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**.

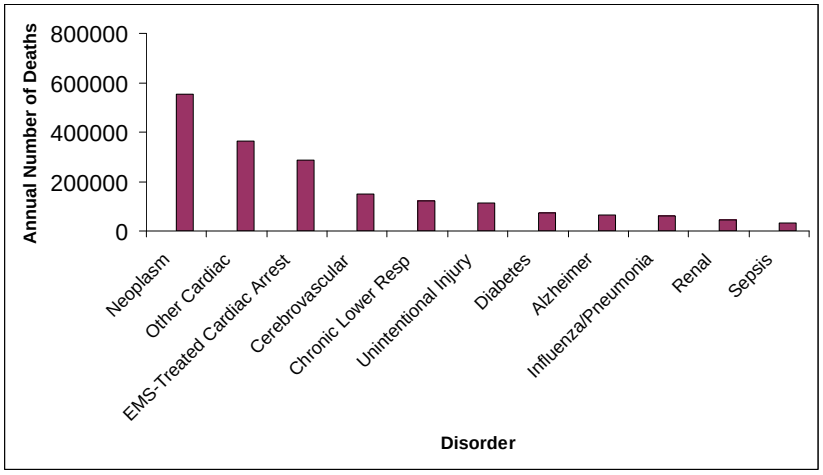
Cardiac Resuscitation System of Care

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

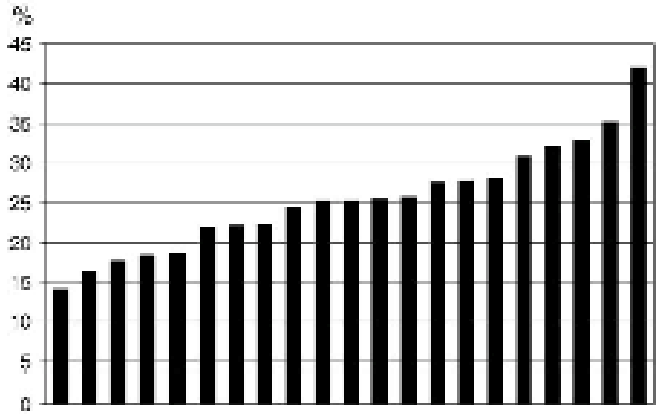
Ventricular Fibrillation

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

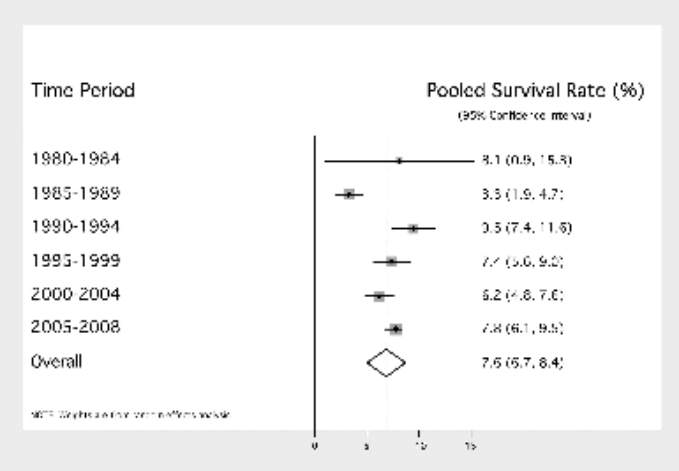
Survival from Admission to One Month

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

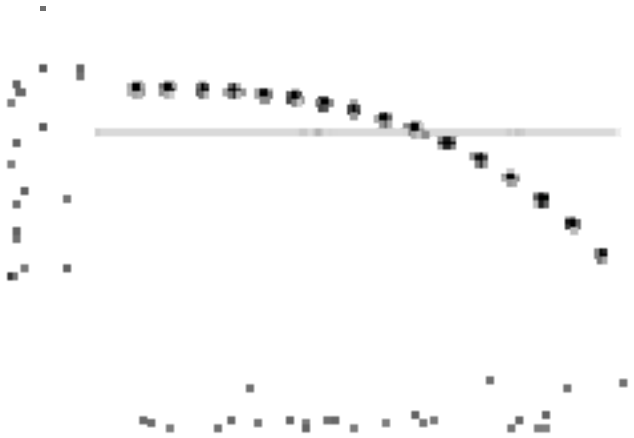
Randomized Trials of Regionalized STEMI Care

