

First Steps in Resuscitation Field to Emergency Department

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Disclosures

- NHLBI, Bethesda, MD; Co-PI, Resuscitation Outcomes Consortium Data Coordinating Center.
- NHLBI, Bethesda, MD; PI, Randomized Trial of Hemofiltration After Resuscitation from Cardiac Arrest.
- NHLBI, Bethesda, MD; Co-I, Randomized Field Trial of Cold Saline IV After Resuscitation from Cardiac Arrest.
- Asmund S. Laerdal Foundation for Acute Medicine Stavanger, NO; PI, Randomized Trial of CPR Training Aid in Community.
- Medtronic Foundation, Minneapolis, MN; PI, Cascade HeartRescue Program.
- Sotera Wireless, San Diego, CA; Research Collaborator.
- Gambro Renal Inc., Denver, CO; Research Collaborator.
- Lifebridge North America Inc., San Antonio, TX; Research Collaborator.
- American Heart Association, Dallas, TX; Travel Expenses.



What Is A Cardiac Resuscitation System of Care?

System

Meadows Thinking in Systems 2008

- **Interconnected** set of **elements** that is coherently organized in a way to **achieve something**.

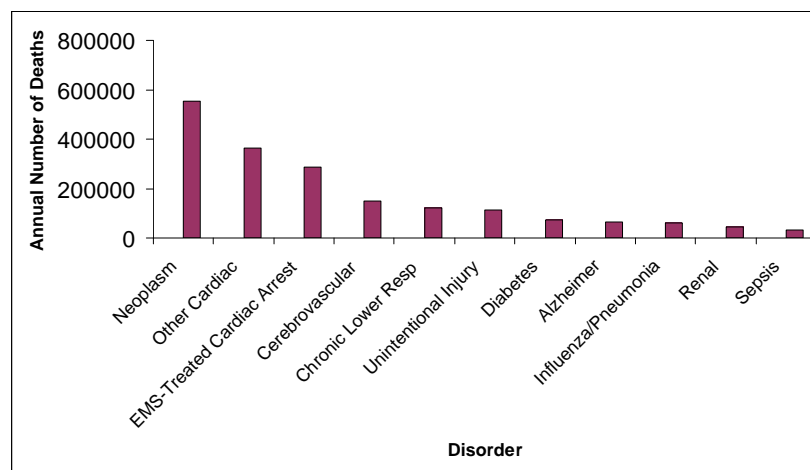
Cardiac Resuscitation System of Care

Nichol Circulation 2010

- **Interconnected community, EMS and hospital** response to out-of-hospital cardiac arrest that is coherently organized to **improve processes and outcome in a region.**

Leading Causes of Death in U.S

Extrapolated from Nichol JAMA 2008 and www.cdc.gov



EMS-Assessed Cardiac Arrest

Nichol JAMA 2008

	Alabama (n=715)	Dallas (n=2,462)	Iowa (n=1,028)	Ottawa (n=2,965)	Pittsburgh (n=1,217)	Portland (n=1,320)	Seattle and KC (n=2,349)	Toronto (n=5,155)	Vancouver (n=2,373)	Overall(n= 19,584)
Incidence, per 100,000	106.7	159.0	93.1	71.8	105.1	77.5	144.0	96.8	75.9	95.0
Survival, %	1.1	2.4	6.1	3.3	3.3	6.5	8.1	3.2	6.7	4.4
Missing VS, %	2.0	1.5	1.2	0.7	0.3	1.5	0.1	0.4	1.2	0.8

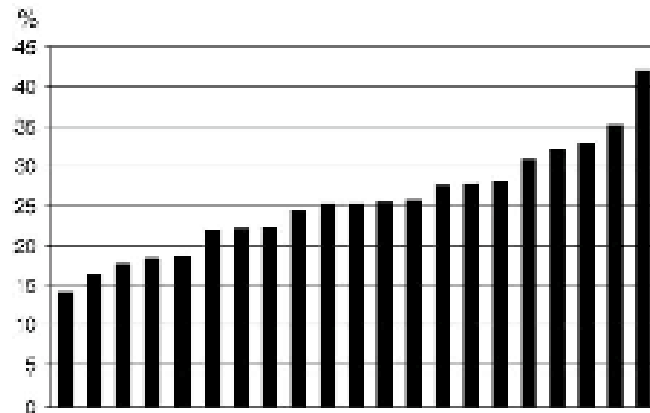
Ventricular Fibrillation

Nichol JAMA 2008

	Alabama (n=267)	Dallas (n=1,265)	Iowa (n=565)	Milwaukee (n=801)	Ottawa (n=1,836)	Pittsburgh (n=575)	Portland (n=793)	Seattle and KC (n=1,170)	Toronto (n=2,992)	Vancouver (n=1,634)	Overall (n=11898)
Incidence, per 100,000	9.9	12.8	12.4	18.7	10.4	9.3	15.1	19.0	11.4	15.2	12.8
Survival, %	7.7	9.5	22.7	26.0	14.8	21.5	22.5	39.9	15.7	25.0	21.0
Missing VS, %	3.1	7.9	4.4	0	2.1	1.0	3.6	0.3	1.3	3.3	2.5

