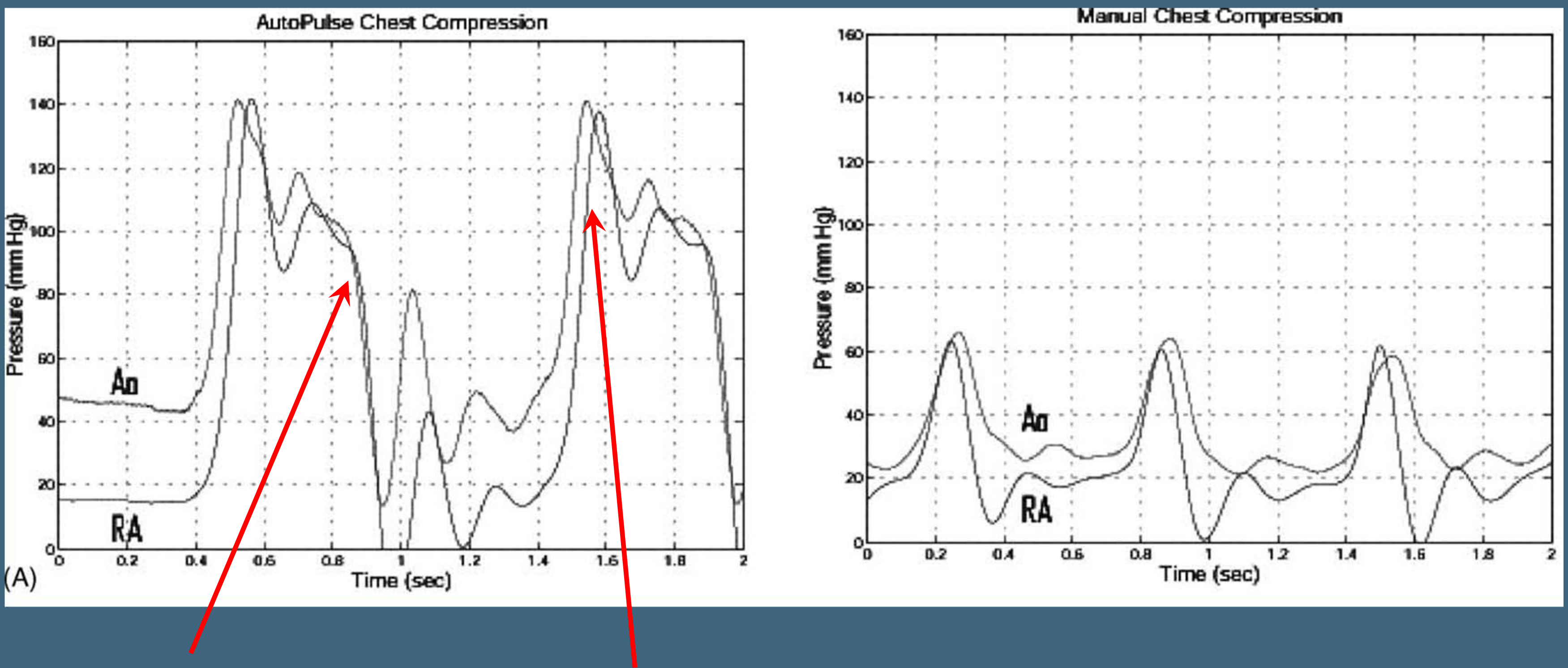
Previous Data on AutoPulse…

Human Hemodynamics Study

Timerman et al. in San Paolo, Brazil

- Objective: to determine if AutoPulse improves hemodynamics compared to conventional CPR
- 16 terminally ill subjects who experienced in-hospital cardiac arrest
- Study initiated after at least 10 minutes of failed ACLS support
- Catheters were placed in the thoracic aorta and right atrium to measure CPP and peak aortic pressure
- AutoPulse and manual compressions were alternated for 90 seconds each

Human Hemodynamics Study



CPP drops quickly when AutoPulse compressions stop

CPP returns after several AutoPulse compressions

During relaxation phase, difference in peak pressure greater in AutoPulse group

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Human Hemodynamics Study

AutoPulse-generated Coronary Perfusion Pressure (CPP) was 33% better than conventional CPR

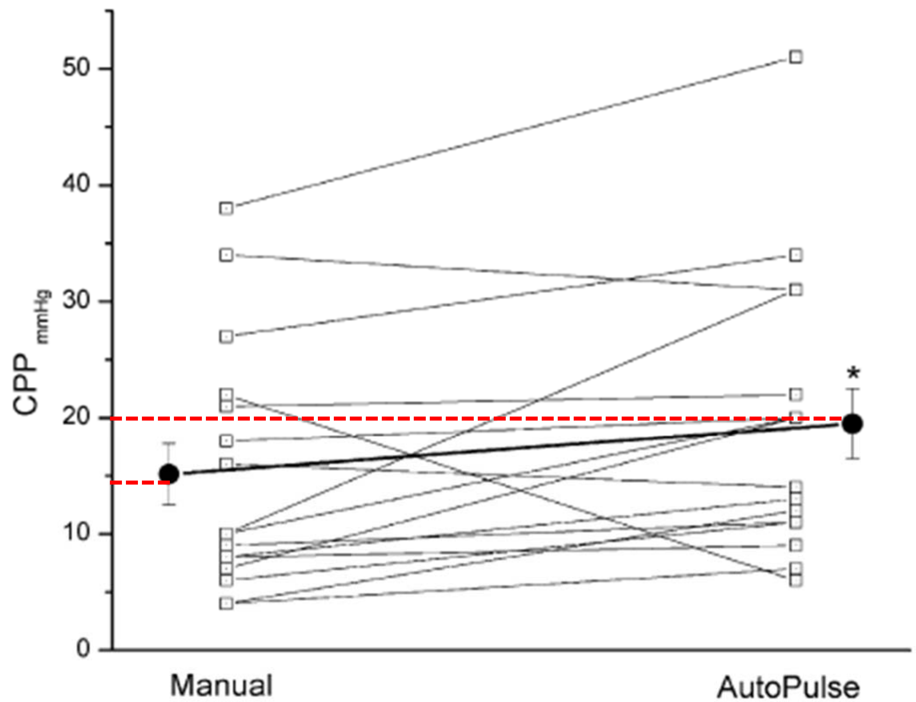


Fig. 4. Coronary perfusion pressure during manual and A-CPR. Each connected pair of squares are data from one patient. Symbols to the left and right of the pressures are means ± S.E. There is a significant increase in vascular pressures with A-CPR (* $P < 0.015$).

