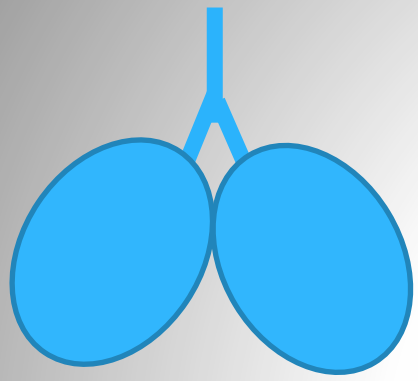
Manual Ventilation: An effective skill or a dangerous delusion?

(Resolving the Problem of "*Inadvertent Hyperventilation*")

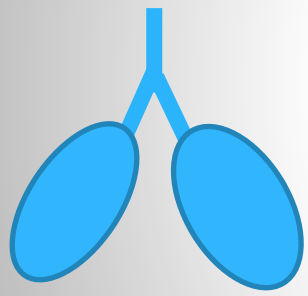
Definition:

"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."

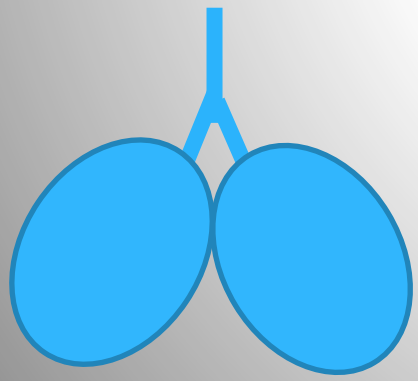
Causes of Inadvertent Hyperventilation



Vt = **1500** / f = 10



Vt = 500 / f = **30**



Vt = **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

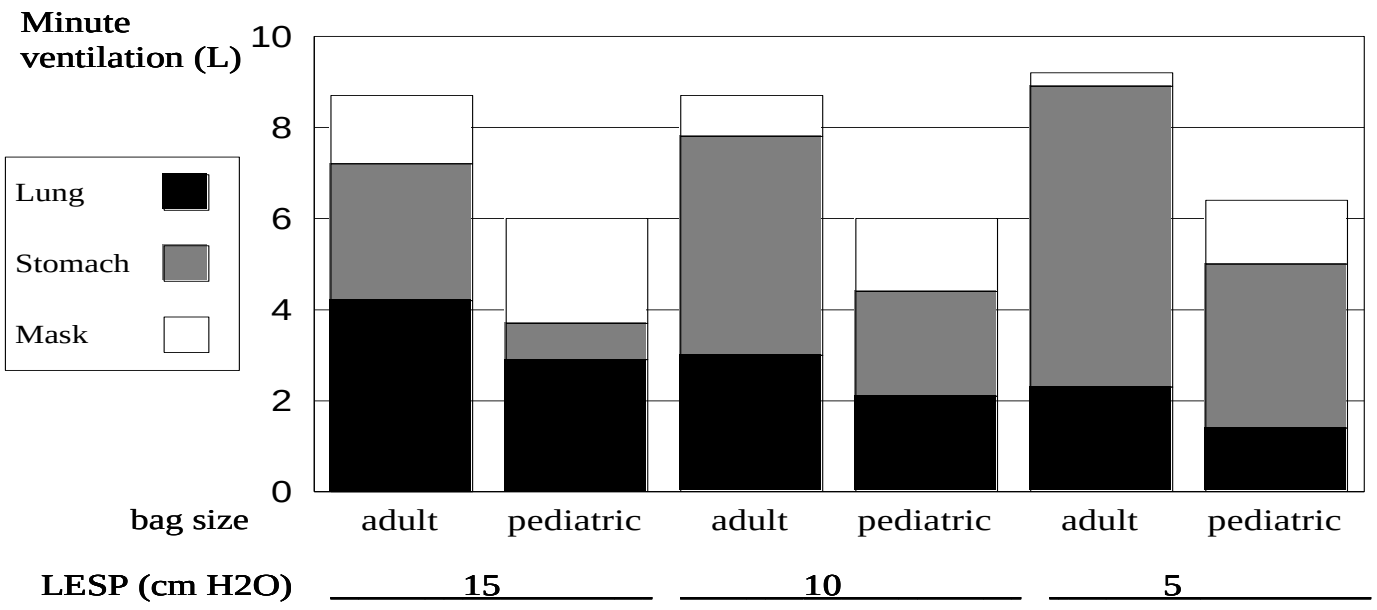
Rescuer

- 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”.

Wenzel V et al., *Crit Care Med* 1998;26:364-369

Figure 2. Mask, lung and stomach minute ventilation applied with an adult and pediatric self inflating bag with different LESP levels