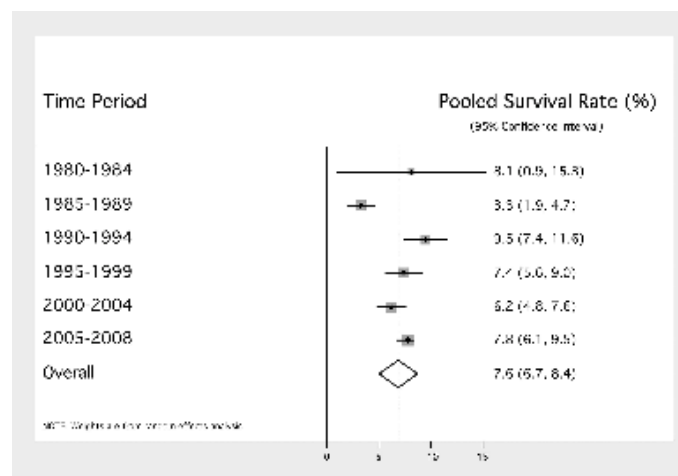
Survival from Admission to One Month

Herlitz Resuscitation 2006



Survival After OOHCA Over Time

Sasson Circ Cardiovasc Qual Outcomes 2010



- Out-of-hospital cardiac arrest is major public health problem.
- Large variation in survival.
- Treatable condition.
- Outcomes have not improved in many communities over time.

Wake County, NC

Hinchey Ann Emerg Med 2010

- Multiphase before-after study
 - Baseline
 - CPR with C:V ratio 15:2
 - Stacked shocks
 - “New” CPR
 - Early intubation deemphasized
 - Minimal interruption in compressions
 - Defibrillation with single rather than stacked shocks
 - Control of ventilation rates
 - Intraosseous vascular access
 - Impedance threshold device
 - Field hypothermia

Wake County, NC

Hinchey Ann Emerg Med 2010

Characteristics	Baseline (N=425)	Phase 1 (N=369)	Phase 2 (N=161)	Phase 3 (N=410)	Absolute Increase* % (95% CI)
Survival outcome					
Any ROSC	105 (24.7)	148 (40.1)	66 (41.0)	178 (43.4)	18.7 (12.4 to 25.0)
Pulse on ED arrival	98 (23.1)	136 (36.9)	52 (32.3)	138 (33.7)	10.6 (4.5 to 16.7)
Admitted to hospital	55 (12.9)	65 (17.6)	31 (19.3)	121 (29.5)	16.6 (11.2 to 22.0)
Discharged from hospital	18 (4.2)	27 (7.3)	13 (8.1)	47 (11.5)	7.3 (3.7 to 10.9)
Survivors' CPC score	n=14	n=25	n=12	n=47	
1 and 2	11 (78.6)	19 (76.0)	10 (83.3)	36 (76.6)	-2.0 (-26.6 to 22.7)
3 and 4	3 (21.4)	6 (24.0)	2 (16.7)	11 (23.4)	2.0 (-22.7 to 26.6)

ROSC, Return of spontaneous circulation; CPC, cerebral performance category.
All data are presented as No. (%) survivors unless otherwise noted.

*Absolute increase and 95% CI for comparison between baseline and phase 3 (full implementation). CPC 1 and 2 denote "good" and "moderate" cerebral performance; 3 and 4 denote "poor" and "vegetative" cerebral performance; 5 denotes "brain death" and thus is not represented.

Patient Volume vs. Outcome for Cardiac Arrest

Callaway Annals of Emerg Med 2010

Annual Volume of Patients Received	Number of Hospitals	Survival to Discharge (%)	Adjusted Odds of Death (95% CI)
1-9	103	28.7	Reference
10-19	55	30.8	0.85 (0.65, 1.12)
20-29	23	32.6	0.89 (0.65, 1.21)
30-39	11	28.3	1.04 (0.75, 1.45)
≥ 40	11	37.3	0.91 (0.67, 1.25)

Adjusted for patient factors (witnessed collapse, initial rhythm, and age) and hospital factors (cath capability)

Randomized Trials of Regionalized STEMI Care

Adapted from Nichol Circulation 2010

AUTHOR STUDY DESIGN	POPULATION	INTERVENTION	COMPARATOR	ALTERNATIVE COMPARATOR
Vermeer Individual randomized trial in 1 province, Netherlands	AMI, presenting at hospitals not capable of PPCI	Transfer for PPCI (n=75) Symptoms to therapy 240 ± NR Door to balloon NR Death ^a 7% Recurrent infarct ^a 1% Stroke ^a 3%	Fibrinolytic in non-PCI hospital (n=75) Symptoms to therapy 135 ± NR Door to balloon NR Death ^a 7% Recurrent infarct ^a 9% Stroke ^a 3%	Fibrinolytic with transfer; rescue PCI if indicated (n=74) Symptoms to therapy 255 ± NR Door to balloon NR Death ^a 8% Recurrent infarct ^a 5% Stroke ^a 4%
Widimsky Individual randomized trial in 1 province, Czech Republic	AMI, presenting within 6 h of symptom onset at hospitals not capable of PPCI	Immediate transfer for PPCI (n=101) Symptoms to therapy 215 ± NR Door to balloon NR Death ^b 7% Recurrent infarct ^b 1% Stroke ^b 0%	Fibrinolytic therapy in non-PCI hospitals (n=99) Symptoms to therapy 132 ± NR Door to balloon NR Death ^b 14% Recurrent infarct ^b 10% Stroke ^b 1%	Fibrinolytic therapy during transport for PCI (n=100) Symptom to therapy 220 ± NR Door to balloon NR Death ^b 12% Recurrent infarct ^b 7% Stroke ^b 3%
Andersen Individual randomized trial in Denmark	AMI with ST elevation presenting at hospital not capable of PPCI	Transfer for angioplasty within 3 h (n=567) Symptoms to therapy 227±NR Door to balloon 26 Death ^b 7% Recurrent infarct ^b 2% Stroke ^b 2%	Fibrinolysis at referral hospital (n=562) Symptoms to therapy 150±NR Door to therapy NR Death ^b 9% Recurrent infarct ^b 6% Stroke ^b 2%	N/A

