Advancements in Mechanical Ventilation
Are the Machines Taking Over? Not Quite!!

David A. Grooms MSHS, RRT

Respiratory Clinical Program Manager

Sentara Norfolk General Hospital

Norfolk, VA

Disclosures

- Speakers list:
  - Hamilton Medical, Hil-Rom & Abbott Nutrition.

- Consultant Honorariums:
  - Kimberly Clark, Hamilton Medical, Hil-Rom, & Phillips.

Disclosures

- No perceived conflict of interest for today's lecture

Objectives

- Open our minds to appreciating industrial evolution
- Review Closed Loop Functionality (Modes)
- Discuss Esophageal Balloon Manometry and its clinical application at the bedside

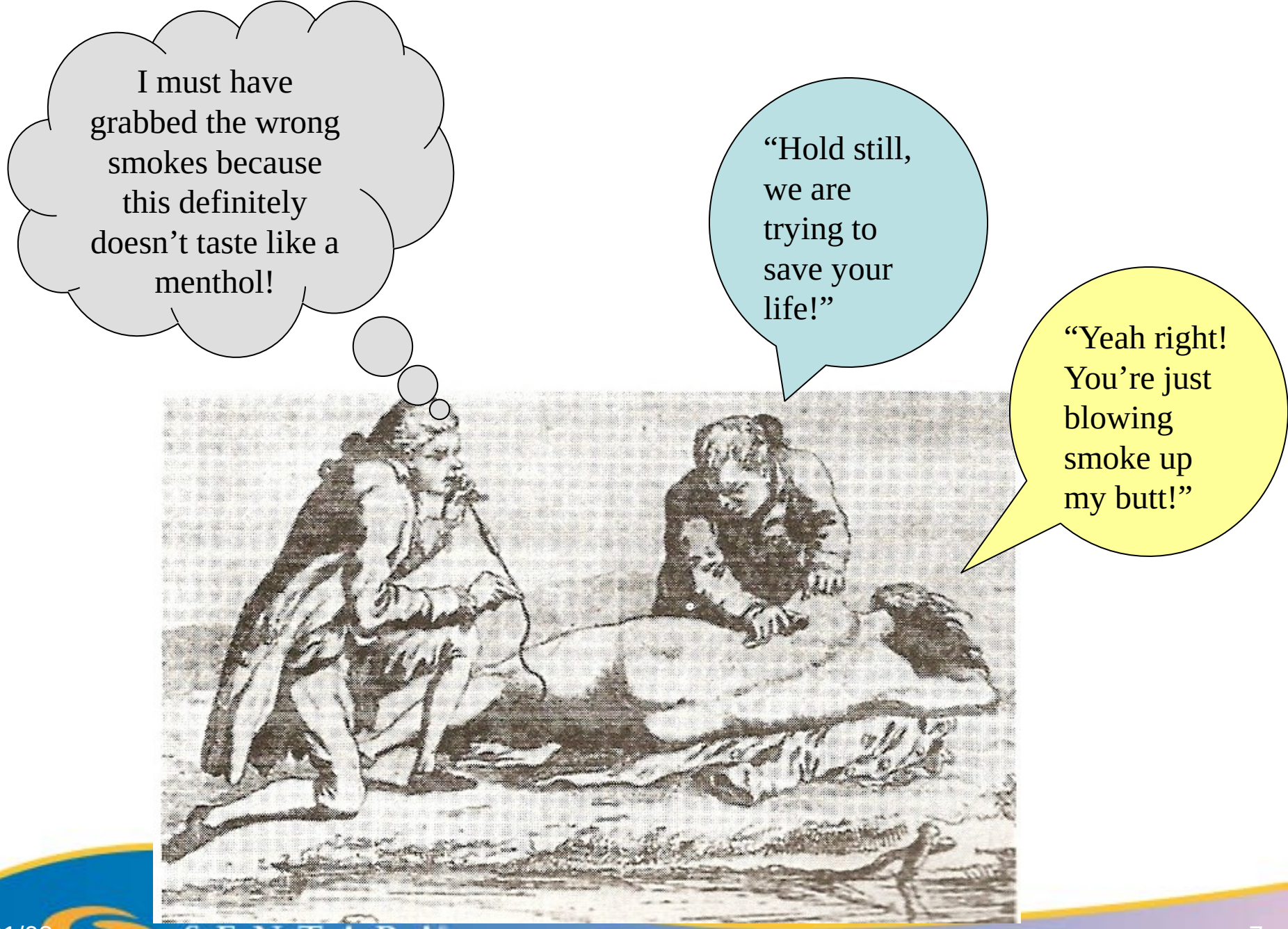
Claudius Galenus
AD 129 – 199

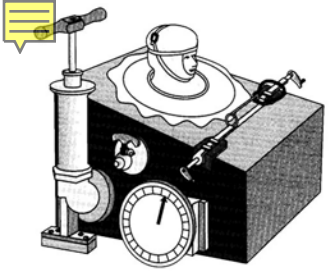
- “If you take a dead animal and blow air through its larynx, [through a reed], you will fill its bronchi and watch its lungs attain the greatest distention.”

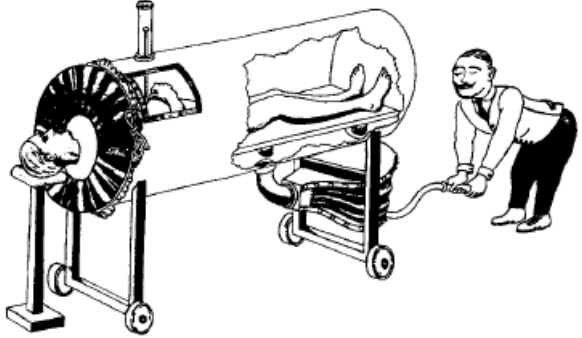
Society For The Rescue of Drowned Person (1767)

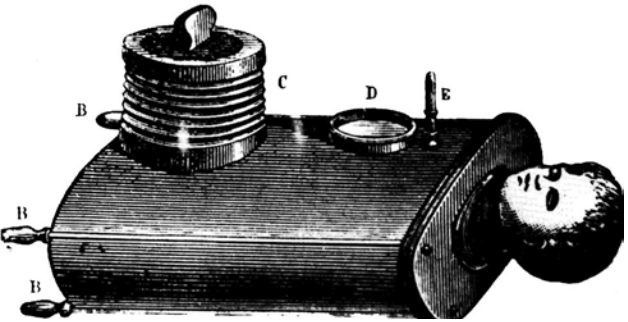
- Dutch method (1774)
- 5 step process:
  1. Keep patient warm
  2. Artificial respirations through the mouth
  3. Stimulants placed orally
  4. Bleeding
  5. Fumigation with tobacco smoke through the rectum.

Morch ET. Mechanical Ventilation, NY 1985.


I must have grabbed the wrong smokes because this definitely doesn't taste like a menthol!
"Hold still, we are trying to save your life!"
"Yeah right! You're just blowing smoke up my butt!"






B
C
D
E
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B

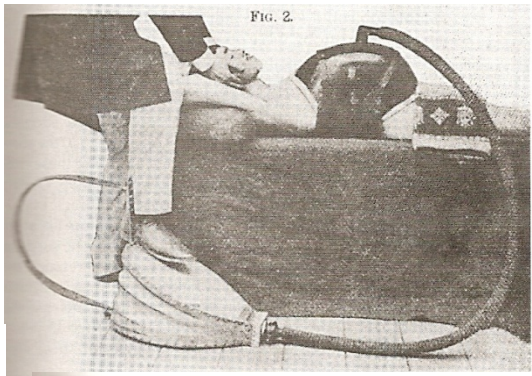
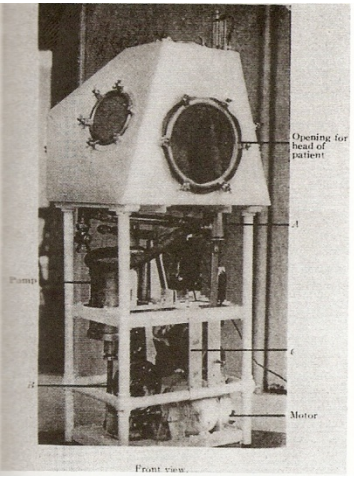
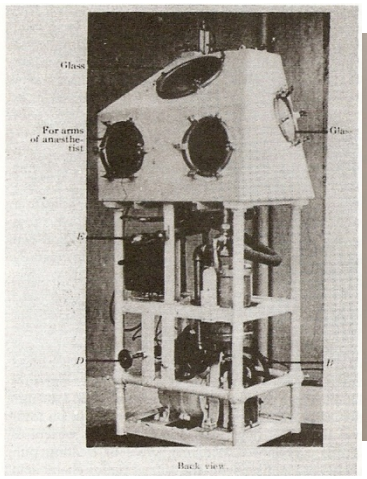
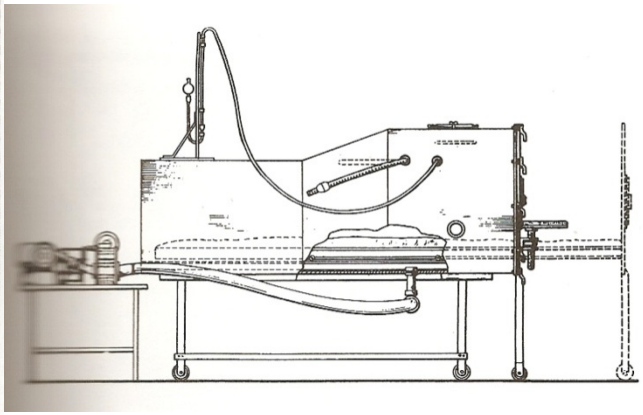
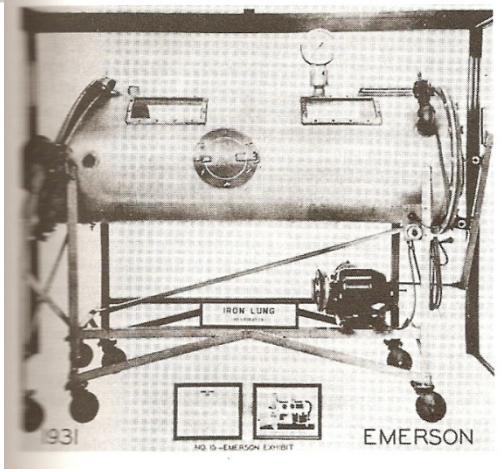


FIG. 2.


Opening for head of patient
Motor
Front view.


Glass
For arms of anaesthetist
Back view.

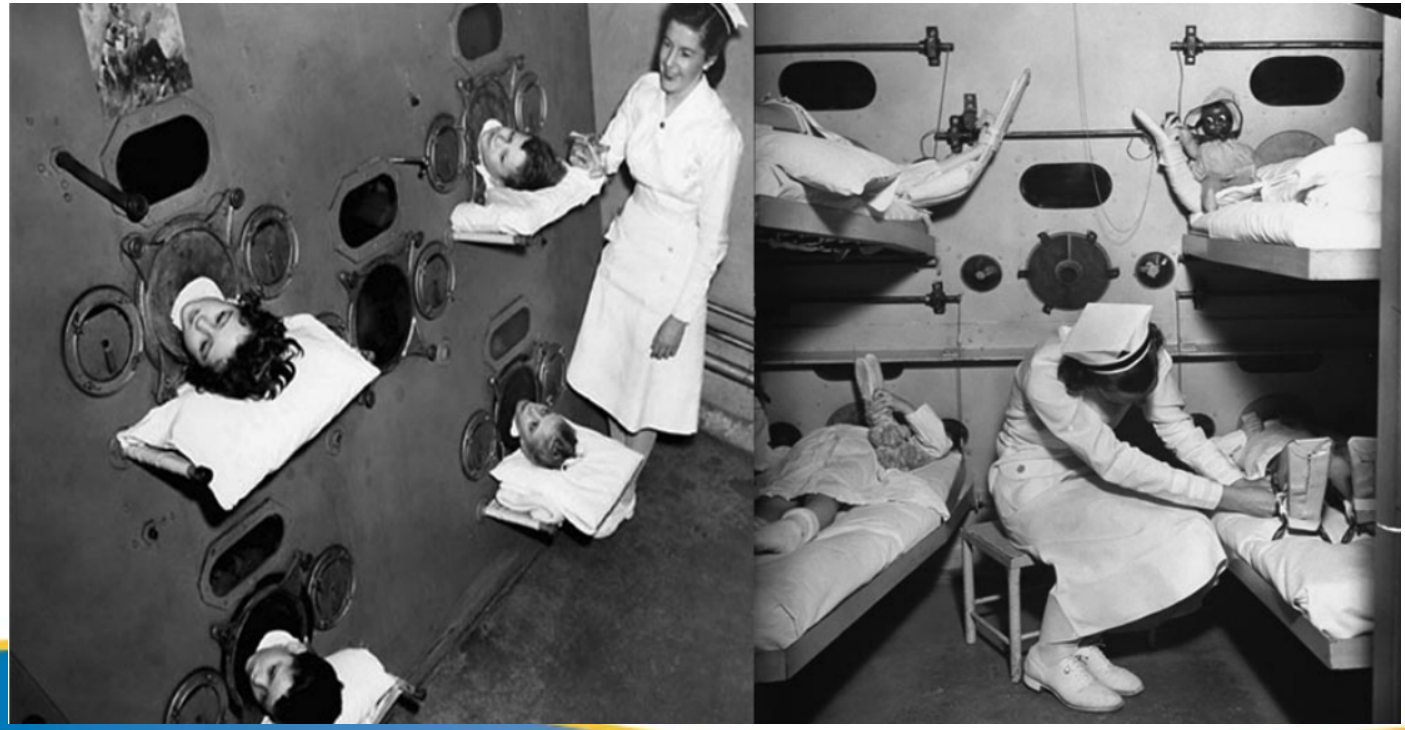



IRON LUNG
1931
EMERSON

Paralytic Polio (1930-40's)

Paralytic Polio (1930-1940's)

- Despite the use of iron lungs and cuirass shells, mortality was around 85%.



1952 Polio Epidemic of Copenhagen, Denmark

- Blegdamshospital hospital for communicable diseases.
- Of the first 31 pts admitted, 27 died within 3 days.
- Out of desperation, Chief Physician & Epidemiologist Henry Lassen called Bjorn Ibsen for consultative advice.

1952 Polio Epidemic of Copenhagen, Denmark

- After reviewing medical records and autopsy results, Ibsen made 2 startling conclusions:
  1. In fatal cases there was not sufficient enough atelectasis within the lungs to make adequate ventilation impossible.
  2. Increased levels of Total CO2 reflected respiratory acidosis.

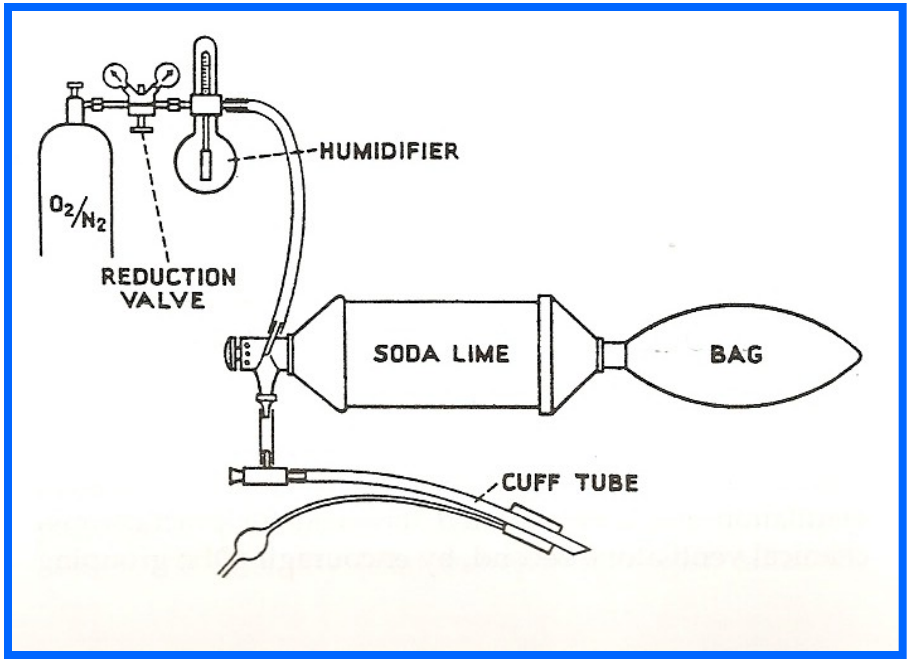
- Inadequate Ventilation cause of death
- Suggested tracheotomy placement for positive pressure ventilation.

Case #32

- 12 year old girl
- During tracheostomy she became comatose.
- Many physicians observed the trial began to leave thinking the outcome would be fatal.
- Ibsen paralyzed her, she collapsed and he was finally able to ventilate her.

Human “Ventilators” 1952

- 1500 medical & dental students, technicians, volunteers, and other personnel worked around the clock providing bag ventilation by hand to support these patients.



Mechanical Ventilation
Years in the making

1948- Bennett TV-2P
1950- Engstrom 150
1954- Drager Poliomat
1954- Thompson Portable Respirator
1955- Morch “Piston”
1955- Bird Mark 7
1955- Emerson High Frequency Vent
1958- Emerson Assistor/Controller
1963- Air-Shields 1000
1963- Puritan Bennett PR-2
1964- Emerson “Post-Op” 3-PV
1964- Bourns LS-104-150
1967- Puritan Bennett MA-1
1968- Ohio/Monaghan 560
1968- Drager Spiromat
1968- Loos Co. Amsterdam
1968- Engstrom 300
1970- Veriflo CV 2000
1970- Hamilton Standard PAD1
1972- Monaghan 225, 225-SIMV
1972- Bird-Baby Bird
1972- Bird- IMV Bird
1972- Siemens Servo 900
1973- Chemtron Gill 1
1974- Emerson IMV
1974- Searle VVA
1974- Ohio 550
1975- Bourns Bear 1
1976- Forreger 210
1978- Puritan Bennett MA 2
1980- Engstrom Erica
1982- Siemens Servo 900C
1983- Biomed IC-5
1984- Puritan Bennett 7200
1984- Sechrist Adult 2200B
1985- Bear Medical Bear 5
1985- Ohmeda CPU
1986- Hamilton Veolar
1986- Bird 6400 ST
1986- Infrasonics Infant Star
1988- Bear 3
1988- Hamilton Amadeus
1988- Siemens E
1988- Bird 8400ST
1989- Bunnell Life Pulse
1989- PPG (Drager) IRISA
1989- Bird VIP
1989- Infrasonics Adult Star
1991- Siemens Servo 300
1993- Bear 1000

Masferrer: Resp Care: 1991.

