Preservation and Maintenance of Negative Intrathoracic Pressure during Circulatory Collapse

Use of Capnography for Monitoring Pressure Status
The medical and ethical performance of EMS professionals has never been more important than it is today.
The emerging of a profession:

Paramedicine
The End of the Beginning
The End of the Beginning

- Innocence is over
- You are COMPLETELY accountable for what you do
- Becoming a professional requires you to always be able to explain your actions
- EMS is ONLY and ALWAYS about patient care
As we assess patients, we must quickly determine fundamental parameters of their respiratory and circulatory status.
How do we do it?

Standardized Patient Examinations!

Makes Sense Out of Chaos!!
Primary Survey

From Basic Trauma Life Support, 1983

Scene/Mechanism/# of Patients
LOC/Airway/Cspine
Respiratory Rate and Labor
Pulses, Rate and Quality, Neck and Wrist
Skin CMT/CRT
Neck appearance, NVD, Trachea
Chest appearance
Breath sounds present and equal, percussion
Brief exam of abd, pelvis, LE, UE, Back
Conclusions:

- Medics learn as adult learners do (rote memorization works poorly)
- Medics must be allowed more practice time in stations, avoid long lectures
- Periodic quality assurance and retraining on patient assessment is vital
- Assuming that all experienced paramedics will retain material from intense training periods is wrong
- Tempus fugit
“Tweaking” the Process

- The Third Survey (MGA ~ 1994)
- Annual Skills Reviews (MGA ~ 1995)
- Improved assessment measures for performance including improving patient care report document and procedure notes
Third Survey

Level of Consciousness
Airway
Breathing
Circulation

Any other pertinent positive or negative following initial resuscitation
Understanding Resuscitation Requirements

We MUST maintain Normal Physiology

Statement of Concern:
What we DO to unstable patients during resuscitation is often BAD physiology
Understanding the body by regions

- Positive pressure
- Negative pressure
- Positive pressure
The negative pressure inside the thorax “pulls” blood back from the positive pressure areas.
Maintaining the “negativity” of the pressure inside of the thorax is one of the most vital areas of understanding resuscitation.
…and!!!

Maintaining negative pressure is one of the LEAST understood requirements!!
How Does Blood Get Back from My Big Toe?
Does the heart PUMP it around?
Nope...
The heart sucks blood back on the intake stroke
Only through MAINTAINING the negative intake stroke can the pumping action (cardiac output) be preserved.
Blood pressure = Cardiac output × Volume × Peripheral resistance
Blood pressure =

A heart thing &
a volume thing &
a blood vessel thing...ALWAYS!
What does a low blood pressure mean?

Either...

Or a combination of any of these

...from BTLS, editions 2, 3, 4, and 5

Fowler, Pepe et al
Signs of Shock

Early
- Weak, thirsty, lightheaded
- Pale, then sweaty
- Tachycardia
- Tachypnea
- Diminished urinary output

Late
- Hypotension
- Altered LOC
- Cardiac arrest
- Death
Shock

Cardiogenic
- Rapid pulse
- Distended neck veins
- Cyanosis

Volume Loss
- Rapid pulse
- Flat neck veins
- Pale

Vasodilatory
- Variable pulse
- Flat neck veins
- Pale or pink
What is the problem with shock?

Oxygen deprivation to the tissues below an absolute level of about 10 mmHg at the tissue level, causing cell membrane damage, ion depolarization, and calcium shifts with cell death.
Rationale for Fluid Resuscitation

Series of Canine Experiments in 1950s and 1960s...

Shed 60 -70% blood volume = 80% Mortality Rate
Mortality Rate in Animals
with 60-70% of their Blood Volume Shed

- No Therapy
ASSUMPTION

Elevating Blood Pressure is Always a Good Thing
Maybe
Not...
Bill Bickell and Paul Pepe
1990’s -- New Series of Animal Experiments
(uncontrolled hemorrhage in rats, dogs, pigs, sheep)

BP < 40 mmHg
May Be a
Hypotension
Threshold
THUS!!!