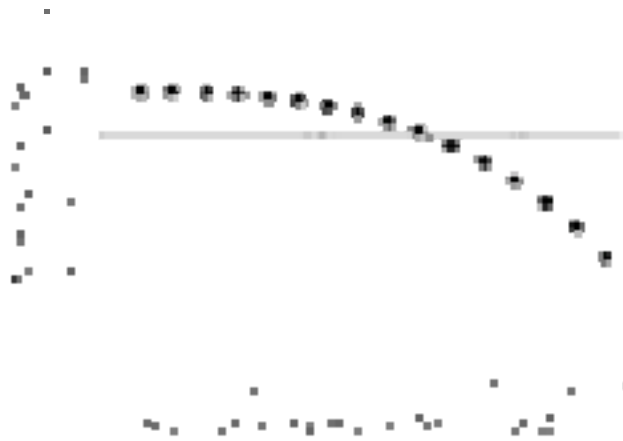
Randomized Trials of Regionalized STEMI Care

(continued)

AUTHOR STUDY DESIGN	POPULATION	INTERVENTION	COMPARATOR	ALTERNATIVE COMPARATOR
Grines Individual randomized trial in US and Europe	High-risk AMI with ST elevation or presumed new left bundle branch block <12h	Transfer for PPCI (n=71) Symptoms to therapy NR Door to balloon 174 ± 80 Death ^a 8% Recurrent infarct ^a 1% Stroke ^a 0%	Fibrinolytic therapy (n=66) Symptoms to therapy NR Door to therapy 63 ± 39 Death ^a 12% Recurrent infarct ^a 0% Stroke ^a 4%	N/A
Bonnefoy Individual randomized trial in France	Patients with STEMI presenting to EMS within 6 h of symptom onset	Primary PCI (n=421) Symptoms to therapy NR Death ^b 5% Recurrent infarct ^b 2% Stroke ^b 0%	Prehospital fibrinolysis (n=419) Symptoms to therapy NR Death ^b 4% Recurrent infarct ^b 4% Stroke ^b 1%	N/A
Widimsky Individual randomized trial in Czech Republic	Patients with STEMI within 12 h of symptom onset presenting to non-PCI-capable hospital	Immediate transfer for primary PCI (n=429) Symptoms to therapy 203 ± NR Death ^b 7% Recurrent infarct ^b 1% Stroke ^b 0%	Fibrinolytic in community hospital (n=421) Symptoms to therapy 185 ± NR Death ^b 10% Recurrent infarct ^b 3% Stroke ^b 2%	N/A

Trauma Systems of Care

Nathens JAMA 2001



Trauma Systems of Care

Nathens JAMA 2000



- Direct and indirect evidence that regional cardiac resuscitation systems of care will improve outcome
- Effects
 - Take time to develop
 - Depend on patient volume

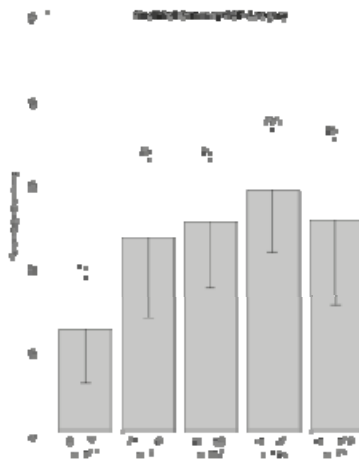


**How Can We Improve Field Care for
Out-of-Hospital Cardiac Arrest?**

Improve Manual CPR!