(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[b] 8% Recurrent infarct[b] 1% Stroke[b] 0%	Fibrinolytic therapy (n=66) Symptoms to therapy NR Door to therapy 63 ± 39 Death[b] 12% Recurrent infarct[b] 0% Stroke[b] 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

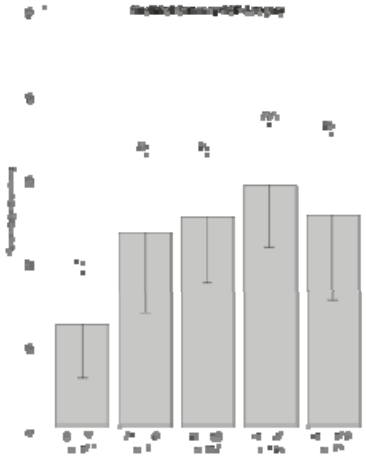
- Direct and indirect evidence that regional cardiac resuscitation systems of care will improve outcome
- Effects
  - Take time to develop
  - Depend on patient volume

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

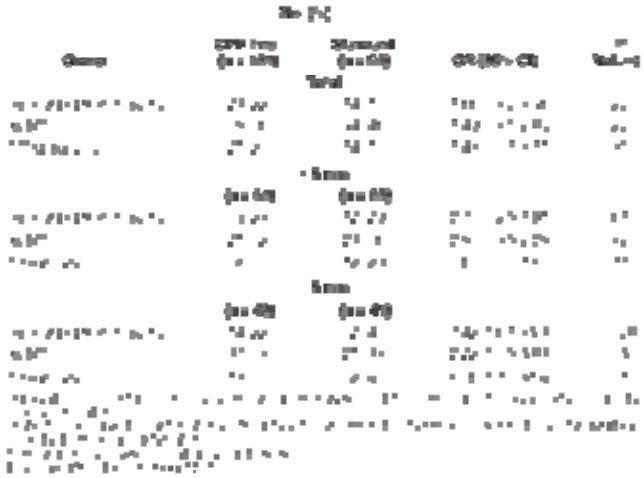


EMS CPR Before Rhythm Analysis

Cobb JAMA 1999

EMS CPR Before Rhythm Analysis

Wik JAMA 2003



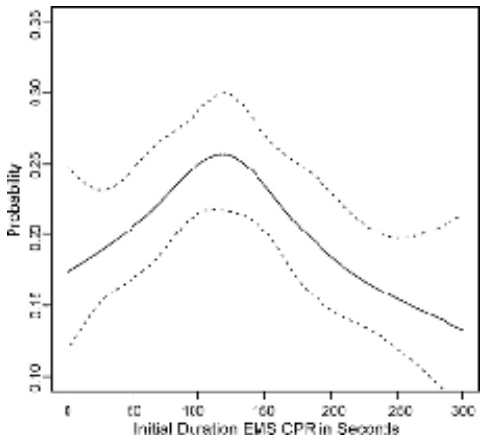
EMS CPR Before Rhythm Analysis

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
Treated, n	210	277	158	108	203	173	93	107	31	60
Survived to discharge (%)	17.6	23.1	24.7	23.1	26.6	21.4	15.1	15.1	9.1	18.3
Adjusted OR of survival in logistic regression model* (95% CI)	Reference	1.15 (0.71, 1.37)	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 random-effects model* (95% CI)	Reference	1.19 (0.73, 1.32)	1.43 (0.81, 2.47)	1.54 (0.97, 2.49)	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)