Providing a base level of a few CC’s of oxygen per 100 cc of blood (far less than normally carried in arterial blood – 15 to 20 cc’s/100 cc blood) may prevent cellular injury and death
Shock Management

Perform a Primary Survey

What is the patient’s circulatory status

Determine Circulatory Status

LOC
Airway
Resp Rate
Pulse
Color
Chest/Abd
Bleeding
BP
Pulse Ox
ET CO₂
Choose the Method for Bleeding Control

- Horizontal Position
- Direct Pressure
- ?? Tourniquets ??
- ?? MAST ??
Establish IV Access

Based on Need for Fluid Administration or IV Drugs

NOT NECESSARILY ROUTINE!!
Based on Need to maintain hemodynamic status

NORMALIZE BP ONLY IN PATIENTS WITH CONTROLLED HEMORRHAGE

Compute IV Fluid Rate
15-20 cc/kg Volume Bolus IF BLEEDING IS CONTROLLED

15-20 cc/kg Volume Bolus IF BLEEDING IS NOT CONTROLLED UP TO THE APPEARANCE OF A RADIAL PULSE ONLY

Compute IV Fluid Rate
• Controlled External Hemorrhage 20 cc/kg until normalized
• Uncontrolled External Hemorrhage = 20 cc/kg until radial pulse appears
• Uncontrolled Internal Hemorrhage = 20 cc/kg until radial pulse appears
• Head-injured trauma with circulatory compromise = 20 cc/kg until radial pulse appears
Begin Intake and Output Recording

Keep NPO

IV Fluids, if any

Note amount of Urine Output
(0.5 – 1 cc/min in adults; adjust down by weight for kiddies)

NG or PEG output

Vomitus or Diarrhea

Don’t forget diaphoresis and burns!!
Hemothorax may develop after a tension

Bleeding from the abdomen may occur later without warning

Volume expansion may blow off a clot

Your selected ventilation rate might drop venous return and cause impaired circulation

Be AWARE that the Patient’s Condition may CHANGE

“Third Survey” every five minutes
Determining the need for HBOC!

- Decreasing CO₂, especially in the setting of hypotension
- Pale patient
- Altered mental status
- Any severe hemorrhage
- Arrhythmia development
- "PROTECTION FROM ANOXIC DAMAGE"
Current Ventilation Concepts in Critical Care
Cardiac Arrest
A 55 year old man is found down in Cardiac Arrest by his wife. EMS is called. Citizen CPR is being done.

He was well until this happened. He has no medical problems and takes no medications.
After defibrillation the patient remains in VF.

He does not improve after administration of CPR, epinephrine, or amiodarone.
What do you do??
Our normal breathing is NEGATIVE PRESSURE breathing!
Negative pressure breaths improve venous return to the heart and increase cardiac output.
Oxygen $\rightarrow$ lungs $\rightarrow$ alveoli $\rightarrow$ blood

breath

CO$_2$

muscles + organs

Oxygen

cells

energy

CO$_2$

Oxygen + Glucose
Alveoli: The Place Where Gas Exchange Happens
Carbon dioxide physiology

$\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$
What is Carbon Dioxide?

- Capnos comes from the Greek word for “smoke”
  - smoke from the fire of metabolism
  - a natural waste product of cellular activity
- $\text{CO}_2$ is a compound molecule
  - 2 elements of oxygen and 1 element of carbon
  - colorless and heavier than air
  - green plants clean up after our exhaled $\text{CO}_2$
Carbon dioxide physiology

• 0.03% concentration in air
• Resting adult produces 2.5 mg/kg/min, or about 185 mg in a guy my size
  
  (okay, okay…195 mg…4% of a teaspoonful)
AVOID OVERVENTILATION!

Only ventilate as fast as the amount of CO2 being produced

Bagging too fast RAISES intrathoracic pressure, drops venous return, and reduces cardiac output
CAT Scans in The Field?

Well, not any time soon,
Though in Odessa, Texas
One of the first studies
On field ultrasound machines
Is now being conducted!
Rates greater than 8 per minute by ET tube in patients with circulatory collapse
\textbf{MAY} drop blood pressure...\textbf{or worse}!
Previous and Ongoing Studies by Pepe et al
A swine model was cannulated and nearly exsanguinated.