Chest Compression Fraction During First CPR by EMS

Christenson Circulation 2009



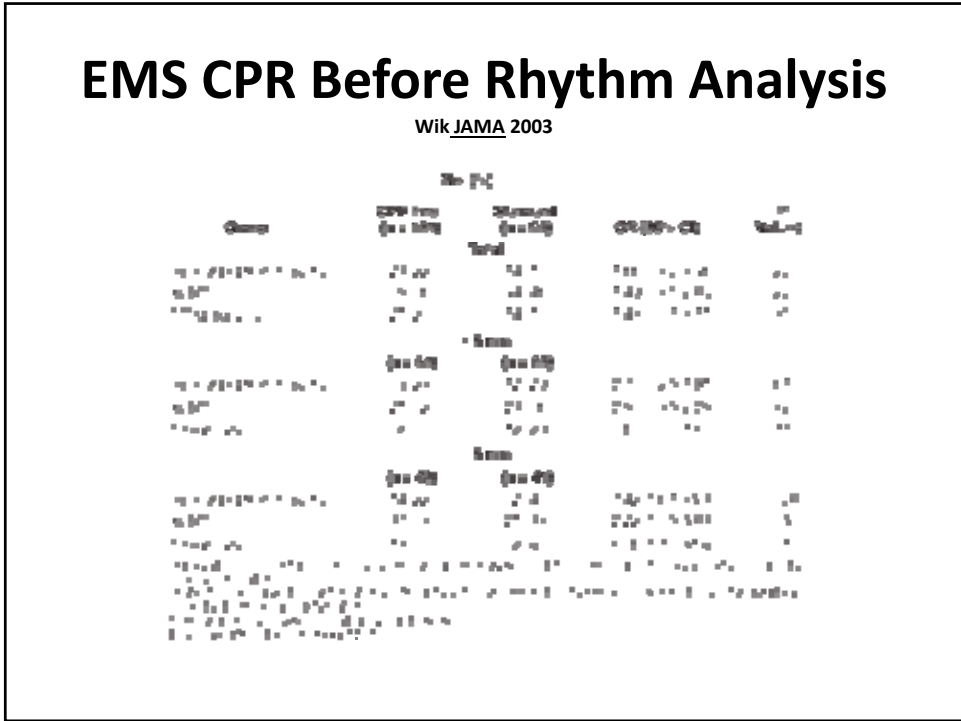
EMS CPR Before Rhythm Analysis

Cobb JAMA 1999



EMS CPR Before Rhythm Analysis

Wik JAMA 2003



EMS CPR Before Rhythm Analysis

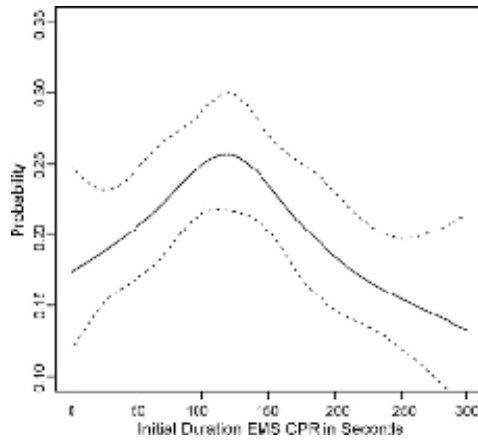
Bradley Resuscitation 2010

Initial CPR duration (s)	≤45	46-75	76-105	106-135	136-165	166-195	196-225	226-255	256-285	286-315
Directed, n	210	177	158	308	203	173	93	102	31	00
Survived to discharge (%)	17.6	23.1	24.7	23.1	26.6	21.4	15.1	15.1	9.4	18.3
Adjusted OR of survival in logistic regression model ^a (95% CI)	Reference	1.15 (0.71, 1.87)	1.37 (0.80, 2.35)	1.51 (0.96, 2.45)	1.24 (0.71, 2.15)	1.47 (0.85, 2.52)	0.55 (0.47, 1.81)	0.91 (0.46, 1.79)	0.46 (0.17, 1.29)	1.29 (0.59, 2.85)
Adjusted OR of survival in multivariable effects model ^b (95% CI)	Reference	1.19 (0.73, 1.92)	1.43 (0.81, 2.47)	1.54 (0.97, 2.40)	1.34 (0.77, 2.33)	1.47 (0.85, 2.52)	0.58 (0.48, 2.02)	0.93 (0.46, 1.83)	0.47 (0.17, 1.35)	1.30 (0.59, 2.90)

^aAdjusted for age, sex, race, season, and time of day. ^bAdjusted for age, sex, race, season, time of day, and initial rhythm.