Lack of Standardization

Mosby's Resp. Equipment 8th edition

56 different names of modes

Ventilator	Assist/Control CMV-Vol	PCV	SIMV-VC	SIMV-PC	PRVC	SIMV PRVC	PSV/CPAP	APRV	Additional Mode(s) or Feature(s)
Cardinal AVEA	Volume A/C	Pressure A/C	Volume SIMV	Pressure SIMV	PRVC	PRVC SIMV	CPAP-PSV	APRV Biphasic	TCPL-A/C and TCPL-SIMV
Cardinal BEAR 1000	Assist CMV	Pressure control	SIMV/CPAP and PSV	PC-SIMV and CPAP PSV	—	—	PS/CPAP	—	Pressure augment and MMV (operates in SIMV/CPAP and increases rate)
Cardinal VELA	Volume A/C	Pressure A/C	Volume SIMV	Pressure SIMV	PRVC A/C	PRVC and SIMV	CPAP-PSV	APRV and Biphasic	—
Dräger Evita 4	CMV	PCV+	SIMV (vol.) + PSV	SIMV (Press.)+ PSV	AutoFlow™	AutoFlow™ with SIMV (volume)	PSV-CPAP	APRV	MMV & MMV + PS (increase f at set volume)
Dräger EvitaXL	CMV	PCV+ (i.e., BiPAP)	SIMV (vol.) and PSV	SIMV (Press.)+ PSV	AutoFlow™	AutoFlow™ with SIMV (volume)	PSV-CPAP	APRV	MMV & MMV + PS (increase f at set volume)
Hamilton GALILEO Gold (two names: U.S. or U.K.)	S(CMV) or A/C	P-A/C or P-CMV	SIMV	P-SIMV	APVcmv	APVsimv	SPONT (PSV-CPAP)	APRV or DuoPAP	ASV
Hamilton RAPHAEL	S(CMV)+	PCV+	SIMV+	PSIMV+	(S)CMV+	SIMV+	SPONT (PSV-CPAP)	DuoPAP and DuPAP+ (extended I:E)	ASV
Maquet Servo 300	VC	PC	SIMV (Vol. Contr.)	SIMV (Press. Contr.)	PRVC	—	PS/CPAP	—	VS
Maquet Servo[i] and Servo[s]	VC	PC	SIMV (Vol. Contr.)	SIMV (Press. Contr.)	PRVC	SIMV (PRVC)	PSV/CPAP	BiVent	VS, NAVA available on Servo[i]
Newport Medical Instruments Wave E200	A/C (volume)	A/C (pressure)	SIMV (volume)	SIMV (pressure)	—	—	SPONT (PS and CPAP/PEEP)	—	—
Newport e500	A/CMV (volume)	A/CMV (pressure)	SIMV (volume)	SIMV (pressure)	VTPC	SIMV-VTPC	SPONT (PS and VTPS)	—	VTPS
PB 840	Assist/control (volume)	Assist/control (Press.)	SIMV (volume)	SIMV (pressure)	VC+	SIMV VC+	SPONT (PSV-CPAP)	Bilevel	PAV+ VS
PB 740	AC-VCV	—	SIMV-VCV	—	—	—	CPAP and PS	—	—
PB 760	AC-VCV	AC-PCV	SIMV-VCV	SIMV-PCV	—	—	CPAP and PS	—	—
PB 7200	CMV	PCV	SIMV (VC)	SIMV (PC)	—	—	CPAP and PSV	—	—
Respironics Esprit	VCV-A/C	PCV-A/C	VCV-SIMV	PCV-SIMV	—	—	CPAP and PSV	—	NPPV

Information Overload

- Limits to human capacity for information processing
- 1956
  - Humans are able to manage 7 variables simultaneously (the input) before decisions (the output) become degraded.

Miller G. The magical number 7, plus or minus two: some limits on our capacity for processing information. Psychol Rev 1957; 63:81-97.

Information Overload

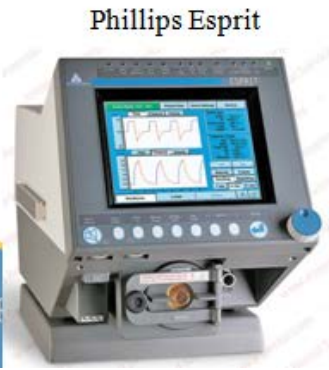
- 2000
  - Human capacity to store and process information is limited to 3-5 (4) variables at a time.

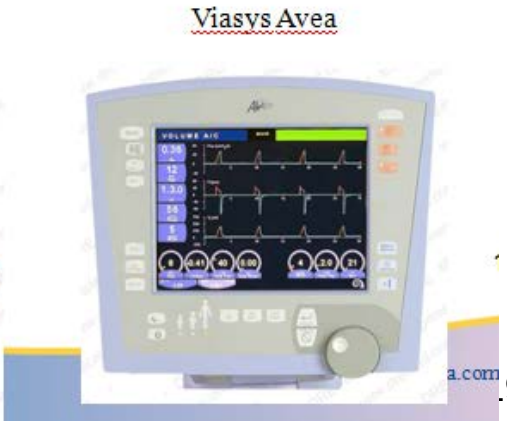
Cowan, N. The magical number 4 in short-term memory: A reconcideration of mental storage capacity. Behavioral and Brain Sciences 2000;24, 87-185.

Information Overload

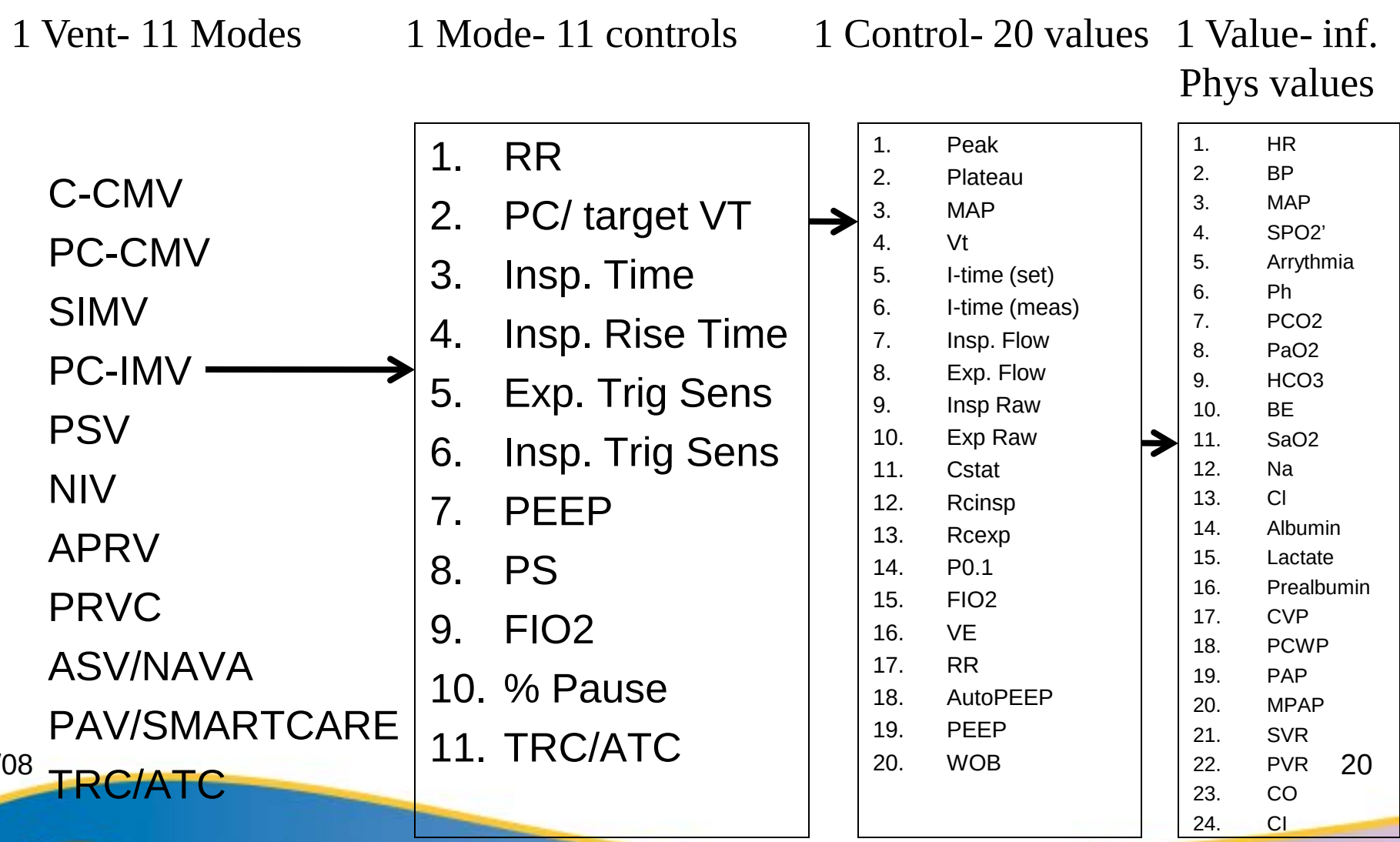
Avg. Ventilator incorporates 11 modes of ventilation

- C-CMV
- PC-CMV
- SIMV
- PC-IMV
- PSV
- NIV
- APRV
- PRVC
- ASV/NAVA
- PAV/SMARTCARE
- TRC/ATC





Information Overload



Information Overload

- More than 236 variable categories noted for an ARDS patient.

Morris et al. Computer Applications: Principles of critical care. New York, McGraw-Hill;1992, 500-514.

What is “Open Loop” Control?

- “If I target a goal, and I get an unwanted result in return, **“I”** make the adjustment to achieve the goal.”

What is “Open Loop” Control?

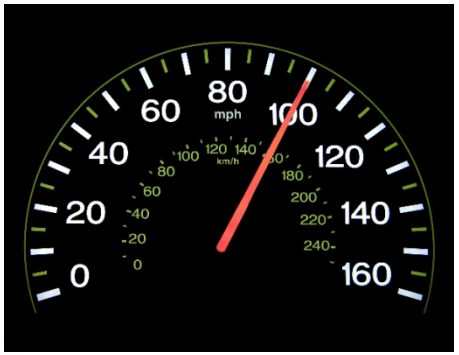
- Goal
  - Output control
  - Operator
  - Feedback Loop
  - Open control response
  - Result
  - Subsequent adjustment by operator to meet goal.

Goal: Drive vehicle at 60 mph.

Output Control: Vehicle with gas pedal

Operator:
(Crazy Old Dude)

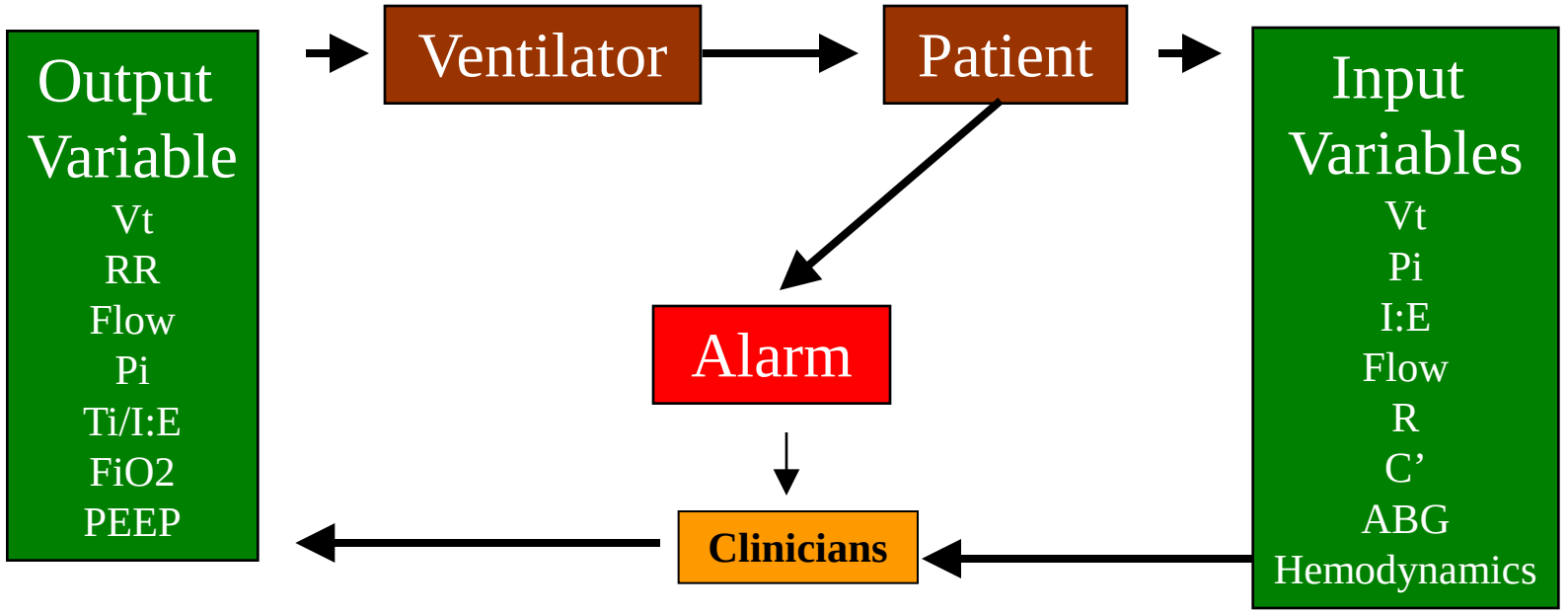
Feedback Loop:
Speedometer



Open Control Response:
Adjust speed

End Result:
Drive @ 60 mph

Open-Loop Control
Mechanical ventilation



What is “Closed Loop” Control?

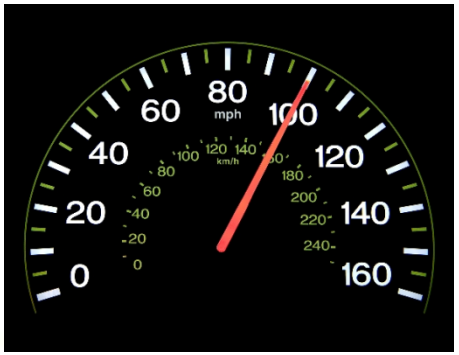
- “If I target a goal, and I get an unwanted result in return, **“the device automatically”** makes the adjustment to achieve the goal.”

Goal: Drive vehicle at 60 mph.

Output Control: Vehicle with gas pedal

Operator:
(Crazy Old Dude)