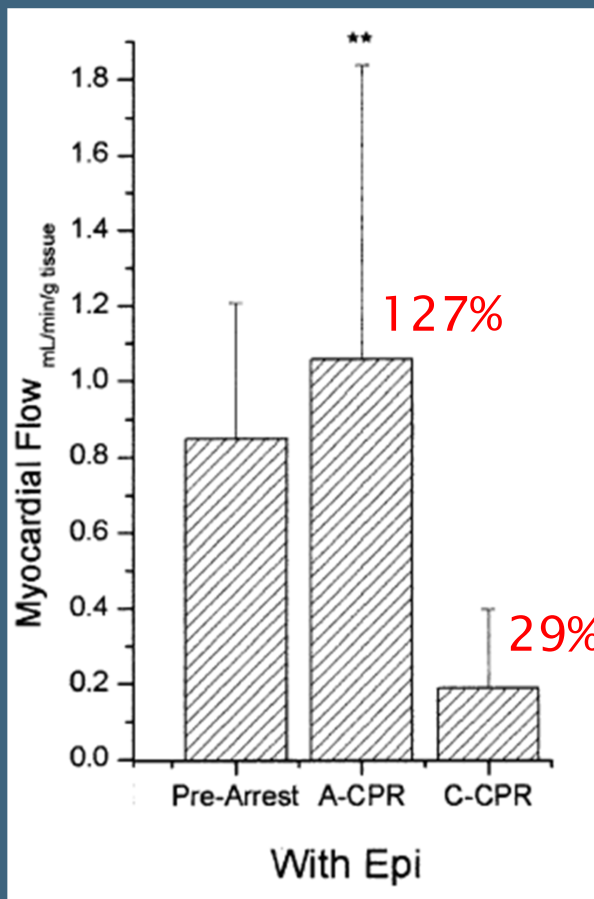
Animal Hemodynamics Study

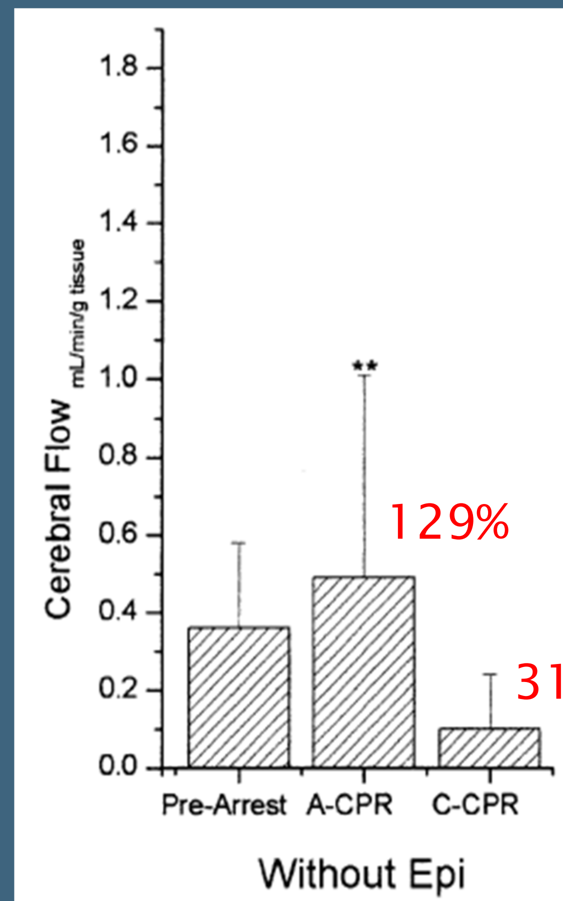
Halperin et al. in Baltimore, Maryland

- Objective: to determine magnitude of HD improvement with AutoPulse compared to conventional CPR
- 20 pigs induced with VF, untreated for one minute
- Catheters placed in right atrium and ascending aorta
- Regional flow measured
- Treatment alternated between conventional CPR ("The Thumper") or AutoPulse for 3 cycles, then manual CPR
- Two arms of study
  - "BLS scenario" – no epinephrine
  - "ALS scenario" – with epinephrine