Hyperventilation was induced.
Pepe showed that coronary perfusion pressures DROPPED dramatically during overventilation.
Rate: 6 breaths x min\(^{-1}\) \text{ (2\textsuperscript{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 \text{ (in Pink)}
Aufderheide found, medics routinely overventilate patients even when specifically trained to avoid overzealous ventilation.
Patient in PEA being Overventilated at Rate of 30 and CO$_2$ of about 15
Same Patient in PEA at Rate of 10 and CO₂ increased to 25
Patient in Severe Sinus Brady
Being Overventilated at a rate of 40
and a CO2 of 8
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.
A one hand squeeze at a rate of one every eight seconds is ALL the ventilation that a patient in circulatory collapse needs!
Breathing the patient faster than that may reduce venous return, worsen shock, and kill the patient!
Let capnography guide you!
Normal Capnography Wave
Capnography Wave with Obstructive Component?
Capnography Wave with Restrictive Component?
What Happened in Block 2?

The endotracheal tube became dislodged!

Misplaced endotracheal tubes by paramedics in an urban emergency medical services system.

Katz SH, Falk JL
Department of Emergency Medicine, JFK Medical Center, Atlantis, FL, USA.

A total of 108 intubated patients were studied
On arrival in the ED, 25% (27/108) of patients were found to have improperly placed endotracheal tubes. Of the misplaced tubes, 67% (18/27) were found to be in the esophagus, whereas in 33% (9/27), the tip of the tube was found to be in the hypopharynx, above the vocal cords.

Of the patients with misplaced tubes noted in the hypopharynx, 33% (3/9) died while in the ED. For the patients found to have tubes in the hypopharynx, 56% (5/9) had evidence of ETCO(2) on ED arrival.

For the patients found to have esophageal tube placement on ED arrival, 56% (10/18) died in the ED.

CONCLUSION: The incidence of out-of-hospital, unrecognized, misplaced endotracheal tubes in our community is excessively high and may be reflective of the incidence occurring in other communities. Data from other communities are needed to clarify the scope of this alarming issue.
DOUGLAS COUNTY FIRE/EMS
PRE-HOSPITAL AIRWAY MANAGEMENT FORM

Patient's Name: ___________________  Age: ______  Case # ____________  Date: __/__/____

Check all appropriate items: Instructing Medics' Name (Print): ____________  Medics' Number:

<table>
<thead>
<tr>
<th>Care prior to EMS arrival</th>
<th>Arrival of EMS</th>
<th>Status of Pt's Airways/Ventilation</th>
<th>Indication(s) for ETT</th>
<th>Indications for ETT continued</th>
</tr>
</thead>
<tbody>
<tr>
<td>URI</td>
<td></td>
<td>Airways not open on arrival</td>
<td>Asthma</td>
<td>Paralytic</td>
</tr>
<tr>
<td>Mouth-to-Mouth</td>
<td></td>
<td>Open, #4 Ventilating Well</td>
<td>Apnea</td>
<td>Major Trauma</td>
</tr>
<tr>
<td>IV/MM</td>
<td></td>
<td>Open, not Ventilating Well</td>
<td>Cardiac Arrest</td>
<td>Low Tidal Volume</td>
</tr>
<tr>
<td>Oral/Nostril Airway</td>
<td></td>
<td>Open, in Respiratory Arrest</td>
<td>Head Injury</td>
<td>Respiratory Rate</td>
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<tr>
<td>Manual Maneuvers</td>
<td></td>
<td>Foreign Body Obstruction</td>
<td>Hypoxia</td>
<td>Other</td>
</tr>
<tr>
<td>ET/Combitube Placed</td>
<td></td>
<td>Oxygen/Blood in Airways</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facial/Tracheal Trauma</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Intubation (ETT)</th>
<th>Verification Check #1 (ETT)</th>
<th>Verification Check #2</th>
<th>Verification Check #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oropharyngeal</td>
<td>Direct Visualization</td>
<td>Aspiration 60cc or more of air</td>
<td>Breath Sounds</td>
</tr>
<tr>
<td>Nasal</td>
<td>(ET seen through vocal cords)</td>
<td></td>
<td>B/S Present left only</td>
</tr>
<tr>
<td>Digital</td>
<td>ET User Asystolic</td>
<td></td>
<td>B/S Absent</td>
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<tr>
<td></td>
<td>Unable to Visualize</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verification Check #4</th>
<th>Verification Check #5</th>
<th>ETT Placement</th>
<th>Combitube Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>False O2 Reading</td>
<td>YES</td>
<td>ETT Size</td>
<td>Number of attempts</td>
</tr>
<tr>
<td>Pre-ETT: ____%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-ETT: ____%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capnometry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-ETT: Yellow/Blue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-ETT: Yellow/Blue</td>
<td></td>
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</tr>
</tbody>
</table>

PLACEMENT SECURED BY:  ☐ ETT HOLDER  ☐ C-COLLAR  ☐ OTHER

PHYSICIAN OR RESPIRATORY THERAPIST STATEMENT

TO THE PHYSICIAN OR RESPIRATORY THERAPIST ACCEPTING CARE OF THIS PATIENT,
PLEASE FILL OUT THIS SECTION AS PART OF OUR QUALITY IMPROVEMENT PROGRAM.