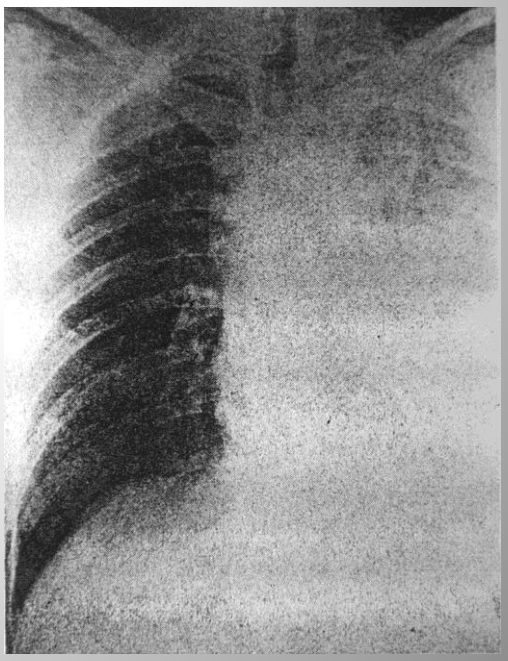


Gastric trauma and pulmonary aspiration at autopsy after CPR

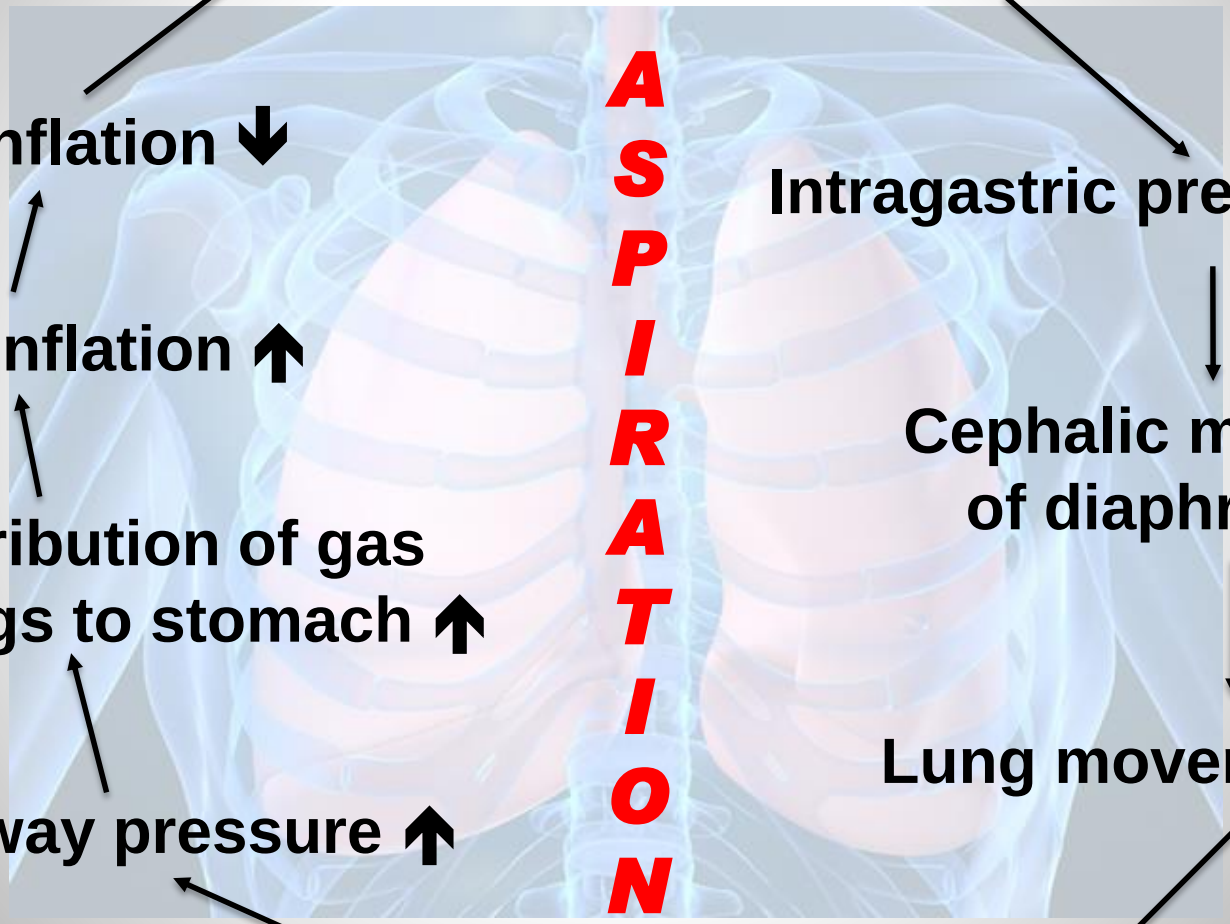
Felegi WB, Doolittle R, Conston A, Chandler SV.
Acad Emerg Med 1996;3:441

"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 ↑

Intragastric pressure ↑

Cephalic movement of diaphragm ↑

Lung movements ↓

Respiratory system compliance ↓

Peak airway pressure ↑

Redistribution of gas from lungs to stomach ↑

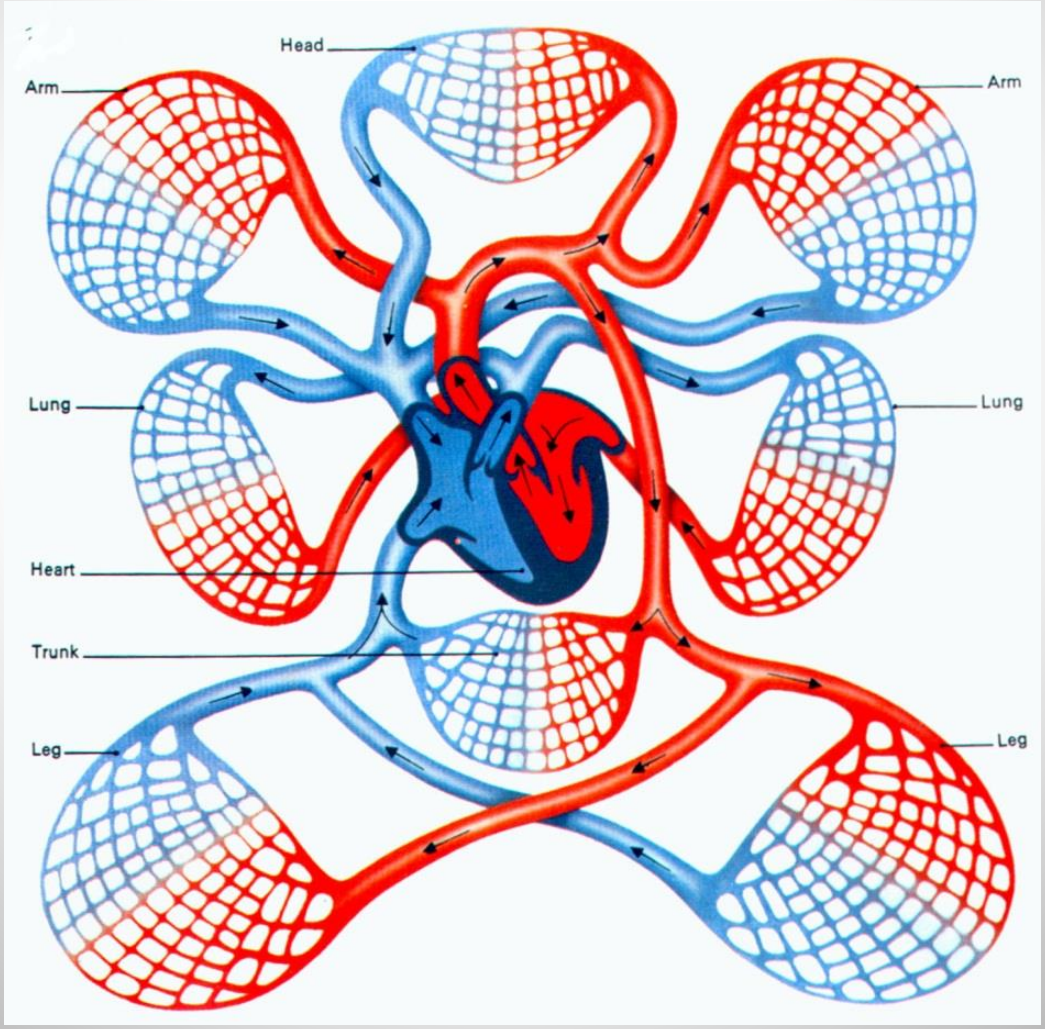
Stomach inflation ↑

Lung inflation ↓

Conclusions:

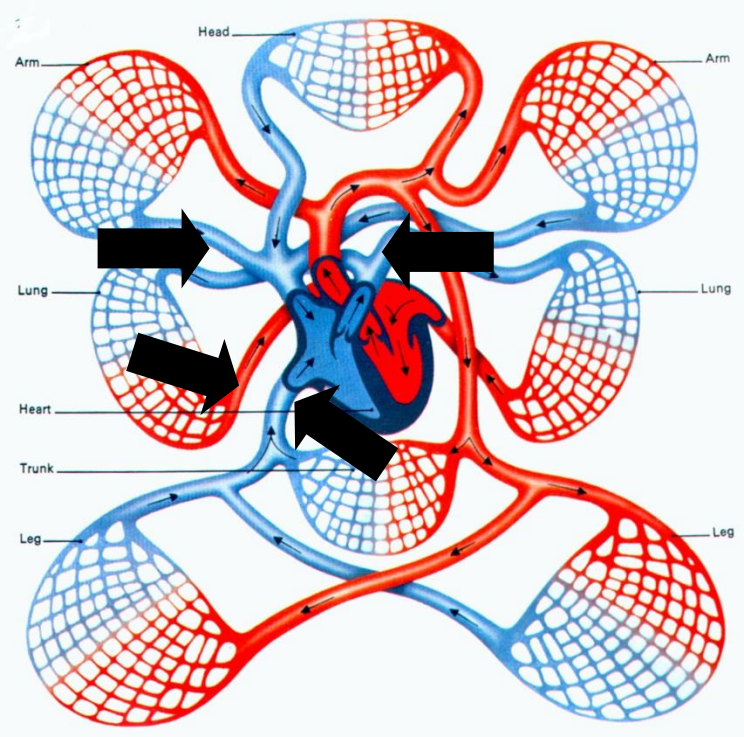
- Gastric Insufflation is a commonly occurring, life threatening, problem
- The high incidence of gastric insufflation and the associated risks of aspiration of stomach contents, need to be strongly conveyed to all those who are trained to provided CPR.
- Better methods of controlling the delivery of 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