Animal Hemodynamics Study

AutoPulse produced pre-arrest levels of blood flow to the heart and brain





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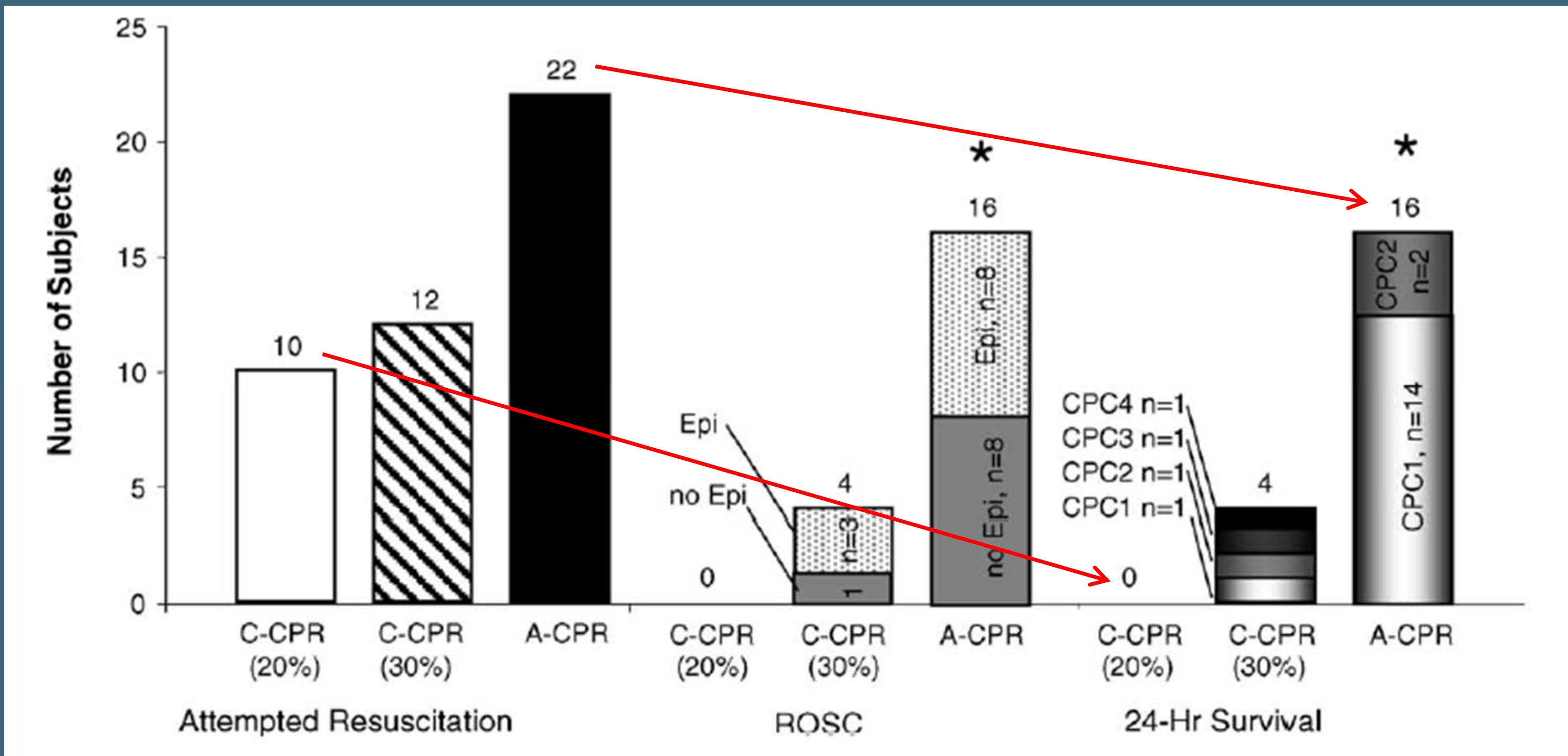
Animal Survival Study

Ikeno et al. at Stanford University

- Objective: to determine efficacy of AutoPulse in improving neurologically intact survival after arrest
- 44 swine – randomized, controlled trial
- Measured right atrial and aortic pressures, ETCO2, and blood flow
- Clinically relevant cardiac arrest model:
  - 8 min untreated VF → 4 min BLS (AutoPulse or conventional CPR) → 4 min ALS (ventilation, defibrillation, epinephrine)
- Swine cerebral performance category score
- Endpoints were ROSC, 24-hour survival and neurologic status at 24-hours

Animal Survival Study

- 73% (16/22) of subjects supported with the AutoPulse returned to normal blood flow and survived – 14/16 normal neurologically
- 0% of the subjects supported with only conventional CPR survived



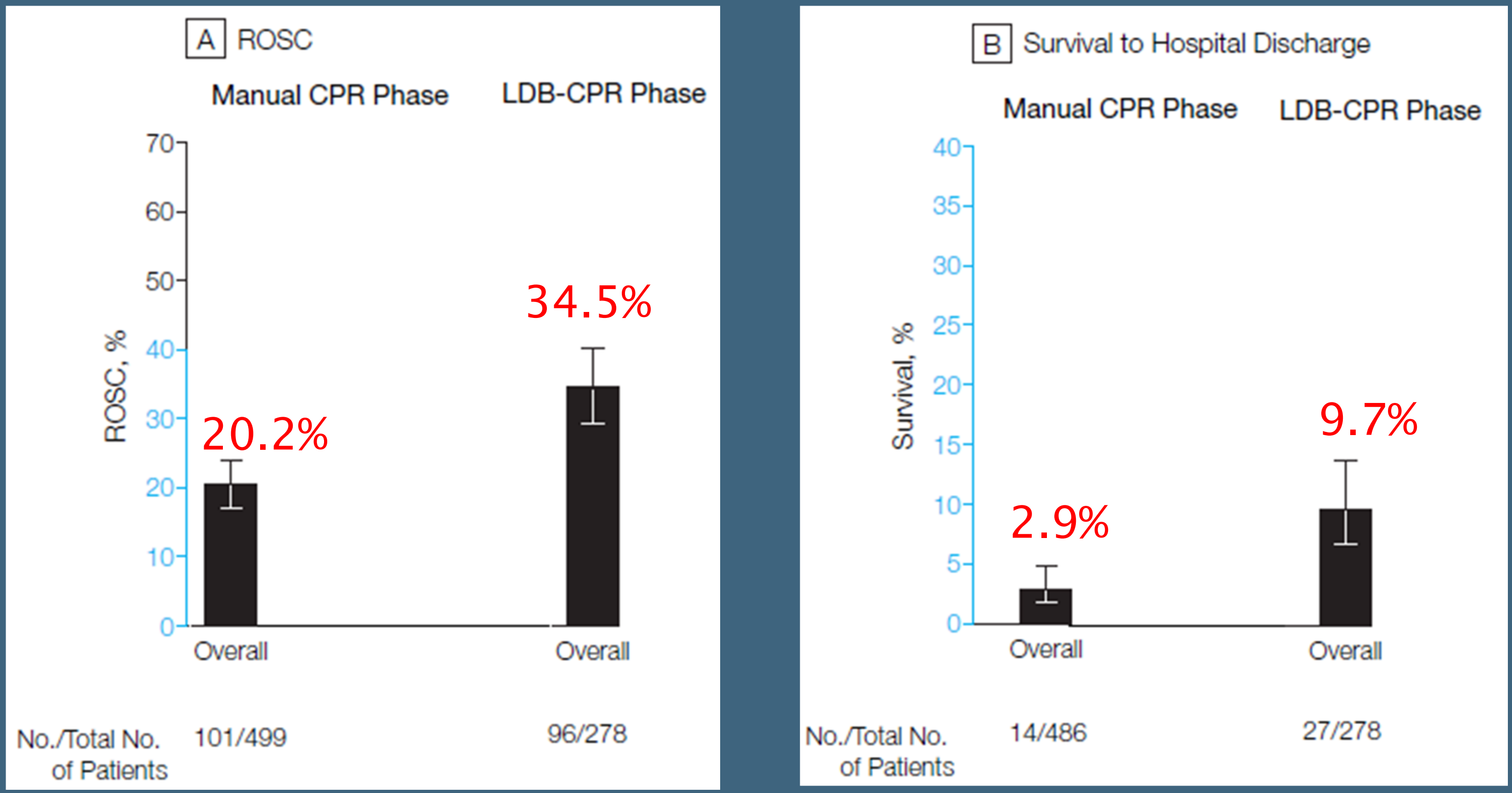
Human Short-Term Survival Study 1

Ong et al. in Richmond, VA

- Objective: to compare resuscitation outcomes before and after urban EMS system implemented AutoPulse
- Phased, observational cohort in 783 adults
  - 499 AutoPulse – CPR
  - 284 manual – CPR
- Primary outcome of ROSC
  - Secondary outcomes of survival to hospital admission and discharge, neurological function at discharge

