Emergency Ventilatory Management of the Critically Ill and Injured: Elemental or Detrimental?

Presented at EMS Today
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That Brings Us to Today’s Sacred Cow...
the A-B-C’s!

What About the “B” Part?
Assisted Breathing with PPV
Rescue Breathing...

Is It Really Necessary?
Q: What are the Typical Teachings & Current National Protocol Standards?

A: 10-15 ml/kg Tidal Volume & 15-20 breaths/min Respiratory Rate
Why Do We Ventilate?
Oxygen and CO₂

Oxygen -> lungs -> alveoli -> blood

breath

CO₂

lungs

CO₂

blood

energy

Oxygen + Glucose

muscles + organs

cells

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Carbon dioxide physiology

\[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \]
Carbon dioxide physiology

• 0.03% concentration in air
• Resting adult produces 2.5 mg/kg/min
• In a 70 kg adult, that is about 175 mg per minute, or about 4% of a teaspoonful
Carbon dioxide physiology

- **Transported in blood**
  - 60-70% bicarbonate ion after conversion in RBCs using carbonic anhydrase
  - 20-30% bound to proteins (e.g., Hb)
  - 5-10% in physical solution (PCO$_2$)

- **Cleared by alveolar ventilation**
Alveoli: The Place Where Gas Exchange Happens
Oxygenation vs. Ventilation

Saturating Red Cells vs. Clearing $CO_2$
Oxygenation

Air Movement

and

Blood Flow
THUS! Cyanosis...

An Air Movement Problem

or

A Circulation Problem
What’s an Adequate Tidal Volume?
IT DEPENDS ON THE CLINICAL SITUATION!!
10 ml per kg
(Intubated, No PEEP, No Diffuse Lung Injury)
Ventilation

Tidal Volume

$\times$

$RR$
“Ventilation”
MEANS
RATE!!
How Fast Should You Breathe Them?
Need to Ventilate

• CO₂ Production
  (depends upon O₂ Consumption & Venous Return)
High Ventilatory Demand...
But Also:

in very low flow states

Oxygen Consumption

Becomes Dependent on

Oxygen Delivery...
For Example, CPR Cases...
Cardiac Arrest

• Little O$_2$ Delivery & Consumption

• Little CO$_2$ Production & Venous Return

...Little Need to Ventilate

...Little Need to Ventilate
O₂ Metabolized (% of baseline)

O₂ Delivery (ml/min/kg)
**CO₂ Production** (% of baseline)

**O₂ Delivery** (ml/min/kg)
Cardiac Arrest....

8 breaths / min

ETCO₂ = 20 mmHg

ETCO₂ = 24 mmHg

...Little CO₂ Excretion
Take Home...

Ventilation Should Match Perfusion...
The “CPR Dilemma”
Chest Compressions & Coronary Perfusion Pressure

5:1 Ratio
- 20 mmHg

15:2 Ratio
- 20 mmHg
- 40 mmHg
“Reality” CPR

In Video Study of Lay Individuals Recently Taught 15:2 CPR ....

...Took 15-16 Seconds to Deliver the 2 Breaths
Is There Evidence That We Can Breathe Less Often?
Sanders, et al

- **15:2** (e.g., *standard CPR*)
- **50:5** (e.g., *Great Britain*)
- **CC** (*chest compressions only*)
- **4 min CC only; then 100:2**

*Porcine model of four different CPR techniques*  
Neurological Outcomes...

- 4 min CC only; then 100:2
  --Did Significantly Better than
  15:2 (e.g., standard CPR)

- CC (chest compression only)
  --Did Much Worse

CONCLUSION: In this experimental model of bystander CPR, the group receiving compressions only for 4 minutes followed by a compression-ventilation ratio of 100:2 achieved better neurologic outcome than the group receiving standard CPR and CC-CPR. Consideration of alternative chest compression-ventilation ratios might be appropriate.

Sources of Ventilation:

- Active Positive Pressure
- Chest Compressions
- Gasping (Agonal Breaths)
Stopping to Breathe...

...Interrupts

Chest Compressions
Normal Breathing...

• Generates Negative Intrathoracic Pressure
• Pulls Lungs Open in a Specific Architecture
• Enhances Venous Return and Cardiac Preload
Assisted Breathing with PPV
PPV...

- Generates Positive Intrathoracic Pressure
- Pushes Lungs Open in a Maldistributive Manner
- Diminishes Venous Return and Cardiac Preload
PPV Cardiovascular Effects

Worsened By...

- Obstructive Lung Disease
- Hypovolemic
- Circulatory Compromise
So Let's Study It!!

It's Not Rocket Science!!
The New England Journal of Medicine

Established in 1812 as The New England Journal of Medicine and Surgery

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Compressions Alone vs Standard ABC’s
Compressions Alone 14.7% vs Standard ABC's 10.4%
But Does This Apply to Children?

Think Hypoxia!!
How About Hypovolemic Patients?

Depends!
Ventilated Pigs with Moderate Hemorrhage

Measuring Coronary Perfusion Pressure
Rate: 6 breaths x min$^{-1}$ (2$^{nd}$ measurement)

one respiratory cycle = 10 sec.

Rate: 12 breaths x min$^{-1}$

one respiratory cycle = 5 sec.