American Heart Association®

Learn and Live℠

CLINICAL OBSERVATIONAL STUDY OF VENTILATION RATES BY PARAMEDICS

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)

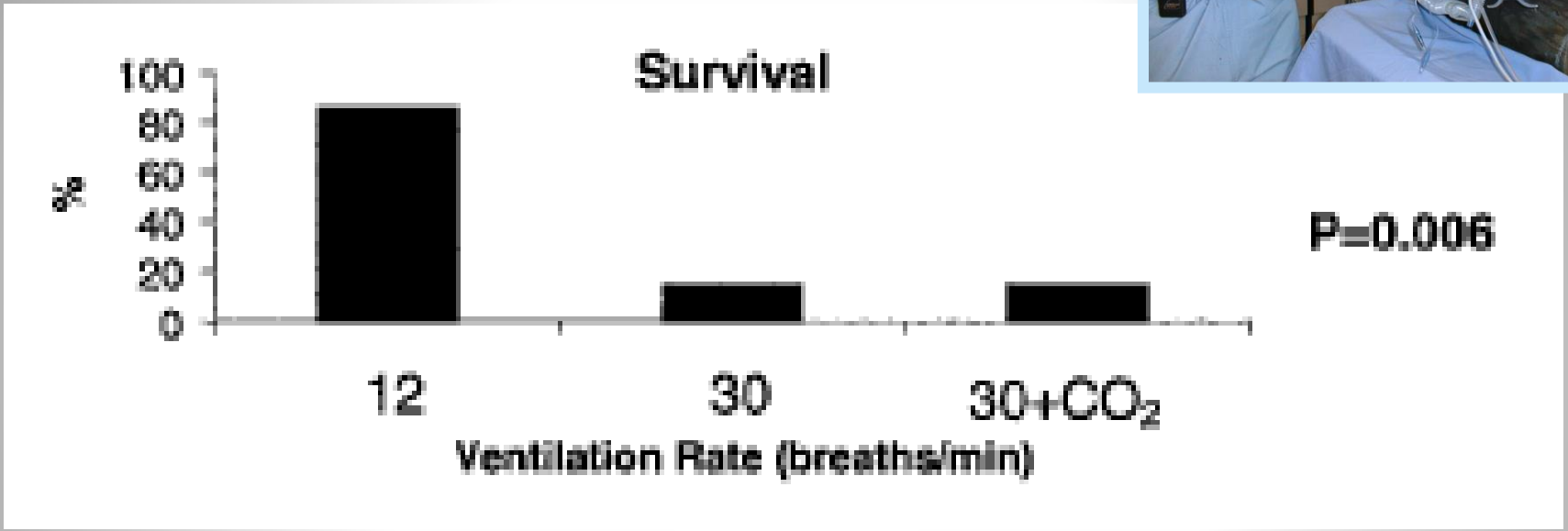
Group	Ventilation Rate (Breaths per Minute)	Ventilation Duration (Seconds per Breath)	% Positive Pressure
Group 1	37 ± 4*	0.85 ± 0.07†	50 ± 4%
Group 2	22 ± 3*	1.18 ± 0.06†	44.5 ± 8.2%
Group 3	30 ± 3.2	1.0 ± 0.7	47.3 ± 4.3%

*$P<0.05$; †$P<0.05$; 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

SURVIVAL RATES FROM HYPERVENTILATION

(Animal Study)



"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

THE LANCET

British Medical Journal

July 24, 2004

Editorial by Pitts and Kellerman

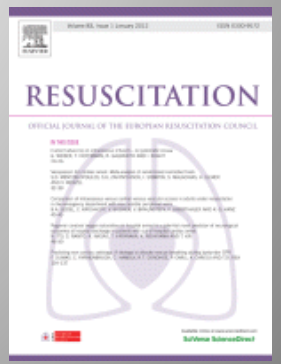
"Unrecognized and <u>unintentional</u> hyperventilation may be contributing to the currently poor survival rates from Cardiac Arrest".

Do we hyperventilate cardiac arrest patients?

O'Neill JF, Deakin CD.: Resuscitation. April 2007

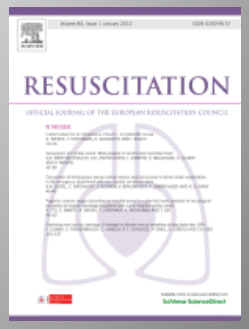
- **Maximum respiratory rate was <u>41 BPM</u>**
- **Mean respiratory rate was <u>21 BPM</u>**
- **Mean tidal volume was <u>619 ml</u>**
- **Mean peak inspiratory pressures was <u>60.6 cm H_2O</u>**

<u>Airway pressure was positive for 95.3% of the respiratory cycle!</u>



"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, <u>90% had median ventilation rates of 20 BPM</u>***