Human Short-Term Survival Study 1

AutoPulse significantly improved both ROSC and survival to discharge rates compared to conventional CPR



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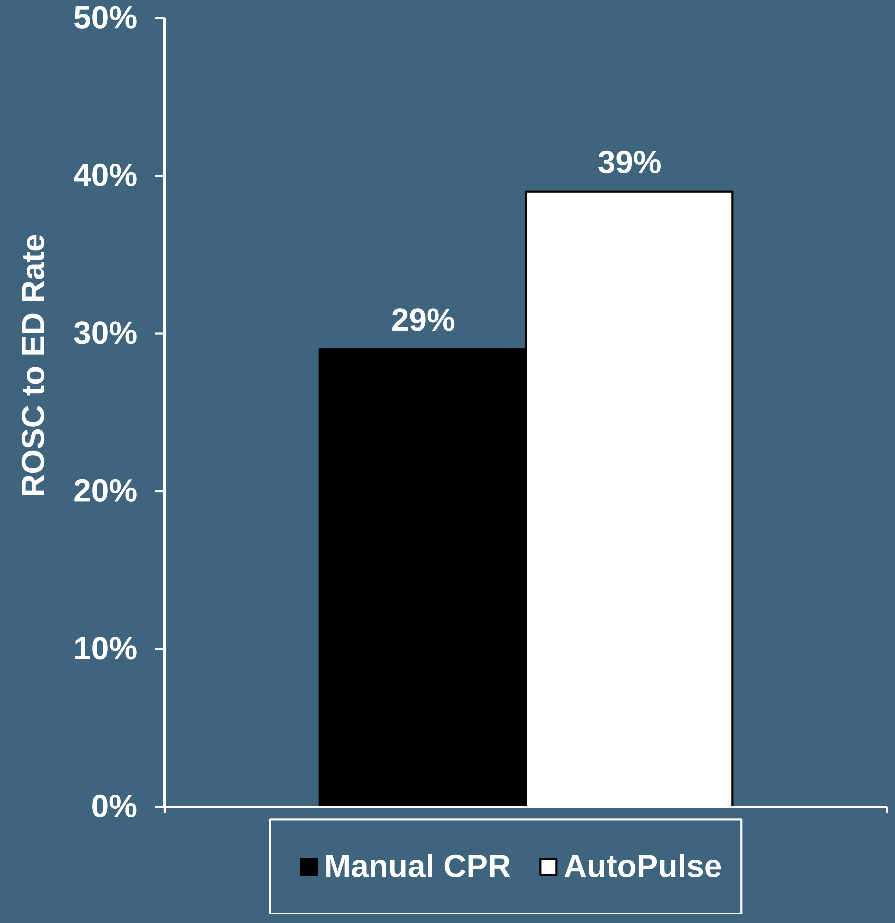
Human Short-Term Survival Study 2

Casner et al. in San Francisco, CA

- Objective: to evaluate new deployment of AutoPulse in the San Francisco EMS system
- Retrospective chart review
- Compared the rate of delivery of 162 patients in ROSC sustained to the ED
  - 93 patients with manual CPR
  - 69 patients with the AutoPulse
- Primary endpoint ROSC on arrival to ED

Human Short-Term Survival Study 2

AutoPulse improved the rate of delivery of patients in ROSC sustained to the ED by 35%



p=0.003

So AutoPulse is exactly what everyone needs.. Right??

AutoPulse Assisted Prehospital International Resuscitation (ASPIRE)

Hallstrom et. Al. multicentre

- Multicentre, randomized, controlled trial for pts experiencing out of hospital cardiac arrest
- 1071 patients
  - 517 manual CPR, 554 AutoPulse CPR
- Primary endpoint survival to 4 hours post 911 call
  - Secondary endpoints survival to hospital discharge, neurological status
- 3 protocol options:
  i. Quick look (<6 s) followed by CPR randomization (A-CPR or C-CPR)
  ii. Manual CPR until first shock, then randomization
  iii. Analysis and shock if appropriate following by CPR randomization

ASPIRE

- Study enrollment was terminated following the first planned interim monitoring (independent board)

	C-CPR (%)	A-CPR (%)
Survival to 4 hrs post 911 call	29.5	28.7 p=0.74
Survival to hospital discharge	9.9	5.8 p=0.06
Grade 1/2 Cerebral Performance Category	7.5	3.1 p=0.006

AHA 2010 Resuscitation Guidelines

- "The load-distributing band (LDB) may be considered for use by properly trained personnel in specific settings for the treatment of cardiac arrest (Class IIb, LOE B). However, there is insufficient evidence to support the routine use of the LDB in the treatment of cardiac arrest"

An AutoPulse study done more locally…

Oxford County Experience

- To evaluate the impact of AutoPulse in patients with an out of hospital cardiac arrest in Oxford County, Canada
- Primary endpoint of the study is patients' ROSC rate on arrival to the emergency department
- Secondary endpoints include scene time, transport time, and survival to hospital discharge

Methods

- Oxford Country is the first Emergency Medical Services (EMS) system in Canada to outfit each ambulance with such a device
- Retrospective chart review
- Ambulance call reports (ACRs) from 2006-2008 were identified
- Patients receiving manual CPR and AutoPulse CPR were compared to determine if implementation of AutoPulse led to increased rates of ROSC upon arrival to the emergency department

Methods

- Information recorded on a structured Excel form
- Data abstractors trained prior to project start
- Interrater reliability of data was obtained by re-abstracting 25% of the charts by a second reviewer
  - This reviewer was blinded to the information obtained by the original reviewer
- Statistical analysis employed to ensure interrater reliability of the data