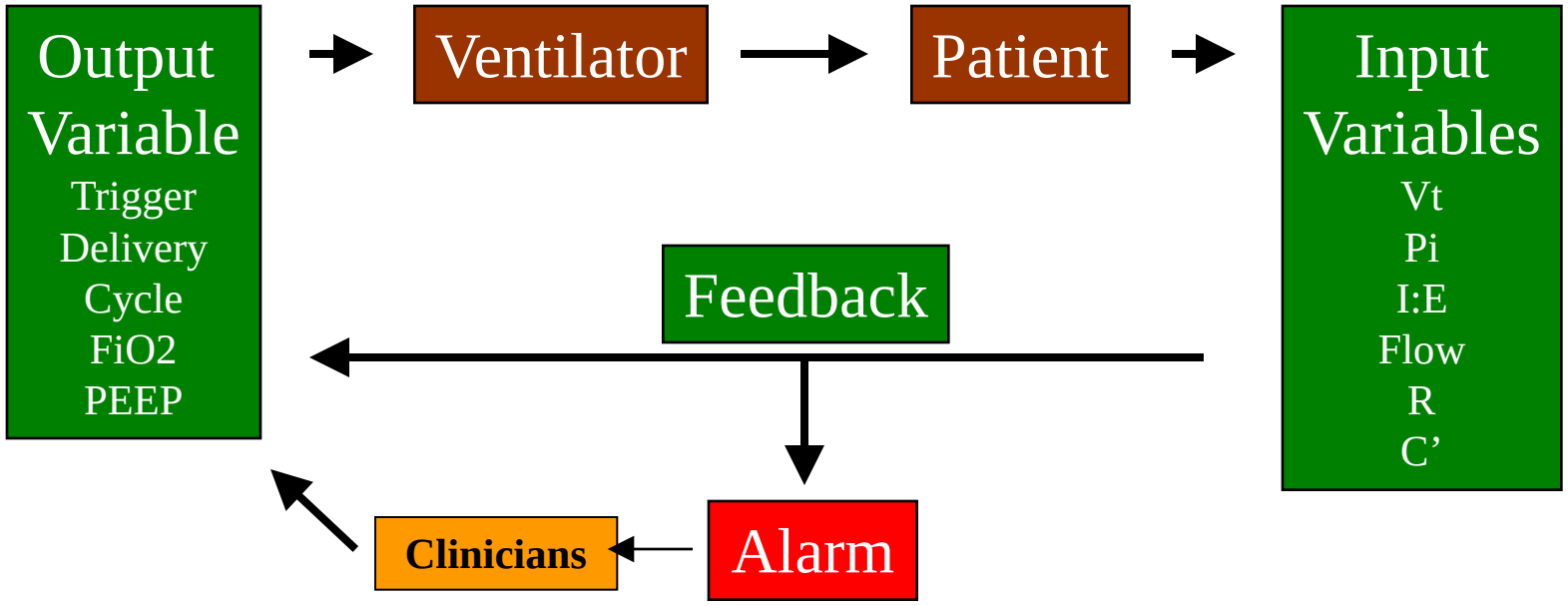
Feedback Loop:
Speedometer



Closed Loop
Control Response:
Adjust speed

End Result:
Drive @ 60 mph

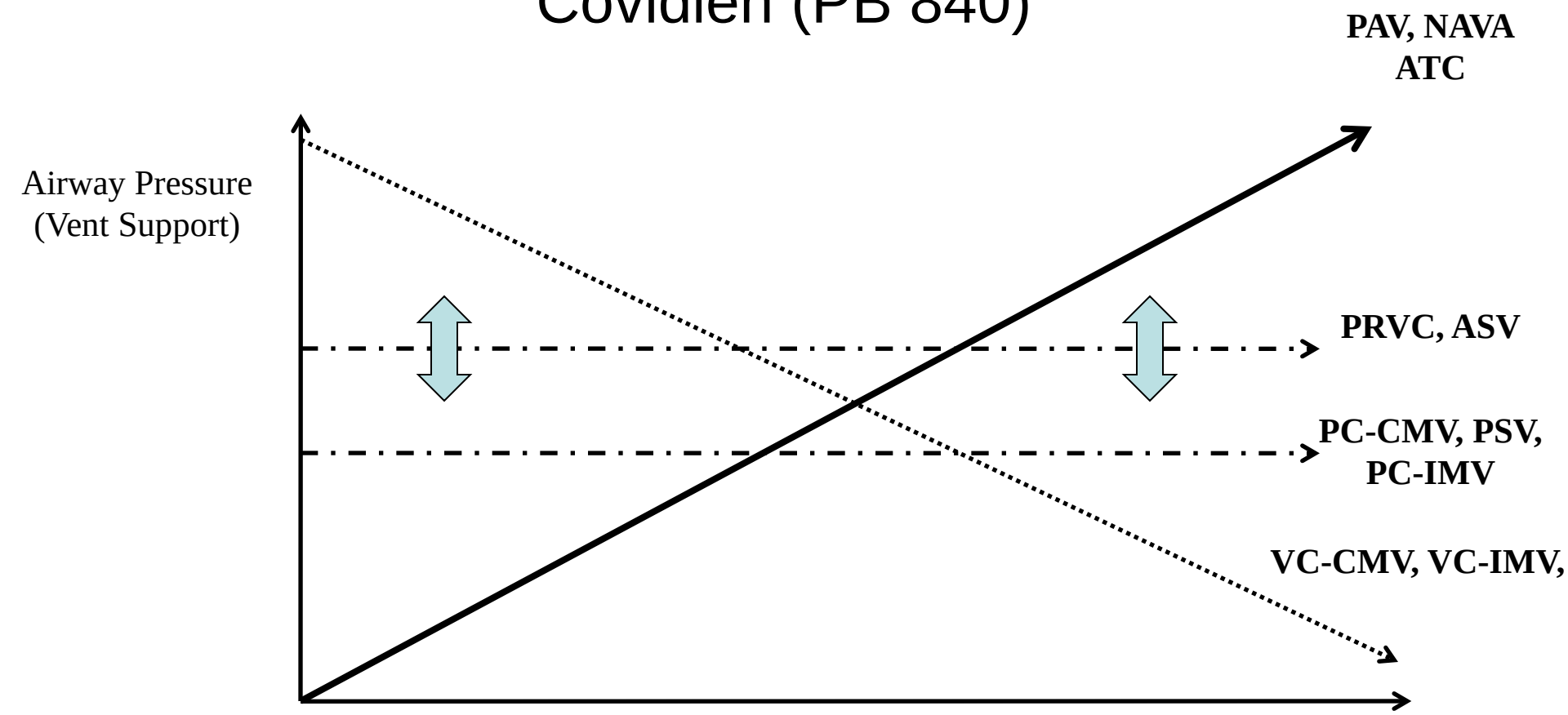
Closed-Loop Control



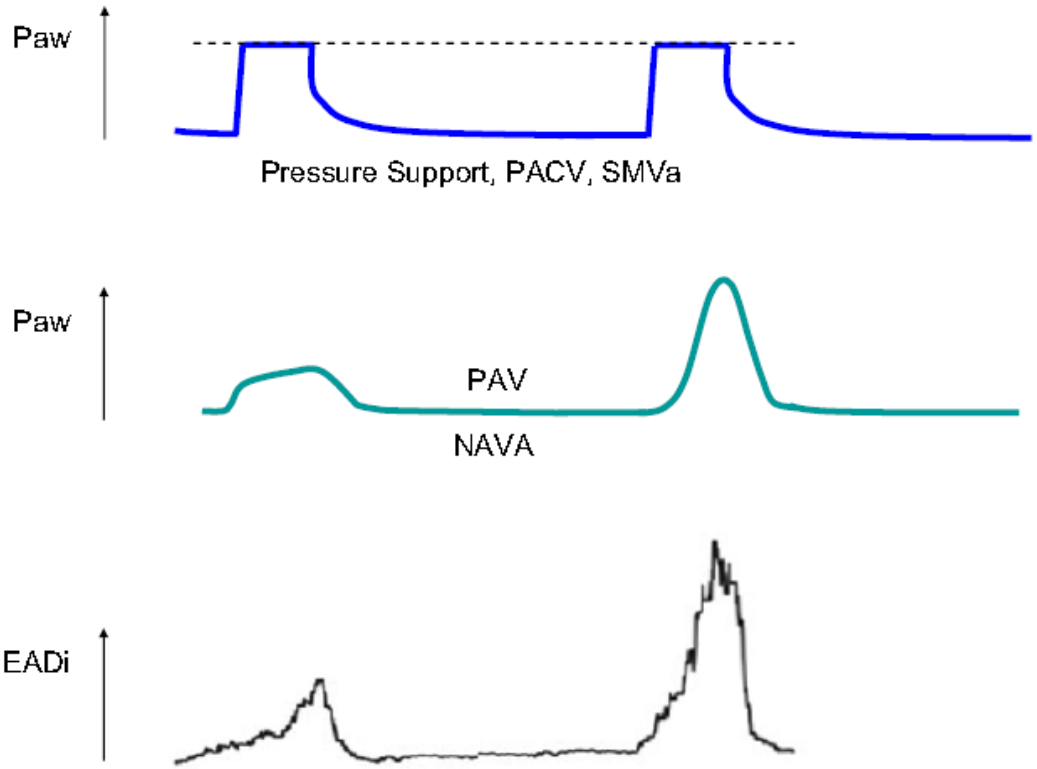
Proportional Assist Ventilation Plus (PAV+) Covidien (PB 840)

- Introduced in 1992 (Dr. Younes) just a few years after Pressure Support.
- Equation of motion:
  - P_{mus} + Pvent = (V)(E) + (V)(R)
  - PAV+ uses an end inspiratory hold to measure Raw & E.
- Influenced by autoPEEP & leaks.

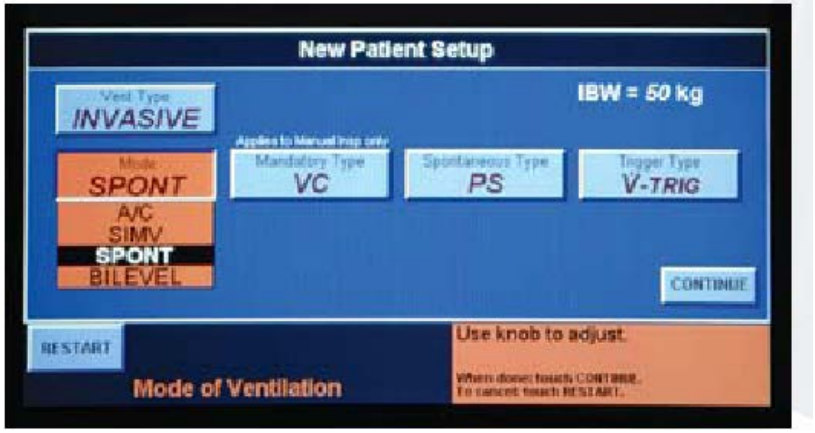
Proportional Assist Ventilation Plus (PAV+)
Covidien (PB 840)

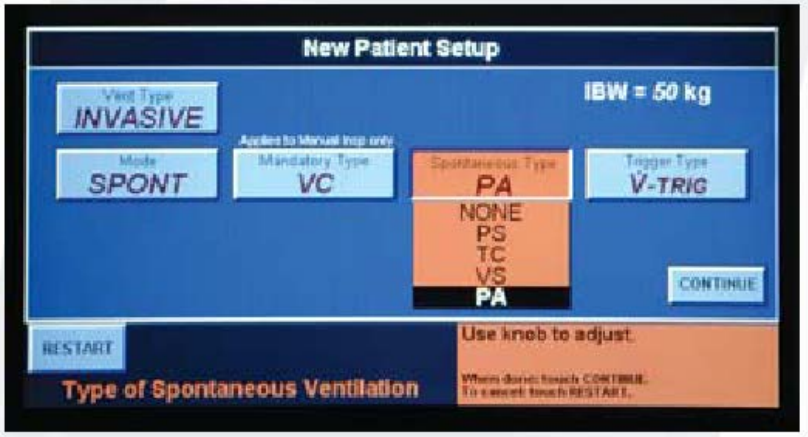


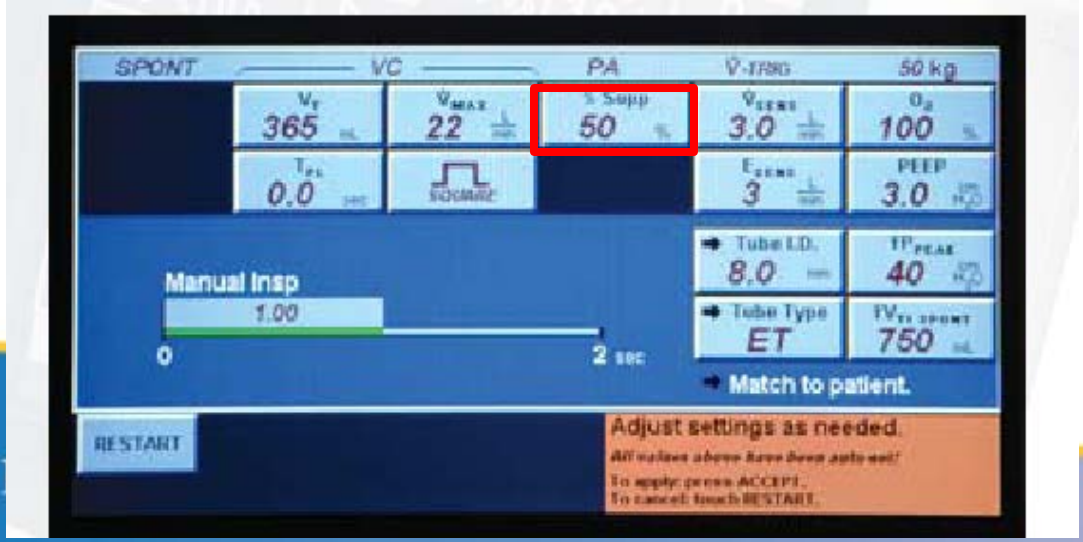
Proportional Assist Ventilation Plus (PAV+) Covidien (PB 840)



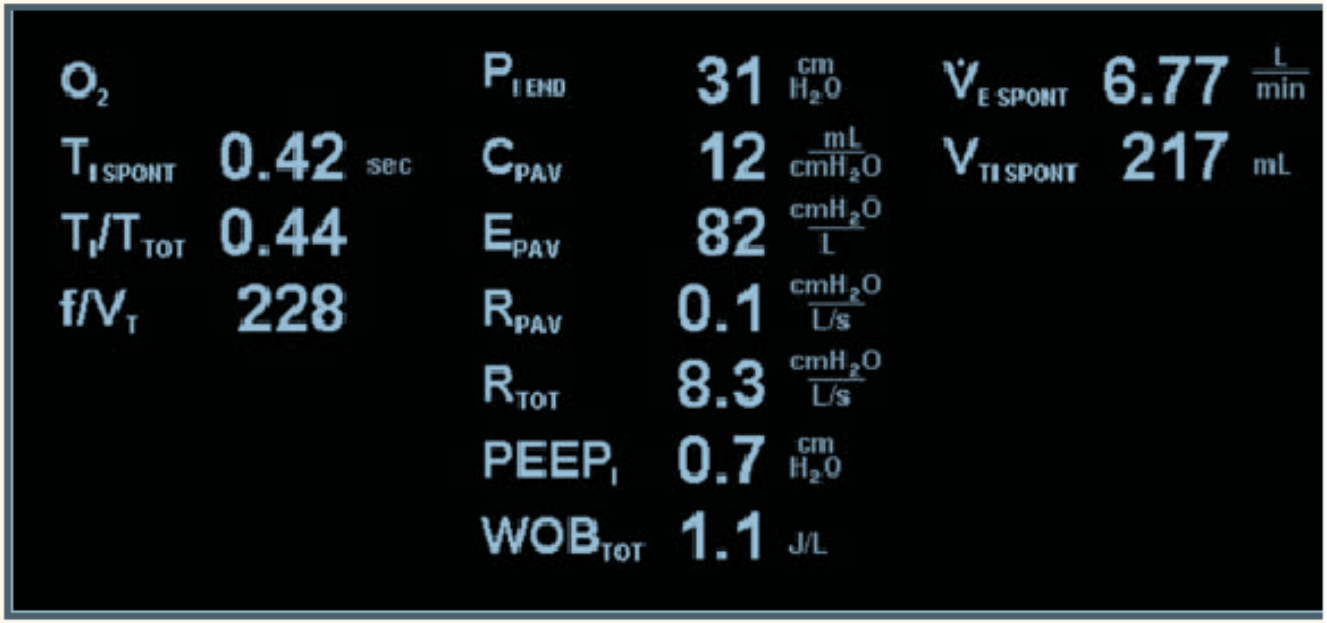
PAV+ Setup


New Patient Setup
Vent Type
INVASIVE
IBW = 50 kg
Mode
SPONT
A/C
SIMV
SPONT
BILEVEL
Mandatory Type
VC
Spontaneous Type
PS
Trigger Type
V-TRIG
CONTINUE
RESTART
Use knob to adjust.
Mode of Ventilation

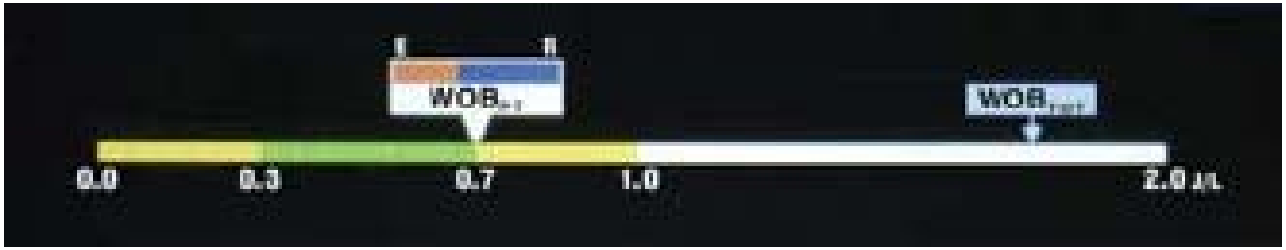

New Patient Setup
Vent Type
INVASIVE
IBW = 50 kg
Mode
SPONT
Mandatory Type
VC
Spontaneous Type
PA
NONE
PS
TC
VS
PA
Trigger Type
V-TRIG
CONTINUE
RESTART
Use knob to adjust.
Type of Spontaneous Ventilation


SPONT
VC
PA
V-TRIG
50 kg
365
22
50
3.0
100
0.0
3
PEEP
3.0
Manual Insp
1.00
0
2 sec
Tube I.D.
8.0
Tube Type
ET
750
Match to patient.
RESTART
Adjust settings as needed.

PAV+ Monitoring Display



$$P_{mus} + Pvent = (V)(E) + (F)(R)$$



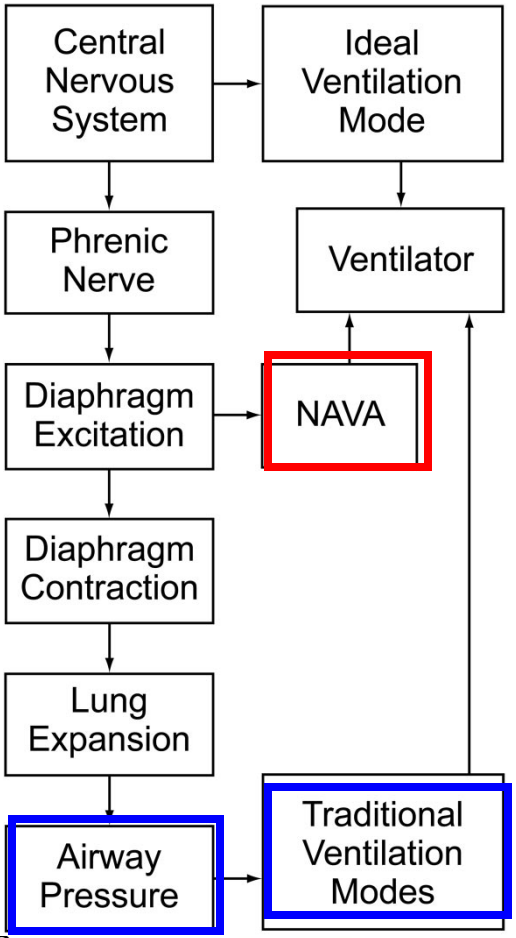
Data supporting PAV+

- Improved Exercise Tolerance
- Improved Sleep
- Improved synchrony in Critically ill pediatric pts.
- Reduced Patient WOB in NIPPV
- Improved patient ventilator synchrony in Invasive MV patients

