Manual Ventilation: An effective skill or a dangerous delusion?

(Resolving the Problem of “Inadvertent Hyperventilation”)
Definition:

“The unintentional, involuntary, accidental, not deliberate delivery of an abnormally increased minute ventilation, resulting in a reduction in carbon dioxide tension, which, if prolonged, may result in alkalosis.”
Causes of Inadvertent Hyperventilation

\[ V_t = \frac{1500}{f} = 10 \]

\[ V_t = \frac{500}{f} = 30 \]

\[ V_t = \frac{1500}{f} = 30 \]
Most common method of ventilating a patient
Problems with standard BVMs

- No control over Vt
- No control over RR
- No control over Pmax
Three Problems Caused by Manual Resuscitators

• Gastric Insufflation – mask ventilated patients

• Reduced Venous Return – patients in low flow states (cardiac arrest, hypovolaemic trauma)

• Cerebral Vasoconstriction – particularly in traumatic brain injury
1. Gastric Insufflation (in the patient with an unprotected airway)
Components determining distribution of gas flow between lungs and stomach during ventilation of an unprotected airway

Patient
- Lower esophageal sphincter pressure
- Airway Resistance
- Airway Compliance

Rescuer
- Inspiratory time
- Inspiratory flow
- Peak airway pressure
“Influence of tidal volume on the distribution of gas between the lungs and stomach in the un-intubated patient receiving positive-pressure ventilation”.


**Figure 2.** Mask, lung and stomach minute ventilation applied with an adult and pediatric self inflating bag with different LESP levels
Gastric trauma and pulmonary aspiration at autopsy after CPR
Felegi WB, Doolittle R, Conston A, Chandler SV.
Acad Emerg Med 1996;3:441

“Aspiration of stomach contents is common during cardiac arrest”

• Found in ~33% of patients after CPR
• Increases mortality in 24 - 96 hours in those successfully resuscitated
• with volumes of vomit >25 ml at a pH < 2.5
Vicious Respiratory Cycle in an Unintubated Patient

Stomach inflation

Lung inflation

Stomach inflation

Redistribution of gas from lungs to stomach

Peak airway pressure

Intragastric pressure

Cephalic movement of diaphragm

Lung movements

Respiratory system compliance
Conclusions:

– Gastric Insufflation is a commonly occurring, life threatening, problem

– The high incidence of gastric insufflation and the associated risks of aspiration of stomach contents, need to be strongly conveyed to all those who are trained to provided CPR.

– Better methods of controlling the delivery of ventilations need to be found to reduce the incidence of gastric insufflation.
2. Decreased Venous Return
Hyperventilation

- Increases intra thoracic pressure
- Compressing the great vessels
- Reducing venous return to the heart
“Hyperventilation-Induced Hypotension During Cardiopulmonary Resuscitation”

Aufderheide et al:
Circulation April 27, 2004
TABLE 1. Clinical Observational Study: Maximum Ventilation Rate, Duration, and Percentage of Time in Which a Positive Pressure Was Recorded in the Lungs (Mean±SEM)

<table>
<thead>
<tr>
<th>Group</th>
<th>Ventilation Rate (Breaths per Minute)</th>
<th>Ventilation Duration (Seconds per Breath)</th>
<th>% Positive Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>37 ± 4*</td>
<td>0.85 ± 0.07†</td>
<td>50 ± 4%</td>
</tr>
<tr>
<td>Group 2</td>
<td>22 ± 3*</td>
<td>1.18 ± 0.06†</td>
<td>44.5 ± 8.2%</td>
</tr>
<tr>
<td>Group 3</td>
<td>30 ± 3.2</td>
<td>1.0 ± 0.7</td>
<td>47.3 ± 4.3%</td>
</tr>
</tbody>
</table>

*P<0.05; †P<0.05; group 1, first 7 consecutive cases; group 2, subsequent 6 consecutive cases (after retraining); group 3, groups 1 and 2 combined.

GROUP 1 – INITIAL FIELD EVALUATION
GROUP 2 – IMMEDIATE POST TRAINING FIELD EVALUATION
GROUP 3 – MEAN VENTILATION RATE FROM BOTH GROUPS
“The data demonstrates that any incidence of hyperventilation is likely to have detrimental hemodynamic and survival consequences during low flow states such as CPR”.

Aufderheide T. et al
Unrecognized and unintentional hyperventilation may be contributing to the currently poor survival rates from Cardiac Arrest.
Do we hyperventilate cardiac arrest patients?


- Maximum respiratory rate was 41 BPM
- Mean respiratory rate was 21 BPM
- Mean tidal volume was 619 ml
- Mean peak inspiratory pressures was 60.6 cm H₂O

Airway pressure was positive for 95.3% of the respiratory cycle!
“Hyperventilation was common, mostly through high respiratory rates rather than excessive tidal volumes.

The persistently high airway pressures are likely to have a detrimental effect on blood flow during CPR. Guidelines on respiratory rates are well known, but it would appear that in practice they are not being observed”.
Patients with cardiac arrest are ventilated two times faster than guidelines recommend

Maertens VL et al
Resuscitation. July 2013

• In manually ventilated patients with cardiac arrest, 90% had median ventilation rates of 20 BPM

• The ventilation rate in patients with cardiac arrest was higher than in patients without cardiac arrest
“Cardiac arrest patients were ventilated two times faster than recommended by the guidelines”.
Conclusions:

- Inadvertent hyperventilation is common.
- It reduces venous return and cardiac pre-load, decreases forward flow and coronary perfusion pressure,
- De-oxygenates heart muscle
- Decreases the effect of defibrillation.
Conclusion

“Unintentional and overly aggressive ventilations must be controlled to reduce the negative effects on the circulatory system of Inadvertent Hyperventilation if survival rates are to improve”
3. Cerebral Vasoconstriction
“Hyperventilation in brain injured patients increases brain ischemia”

Brain Trauma Foundation - 1995
“Hyperventilation reduces CO2 levels in the blood”

“Hyperventilation increases brain ischemia”

“Cerebral blood flow is low and consistent with brain ischemia”

“Hyperventilation does not decrease intracranial pressure”

“Hyperventilation may actually exacerbate the problem”

“Outcomes of TBI patents are worse when hyperventilation is employed”
Reduced cerebral oxygenation
Poor neurological outcomes for cardiac arrest survivors?
Conclusions:

1. There is a significant difference between CPR performance in the classroom and performance during an actual cardiac arrests.