ETT Position upon Arrival in your ER:  ☐ Trachea  ☐ Esophagus  RECEIVING HOSPITAL:________
Combitube Position upon Arrival in your ER: ☐ Trachea  ☐ Esophagus
Method of Verification:  ☐ Direct Visualization  ☐ Breaths Sounds

Comments: ____________________________________________

PHYSICIAN/RT SIGNATURE: ___________________________ DATE OF SIGNATURE: __/__/____

EMS MEDICAL DIRECTOR SIGNATURE: _______________________ DATE OF SIGNATURE: __/__/____

Please attach this form to the Douglas County Fire Department's copy of the DBR on this patient.
The era is over when we can justify not knowing whether an endotracheal tube is in place or not.

We may not be able to intubate everybody, but we must ALWAYS know if the tube is in place or not.
Critical Care Ventilation

Perform a Primary Survey

Determine Ventilation Status

What is the patient’s ventilatory status

LOC
Airway
Resp Rate
Pulse
Color
Pulse Ox
ET CO₂
Compute Tidal Volume

Based on Need for Oxygen:
10-15 cc/kg
Big squeeze big folks, full bag

Little squeeze little folks
(1/3 bag for 12 y/o)
On the low side if using BVM

Tidal Volume

On the low side if tension pneumo

10-15 cc/kg

Big squeeze big folks
Little squeeze little folks
Based on Need to remove CO$_2$

Compute Respiratory Rate
• Trauma Arrest = 6-8/min
• Cardiac Arrest = 8-10/min
• Altered LOC with unilateral blown pupil no circ comp = 15/min
• Head-injured trauma with circulatory compromise = 8-10/min
• Asthma = 8-10/min
• Hypovolemia = 8-10/min
• COPD = 8-10/min
Based on Capnometry:
Slow ventilation rate until you see yellow in the capnometry reading (or better, use waveform and slow ventilation until CO₂ crosses about 20 or greater)

Adjust Ventilation Rate
Capnometry

- A (purple) = < 4 mm Hg
- B (tan) = 4-15 mm Hg
- C (yellow) = > 15 mm Hg
Wayne et al:showed that in cardiac arrest patients whose endtidal CO$_2$ was less than 10 mmHg, no one survived.
So, what do we do with this guy??
Make SURE that his ventilation rate is a one hand squeeze every eight seconds
Evaluate capnography or capnometry five minutes later
Adjust the ventilation rate from there
Slow the ventilation rate down until exhaled CO2 rises above 20, paired with good, deep compressions and little time off chest.
...and, if you do this...
AND YOU MUST...
you will likely be the only guy on the team who understands that this is now the standard
Major Trauma
Bubba was shot in the chest during an intellectual discussion about the value of certain goods and services where one individual did not feel that the goods rendered equaled the value transferred.

He was well until this happened. He has no medical problems and takes no medications.
Enroute his capnography shows 40 on exhalation, and you begin O’s, IV’s, and rapid transport.

Shortly thereafter, his CO2 drops to 20 and he is acting a little confused.

What is happening?
He is going into circulatory collapse

What do you do?
Administer sufficient fluid to maintain radial ("permissive hypoperfusion")
Examine for the development of a tension

If you have to assist ventilation
start with a one hand squeeze
at a rate of eight and
keep your eye on the Capnography Waveform
...and contact the trauma team...

...and drive fast...

...but not too fast...
EMS professionals have never been more important to emergency medicine than they are today...

...and their knowledge base must continue to grow indefinitely...
The Medics of the Near Future will be “Out of Hospital Intensivists”

BP = 88/55
P = 160
Resp = 36
TV = 800
Glu = 425
Hgb = 9
QUESTIONS
and
COMMENTS??