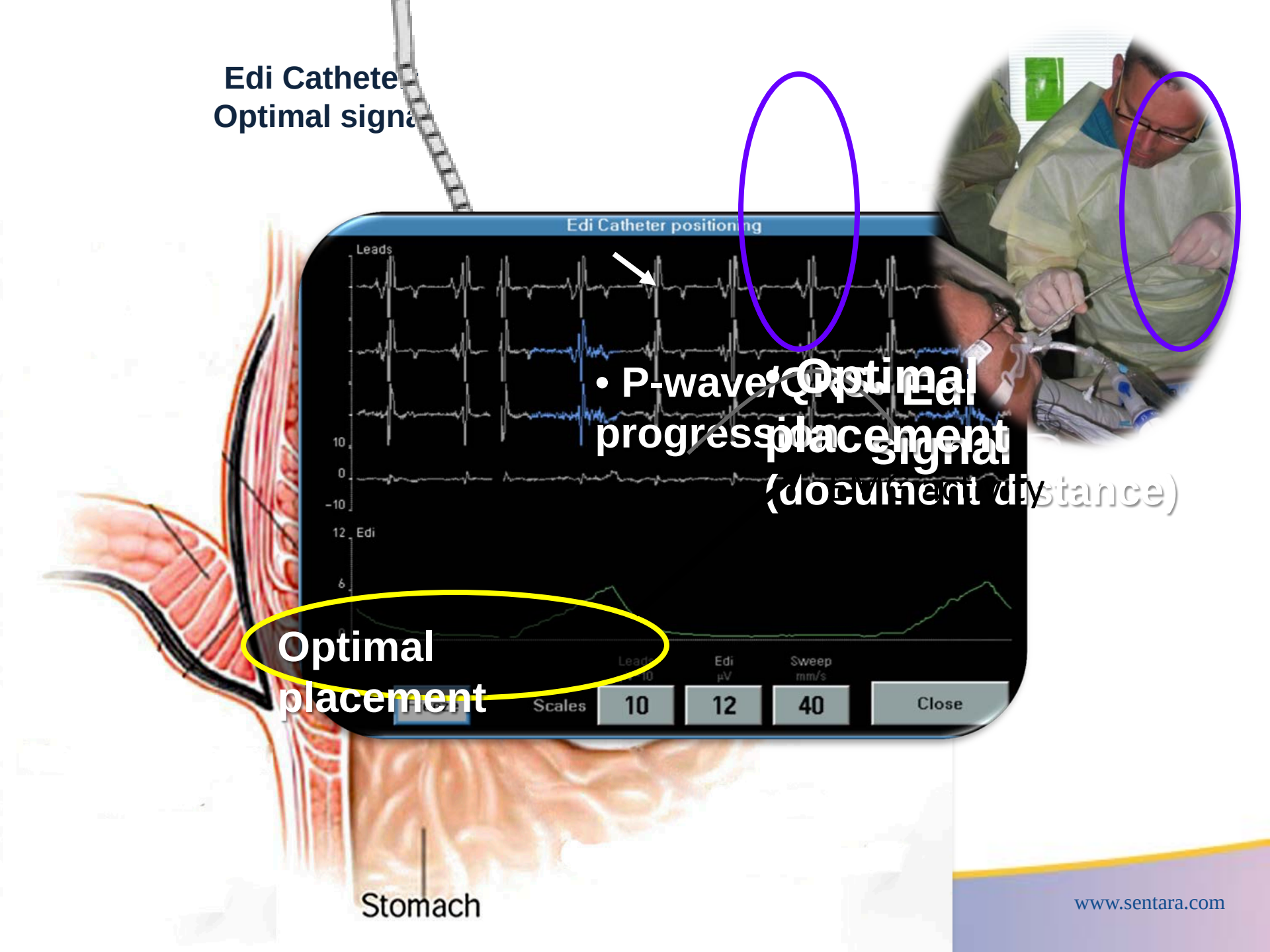
Neurally Adjusted Ventilator Assistance (NAVA)
Maquet Servo-i

- Introduced 1999 (Dr. Sinderby)
- Uses esophageal catheter to measure electrical activity of the diaphragm (EADi).
- No influence of leaks or auto-PEEP on initiation of the vent cycle.

Neurally Adjusted Ventilator Assistance (NAVA)
Maquet Servo-i



Edi Catheter
Optimal signa

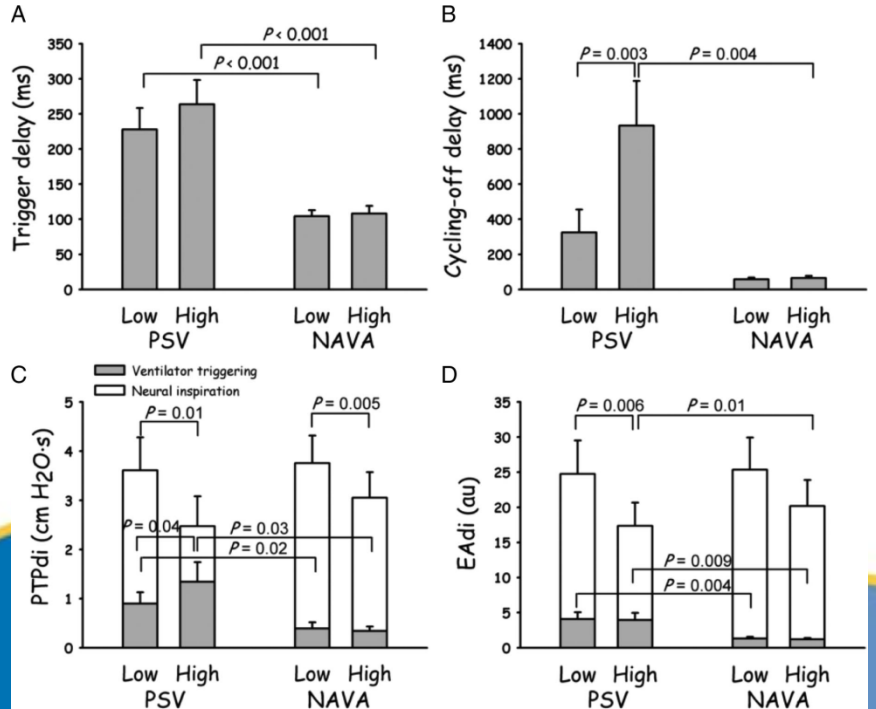


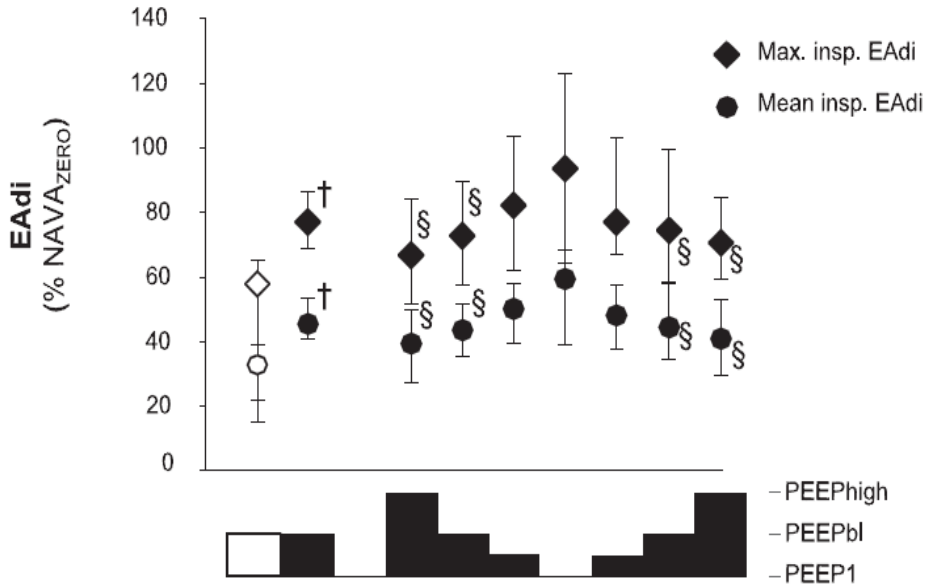
- P-wave/QRS
progress

- Optimal Edi placement signal
(document di stance)

NAVA invasive ventilation

First Author	Year	Patient Type	Key Findings
Colombo D.	2008	ARF without chronic RF	Improved ventilator synchrony, trigger delay, cycle delay,
Brander L.	2009	Stable hypercapnic pts w/COPD	
Lecomte F.	2009	COPD and ARF	
Jalde F.	2010	ARF	
Schmidt M.	2010	Stable chronic ventilatory failure	
Sphahija J.	2010	Hypercapnic ARF	
Passath C	2010	CF and chronic RF	

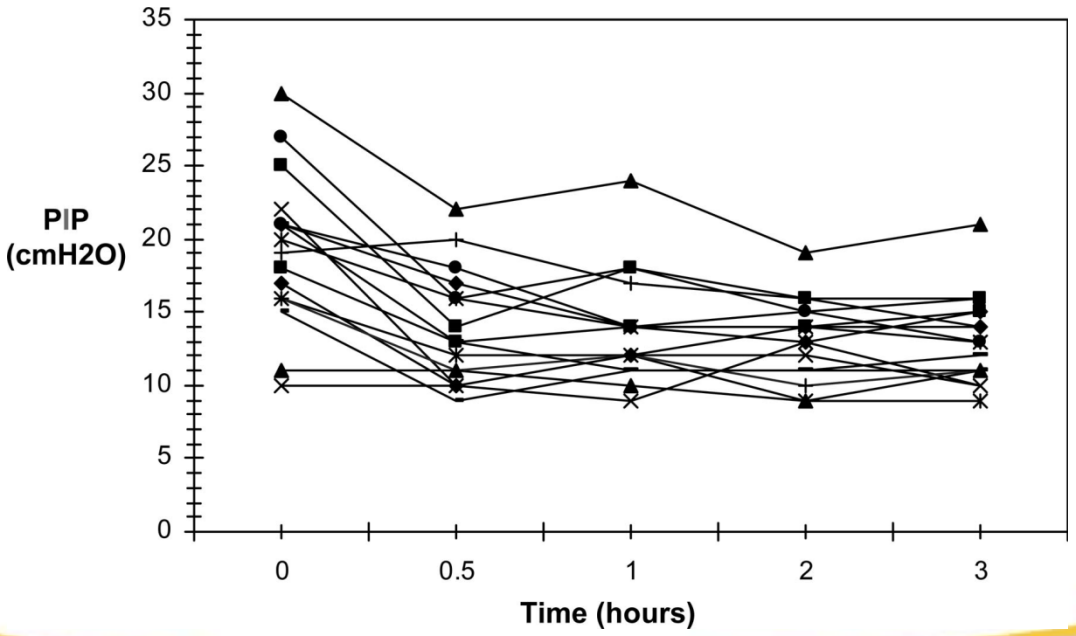




NAVA in Neonates/Children

First Author	Year	Patient Type	Key Findings
Beck J	2009	26 week (936 g)	No diff in trig and cycling delays
Bengtsson J.	2010	21 MV children (2days-15 years)	Improved neural trigger and cycling
Breatnach C.	2010	16 Infants (mean 9.6 months of age)	Improved synchrony & Lower PIP

Breatnach C. et al. Ped Crit Care Med 2010;11(1):7-11



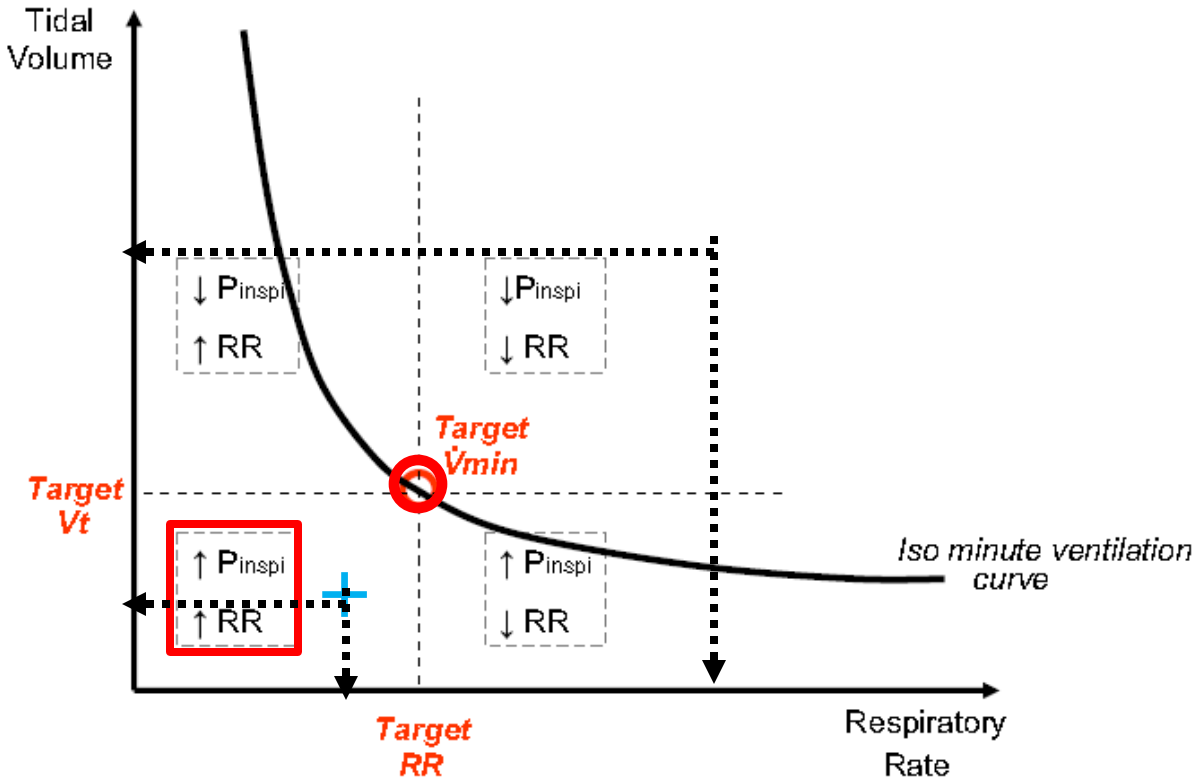
Adaptive Support Ventilation (ASV)
Hamilton Medical (Galileo, G5, & C2)

- Introduced in 1994 by Laubsher as adaptive lung ventilation
- Based on Otis Least work of Breathing equation:

$$f = \frac{\sqrt{1 + 2a \times RCexp \times (MinVol - f \times Vd)/Vd} - 1}{a \times RCexp}$$

Automatically generates a RR/Vt combination to achieve desired MV.

Adaptive Support Ventilation (ASV)
Hamilton Medical




2012-01-25
13:29:24
INTELLIVENT
ASV
Adult
Patient
Additions
Modes
85
2
15
Ppeak
cmH2O
35
0
6.4
ExpMinVol
l/min
2850
110
504
VTE
ml
69
0
12
fTotal
b/min
24
RSB
1/(l*min)
Paw
cmH2O
20
10
0
-10
s
2
4
6
8
10
Flow
l/min
50
25
0
-25
-50
Adult Male
69 inch
IBW = 72 kg
Rinsp
7
cmH2O/l/s
Cstat
56.6
ml/cmH2O
100
%
%MinVol
5
cmH2O
PEEP/CPAP
21
%
Oxygen
Target
Current
MinVol
l/min
7.2
544
504
Vt
ml
13
12
fTotal
b/min
Insp time
s
2.00
2.00
V
ml
1600
1200
800
400
0
Target
Current
MinVol
7.2
l/min
b/min
0
10
20
30
40
50
60
fSpont
0
b/min
fControl
12
b/min
Pinsp
10
cmH2O
1 / 8
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC

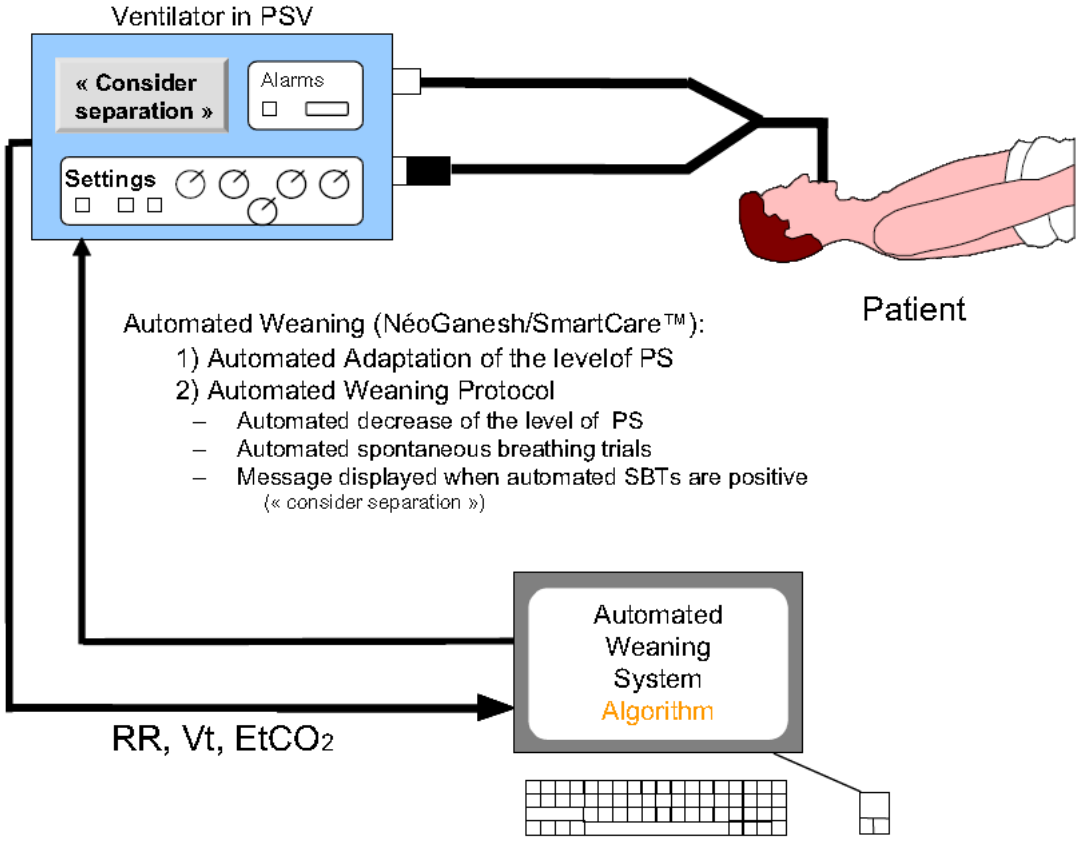
ASV Invasive Ventilation

First Author	Year	Patient Type	Key findings
Sulzer C.	2001	Cardiothoracic Surgery	Faster wean times, less alarms, better adaptation of RR/Vt combination, and Vt selection in response to respiratory mechanic changes.
Tassaux D.	2002	10 pts with diverse causes & ARF	
Cassina T.	2003	COPD and ARF	
Petter A.	2003	45 ARF pts	
Belliato M.	2004	ARF, CRF, and normal lungs	
Linton D.	2006	27 ventilator dependent pts.	
Arnal J.	2008	Lung model	
Gruber P	2008	Cardiothoracic surgery	
Donglemans D.	2009	Cardiothoracic surgery	
Donglemans D.	2010	Cardiothoracic surgery	
Chen C.	2011	Ahead of print, Medical ICU pts	
Donglemans D.	2011	10 ARDS pts.	