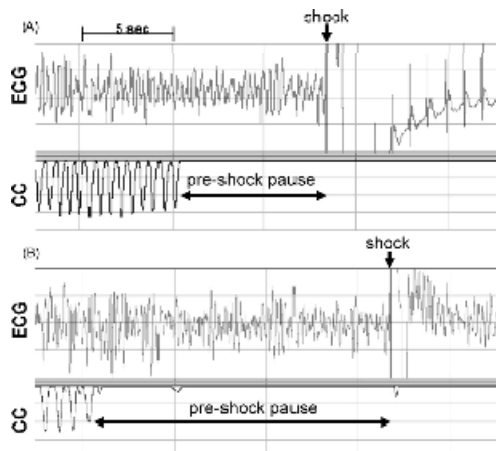
EMS CPR Before Rhythm Analysis

Bradley Resuscitation 2010



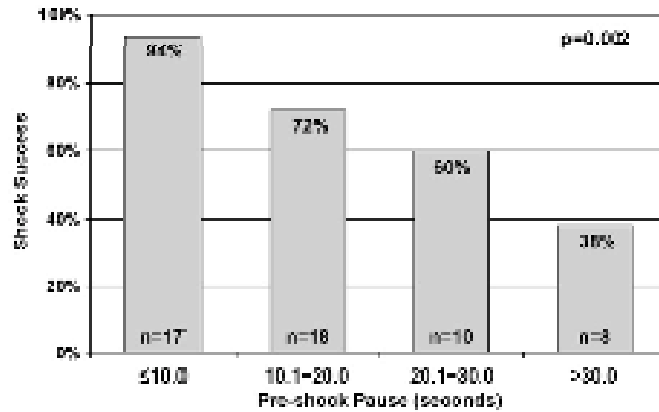
Preshock Pause

Edelson Resuscitation 2008



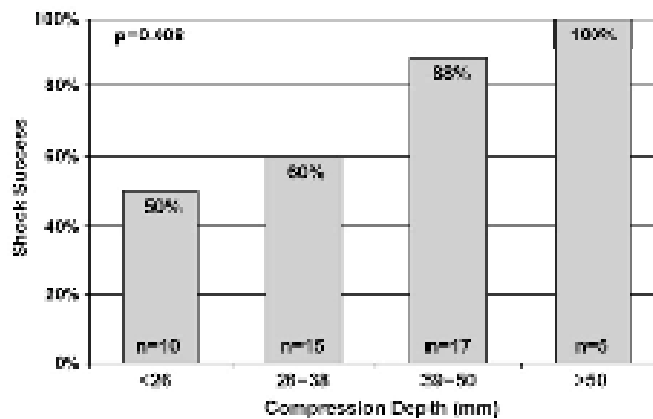
Preshock Pause

Edelson Resuscitation 2008



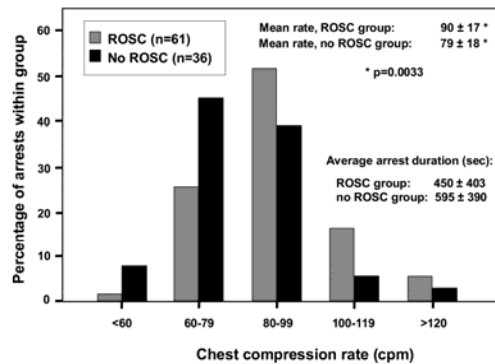
Compression Depth

Edelson Resuscitation 2008



Chest Compression Rate

Abella Circulation 2005



**Use Single Rather
than Stacked Shocks!**

Shock to Perfusing Rhythm

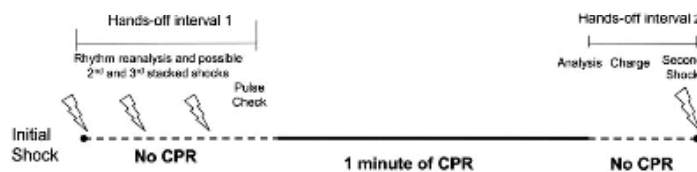
Sunde Resuscitation 1999

- Observational study of out-of-hospital cardiac arrest in Norway (n=156 patients, 883 shocks).
- Pulse generating rhythm regardless of duration after shock:
 - 90 shocks (10%) in 51 patients had any ROSC;
 - 35 (4%) had sustained ROSC after shock;
 - 14 after first shock
 - 2 after second shock
 - 3 after third

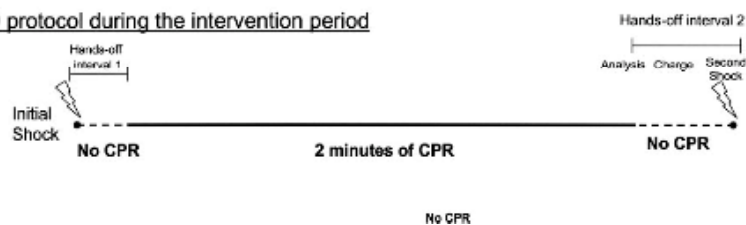
Single versus Stacked Shock

Rea Circulation 2006

AED protocol during the control period



AED protocol during the intervention period



Single versus Stacked Shock

Rea Circulation 2006

	Control Period 2002-2004	Intervention Period 2005-2007
Outcome	10.1%	11.3%
Number of patients who survived	121	131
Number of shocks	121	131
Number of shocks per patient	1.0	1.0

Values are n (%)

**Ignore Manual Compression
Devices!**

Mechanical Compressions Using Load-Distributing Band Device

Ong JAMA 2006

	Standard CPR		LDB CPR		All Patients (n=210)	
	No. of Patients	% 90% CR	No. of Patients	% 90% CR	Unadjusted	Adjusted
Survived to hospital admission	18	18.1%	38	18.1%	18.1%	18.1%
Survived to hospital discharge	12	5.7%	12	5.7%	5.7%	5.7%

Of 210 patients in whom LDB device was applied,
 38 patients (18.1%) survived to hospital admission (95% CI 13.4%, 23.9%)
 12 patients (5.7%) survived to hospital discharge (95% CI, 3.0%, 9.3%).

Mechanical Compressions Using Load-Distributing Band Device

Hallstrom JAMA 2006

	Standard CPR		Patients Without Activity		Any-Tab		All Patients (n=100)	
	Mean CPR (n=100)	Mean CPR (n=100)	Mean CPR (n=100)	Mean CPR (n=100)	Mean CPR (n=100)	Mean CPR (n=100)	Mean CPR (n=100)	Mean CPR (n=100)
Survived to hospital admission	18	18.1%	38	18.1%	38	18.1%	38	18.1%
Survived to hospital discharge	12	5.7%	12	5.7%	12	5.7%	12	5.7%

Mechanical Compressions Using Load-Distributing Band Device

Hallstrom JAMA 2006

APPROXIMATE TO UNLOADING

	Unassisted CPR (50% CPT)	P Value	Unassisted CPR (50% CPT)	P Value
Survival to discharge	10 (10%)	0.001	20 (20%)	0.001
Survival to hospital discharge	10 (10%)	0.001	20 (20%)	0.001
Survival to 30 days	10 (10%)	0.001	20 (20%)	0.001
Survival to 90 days	10 (10%)	0.001	20 (20%)	0.001
Survival to 180 days	10 (10%)	0.001	20 (20%)	0.001
Survival to 360 days	10 (10%)	0.001	20 (20%)	0.001
Survival to 720 days	10 (10%)	0.001	20 (20%)	0.001
Survival to 1440 days	10 (10%)	0.001	20 (20%)	0.001

Consider Continuous Chest Compressions?