Unique Study ID: ____________ Hospital chart number (if applicable): ____________

Patient DOB: ____________ Patient gender: ☐ Male ☐ Female

PMHx:

DM ☐ Yes ☐ No ☐ Unknown

HTN ☐ Yes ☐ No ☐ Unknown

CAD ☐ Yes ☐ No ☐ Unknown

CVD ☐ Yes ☐ No ☐ Unknown

Elevated Cholesterol ☐ Yes ☐ No ☐ Unknown

Smoker ☐ Yes ☐ No ☐ Unknown

FHx CAD ☐ Yes ☐ No ☐ Unknown

Complaint recorded on ambulance call report (ACR):

____

Time of 911 call: __________ **Time of ambulance arrival on scene:** __________

Total scene time (min): ____________ **Total transport time (min):** ____________

Type of ambulance crew:
☐ PCP only ☐ ACP only ☐ Both (PCP "backed up" by ACP) ☐ Fire ☐ Police ☐ Unknown

Bystander CPR: ☐ Yes ☐ No ☐ Unknown

1st responders (Fire/Police): ☐ Yes ☐ No ☐ Unknown

EMS witnessed arrest: ☐ Yes ☐ No ☐ Unknown

Initial rhythm: ☐ VF ☐ VT ☐ AS ☐ PEA ☐ Unknown

AutoPulse used: ☐ Yes ☐ No ☐ Unknown

Time of manual CPR start: __________ **Time for AutoPulse CPR start:** __________

ROSC (upon ED arrival): ☐ Yes ☐ No ☐ Unknown

Survival to hospital discharge: ☐ Yes ☐ No ☐ Unknown

Results

Patient Demographics

Kappa=0.983

	Manual CPR (n=104)	AutoPulse (n=52)
Mean (SD) age	65.6 (19.6)	67.9 (13.1)
Male	77.4%	71.7%
Comorbidities		
DM	11.5%	18.8%
HTN	14.6%	25.0%
CAD	51.0%	45.8%
CVD	7.3%	0%
Chol	3.1%	4.2%
Smoker	3.1%	4.2%

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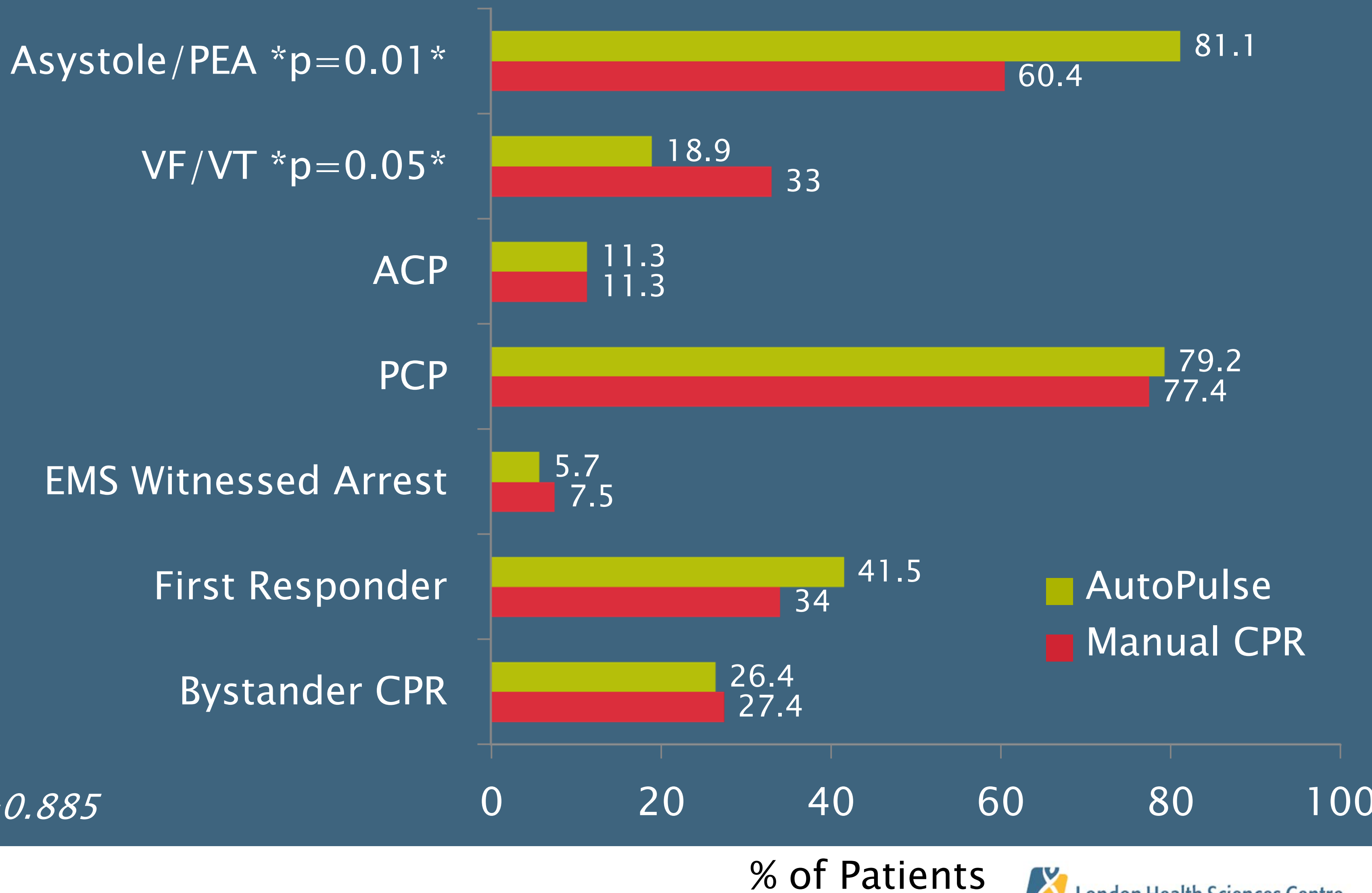
Results