SmartCare (NeoGanesh)
Draeger Medical

- Introduced by Dr. Dojet 1992.
- Knowledge based system:
  - RR
  - Vt
  - EtCo2
  - Automatic SBT

Smart Care Working Principles
Draeger Medical

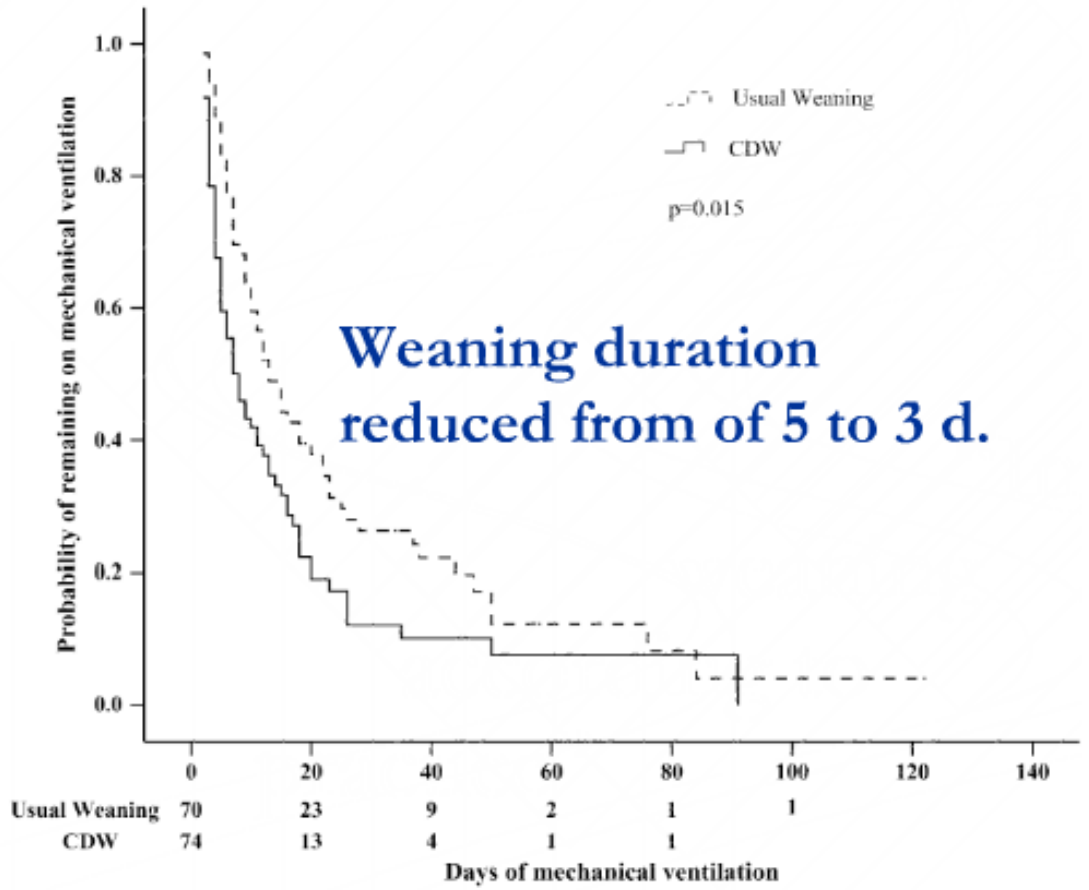


SmartCare (Draeger Medical)

- Algorithm for weaning is based on RR, Vt, & ETCO2 measured every 2—5 minutes.
- Automation:
  - Adjust PS to keep patient in comfort zone
  - Automatically initiate SBT when

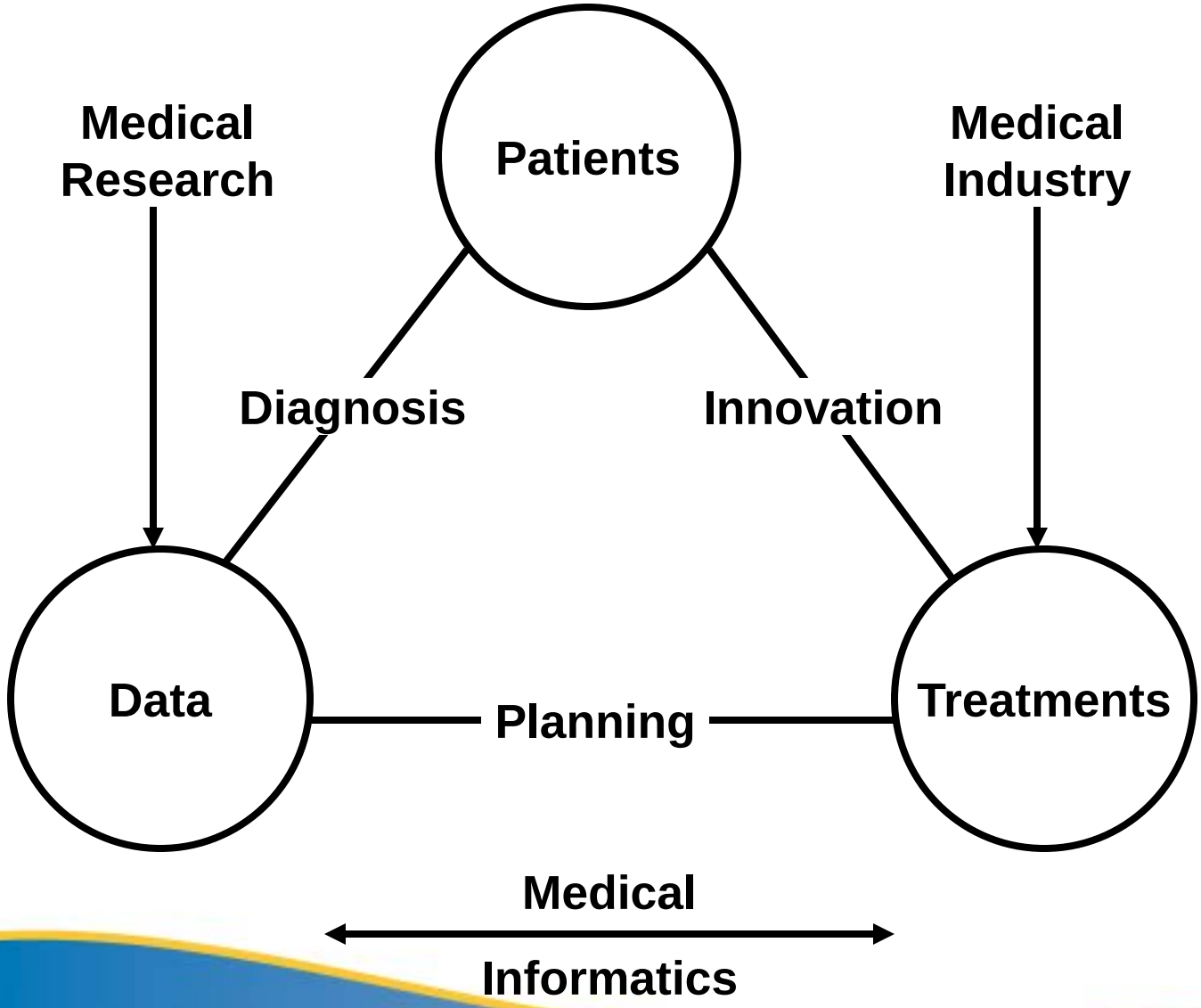
SmartCare (Draeger Medical)

First Author	Year
Dojat	1992
Dojat	1996
Dojat	1996
Dojat	2000
Lellouche	2006
Rose L.	2008



Esophageal Manometry guided Mechanical Ventilation
What's old is new again!

Case Reports



Mireles-Cabodeila et al. Resp Care. Feb 2013

The World We Live in…..

- No two people are alike!

Not everyone fits in a box…
(Hypothetical example)

ph >7.32

Plateau ≤30 cm H2O

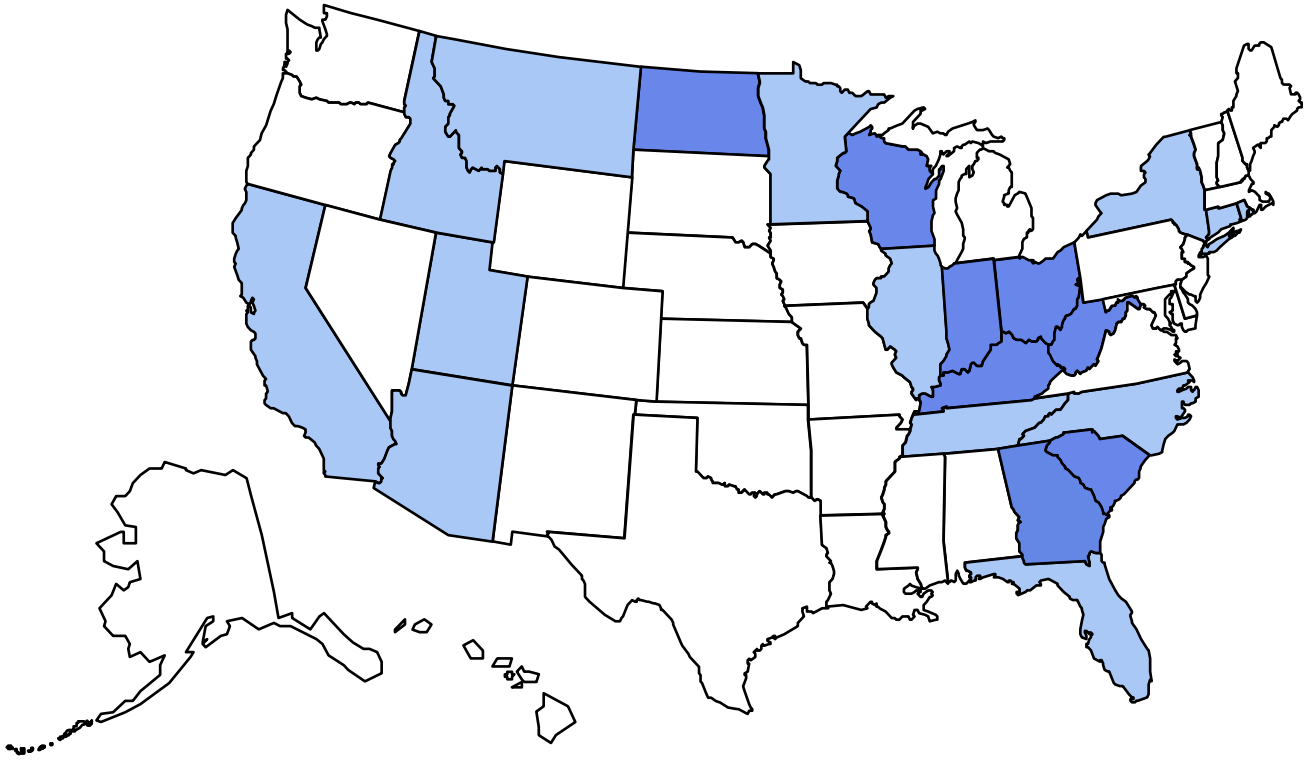
PCO2 <50

SPO2 >94%

Obesity Trends* Among U.S. Adults

BRFSS, 1985

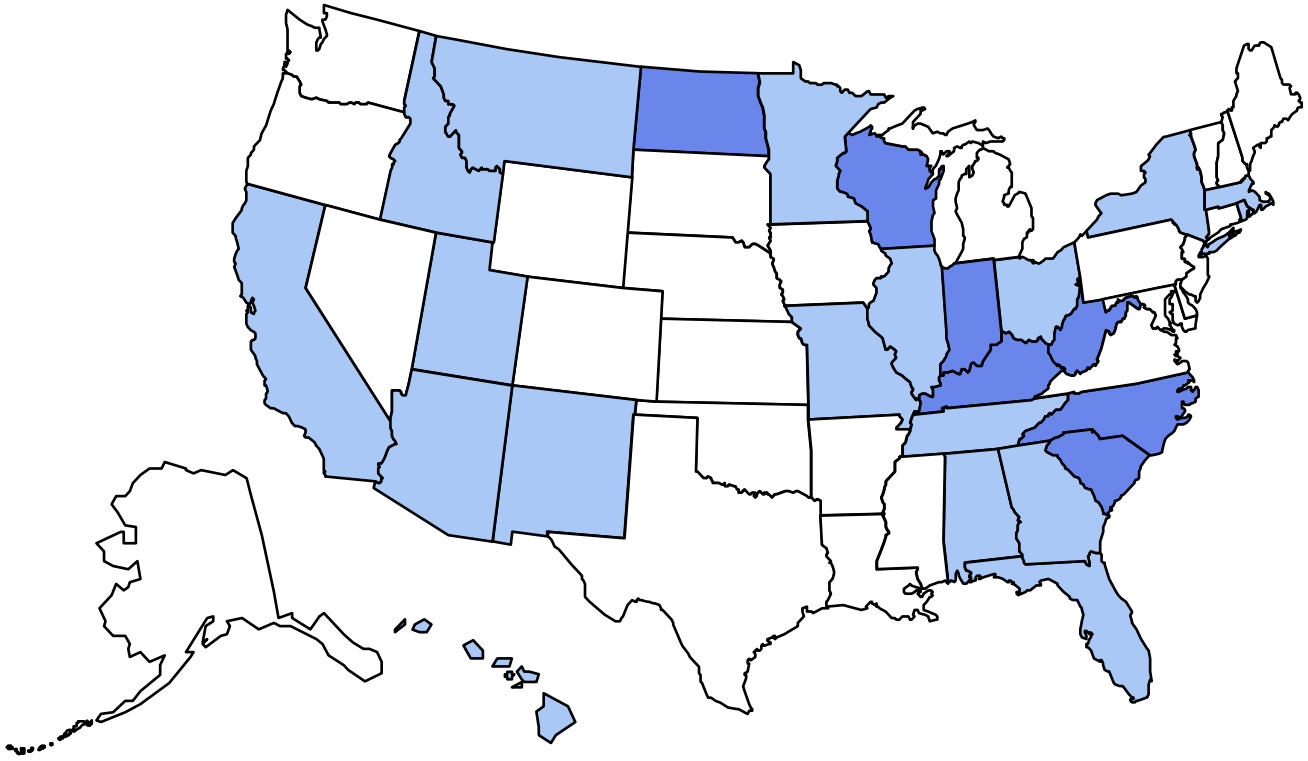
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1986

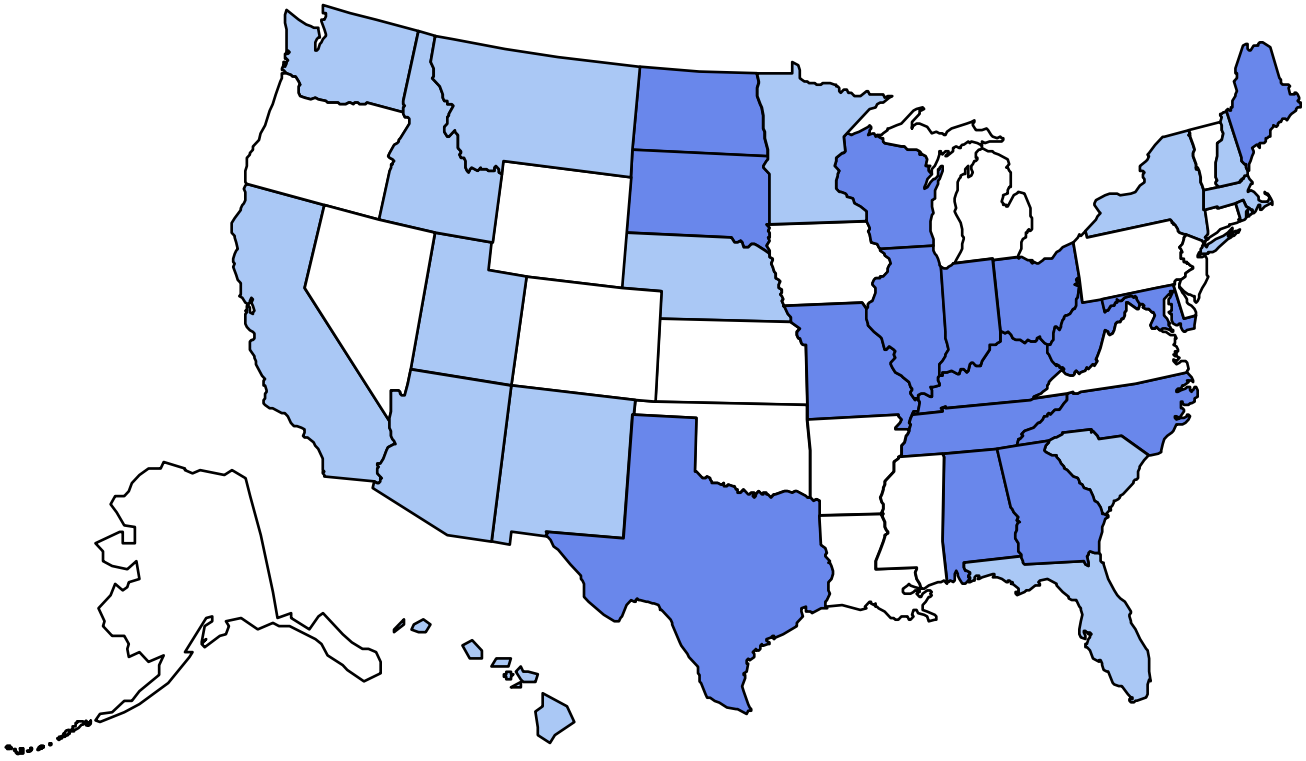
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1987