- ***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,***

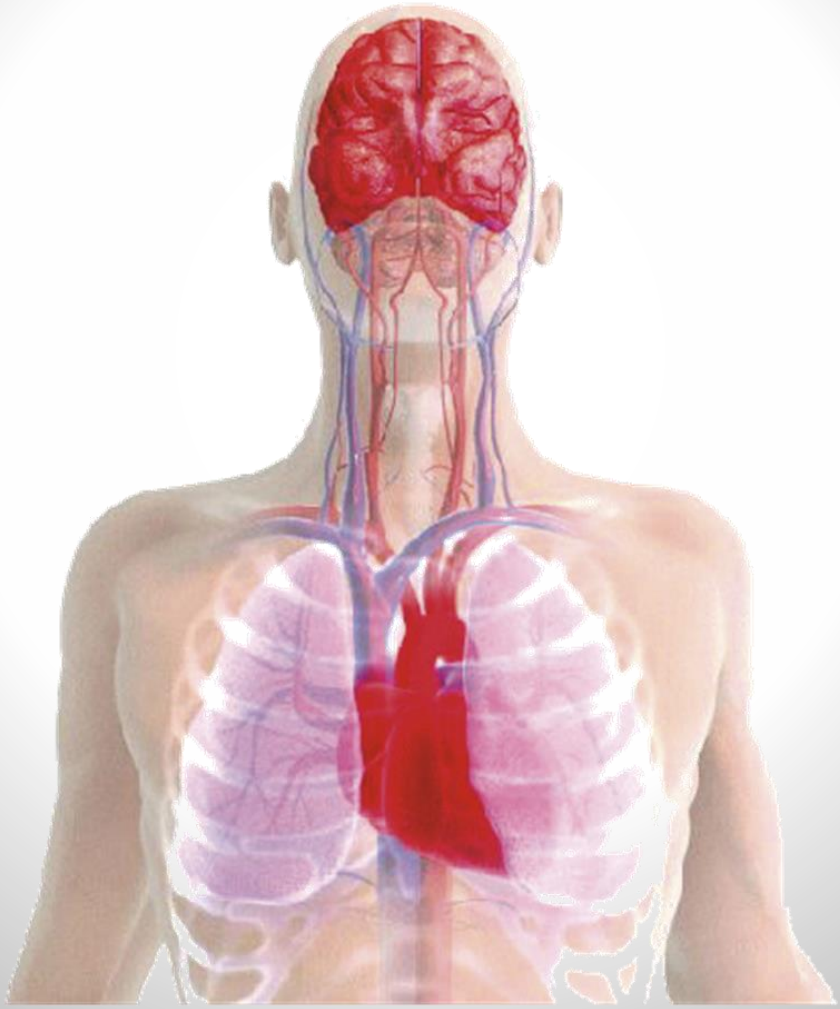
- ***De-oxygenates heart muscle***

- ***Decreases the effect of defibrillation.***

Conclusion

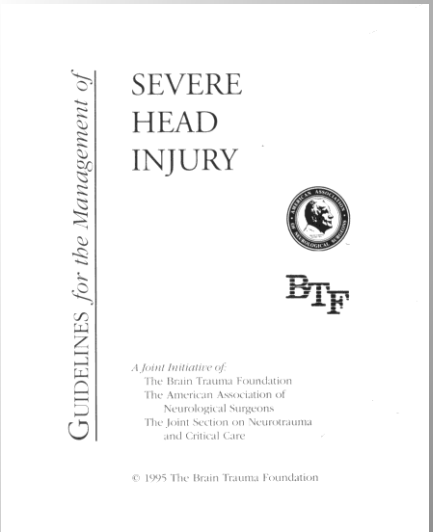
"Unintentional and overly aggressive ventilations must be controlled to reduce the negative effects on the circulatory system of Inadvertent Hyperventilation if survival rates are to improve"

3. Cerebral Vasoconstriction



“Hyperventilation in brain injured patients <u>increases brain ischemia</u>”

Brain Trauma Foundation - 1995


GUIDELINES *for the Management of*

SEVERE
HEAD
INJURY

BTF

A Joint Initiative of:
The Brain Trauma Foundation
The American Association of Neurological Surgeons
The Joint Section on Neurotrauma and Critical Care

© 1995 The Brain Trauma Foundation

"Hyperventilation reduces CO2 levels in the blood"

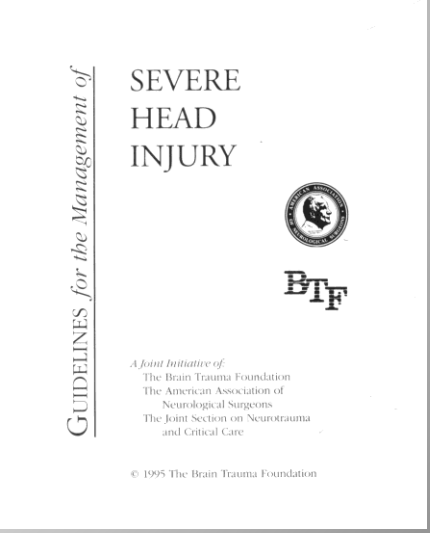
"Hyperventilation <u>increases</u> brain ischemia"

"Cerebral blood flow is low and consistent with brain ischemia"

"Hyperventilation does not decrease intra-cranial pressure"

"Hyperventilation may actually exacerbate the problem"

"Outcomes of TBI patents are worse when hyperventilation is employed"


GUIDELINES *for the Management of*

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HEAD
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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.**

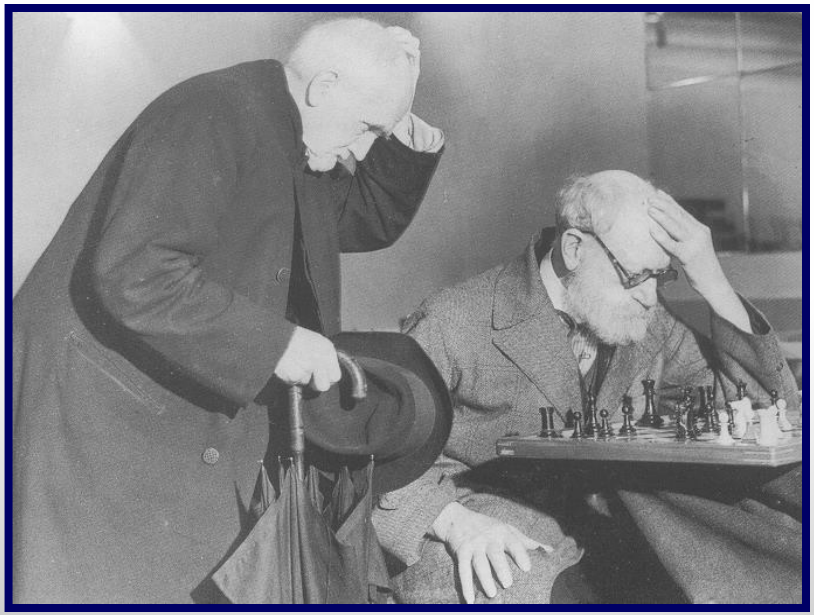
Hyperventilation 
is never a substitute
for <u>GOOD</u> Ventilation! 

“Why does Inadvertent Hyperventilation occur?”

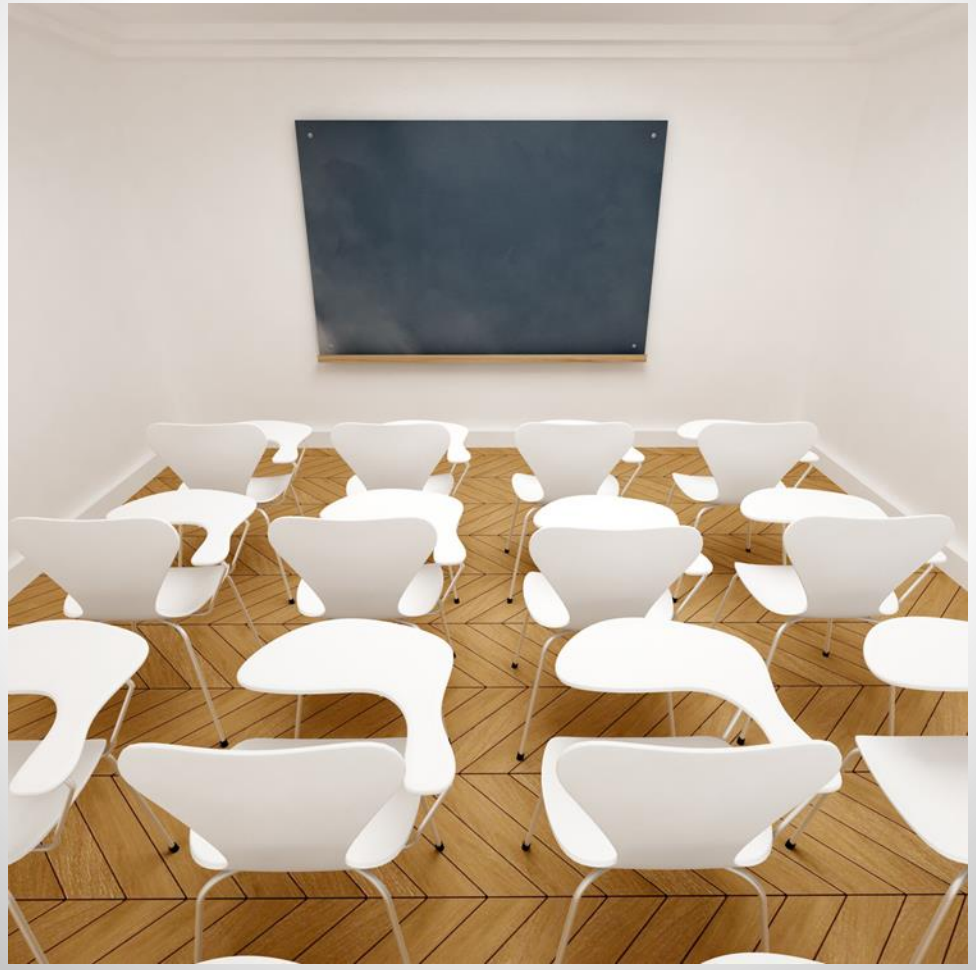
Potential Causes of Inadvertent Hyperventilation