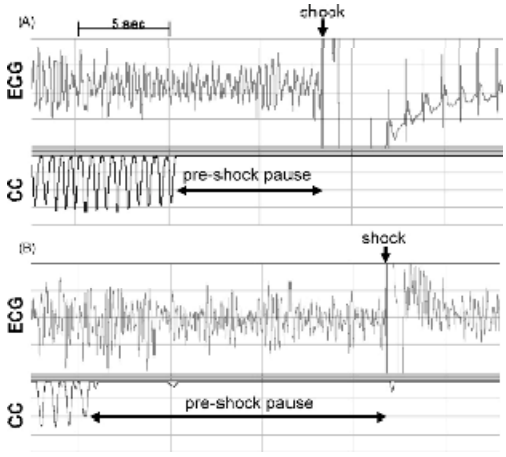
EMS CPR Before Rhythm Analysis

Bradley Resuscitation 2010



Preshock Pause

Edelson Resuscitation 2008



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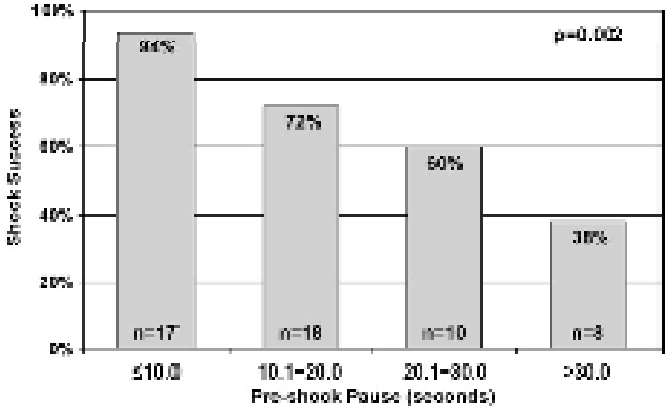
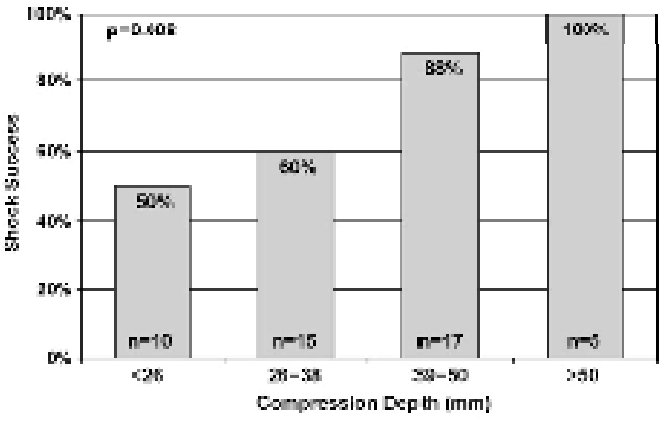


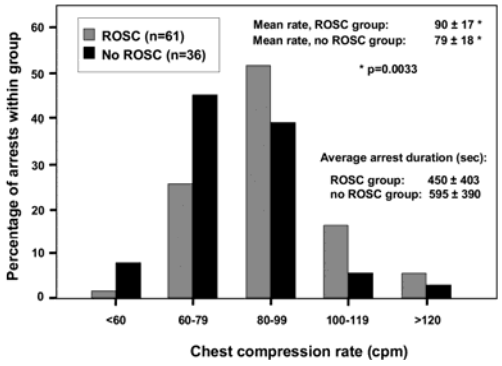
Compression Depth

Edelson Resuscitation 2008



Chest Compression Rate

Abella Circulation 2005



Use Single Rather than Stacked Shocks!