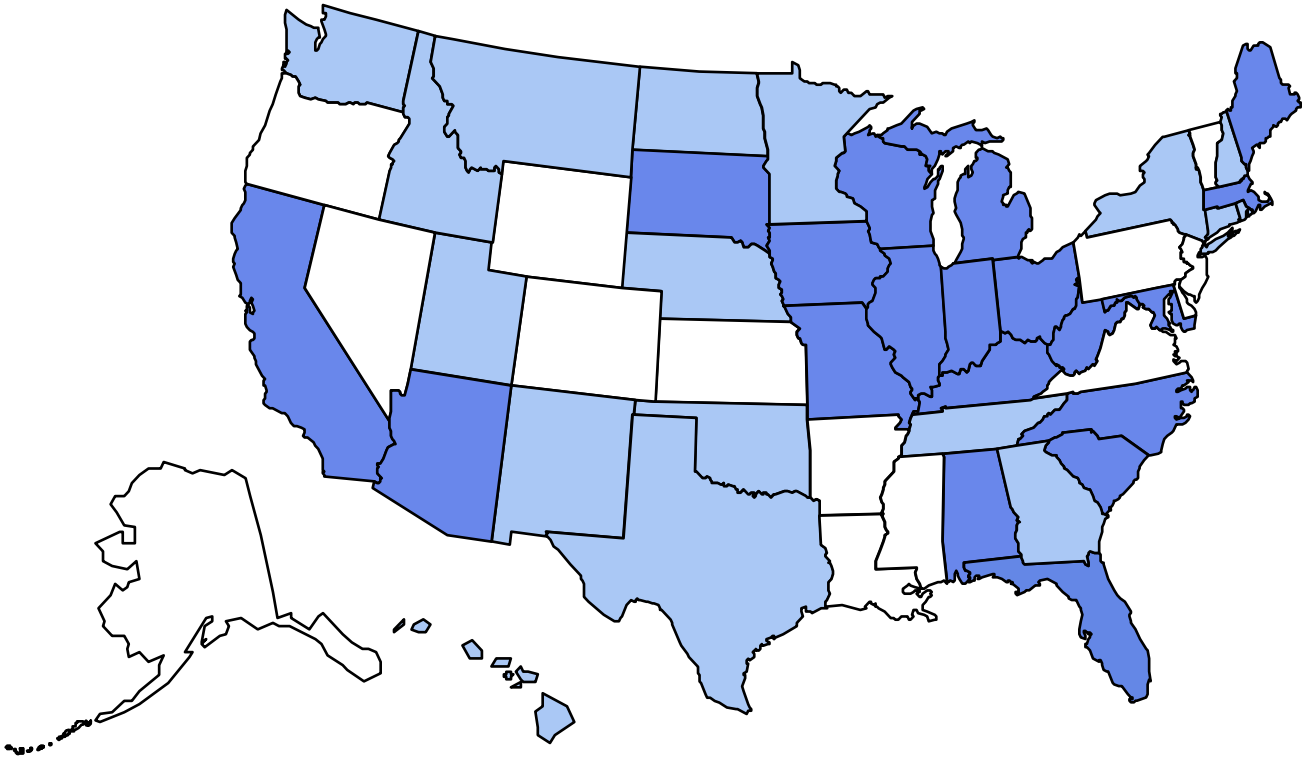
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1988

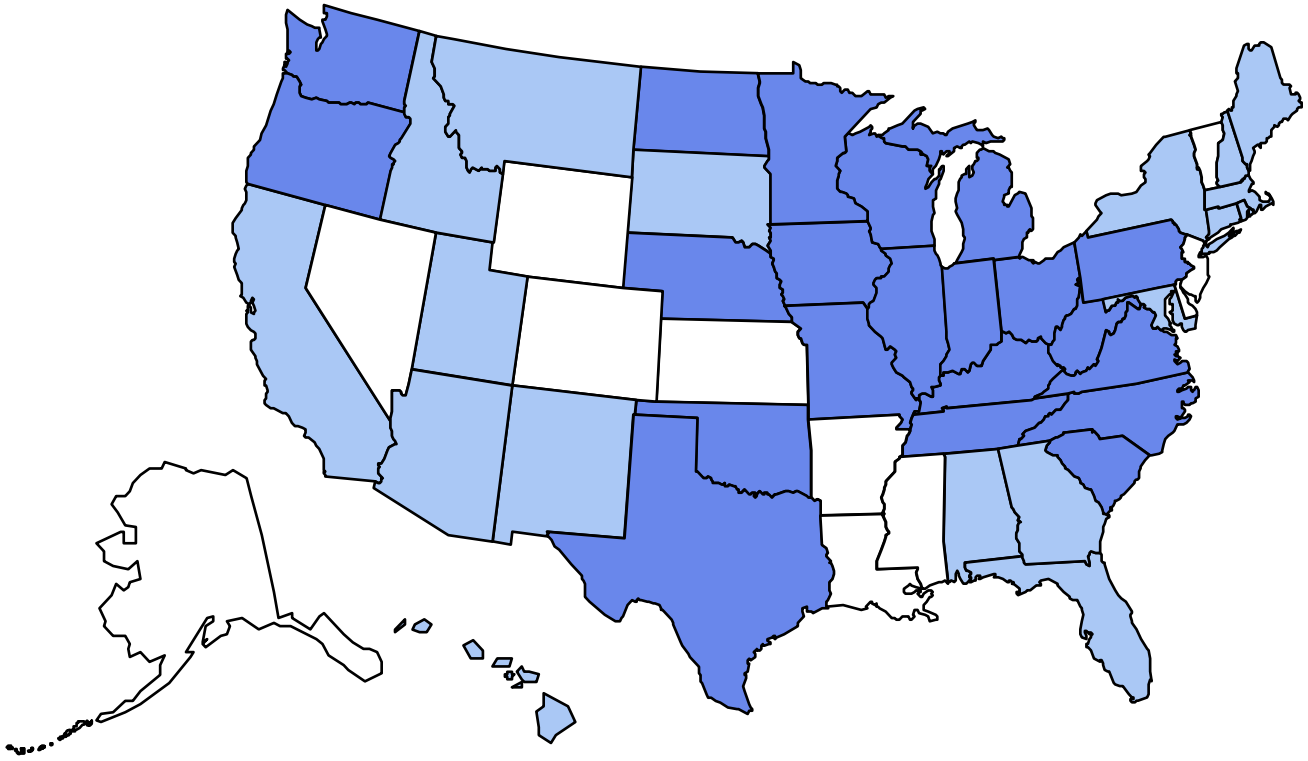
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1989

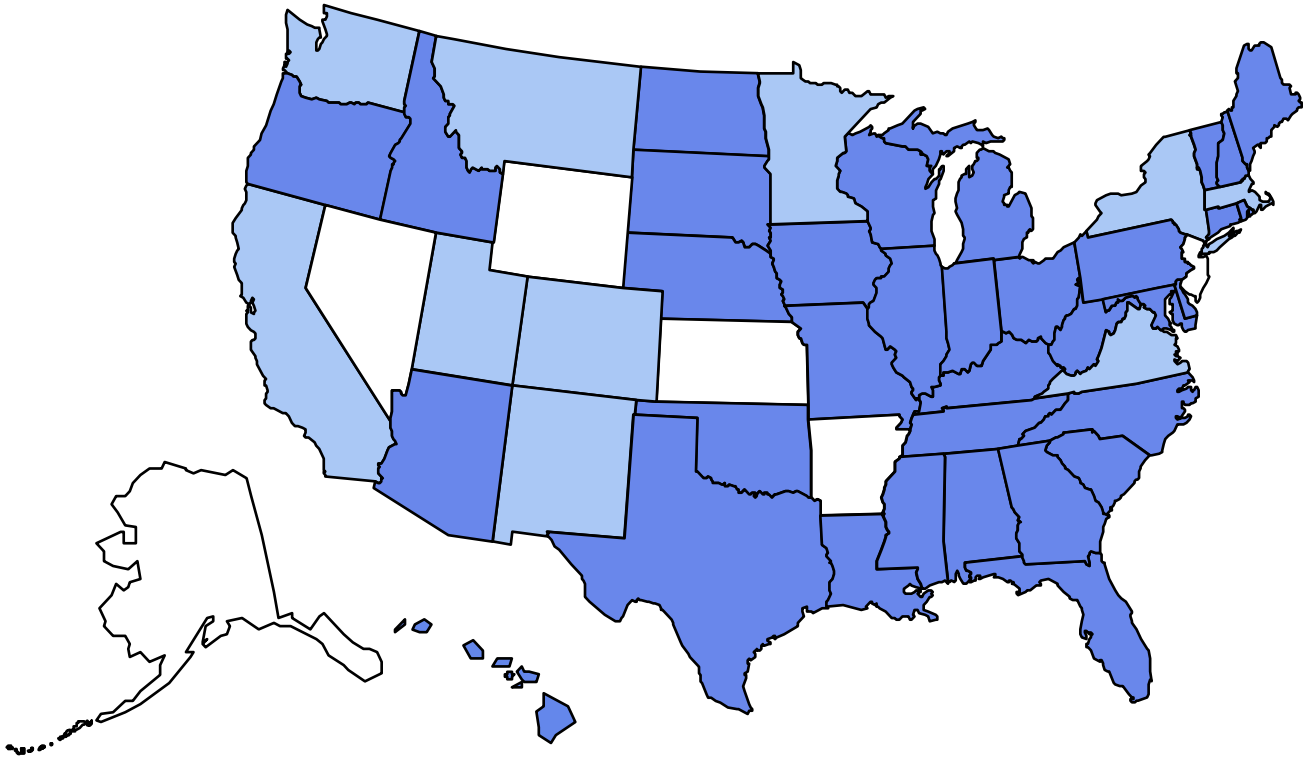
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1990

(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



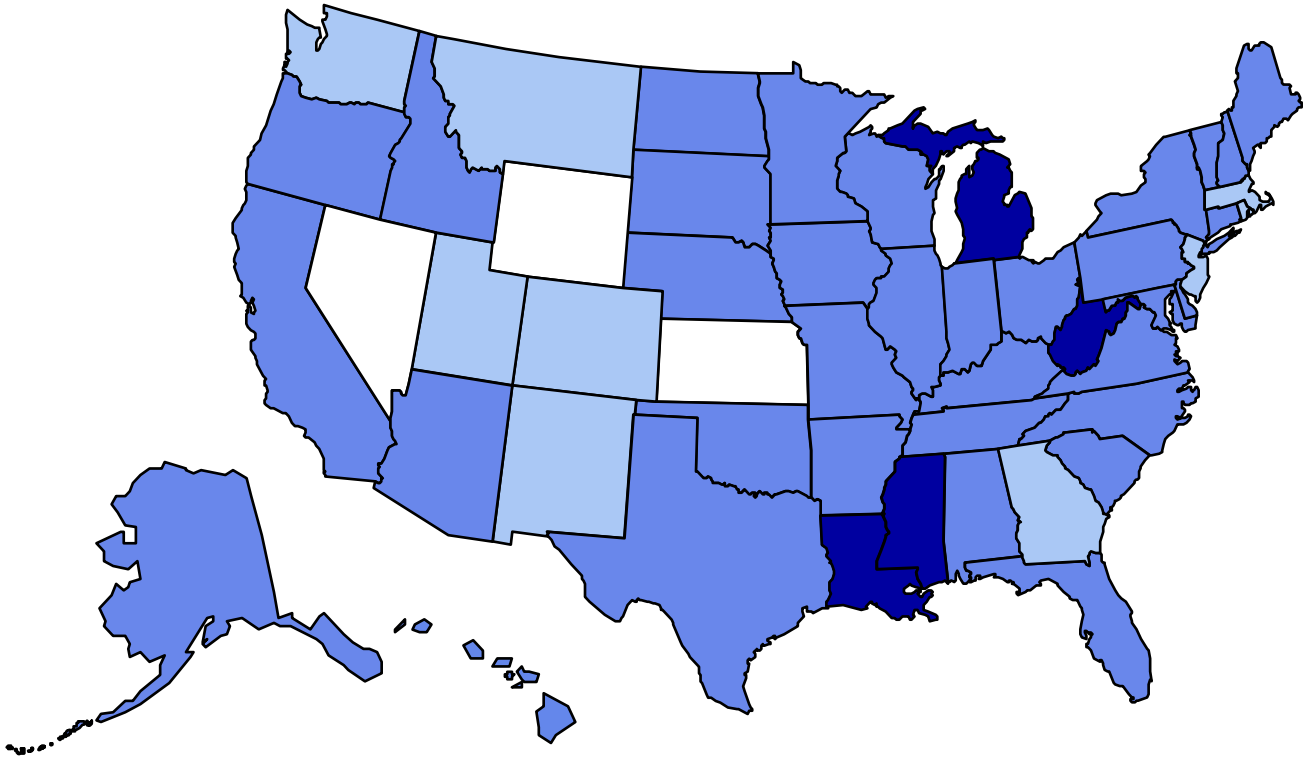
SENTARA

CDC

Obesity Trends* Among U.S. Adults

BRFSS, 1991

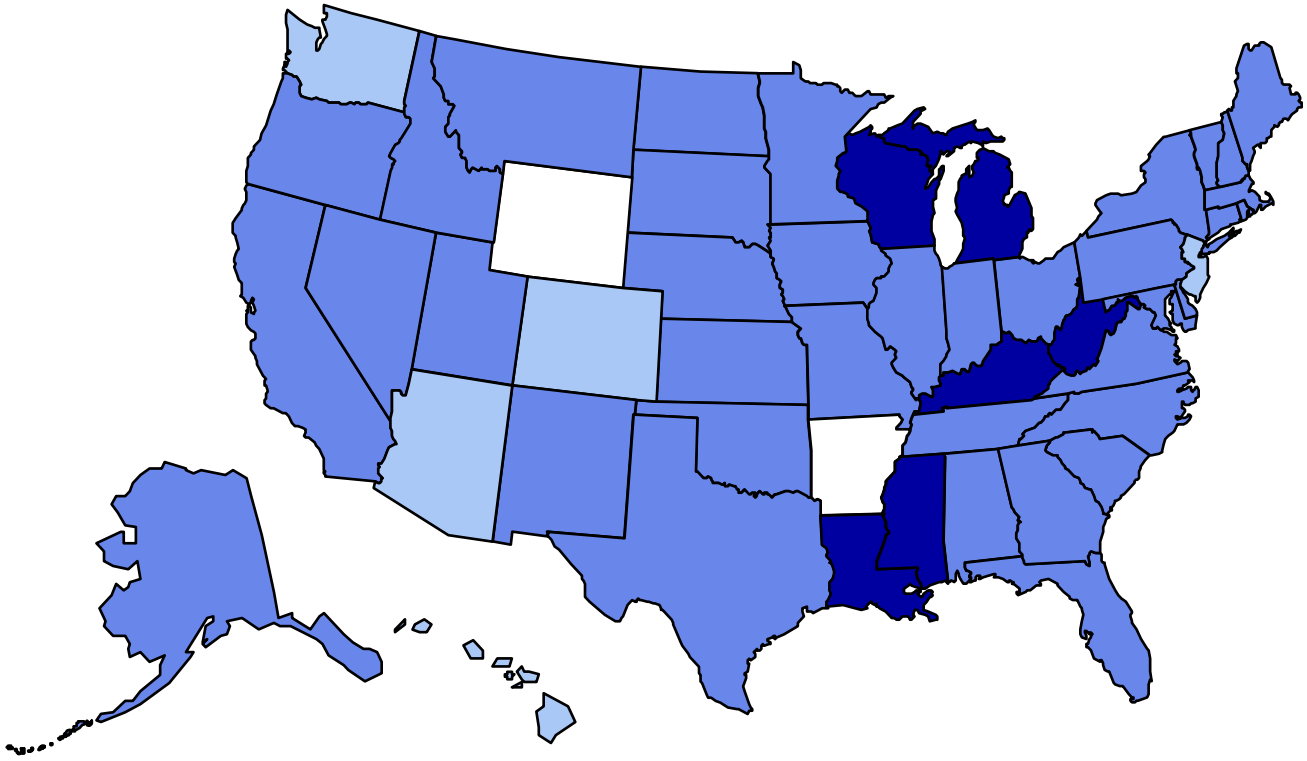
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1992

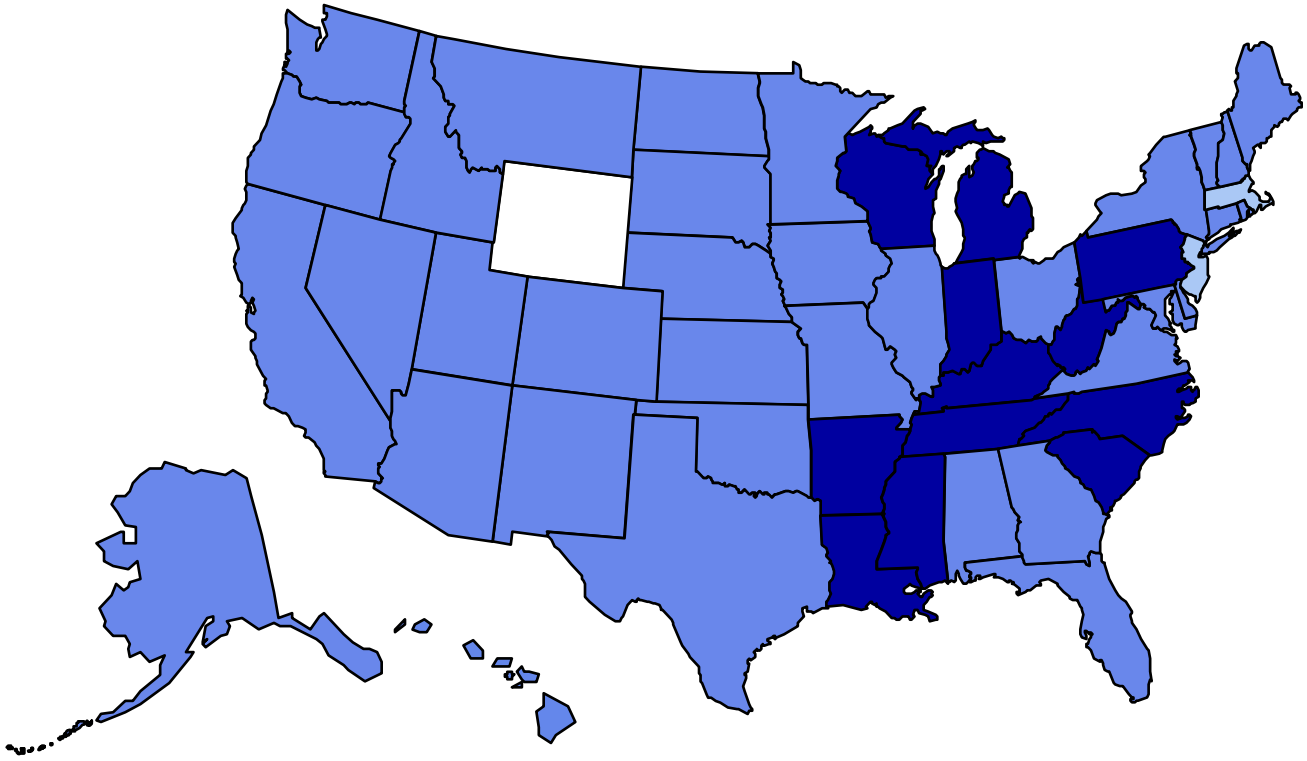
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1993