- ***Incident stress***
- ***Adrenaline rush***
- **"Ventilation Fever"!**
- ***"Brain/Hand disassociation"***

“How do we improve the control of ventilation”



MORE TRAINING?



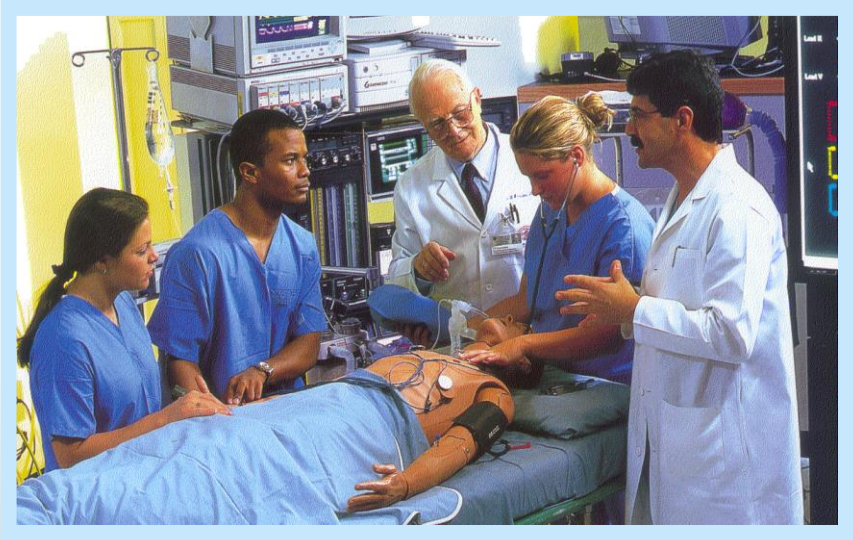
Ventilation skills of emergency medical technicians:

“A teaching challenge for emergency medicine”

Cummins et al. Ann Emerg Med. 1986 Oct;15(10):1187-92

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
(Resuscitation 62 (2004) 319-320)

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 class room.***
- ***Classroom training does not take into consideration the effect of <u>"incident stress"</u> ……..***
- ***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!

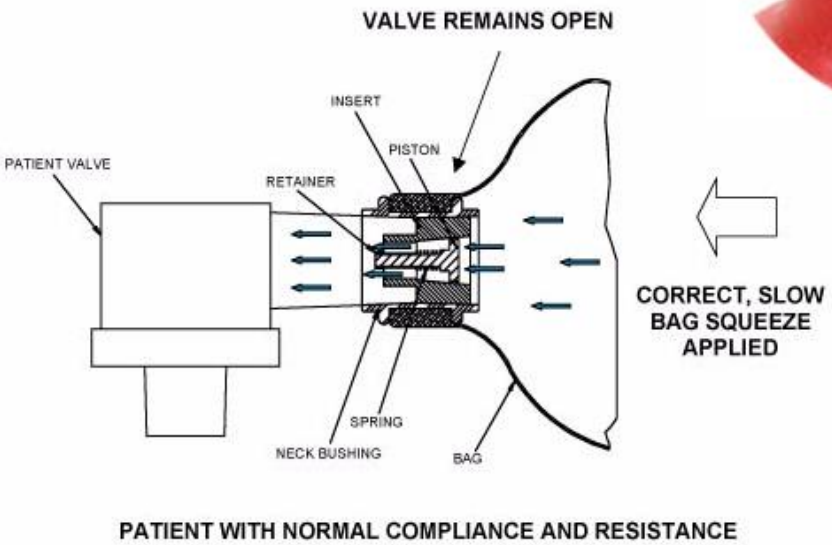
Does not require any significant training!

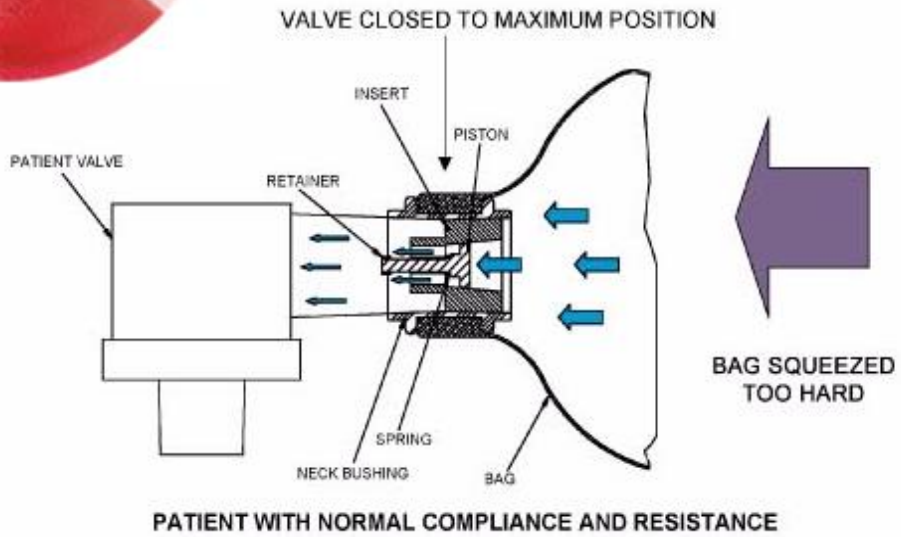
Does not change the way in which manual ventilation is provided!

Removes the risks associated with inadvertent hyperventilation!