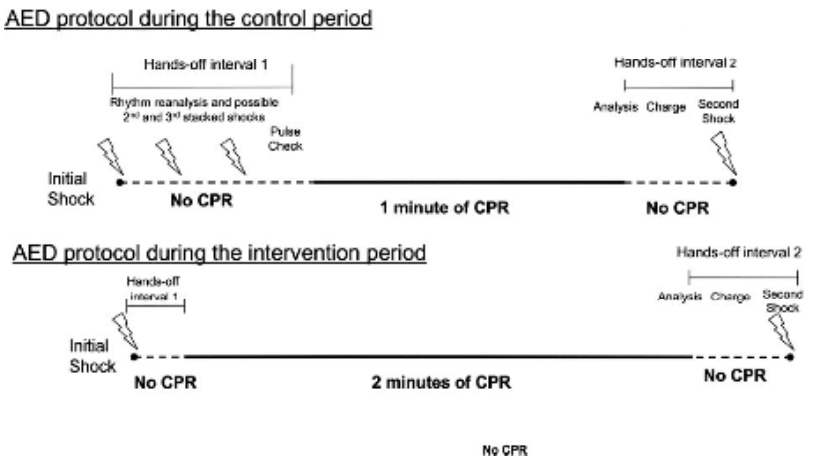
Shock to Perfusing Rhythm

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



Single versus Stacked Shock

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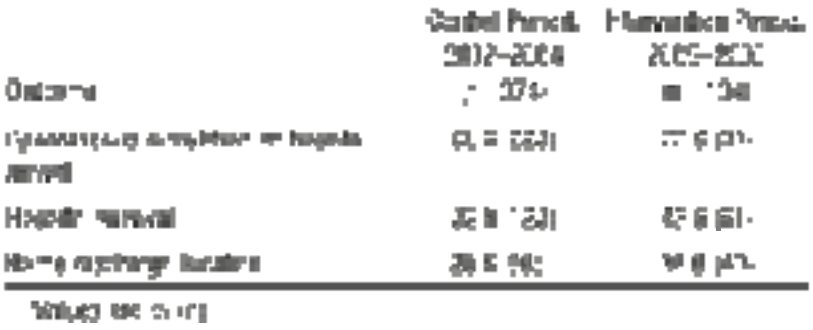
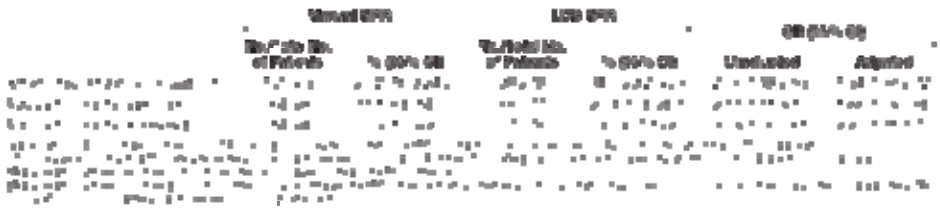


Ignore Manual Compression Devices!