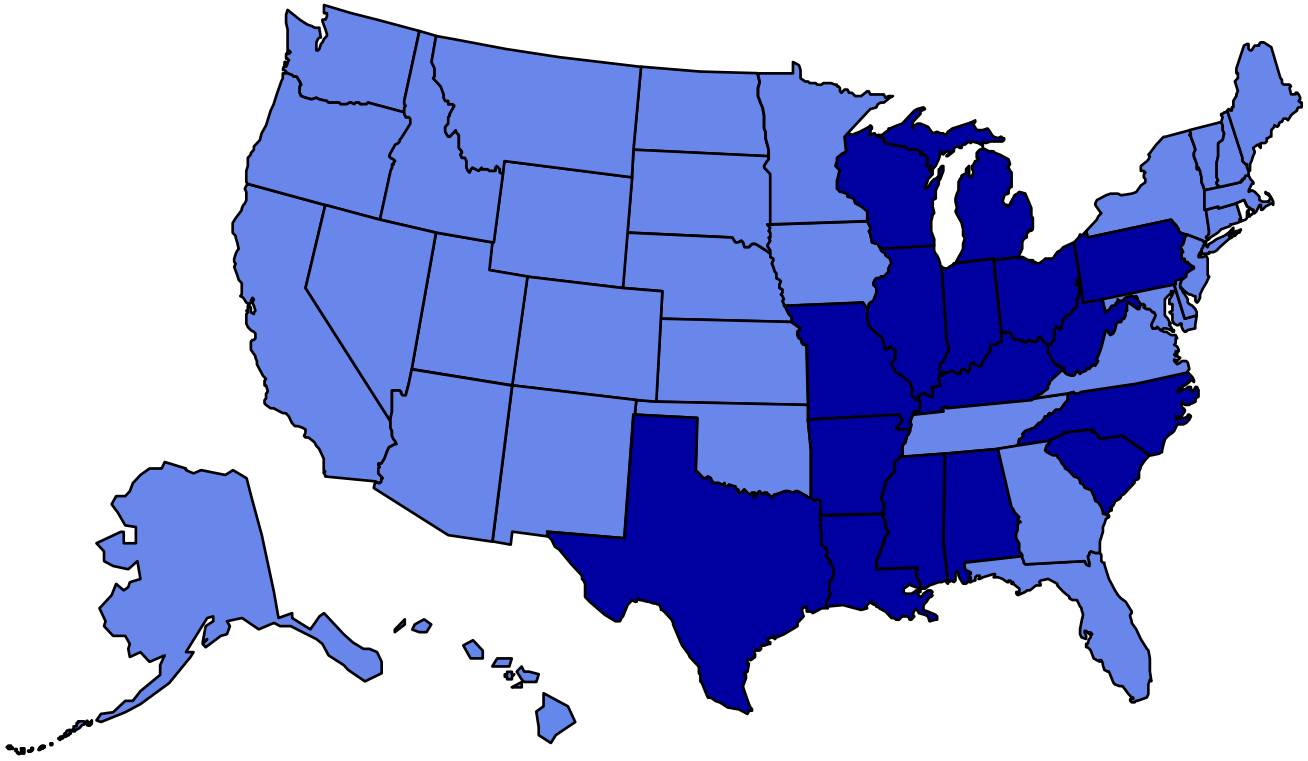
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1994

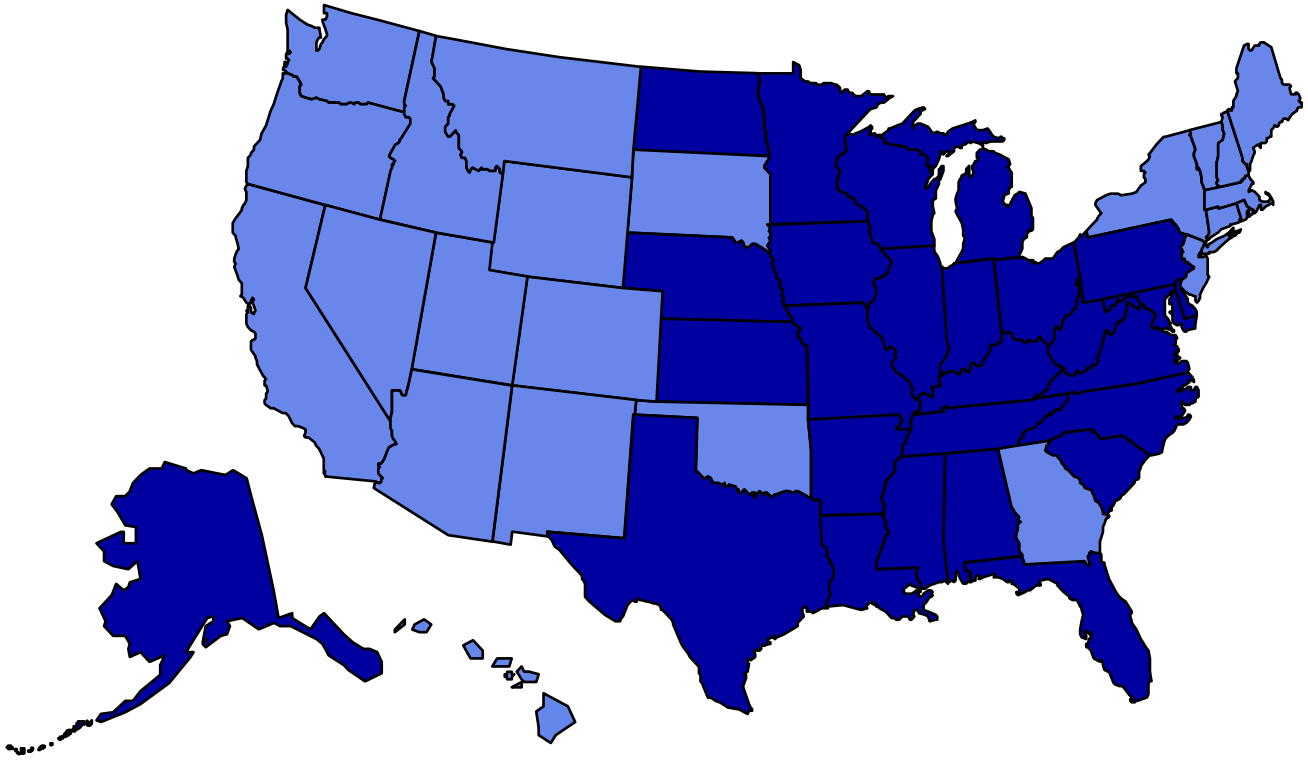
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1995

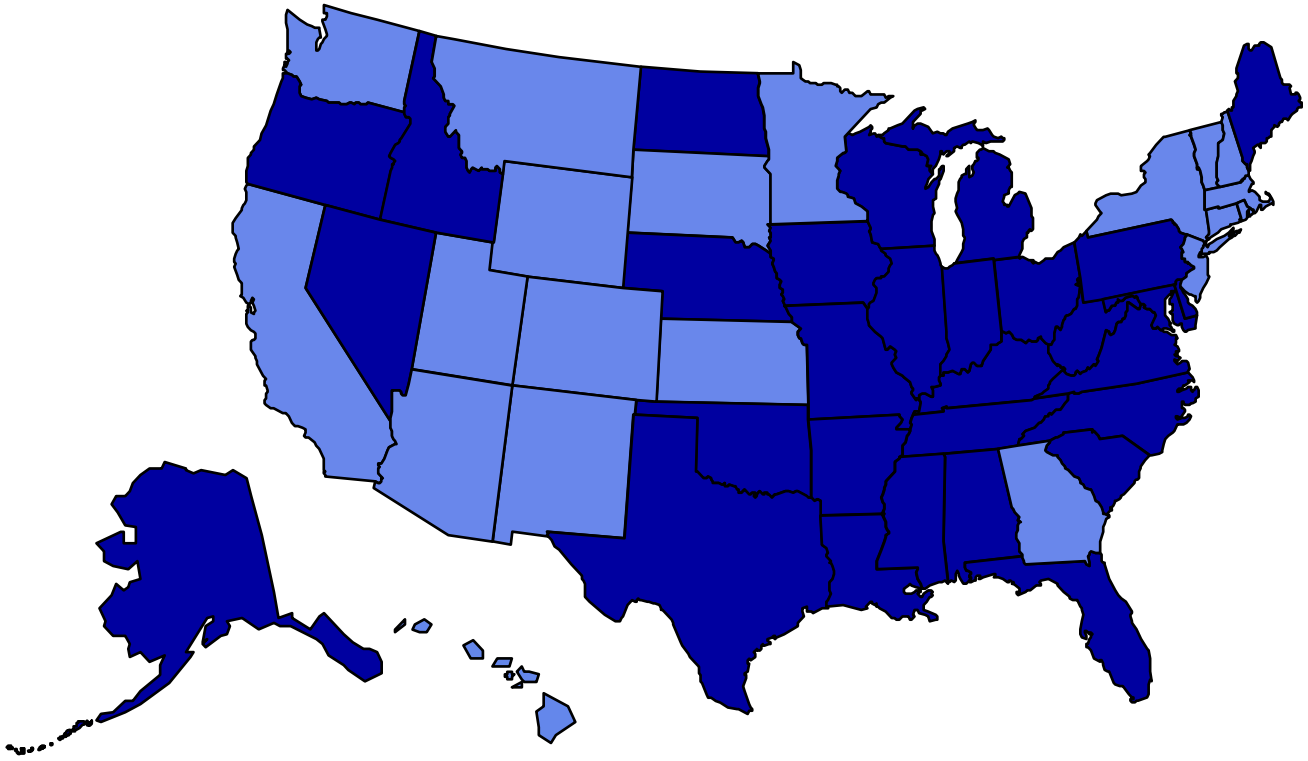
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1996

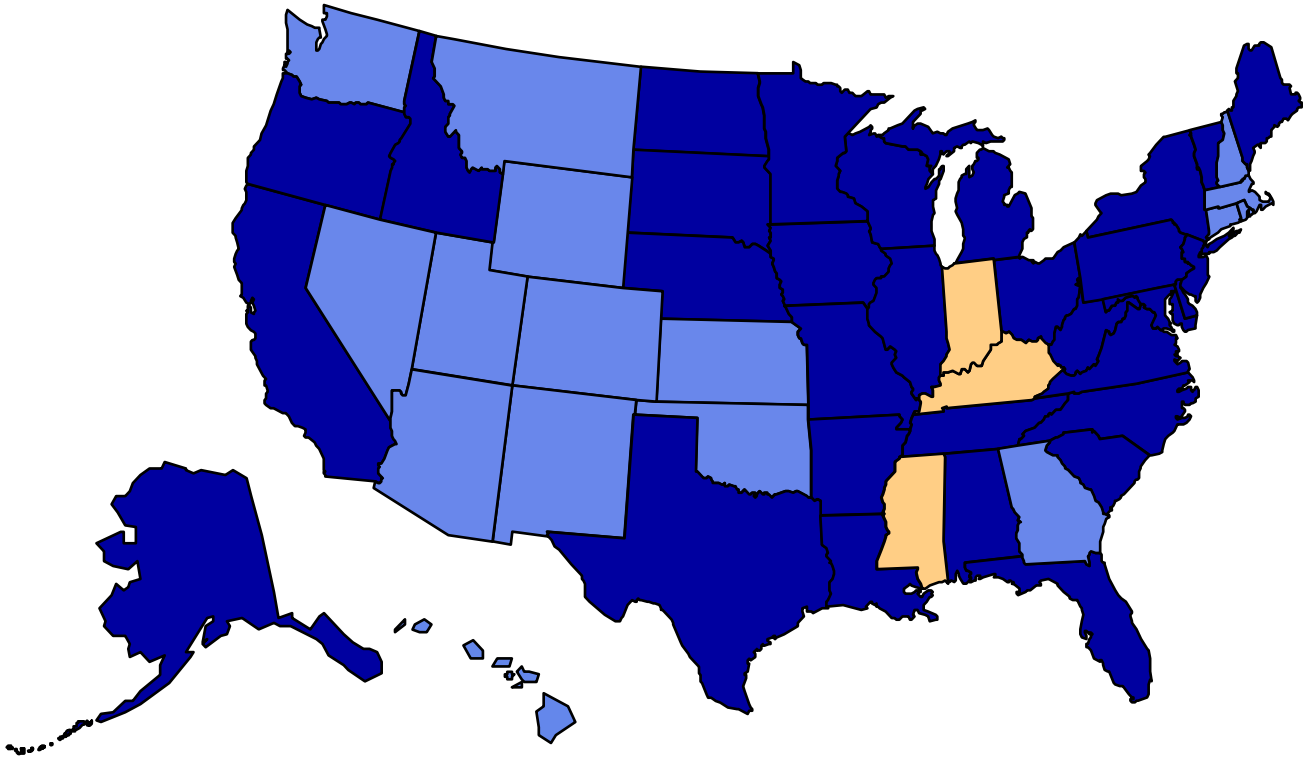
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1997

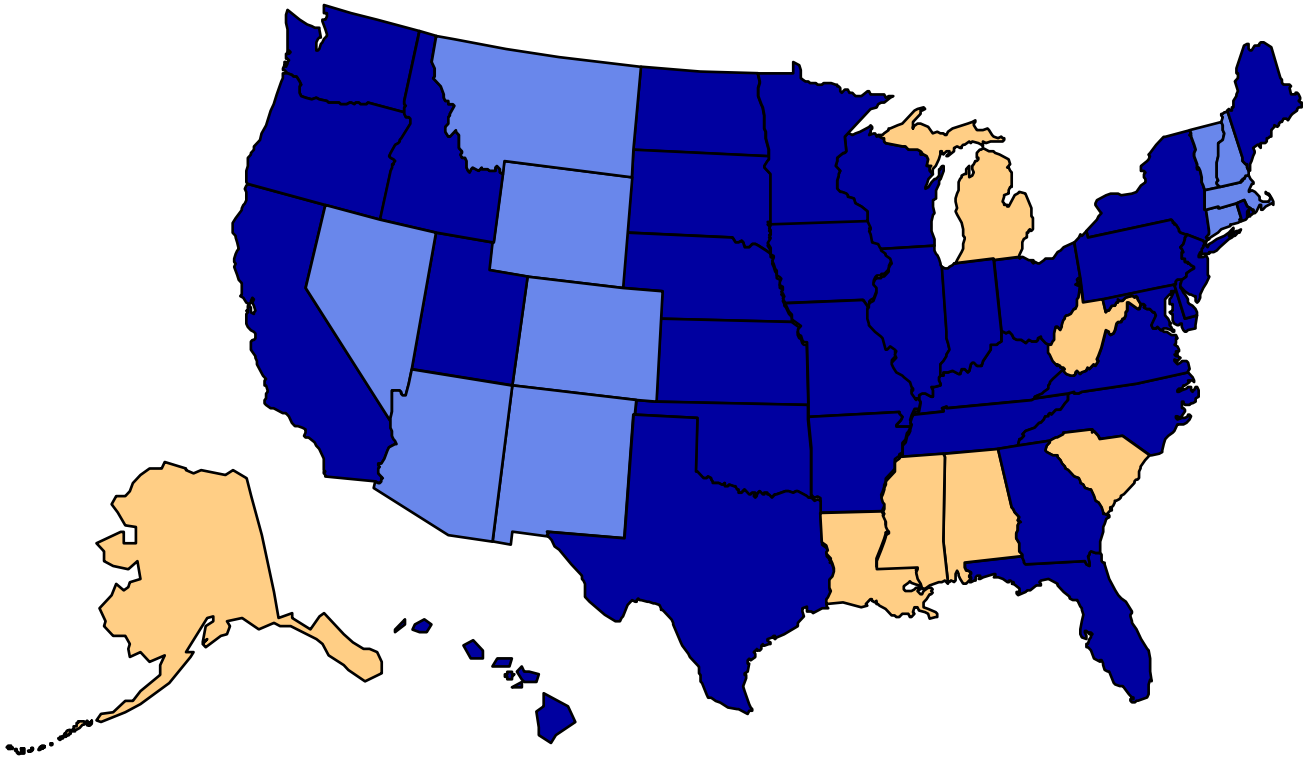
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1998

