The Positive Effect of Negative Pressure
(Future Direction in Resuscitative Care)

Brent Parquette, NRP
Lucas County EMS, Toledo, OH
Toledo, Ohio
Lucas County EMS (Toledo, OH)

- Primary service area: 340 sq mi
- Population: 500,000
  - City of Toledo - 305,000
- County-operated ALS transport agency
  - ALS transport vehicles: 11
  - ALS/ BLS first response: 13 area FDs
- Transport to 8 area hospitals
- Annual call volume: ~100,000
  - ALS/ BLS
Brent Parquette, NRP

- 39 years pre-hospital service
  - Toledo Fire Department (20 years)

- Lucas County Emergency Services
  - Training and Quality Assurance Specialist
  - Continuing Education Program Administrator
The Positive Effect of Negative Pressure
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Brent Parquette, NRP
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Disclosure Information

Brent Parquette, NRP
Intrathoracic Pressure Regulation (IPR)

FINANCIAL DISCLOSURE:

Contract Clinical Educator – Zoll Medical
- IPR Division
What’s on the EMS Radar screen for 2018?

“We continue to learn so much about what really makes a difference in cardiac arrest. **Subtle changes in our approaches to maximizing continuous perfusion can have a dramatic impact on survival.**”

-Ed Racht, M.D.
Resuscitation: An Unsolved Puzzle
No Silver Bullet for CA Management

But, Consider this. . . . .

A collection of Transformative Technologies
U.S. cardiac arrest survival

All rhythms: 10%
Witnessed VF: 30%
Disparity

All rhythms: 3% to 30%
10 fold disparity

VF witnessed: 4% to 62%
15 fold disparity
blunt

Where you live should not determine if you live!
The Goal

>30% Survival  >50%  >60%
How do we get there?
What does the science tell us?

Is there evidence?
CPR
PERFORMANCE COUNTS
QUALITY IMPROVES SURVIVAL
Cardiac resuscitation after cardiac arrest or ventricular fibrillation has been limited by the need for open thoracotomy and direct injection of external shock. This has been due to the lack of definitive measures.

CLOSED-CHEST CARDIAC MASSAGE

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

The use of this technique on 20 patients has given an overall permanent survival rate of 70%. Anyone, anywhere, can now initiate cardiac resuscitative procedures. All that is needed are two hands.

Courtesy Depart. of Surgery
Johns Hopkins Univ. Hosp.

UHS/CMS MHW 9/82
Unaided Manual CPR

• The cornerstone of resuscitation
• Generally the first option for rescuers
• Has remained essentially unchanged for >50 years
• HQ-CPR only circulates 25-40% of normal blood flow

... Can we do better?
CHANGE AHEAD:

HIGH-PERFUSION CPR
Mechanism of CPR: Heart vs Thoracic Pump

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. Weinfield, 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.

Pressure-synchronized Cineangiography During Experimental Cardiopulmonary Resuscitation

James T. Niemann, M.D., John F. Rosborough, Ph.D., Mark Hausknecht, M.D., Daniel Garner, M.S., and J. Michael Creile, M.D.
The thoracic cavity is like a bellows…

**Compression**

- PUSHES air away, fluid out
- Inhibits blood return

**Passive Recoil**

- Creates a vacuum
- PULLS fluid and air in

**Positive Pressure**

- PUSHES air away, fluid out
- Inhibits blood return

**Negative Pressure**
Airway Pressures During Conventional CPR
Agonal Gasping: Dying Breath
Reflex Survival Mechanism: Perfusion
Gasping Bodes Well for Survival After Cardiac Arrest

- Journal of American College of Cardiology
- September 19, 2017

A “major prognostic variable” in predicting 1-year survival with favorable brain function
Effect of Gasping During Cardiac Arrest

Airway

Ao

RA

ICP
Intrathoracic Pressure Regulation (IPR) is a therapy that enhances negative pressure in the chest and has been shown in studies to effectively improve circulation of blood to the brain and other vital organs.
Intrathoracic Pressure and Blood Flow

As intrathoracic pressure decreases...
Blood flow increases

Respiration and circulation are closely linked. Dating back to 1967, we have known there is an inverse relationship between intrathoracic pressure and blood flow.

Evolution: Impedance Threshold Device (ITD)

Concept:
- Lower intra-thoracic pressure in the chest during the decompression phase of CPR
- Enhance venous return to the thorax.
Insert: ITD Animation Video
**Airway Pressures During CPR**

**Conventional CPR**

Vacuum is limited as air is drawn in (minimal preload)

**CPR with ITD**

Enhanced vacuum during chest wall recoil draws more blood back into heart (increases preload)
Intra thoracic Pressure Regulation: Effect

Tracheal Pressure

Aortic Pressure

Intracranial Pressure

ITPR On

30 sec.
ITD on a Facemask or Advanced Airway

Important: Maintain Tight Seal on Mask
Death by Hyperventilation

Ventilation rate: 47/min
ITD: Clinical Evidence / Experience

Clinical research has demonstrated that use of the ITD:

- Increases survival by 25% or more
- Doubles blood flow to the heart
- Increases blood flow to the brain by 50%
- Doubles systolic blood pressure
- Lowers intracranial pressure

Implementation of Pit Crew Approach and Cardiopulmonary Resuscitation Metrics for Out-of-Hospital Cardiac Arrest Improves Patient Survival and Neurological Outcome

Christy L. Hopkins, MD; Chris Burk, NR; MT-P; Shane Moser, AAS; Jack Mearsman, NREMT-P; Clair Baldwin, NREMT-P; Scott T. Youngquist, MS, MSc

Introduction—Survival from out-of-hospital cardiac arrest (OHCA) varies by community and emergency medical services (EMS) system. We hypothesized that the adoption of multiple best practices to focus EMS crews on high-quality, minimally interrupted cardiopulmonary resuscitation (CPR) would improve survival of OHCA patients in Salt Lake City.

Methods and Results—In September 2011, Salt Lake City Fire Department EMS providers underwent a systemwide restructuring of care for OHCA patients that focused on the adoption of high-quality CPR with minimal interruptions and offline medical review of defibrillator data and feedback on CPR metrics. Victims were directed to ST-elevation myocardial infarction receiving centers. Prospectively collected data on patient survival and neurological outcome for all OHCA patients were compared. In the postintervention period, there were 407 cardiac arrests with 65 neurologically intact survivors (16%), compared with 330 cardiac arrests with 25 neurologically intact survivors (8%) in the preintervention period. Among patients who survived to hospital admission, a higher proportion in the postintervention period survived to hospital discharge (71/141 [50%] versus 36/93 [37%], P=0.03) and had a favorable neurological outcome [65 (44%) versus 25 (29%), P=0.0056] compared with patients treated before the protocol changes. The univariate odds ratio or the association between neurologically intact survival (cerebral performance category 1 and 2) and protocol implementation was 2.3 (95% CI: 1.4 to 3.7, P=0.0001). Among discharged patients, the distribution of cerebral performance category scores was more favorable in the postintervention period (P<0.0001).

Conclusions—A multifaceted protocol, including several American Heart Association best practices for the resuscitation of patients with OHCA, was associated with improved survival and neurological outcome. (J Am Heart Assoc. 2016;5:e002892 doi: 10.1161/JAHA.115.002892)
# Methodology

| BEFORE (n = 330)  
Sept 2008 - Sept 2011 | AFTER (n = 407)  
Oct 2011 - Dec 2014 |
|----------------------|---------------------|
| • Adoption of electronic medical record that permitted performance evaluation and structured electronic queries | • CPR Quality Initiatives  
  • Real-time CPR feedback  
  • On-scene resuscitation  
  • Post-incident review/debrief |
| • Not directly measuring CPR quality | • Added ITD  
• Simplified Medication Algorithm  
• EMS Crew Team Training |
Results: Improved Functional Survival

Favorable Neurological Outcome (CPC 1 or 2) at Hospital Discharge (%)

- **100% Improvement**
  - 2008 - 2011: 8%
  - 2011 - 2014: 16%
  - All Patients: n=330

- **86% Improvement**
  - 2008 - 2011: 21%
  - 2011 - 2014: 39%
  - Witnessed V-Fib: n=70

P<0.05 for both comparisons

Hopkins et al. J Am Heart Assoc 2016
Alameda County, CA Experience

Sporer et al
Prehosp Emerg Care 2016
Survival

Survival From V-Fib/V-Tach Cardiac Arrest

System Enhancements to Prehospital Resuscitation

- **2005**
  - 2005 AHA updates (drug, defib & CPR changes)
  - MPDS Center added

- **2006**
  - AEDs required in health clubs

- **2007**
  - Changes to intubation procedures
  - Intensive airway and enhanced CPR training by MD

- **2008**
  - ITD added
  - CPR in the Schools pilot project
  - 28%

- **2009**
  - Re-emphasis on CPR techniques
  - CPR7 Program implemented
  - Second MPDS Center added
  - 28%

- **2010**
  - Therapeutic cooling
  - Introduction of Cardiac Arrest Centers
  - 32%

Sporer et al. AHA Scientific Sessions 2015
CPR Inefficiency

- Incomplete chest wall relaxation / recoil
  - Vacuum development affected
  - Loss of enhanced negative pressure
    - Preload minimized

Again... Can we do better?
Airway Pressure Waveforms

Inefficiency: CPR with Incomplete Chest Relaxation

Vacuum fails to develop because rescuer is leaning on chest during recoil

Intrathoracic pressure (mmHg)

Optimizing Chest Wall Recoil

Index Case
1987

Pt. saved by a Household Plunger
San Francisco General Hospital

Active Compression-Decompression CPR
ACD-CPR
Active Compression-Decompression (ACD)

Passive Recoil

Conventional CPR

Active Decompression

ACD-CPR

10 kg of lifting force
Putting it all together - ACD-CPR + ITD
Airway Pressures During CPR

Conventional CPR  CPR with ITD  CPR with ACD-CPR +ITD

Heart Refills (preload)  Chest Wall Recoil Phase

\( \text{cmH}_2\text{O} \)
S-CPR vs ACD-CPR + ITD

- **S-CPR**
- **ACD-CPR w/ ITD**

**Graphs showing**
- ITP
- Ao
- RA
- ICP
- CoPP
- CePP
Using the ACD-CPR Device
Near-Normal Blood Flow to the Brain

67% Improvement in Blood Flow with ACD-CPR + ITD

Pre-clinical data may not be indicative of clinical outcomes.