Kappa=0.885

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Results

	Manual CPR (n=104)	AutoPulse (n=52)	Effect Size (95% CI)	p-value
Mean (SD) time to AutoPulse setup (minutes)	n/a	5.8 (4.9)		
Mean (SD) time to start of manual CPR (minutes)	2.4 (8.4)	1.6 (3.2)	0.83 (-1.7, 3.4)	0.52
Mean (SD) time on scene (minutes)	17.6 (8.8)	16.3 (6.6)	1.3 (-1.4, 4.0)	0.35
Mean (SD) time to hospital transport (minutes)	6.7 (6.1)	7.8 (6.2)	-1.1 (-3.2, 0.9)	0.28

Results

	Manual CPR	AutoPulse	p-value	Odds Ratio (95% CI)
ROSC	5/104 (4.8%)	8/52 (15.1%)	0.03	3.5 (1.1, 11.4)
Survival to hospital discharge	4/103 (3.9%) 1 patient outcome unknown	2/51 (3.9%) 1 patient outcome unknown	1.0	1.0 (0.2, 5.7)

Conclusions

- AutoPulse led to a significant (3-fold) increase in proportion of patients who achieved ROSC on arrival to an ED
- AutoPulse did not affect length of time to beginning CPR, time on scene, or transport time
- There was no significant difference in the proportion of patients who survived to hospital discharge

Limitations

- Retrospective nature of the data
- Differences amongst of the groups with respect to presenting rhythm
- Two patients lost to follow up
- AutoPulse was used inconsistently even though each ambulance is outfitted with a unit
  - Size, weight, malfunction, preference?
- Further evaluation required before widespread use

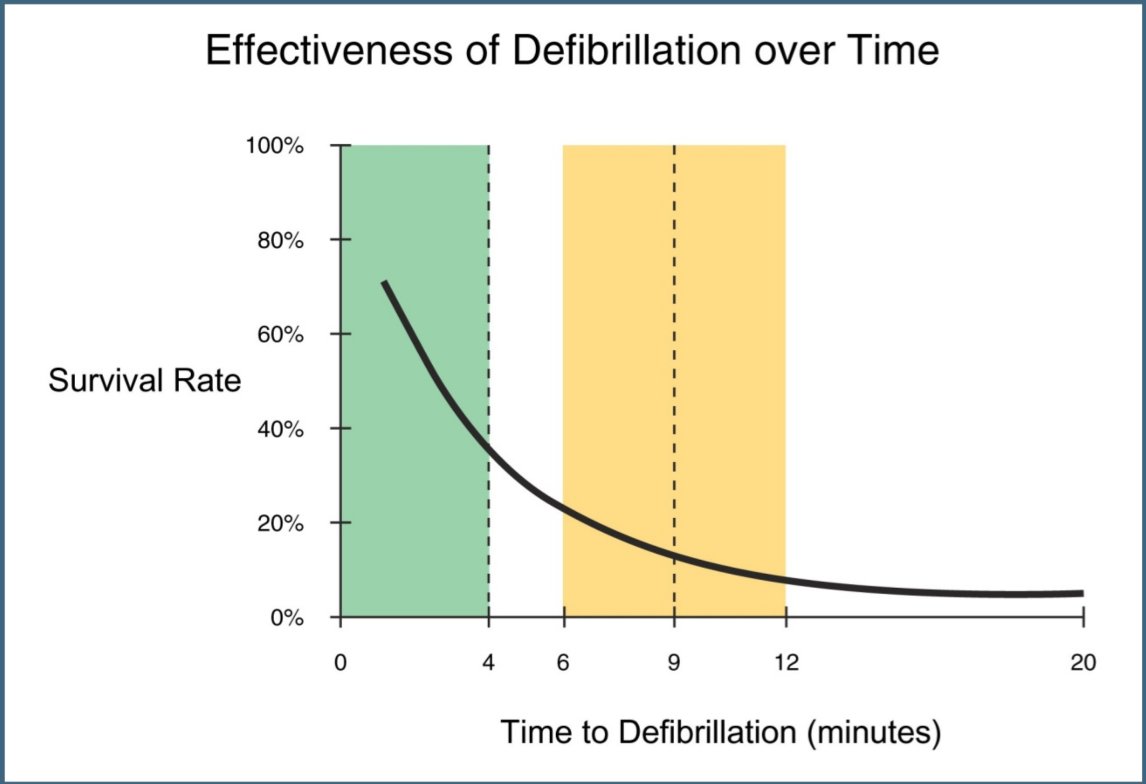
Combining what we know about good quality CPR and defibrillation…

Simultaneous CPR and Defibrillation

- Pauses for shock delivery in chest compressions are detrimental to the success of resuscitation
- Mechanical CPR/defibrillation devices have the potential to cut out the delays
- Optimal phasic relationship between chest compressions and defibrillation is unknown
- Two recent studies using an animal model of arrest with manual and automated CPR explored this relationship

Effectiveness of Defibrillation

Defibrillation is most effective during the first few minutes after cardiac arrest



"Prime the pump" – (JAMA 2003) patients with ventricular fibrillation and ambulance response intervals longer than 5 minutes had better outcomes with CPR first before defibrillation was attempted