2. Professional rescuers were observed to excessively ventilate patients during CPR despite recent re-training.

3. Excessive ventilation rates resulted in significantly increased intra-thoracic pressure and markedly decreased venous return, coronary perfusion pressures and survival rates in a porcine model.

4. Traumatic Brain Injured patients have worse outcomes when hyperventilated.

5. Hyperventilation may also contribute to poor neurological outcomes for cardiac arrest survivors.
Hyperventilation 🤡 is never a substitute for GOOD Ventilation!
“Why does Inadvertent Hyperventilation occur?”
Potential Causes of Inadvertent Hyperventilation

- **Incident stress**
- **Adrenaline rush**
- “Ventilation Fever”!
- “Brain/Hand disassociation”
“How do we improve the control of ventilation”
MORE TRAINING?
Ventilation skills of emergency medical technicians:

“A teaching challenge for emergency medicine”

TRAINING METHODS

- Instructor-directed, videotape/computer training aids
- Auditory and visual prompts
- BLS and ACLS Simulators
Retention of Ventilation Skills by Emergency Nurses

“Skill retention, even immediately post training, was insufficient using current technology”

De Regge M., et al

Presented at the ERC meeting in Budapest, Hungary - September 2004
Conclusions:

• Improved and more frequent training may have an effect on ventilation skills in the classroom.

• Classroom training does not take into consideration the effect of “incident stress” ............

• Or the effect of this on the rescuer’s skill performance in the field
Is Technology therefore the answer?
Automatic Transport Ventilators.....

The **GOLD** Standard!
Currently available manual ventilation technology that....

Does not require any capital outlay!

Does not require any significant training!

Does not change the way in which manual ventilation is provided!

Removes the risks associated with inadvertent hyperventilation!
Flow controlling
Technology
How It Works

Valve Remains Open

Correct, Slow Bag Squeeze Applied

Patient with Normal Compliance and Resistance

Valve Closed to Maximum Position

Bag Squeezed Too Hard

Patient with Normal Compliance and Resistance
“FLOW VALVE” APPEARING IN THE NECK OF THE BAG SHOWING THAT THE BAG HAS BEEN SQUEEZED TOO HARD OR TOO FAST
PISTON IN THE “PRESSURE BALANCED” POSITION DUE TO AIRWAY COMPLIANCE/RESISTANCE ISSUES
“My manual resuscitator has a pressure relief, doesn’t that stop me hyperventilating the patient”
Pressure relief valves merely indicate that the airway pressure has reached a level that is well past critical.

Flow controlling valves limit the airway pressure to the level required for adequate ventilation to take place.

The Pressure Relief level is not reached unless significant compliance or resistance issues exist.”
Research Supporting the SMART BAG®
Ventilation of an unprotected airway in a mechanical model

Ventilation of an unprotected airway in patients


(Anesthesiologists ventilating Gynecology patients in the Operating Room).
Effects of Decreasing Peak Flow Rate on Stomach Inflation during Bag-Valve-Mask Ventilation


[Bar chart showing comparison between Std BVM and Smart Bag for Magenbeatmung (%) and Magenbeatmung (ml).]
ADDITIONAL STUDIES THAT CONFIRM THE PERFORMANCE OF FLOW CONTROL


- Decreasing peak flow rate with a new bag-valve-mask device: effects on respiratory mechanics, and gas distribution in a bench model of an unprotected airway

- Comparison of Ventilatory Efficacy of the Standard Bag-Valve Mask and the SMART BAG®
  Busko, Dailey, & Goodwin (Prehosp Emerg Care. 2004 Jan-Feb;8(1):88)

- Retention of Ventilation Skills by Emergency Nurses - SMART BAG® Compared with Standard Bag.

- Impact of a pressure-responsive flow-limiting valve on bag–valve– mask ventilation in an airway model


Studies Awaiting Publication

- An ICU study using PiCCO (pulse contour cardiac analysis) to measure cardiac output showing the SMART BAG® performing equivalent to an ICU ventilator.
- Bench study of the effects of supraglottal obstruction and mask leak on delivered lung volume between a standard BVM and a SMART BAG®
- Guidelines 2005 Compliance and the SMART BAG®
Conclusions:

1. There is a significant difference between CPR performance in the classroom and performance during an actual cardiac arrest.

2. Professional rescuers were observed to excessively ventilate patients during CPR despite recent re-training.

3. Excessive ventilation rates resulted in significantly increased intra-thoracic pressure and markedly decreased venous return, coronary perfusion pressures and survival rates in a porcine model.

4. Traumatic Brain Injured patients have worse outcomes when hyperventilated.

5. Hyperventilation may also contribute to poor neurological outcomes for cardiac arrest survivors.
Flow controlling technology has been clearly shown to:

- Improve ventilation performance
- Reduce peak airway pressure
- Provide for an increase in venous return
- Reduce Cerebral Vasoconstriction
- Meet the requirements of the current Resuscitation Guidelines