Mechanical Compressions Using Load-Distributing Band Device

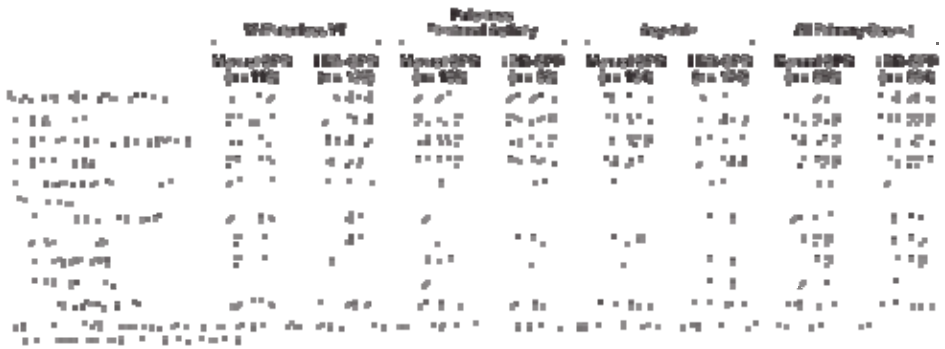
Ong JAMA 2006



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



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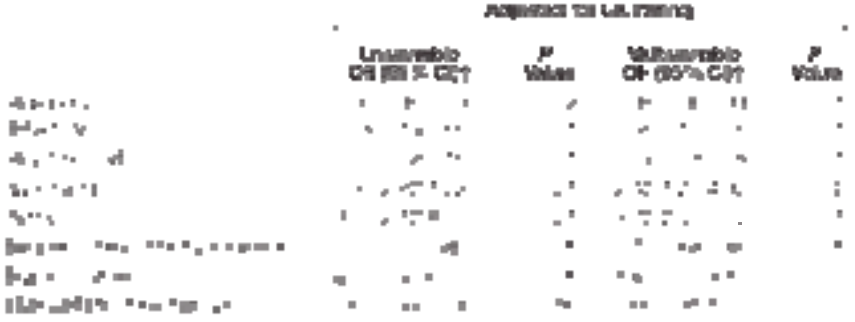


Consider Continuous Chest Compressions?

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

Minimally Interrupted Cardiac Resuscitation by EMS

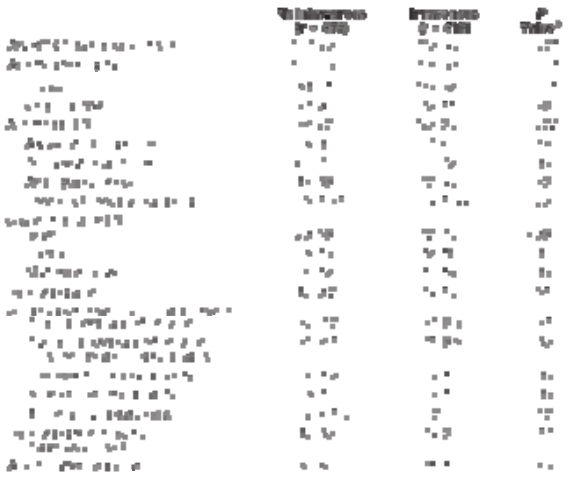
Bobrow Ann Emerg Med 2009

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)

Ignore Intravenous Drugs!

Intravenous Drugs

Olasveengen JAMA 2009

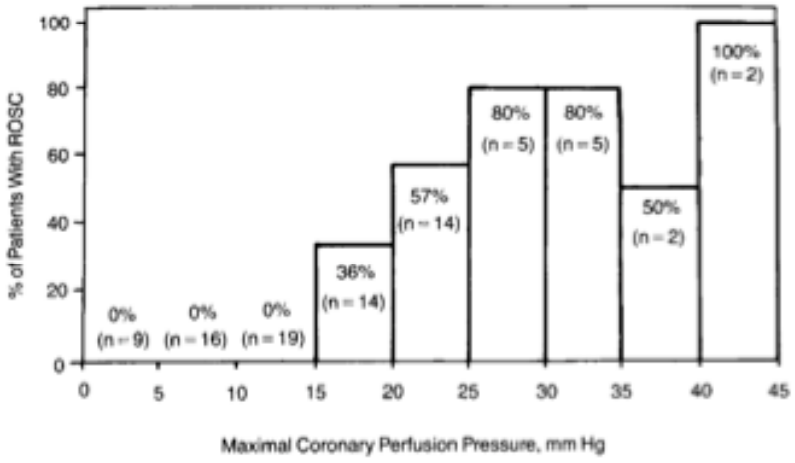


Impedance Threshold Device

Coronary Perfusion Pressure

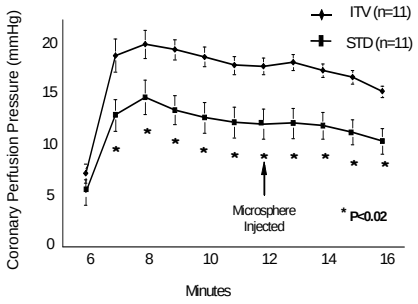
Paradis JAMA 1990

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



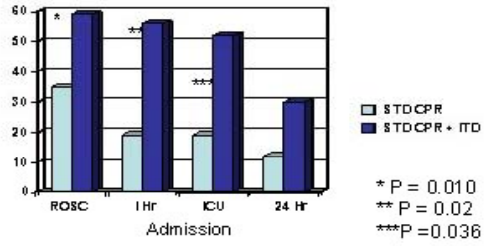
Impedance Threshold Device Improves Coronary Perfusion Pressure