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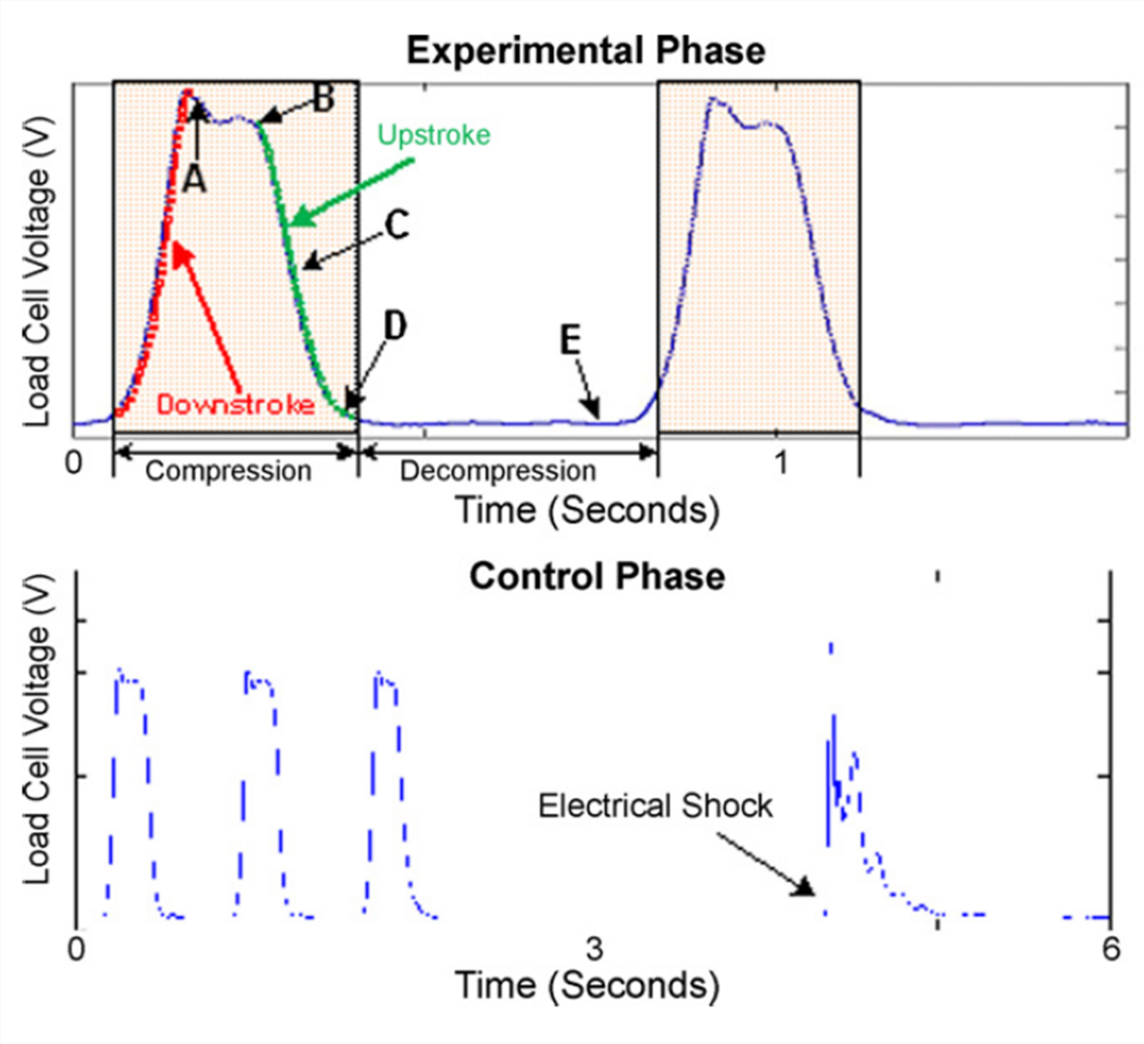
Resuscitation 2010

Li et. Al. California

- Randomized, controlled trial in 8 domestic pigs
- VF electrically induced and untreated for 10 seconds
- Mechanical CPR was then performed for 25 seconds using AutoPulse
- Followed by biphasic electrical shock delivered randomly in 1 of 6 coupling phases
- Control phase was 2 seconds following discontinued CPR

Resuscitation 2010



Resuscitation 2010

- Success rate increased by 23.7% when shocks delivered in the later upstroke phase