Minimally Interrupted Cardiac Resuscitation by EMS

Bobrow JAMA 2008

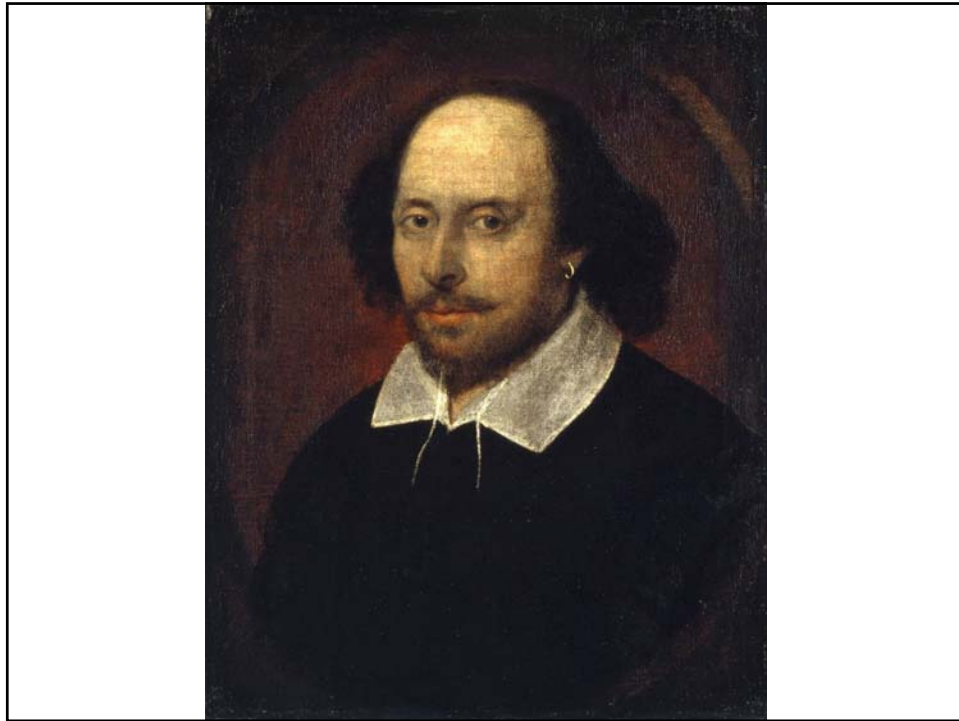
Continuous compressions, passive or positive pressure ventilation, early use of epinephrine, deferred use of advanced airway

Outcome	Adjusted Odds Ratio (95% CI)	
	Continuous Compressions	Standard EMS
ROSC	0.8 (0.7, 1.0)	1.0
Adjusted neurologically intact survival to hospital discharge	1.2 (0.8, 1.9)	1.0
Adjusted neurologically intact survival with witnessed VF/VT	2.5 (1.3, 4.6)	1.0
Adjusted neurologically intact survival with VF/VT, not witnessed	0.5 (0.2, 1.6)	1.0
Adjusted neurologically intact survival with nonshockable rhythm	0.3 (0.1, 1.0)	1.0

Minimally Interrupted Cardiac Resuscitation by EMS

Bobrow Ann Emerg Med 2009

Outcomes	PV (n459) n/N (%)	BVM (n560) n/N (%)	Adjusted OR (95% CI)
ROSC	123/459 (26.8)	169/560 (30.2)	0.8 (0.7, 1.0)
Adjusted neurologically intact survival to hospital discharge	46/459 (10.0)	53/560 (9.5)	1.2 (0.8, 1.9)
Adjusted neurologically intact survival with witnessed VF/VT	39/102 (38.2)	31/120 (25.8)	2.5 (1.3, 4.6)
Adjusted neurologically intact survival with VF/VT, not witnessed	3/41 (7.3)	8/58 (13.8)	0.5 (0.2, 1.6)
Adjusted neurologically intact survival with nonshockable rhythm	4/316 (1.3)	14/381 (3.7)	0.3 (0.1, 1.0)



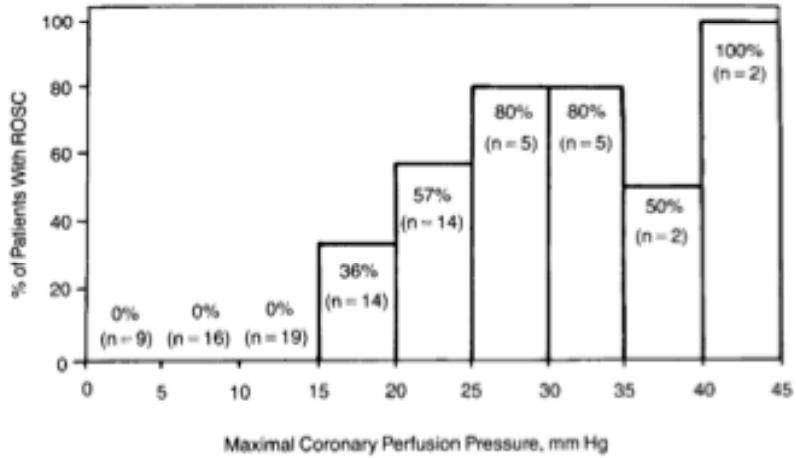
Impedance Threshold Device



Coronary Perfusion Pressure

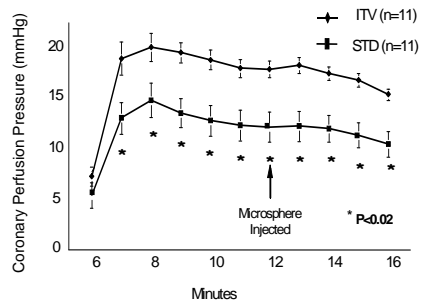
Paradis JAMA 1990

Aortic-to-right atrial pressure gradient during relaxation phase of cardiopulmonary resuscitation