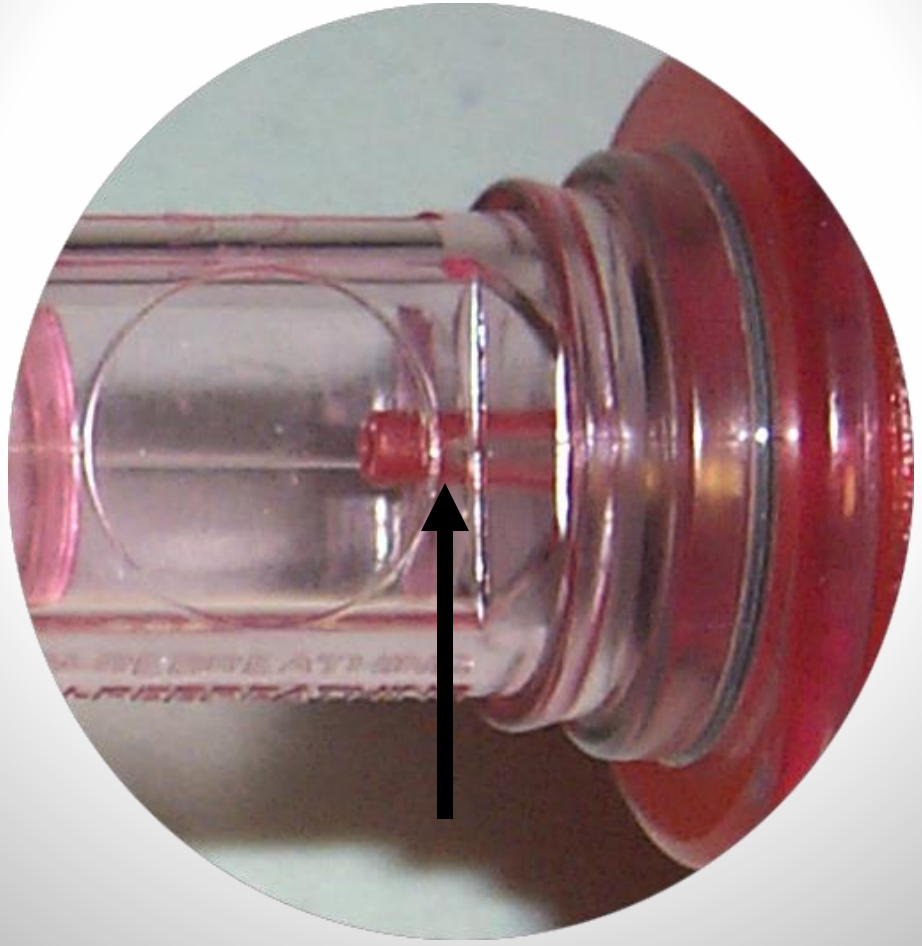
Flow controlling Technology

How It Works

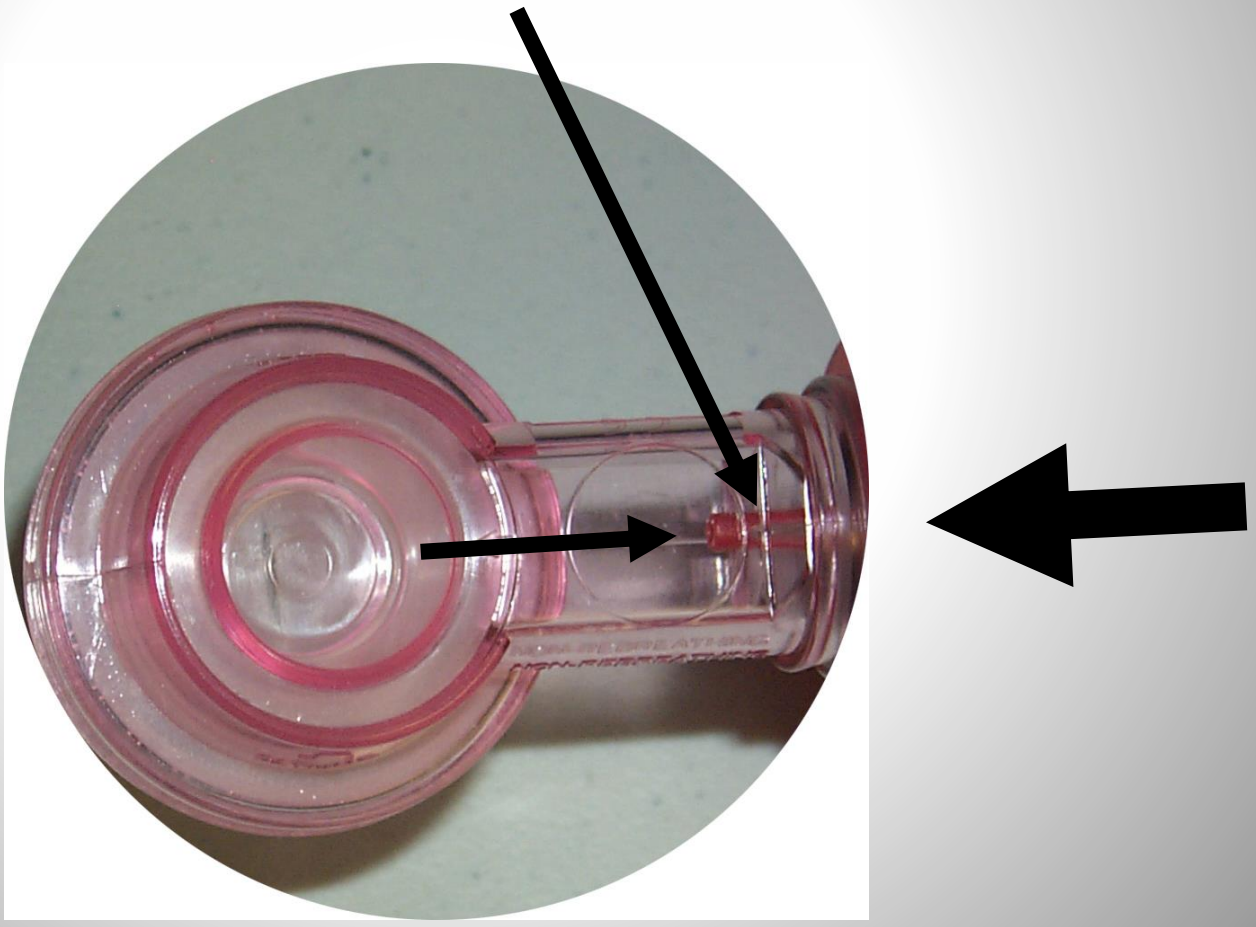

VALVE REMAINS OPEN
INSERT
PISTON
PATIENT VALVE
RETAINER
SPRING
NECK BUSHING
BAG
CORRECT, SLOW BAG SQUEEZE APPLIED
PATIENT WITH NORMAL COMPLIANCE AND RESISTANCE


VALVE CLOSED TO MAXIMUM POSITION
INSERT
PISTON
PATIENT VALVE
RETAINER
SPRING
NECK BUSHING
BAG
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