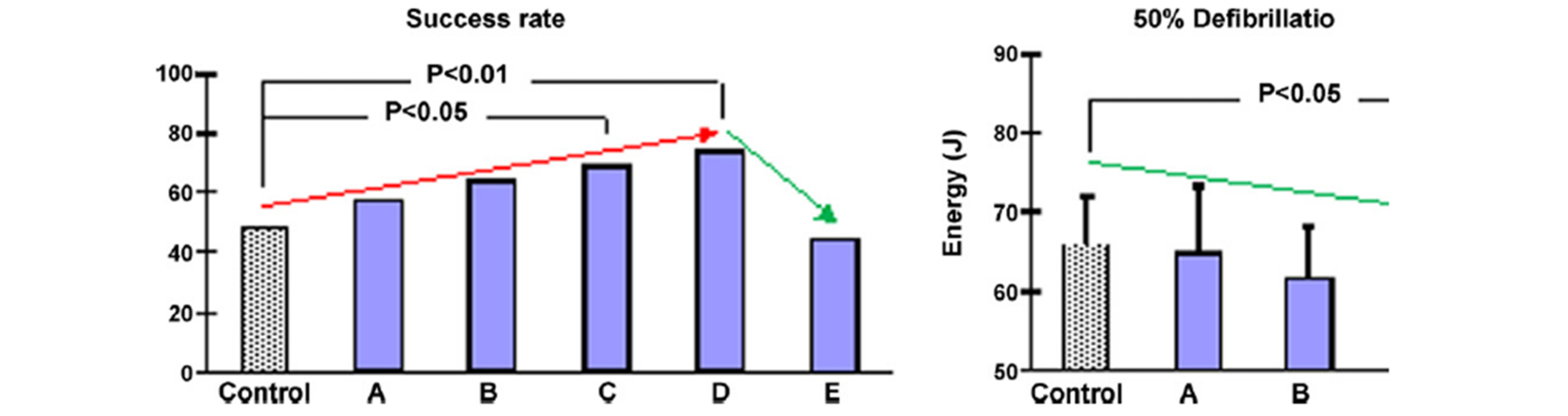


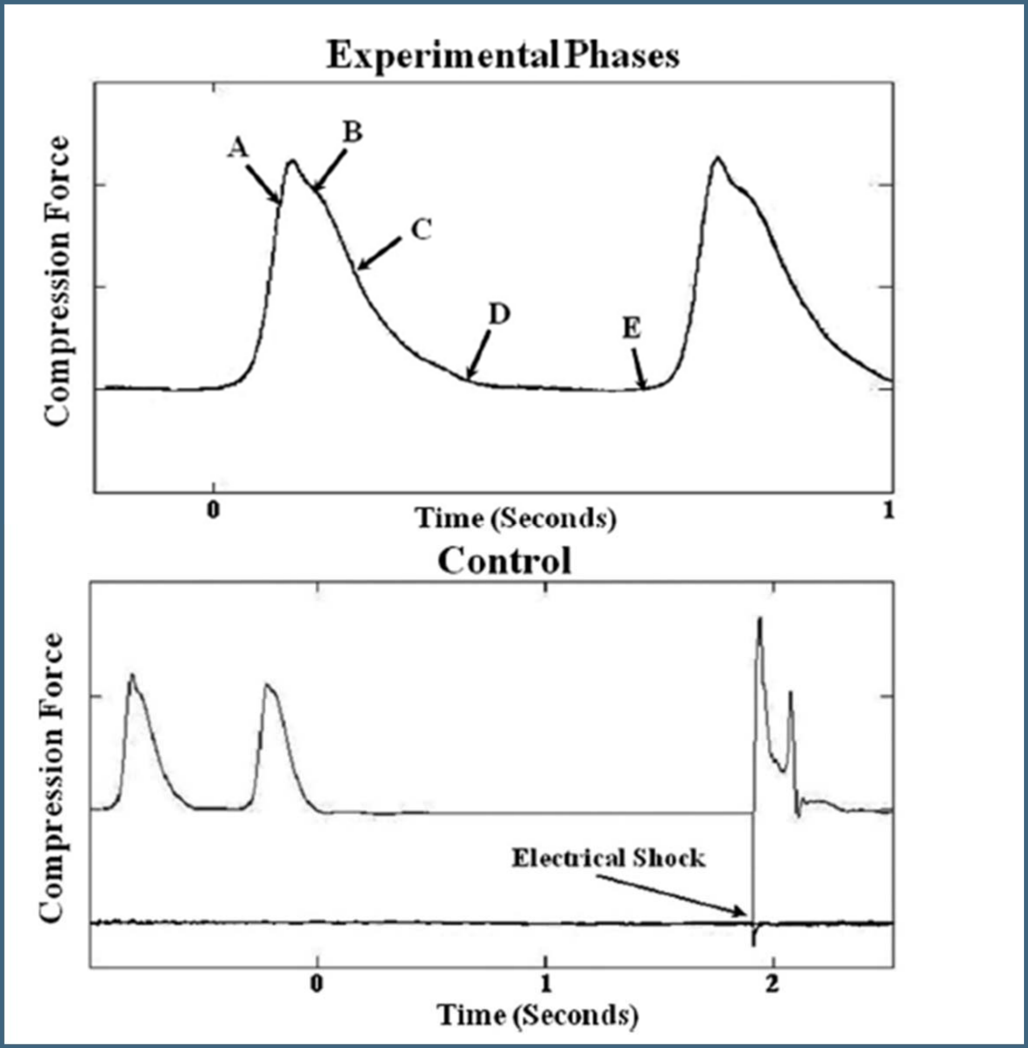
Fig. 2. The primary experimental results based on various intervals of defibrillation during uninterrupted compression. Phases A–E refers to legend of Fig. 1.

Critical Care Medicine 2010

Li et. al. California

- Prospective, randomized controlled study
- 8 domestic pigs
- VF electrically induced and untreated for 10 seconds
- Manual CPR done for 25 seconds with protection of an isolation blanket
- Biphasic electric shock delivered in 1 of 6 different coupling phases
- Control was 2 seconds after compressions discontinued

Critical Care Medicine 2010



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Critical Care Medicine 2010

- 21% increase in defibrillation success rate during upstroke phase of CPR compared to control

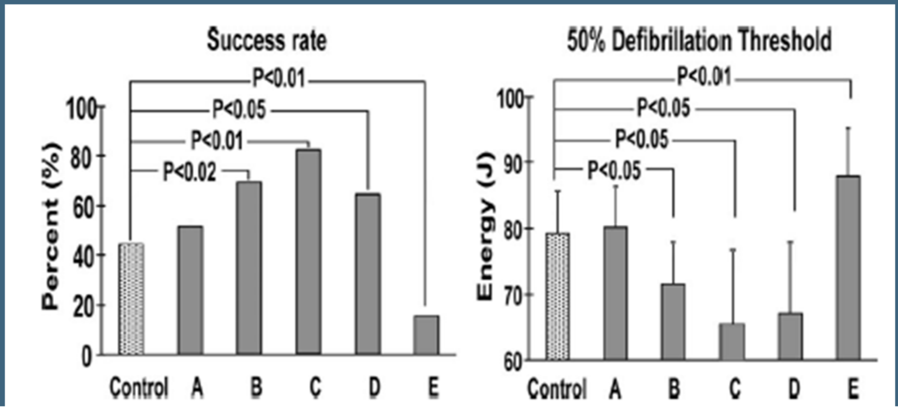

Table 3. Experiment results based on pooled data in upstroke phases

Parameters	Control	Downstroke (Phase A)	Upstroke (Phases B + C + D)	Precompression (Phase E)
		Experimental Phases		
Number of shocks	39	39	108	39
CPP, mm Hg	31.8 ± 13.7 (27.4–36.2)	29.8 ± 11.7 (26.0–33.6)	31.7 ± 14.0 (29.0–34.4)	31.4 ± 13.5 (27.0–35.8)
Voltage, V	566 ± 78 (541–591)	592 ± 84 (565–619)	595 ± 81 (580–610)	575 ± 83 (548–602)
Energy, J	63.4 ± 15.6 (58.3–68.5)	65.4 ± 16.2 (60.1–70.7)	65.9 ± 16.0 (62.8–69.0)	64.0 ± 16.1 (58.8–69.2)
Current, A	13.9 ± 1.9 (13.3–14.5)	13.5 ± 1.9 (12.9–14.1)	13.5 ± 1.8 (13.2–13.8)	13.8 ± 1.9 (13.2–14.4)
Impedance, Ohm	40.7 ± 2.9 (39.8–41.6)	44.1 ± 3.3[a] (43.0–45.2)	44.3 ± 3.8[a] (43.6–45.0)	42.0 ± 3.9 (40.7–43.3)
Success rate, %	44	51	65[a]	15[a]
50% DFT, J	79.1 ± 6.7 (73.5–84.7)	80.3 ± 6.2 (75.1–85.5)	68.1 ± 10.2[a] (59.6–76.6)	88.0 ± 7.3[b] (81.9–94.1)

CPP, coronary perfusion pressure; DFT, defibrillation threshold.
[a]Compared with control, $p < .01$; [b]compared with control, $p < .05$.

Conclusions

- Good quality CPR and a minimization of its interruptions are vital to successful outcomes
- Automated devices such as AutoPulse have the potential to provide both these conditions.. However the evidence is weak/contradictory
- Defibrillation can be performed during ongoing CPR and initial work supports its use during the upstroke phase of chest compressions