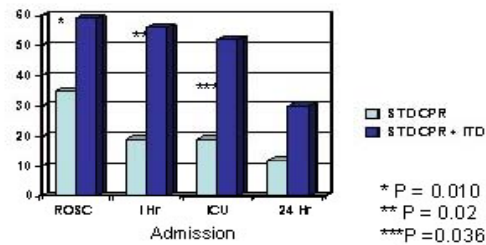
Impedance Threshold Device Improves Coronary Perfusion Pressure

Aufderheide Crit Care Med 2005



Use of ITD Associated with Better Outcomes for Patients with PEA at any time during Resuscitation in Milwaukee Trial

Aufderheide *Crit Care Med* 2005



Post hoc subgroup analysis susceptible to bias

No significant difference btwn CPR and CPR+ITD when adjusted for multiple comparisons

Effect Observed in Blinded vs. Unblinded Trials

Bero *PLOS Medicine* 2007

Characteristic	Category	Favorable Favor Not Fav		p-Value	Conducive Favor Not Fav		p-Value
		Favorable of Total n (%)	OR (95% CI)		Favorable of Total n (%)	OR (95% CI)	
Impact factor	Quartile 1 (0.21-1.76)	17/46 (37)	1.00		17/46 (37)	1.00	
	Quartile 2 (1.76-3.14)	26/47 (55)	2.5 (1.09-5.8)	0.03	26/47 (55)	2.1 (0.92-4.8)	0.08
	Quartile 3 (3.14-3.75)	28/47 (60)	2.8 (1.18-6.6)	0.02	28/47 (60)	2.4 (1.07-5.1)	0.03
Concealment of allocation	Not adequate	70/151 (46)	1.00		7/151 (46)	1.00	
	Adequate	7/146 (50)	1.00		7/146 (49)	1.00	
Blinding	Not adequate	6/103 (59)	1.00		34/103 (34)	1.00	
	Adequate	22/103 (21)	0.37 (0.17-0.81)	0.01	22/103 (21)	0.27 (0.12-0.61)	0.002
Funding source	Quartile 1 (0-1.9)	20/48 (42)	1.00		20/48 (42)	1.00	
	Quartile 2 (1.9-3.4)	20/48 (42)	0.88 (0.39-1.90)	0.75	19/48 (42)	1.49 (0.64-3.4)	0.36
	Quartile 3 (3.4-5.0)	20/48 (42)	0.88 (0.39-1.90)	0.75	19/48 (42)	1.49 (0.64-3.4)	0.36
Funding source	Industry	46/95 (48)	1.00		55/95 (58)	1.00	
	No funding disclosed	38/74 (51)	1.12 (0.61-2.1)	0.71	25/74 (39)	0.47 (0.25-0.87)	0.02

Shiny Object Syndrome

- National Geographic studied a group of monkeys.
- Local tribe would trap monkeys by putting bright shiny objects in small holes in trees, making sure monkeys saw them doing it.
- Tribesmen watched from a distance as monkeys would reach into trees to retrieve bright shiny objects.
- With their hands clenched around shiny object, they could not pull hands out of tree.
- Monkeys were so intent on hanging onto bright shiny objects that they would not let go, even when tribesmen would approach and slip bags over heads of monkeys.

Shiny Object Syndrome (2)

- Whatever real priority is in the moment, i.e., that thing I really want to get done, has pressure attached to it.
- It has to be good or right.
- Faced with an unconscious decision between working on this thing that has to be exactly right (e.g. CPR) or something that's marginally effective but that I will not judge myself about (e.g. ITD).
- My ego chooses for me.

Wake County, NC

Hinchey Ann Emerg Med 2010

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Admitted to hospital	55 (12.9)	65 (17.6)	31 (19.3)	121 (29.5)	16.6 (11.2 to 22.0)
Discharged from hospital	18 (4.2)	27 (7.3)	13 (8.1)	47 (11.5)	7.3 (3.7 to 10.9)
Survivors' CPC score	n=14	n=25	n=12	n=47	
1 and 2	11 (78.6)	19 (76.0)	10 (83.3)	36 (76.6)	-2.0 (-26.6 to 22.7)
3 and 4	3 (21.4)	6 (24.0)	2 (16.7)	11 (23.4)	2.0 (-22.7 to 26.6)

ROSC, Return of spontaneous circulation; CPC, cerebral performance category. All data are presented as No. (%) survivors unless otherwise noted.
 *Absolute increase and 95% CI for comparison between baseline and phase 3 (full implementation). CPC 1 and 2 denote "good" and "moderate" cerebral performance; 3 and 4 denote "poor" and "vegetative" cerebral performance; 5 denotes "brain death" and thus is not represented.