Pressure Relief
v
Flow Control

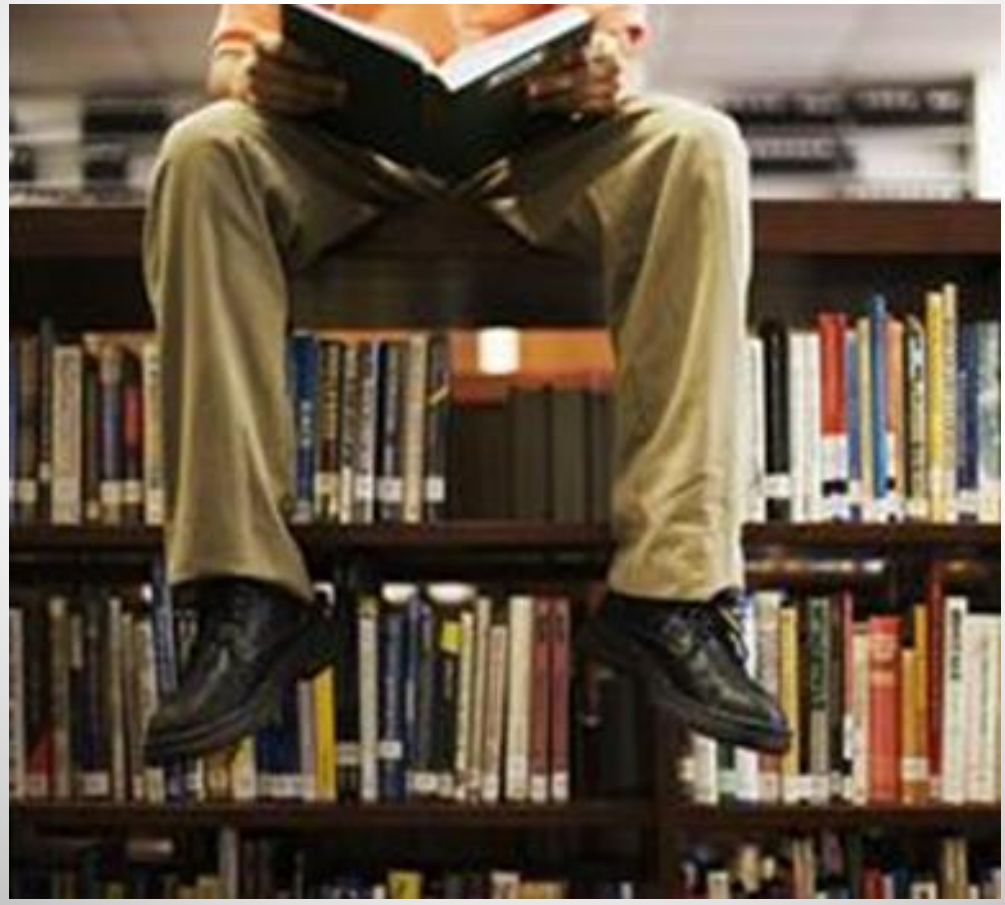
“My manual resuscitator has a pressure relief, doesn’t that stop me hyperventilating the patient”

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.

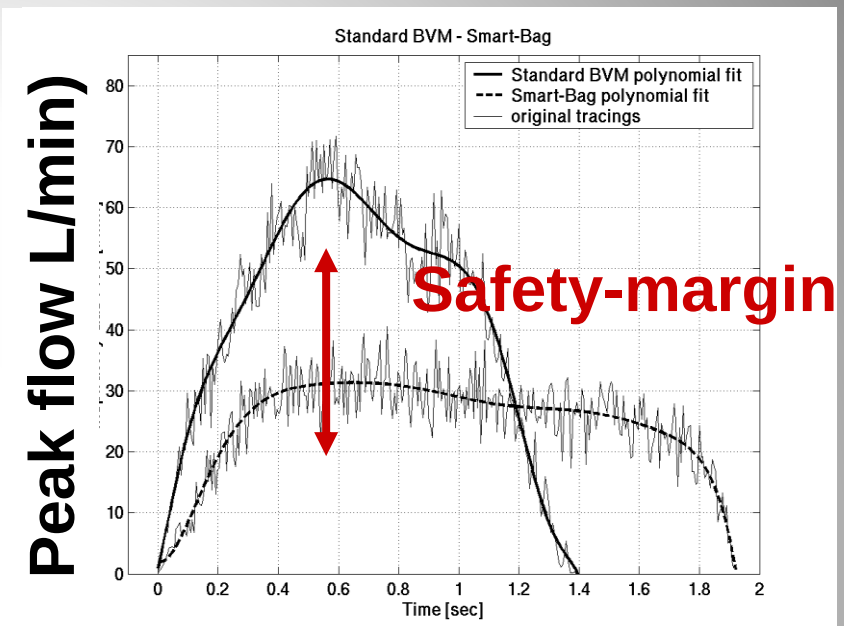
The Pressure Relief level is not reached unless significant compliance or resistance issues exist".