RR = 6 / min

RR = 12 / min

Time-Averaged Coronary Perfusion Pressure

= Area Under the Curve (in Pink)
Hyperventilation-Induced Hypotension During Cardiopulmonary Resuscitation

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Background—A clinical observational study revealed that rescuers consistently hyperventilated patients during out-of-hospital cardiopulmonary resuscitation (CPR). The objective of this study was to quantify the degree of excessive ventilation in humans and determine if comparable excessive ventilation rates during CPR in animals significantly decrease coronary perfusion pressure and survival.

Methods and Results—In humans, ventilation rate and duration during CPR was electronically recorded by professional rescuers. In 13 consecutive adults (average age, 63±5.8 years) receiving CPR (7 men), average ventilation rate was 30±3.2 per minute (range, 15 to 49). Average duration per breath was 1.0±0.07 per second. No patient survived. Hemodynamics were studied in 9 pigs in cardiac arrest ventilated in random order with 12, 20, or 30 breaths per minute. Survival rates were then studied in 3 groups of 7 pigs in cardiac arrest that were ventilated at 12 breaths per minute (100% O₂), 30 breaths per minute (100% O₂), or 30 breaths per minute (5% CO₂/95% O₂). In animals treated with 12, 20, and 30 breaths per minute, the mean intrathoracic pressure (mm Hg/min) and coronary perfusion pressure (mm Hg) were 7.1±0.7, 11.6±0.7, 17.5±1.0 (P<0.0001), and 23.4±1.0, 19.5±1.8, and 16.9±1.8 (P=0.03), respectively. Survival rates were 6/7, 1/7, and 1/7 with 12, 30, and 30+ CO₂ breaths per minute, respectively (P=0.006).

Conclusions—Professional rescuers were observed to excessively ventilate patients during out-of-hospital CPR. Subsequent animal studies demonstrated that similar excessive ventilation rates resulted in significantly increased intrathoracic pressure and markedly decreased coronary perfusion pressures and survival rates. (Circulation. 2004;109: 1960–1965.)
Aufderheide Study of Paramedics

- Averaged $37 \pm 4$ breaths/min
- Re-trained at 12 / min
- Averaged $22 \pm 3$ breaths/min
CONCLUSIONS:
Despite seemingly adequate training, professional rescuers consistently hyperventilated patients during out-of-hospital CPR.
And on the Road to the 22nd Century...
...Phrenic Nerve Pacemaker?
Diaphragm Pacing Device Offers Ventilator Freedom

By Debra Yemenijian

For more than 20 years, researchers have sought ways to stimulate the nerves that control the diaphragm. Today, Christopher Reeve is reaping the benefits of their work after undergoing what the actor has called “a drastic and dangerous procedure.”

Reeve underwent surgery for diaphragm pacing at the University Hospitals of Cleveland in February. During the surgery, Raymond Onders, MD, Anthony DiMarco, MD, and a team of experts implanted electrodes attached through wires to a small external battery pack that electrically stimulates Reeve’s diaphragm muscle and phrenic nerves. The procedure carries some risk of damaging these nerves, which lead from the brain to the diaphragm.

When the diaphragm muscle is stimulated, it contracts, causing a vacuum-like effect conditioning, that patient weaned off mechanical ventilation, and he has been independent of the ventilator for more than two years. This has allowed him to speak more normally, improved his sense of smell and increased his mobility.

Reeve’s operation “yielded impressive results,” Dr. Onders said.

Every year, 10,000 new cases of spinal cord injury are reported in the United States. About 1,000 of these patients require mechanical ventilation following injury. Some patients recover on their own, but others, like Reeve, may require lifelong ventilation.

“The constant and high cost of care for ventilator-dependent patients not only exhausts most insurance policies but contributes to strain on families and caregivers,” Reeve said in a press release.

These patients could benefit from lifelong breathing support, such as that offered by the diaphragm pacing device.

FURTHER DEVELOPMENT

Currently, this procedure is being conducted under a Food and Drug Administration protocol, with research funds covering the costs of the device and its implementation. The cost of the standard diaphragm pacing procedure and the device can exceed $100,000.

The investigational diaphragm pacing system Reeve uses received FDA approval to be tested in ventilator-dependent patients who have undamaged phrenic nerve function.
Inspiratory Impedance
Threshold Valve
- 12 cm H₂O
Let’s do a Case Study
Case #1...

- 24 yo Male, Involved in MVC
- Altered MS
- PERLA (but sluggish), Thrashing
- 80/60, HR 130, pale
Case # 1...

- Chest wall tender
- Diminished BS on Right, dull
- Tender abdomen
Case # 1...

- Sick or not sick?
- REAL SICK, or kinda sick?
Remember!!

Normal Breathing...

- Generates Negative Intrathoracic Pressure
- Pulls Lungs Open in a Specific Architecture
- Enhances Venous Return and Cardiac Preload
SO????

How to assist ventilation on this guy??
Moribund Trauma Pt.

• Little $O_2$ Transport & Consumption

• Little $CO_2$ Production & Venous Return

Little Need to Ventilate
And There’s a Key Problem...

Positive Pressure Breaths *Can* Impair Cardiac Output...

...*in the Face of Severe Circulatory Compromise*
Moribund Trauma Patient

- Adequate Tidal Volume
- Breath q 7 - 10 seconds
Thank you for your kind attention!!