Western Electric Company, Hawthorne Plant, Chicago, IL



Series of studies conducted in the 1920s by Shewhart: worker productivity increased during observation.

Consider Limiting Oxygenation?

Pilot Randomized Trial of 30% vs. 100% Oxygen After Resuscitation

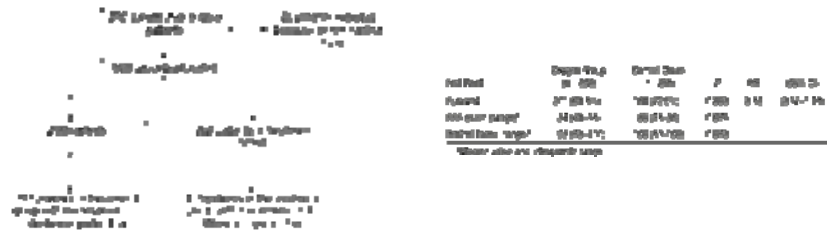
Kuisma et al Resuscitation 2006

	Group A (n=14)	Group B (n=14)	p
All patients (n=28)			
NSE (µg/l)			
30 min after ROSC	10.5 ± 3.3	9.8 ± 2.3	0.6652
24 h after ROSC	10.9 ± 7.7	13.0 ± 7.3	0.1985
48 h after ROSC	14.2 ± 19.4	18.6 ± 21.0	0.5913
S-100 (µg/l)			
30 min after ROSC	0.79 ± 0.45	1.33 ± 1.31	0.6256
24 h after ROSC	0.21 ± 0.15	0.47 ± 0.79	0.2766
48 h after ROSC	0.23 ± 0.21	0.39 ± 0.43	0.3600
	Group A (n=8)	Group B (n=7)	p
Patients who were not treated with therapeutic hypothermia in hospital (n=15)			
NSE (µg/l)			
30 min after ROSC	10.1 ± 4.0	10.8 ± 2.6	0.8615
24 h after ROSC	7.6 ± 4.2	13.5 ± 9.6	0.0487
48 h after ROSC	7.4 ± 2.9	21.4 ± 25.0	0.4233
S-100 (µg/l)			
30 min after ROSC	0.77 ± 0.51	2.08 ± 1.55	0.1213
24 h after ROSC	0.17 ± 0.05	0.73 ± 1.1	0.2012
48 h after ROSC	0.15 ± 0.08	0.49 ± 0.61	0.3913

Group A was ventilated with 30% oxygen and group B with 100% oxygen.

Quasi Randomized Trial of Oxygen Supplementation in Patients with Stroke

Rønning Stroke 1999

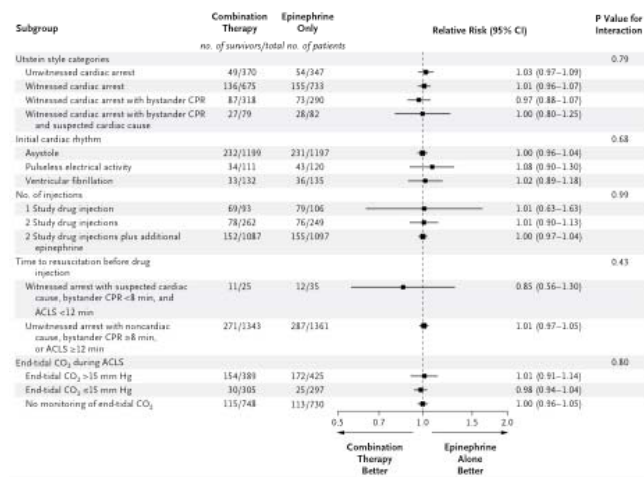


No animals were harmed during the preparation of this talk.

 AMERICAN HUMANE ASSOCIATION

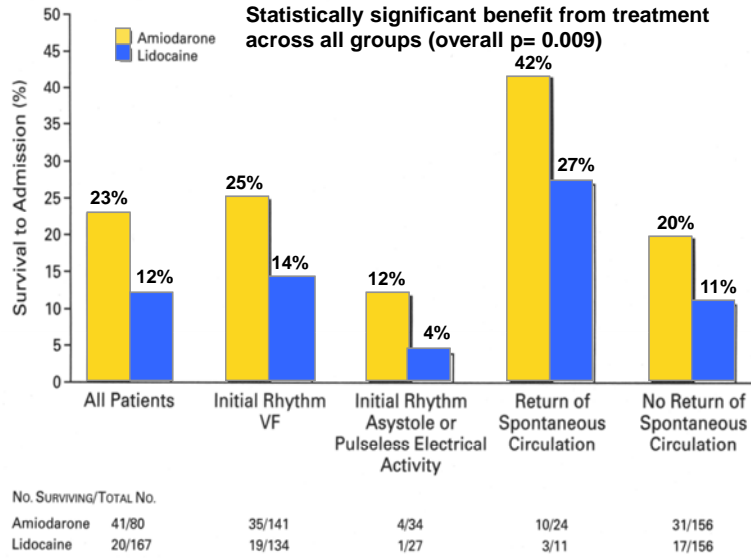
Epinephrine + Vasopressin vs. Epinephrine Alone

Gueugniaud *N Engl J Med* 2008



Amiodarone vs. Lidocaine

Dorian N Engl J Med 2002



Amiodarone vs. Placebo

Kudenchuk N Engl J Med 1999