Improved Survival

ACD-CPR + ITD showed an improvement in survival at discharge and one-year compared to conventional CPR

Experience: Collierville, TN

Insert: ROSC Data

62.5% improvement in ROSC
ACD-CPR + ITD Combination
Henry County, Georgia Experience

Insert: ROSC / Survival Data
“Resuscitation Bundle” Approach to CA

LCEMS: ~400 cardiac arrests/yr.

BLS:
- Perfusion: ACD-CPR + ITD
- Pit Crew Concept

ALS
- ETC02
- Automatic Transport Ventilators
- CFR >90%
- Minimize Peri-shock pauses
- Pre-charged defibrillation
- Automated CPR – Transport
- Transport to Cardiac Specialty Centers
Lucas County EMS, (Toledo, Ohio)

Field ROSC Rates

ITD Added

ITD + Automated CPR

ACD-CPR + ITD Automated CPR

2011-2017: Intra-arrest cooling / PCI-Capable Hospital

Insert: Field ROSC Data
Lucas County EMS, (Toledo, Ohio)

Utstein Survival

- ITD Added
- ITD + Automated CPR
- ACD-CPR + ITD
  Automated CPR

Insert: Witnessed VF Data

2011-2017: Intra-arrest cooling / PCI-Capable Hospital
Lucas County EMS, (Toledo, Ohio)

Overall Functional Survival

- ITD Added
- ITD + Automated CPR
- ACD-CPR + ITD

Insert: Overall Survival

2011-2017: Intra-arrest cooling / PCI-Capable Hospital
Future Direction

IPR Therapy
“Heads Up” CPR

ITD + Automated CPR + head elevated:
- Enhanced venous return
- Decreased ICP
- Increased cardiac output
- Increased cerebral perfusion

Debaty and colleagues
Change of Position: Head Up

Supine 0° CPR  30° Head up CPR + ITD

Ao

ICP

CerPP

Change of position
(CPR rate 100/min)

Debaty et al, Resuscitation, 2014
Post-ROSC Active IPR
Intrathoracic Pressure Regulation (IPR) Device for During CPR and Post-ROSC

1. Lowers intrathoracic pressure
2. Lowers ICP
3. Refills the heart
4. Increases cerebral and systemic circulation
Study Hypothesis

- Active IPR after ROSC may enhance cerebral perfusion and simultaneously reduce the need for vasopressor support.
Results: Cumulative Epinephrine (mg) Administration

Total epinephrine during the post-ROSC period significantly reduced with a-IPR (0.08 ± 0.09 vs 0.29 ± 0.12 mg, p<0.01).
Intrathoracic Pressure Regulation During CPR in Patients in Prolonged Arrest

- ETCO2 values increased from 20.1 mmHg at baseline to 43.6 mmHg during active (a) Intrathoracic Pressure Regulation (IPR) treatment.

- ROSC rate was 73% v. 46% for control; mean BP 3 minutes after ROSC in the aIPR group was 133/79 mmHg.

IPR During Hypotension

ITD-7
IPR FOR HYPOTENSION: ITD-7

Patient / Inspiration Port
Connects to a mouthpiece or facemask.

Atmospheric Pressure Sensing Valve
Provides therapeutic inspiratory resistance until the patient creates at least -7 cmH₂O pressure with respiratory effort.

Exhalation Port

O₂ Port
Permits administration of up to 15 lpm supplemental oxygen
APPLICATION: SPONTANEOUSLY BREATHING HYPOTENSIVE PATIENTS

- Trauma
- Sepsis
- Dehydration
- Orthostasis
- Dialysis
- Heat exhaustion
- Etc. . . . . .
**Indications:**

- Patients >25 lbs
- Hypotension
- Various etiologies:
  - Hypovolemia
  - Dehydration
  - Sepsis
  - Dialysis
  - Orthostatic intolerance

**Contraindications:**

- Shortness of breath
- Active congestive heart failure
- Flail chest
- On-going, uncontrolled blood loss
RESULTS: ALL PATIENTS

N = 259, p < 0.01 for SBP and DBP Before vs After ITD

S. Smith et al; Journal of Emergency Medicine 2011
Results: Patients Without Fluids

N = 55, p < 0.01 for SBP and DBP Before vs After ITD
“Positive Effect of Negative Pressure”

Therapy that enhances negative pressure in the chest to effectively improve circulation of blood to the brain and other vital organs.

Perfusion: Future Direction in Resuscitative Care
Thank You!

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