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	Unadjusted Favor Not Drug			Unadjusted Favor Not Drug		
		Favorable of Total n (%)	OR (95% CI)	p-Value	Favorable of Total n (%)	OR (95% CI)	p-Value
Impact factor	Quartile 1 (0.21–1.79)	17/46 (37)	1.00		17/46 (37)	1.00	
	Quartile 3 (3.14–3.75)	28/47 (60)	2.5 (1.09–5.8)	0.03	26/47 (55)	2.1 (0.92–4.8)	0.08
Concealment of allocation	Not adequate	70/151 (46)	1.00		71/151 (46)	1.00	
Inclusion of all in analysis	Not adequate	73/146 (50)	1.00		71/146 (49)	1.01	
Blinding	Not adequate	61/103 (59)	1.00		54/103 (54)	1.03	
	Quartile 3 (93–272)	20/48 (42)	0.88 (0.39–1.96)	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	29/74 (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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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	0.8815
24 h after ROSC	7.6 ± 4.2	13.5 ± 9.6	0.0487
48 h after ROSC	7.4 ± 2.9	21.4 ± 25.8	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

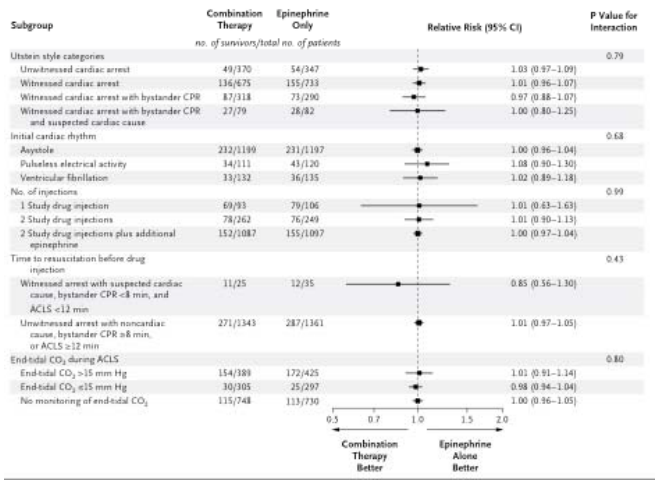
Rønning Stroke 1999

No animals were harmed during the preparation of this talk.