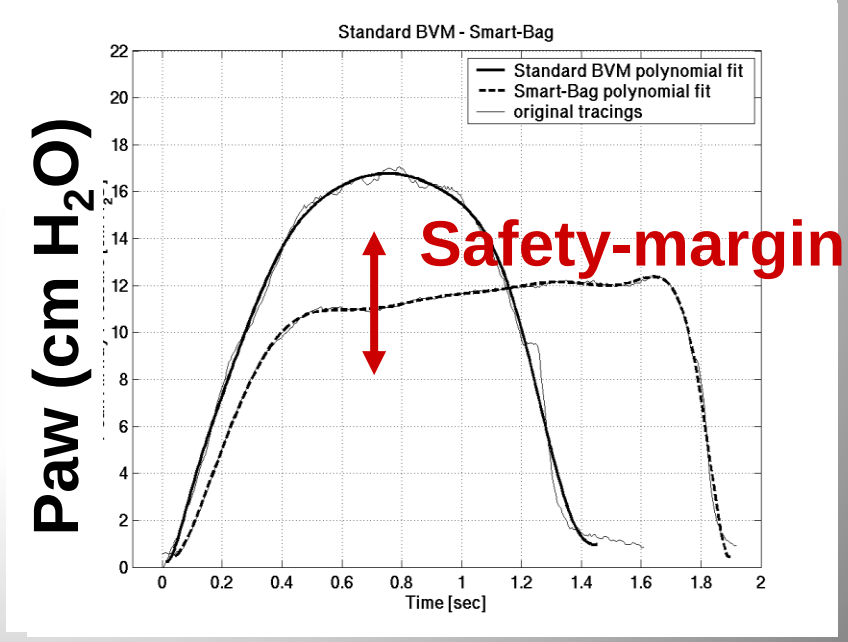
Research Supporting the SMART BAG®



Ventilation of an unprotected airway in a mechanical model

Wagner-Berger H et al., Resuscitation 57 (2003) 193-199

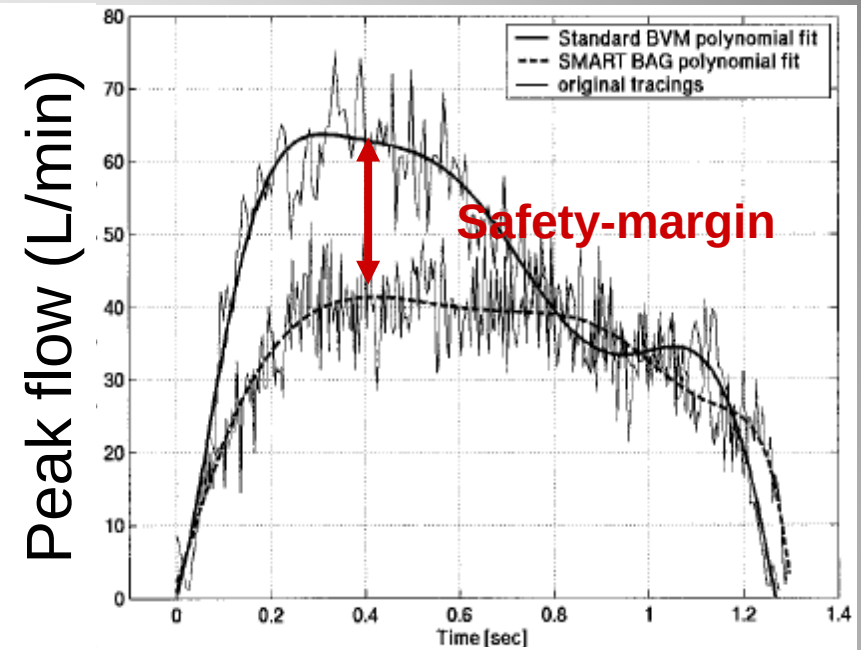


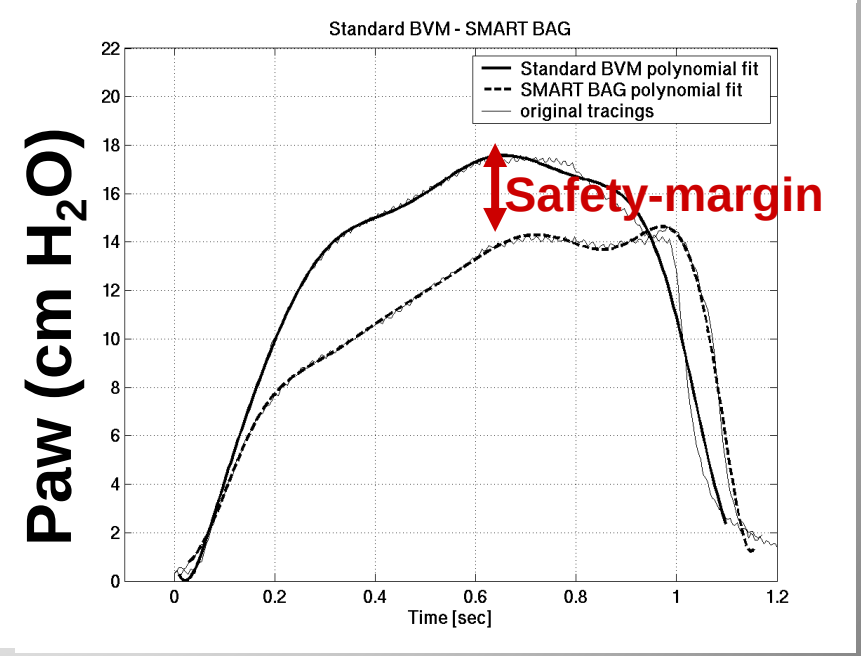


Ventilation of an unprotected airway in patients

Wagner-Berger H et al., (Resuscitation 57 (2003) 193-199)

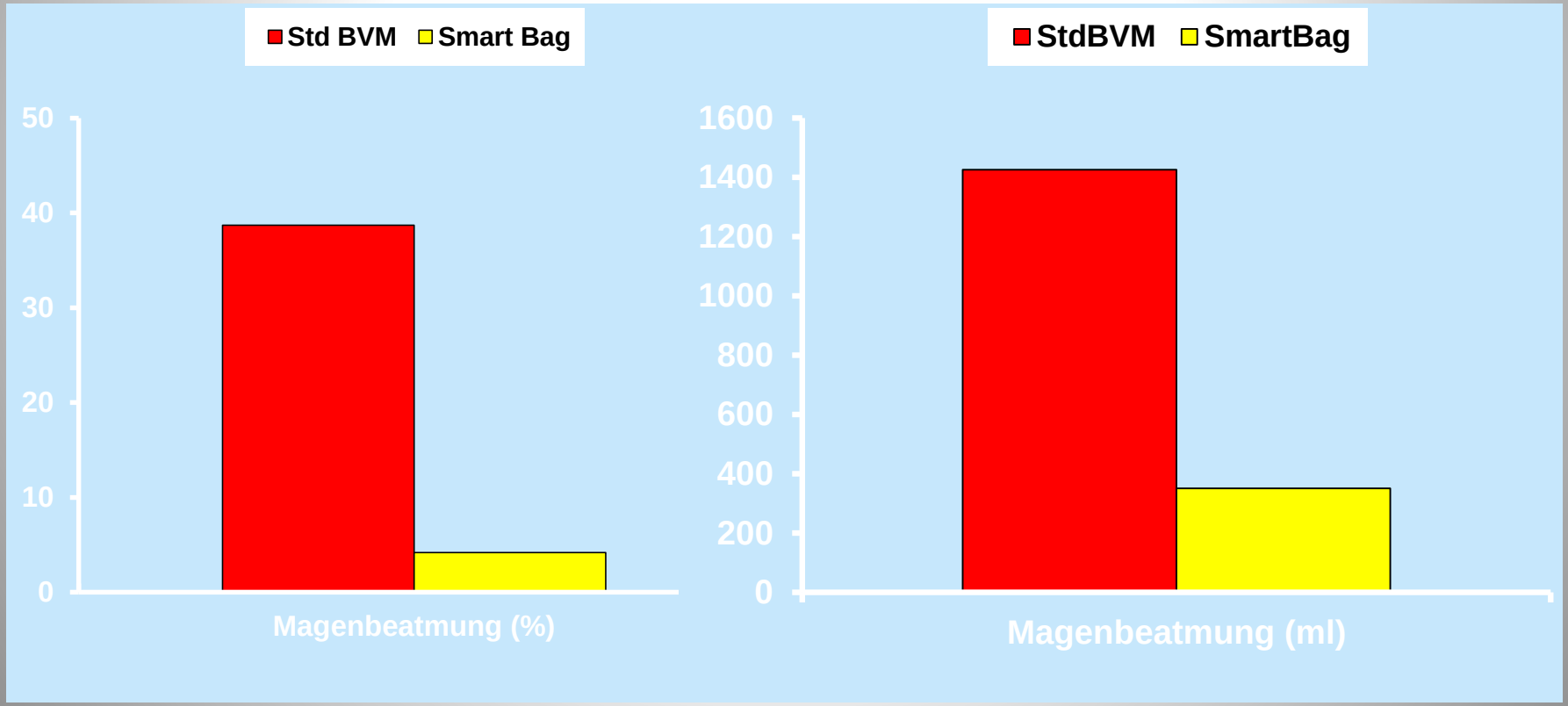
(Anesthesiologists ventilating Gynecology patients in the Operating Room).





Effects of Decreasing Peak Flow Rate on Stomach Inflation during Bag-Valve-Mask Ventilation

Von Goedecke A et al., *Resuscitation* 2004;63: 131–136.



ADDITIONAL STUDIES THAT CONFIRM THE PERFORMANCE OF FLOW CONTROL

- **A Pilot Study to Evaluate the SMART BAG® : A New Pressure-Responsive, Gas-Flow Limiting Bag-Valve-Mask Device - Wagner-Berger, Wenzel et al (Anesth Analg 2003;97:1686 –9)**
- **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**
  Wagner-Berger, Karl H. Lindner et al (Resuscitation 57 (2003) 193-199)
- **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.**
  De Regge, Vogels, Calle, Monsieurs (Resuscitation 62 (2004) 319-320)
- **Impact of a pressure-responsive flow-limiting valve on bag–valve– mask ventilation in an airway model - Busko, Blackwell, (*Can J Emerg Med* 2006;8(3):158-63)**
- **Ventilation of an unprotected airway. Evaluation of a new peak inspiratory flow and airway pressure limiting bag-valve-mask - Von Goedecke, Paal et al (Anaesthesist 2006 · 55:629–634)**

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 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.**

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