AMERICAN HUMANE ASSOCIATION

Epinephrine + Vasopressin vs. Epinephrine Alone

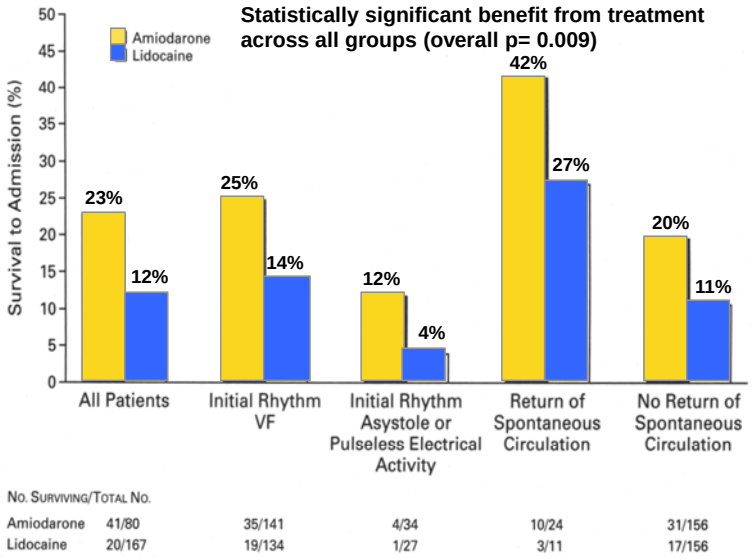
Gueugniaud N Engl J Med 2008



Subgroup	Combination Therapy	Epinephrine Only	Relative Risk (95% CI)	P Value for Interaction
	no. of survivors/total no. of patients			
Utstein style categories				0.79
Unwitnessed cardiac arrest	49/370	54/347	1.03 (0.97–1.09)	
Witnessed cardiac arrest	136/675	155/733	1.01 (0.96–1.07)	
Witnessed cardiac arrest with bystander CPR	87/318	73/290	0.97 (0.88–1.07)	
Witnessed cardiac arrest with bystander CPR and suspected cardiac cause	27/79	28/82	1.00 (0.80–1.25)	
Initial cardiac rhythm				0.68
Asystole	232/1199	231/1197	1.00 (0.96–1.04)	
Pulseless electrical activity	34/111	43/120	1.08 (0.90–1.30)	
Ventricular fibrillation	33/132	36/135	1.02 (0.89–1.18)	
No. of injections				0.99
1 Study drug injection	69/93	79/106	1.01 (0.63–1.63)	
2 Study drug injections	78/262	76/249	1.01 (0.90–1.13)	
2 Study drug injections plus additional epinephrine	152/1087	155/1097	1.00 (0.97–1.04)	
Time to resuscitation before drug injection				0.43
Witnessed arrest with suspected cardiac cause, bystander CPR <8 min, and ACLS <12 min	11/25	12/35	0.85 (0.56–1.30)	
Unwitnessed arrest with noncardiac cause, bystander CPR ≥8 min, or ACLS ≥12 min	271/1343	287/1361	1.01 (0.97–1.05)	
End-tidal CO_2 during ACLS				0.80
End-tidal CO_2 >15 mm Hg	154/389	172/425	1.01 (0.91–1.14)	
End-tidal CO_2 ≤15 mm Hg	30/305	25/297	0.98 (0.94–1.04)	
No monitoring of end-tidal CO_2	115/748	113/730	1.00 (0.96–1.05)	

Amiodarone vs. Lidocaine

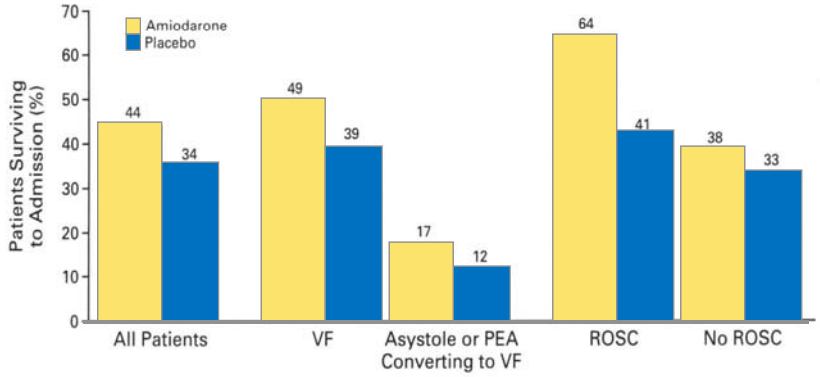
Dorian N Engl J Med 2002



No. Surviving/Total No.					
Amiodarone	41/80	35/141	4/34	10/24	31/156
Lidocaine	20/167	19/134	1/27	3/11	17/156

Amiodarone vs. Placebo

Kudenchuk N Engl J Med 1999



No. Surviving/ Total No.								
	108/246	89/258	101/205	84/216	7/41	5/42	35/55	22/53	73/191	67/205