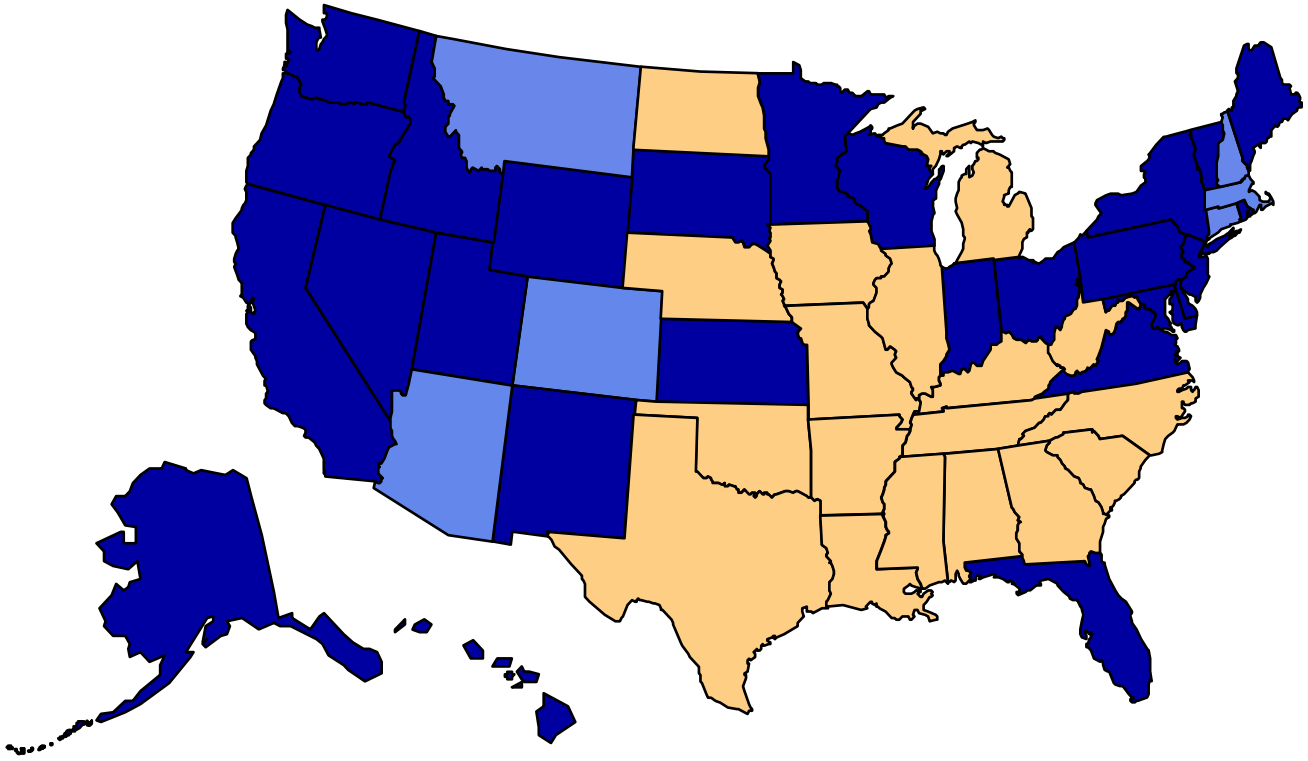
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 1999

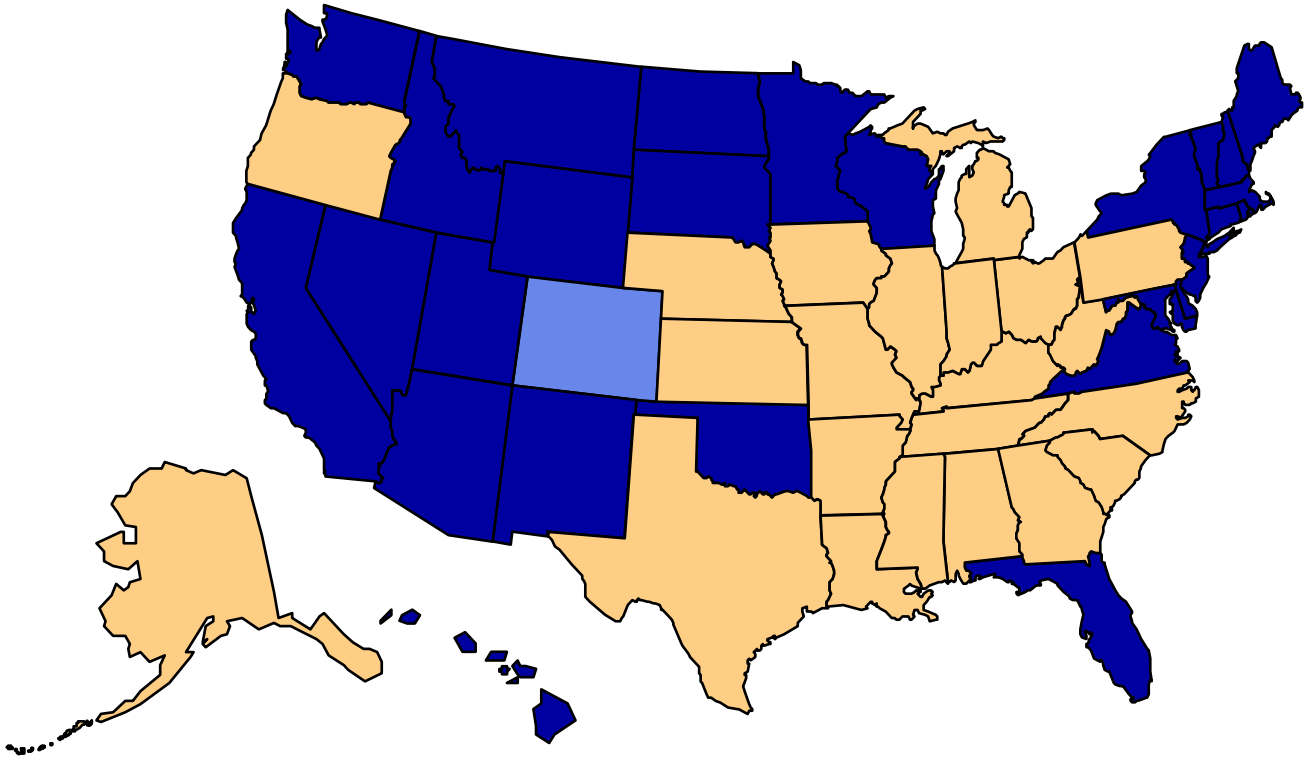
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2000

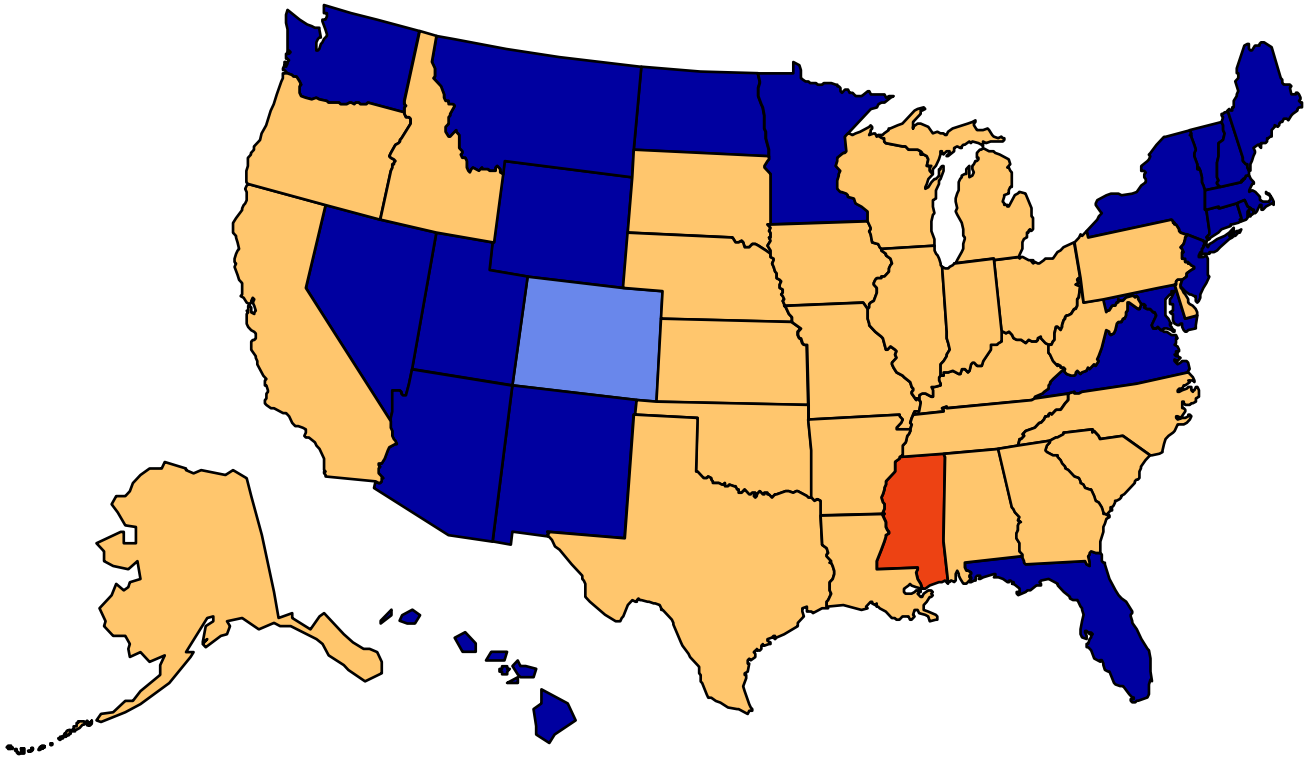
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2001

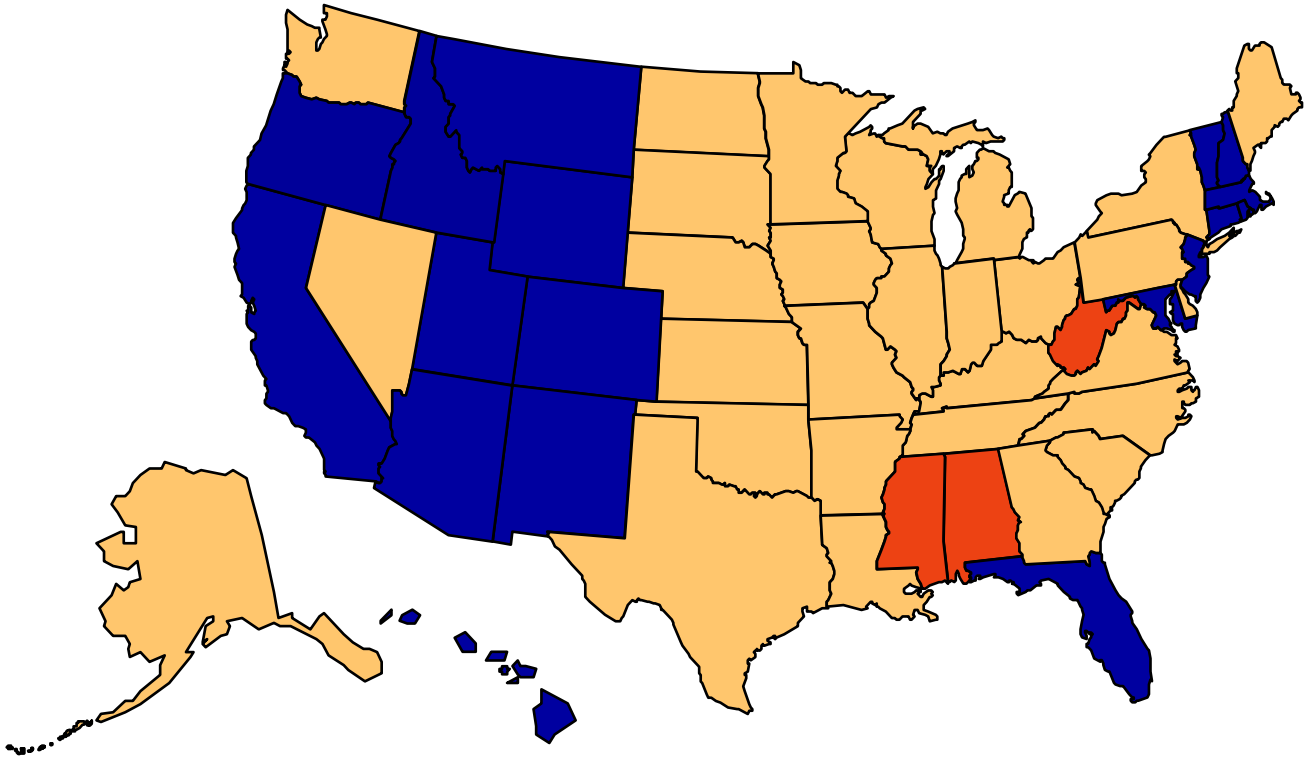
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2002

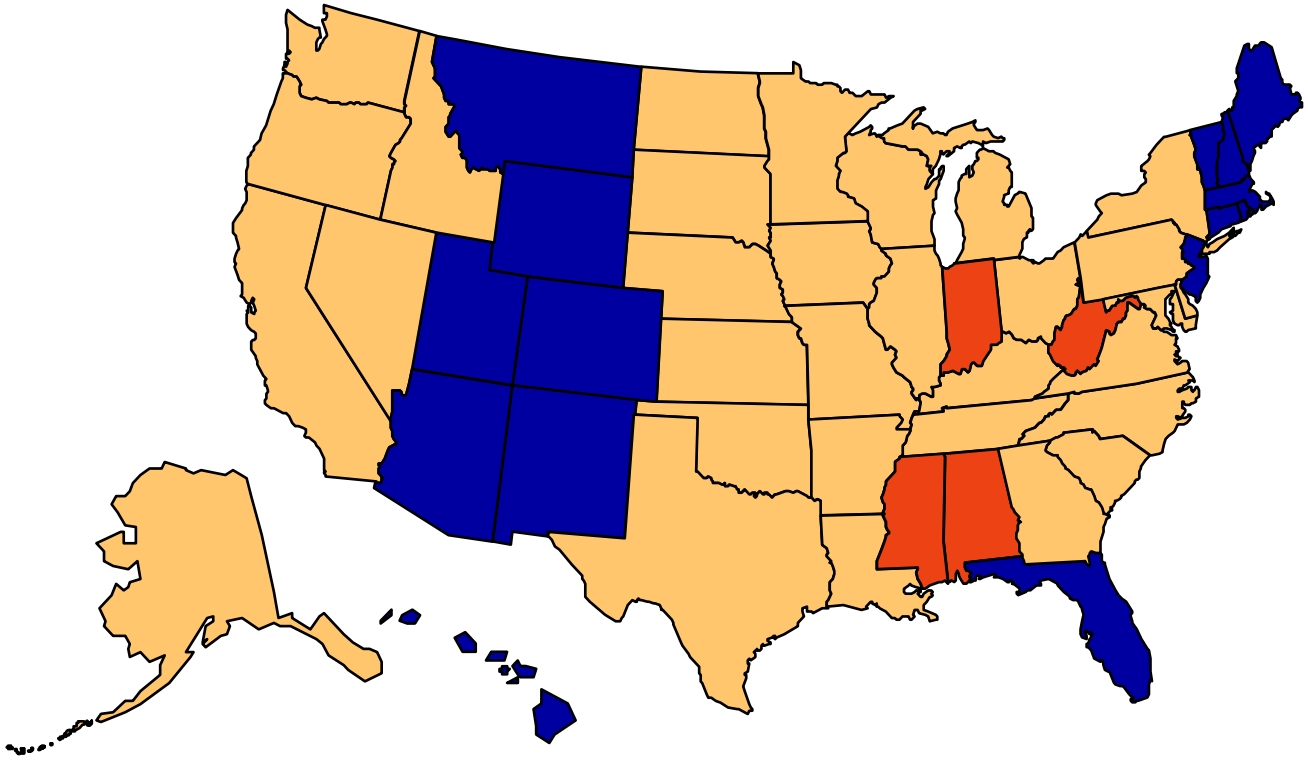
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2003

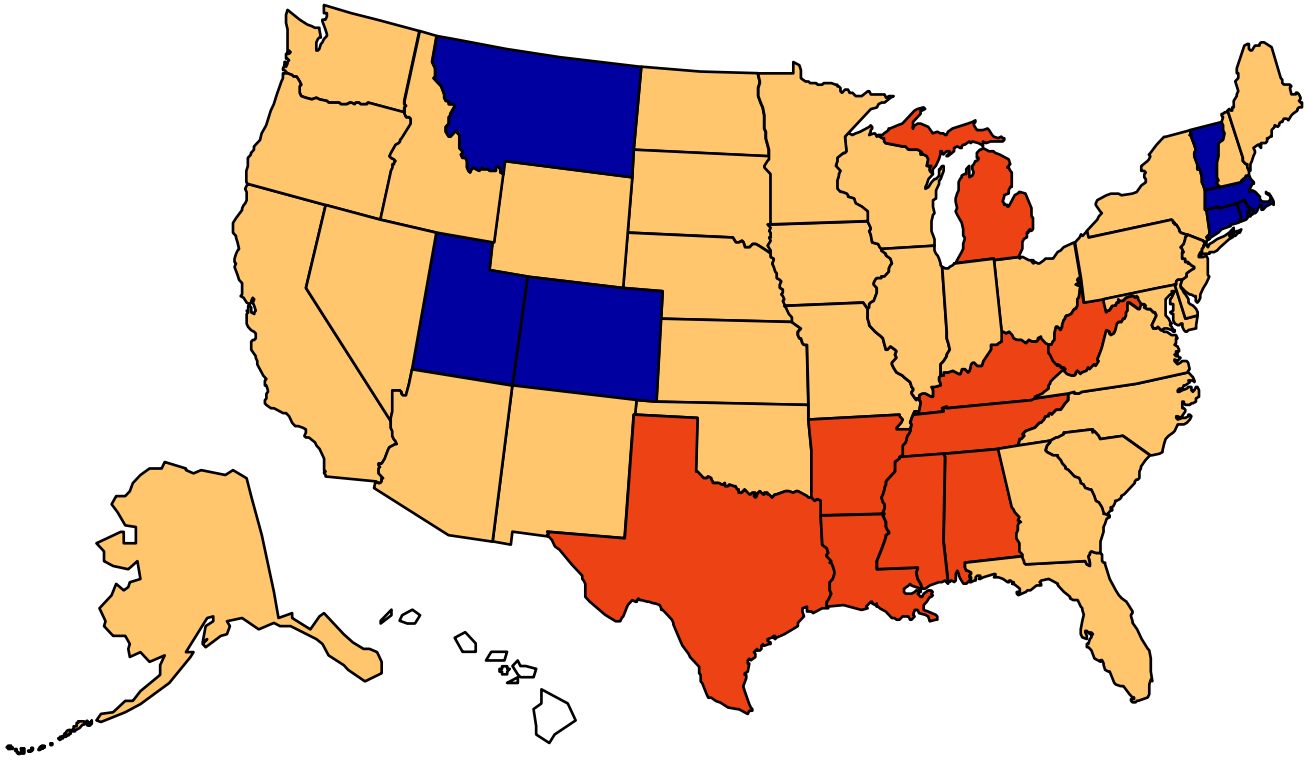
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2004

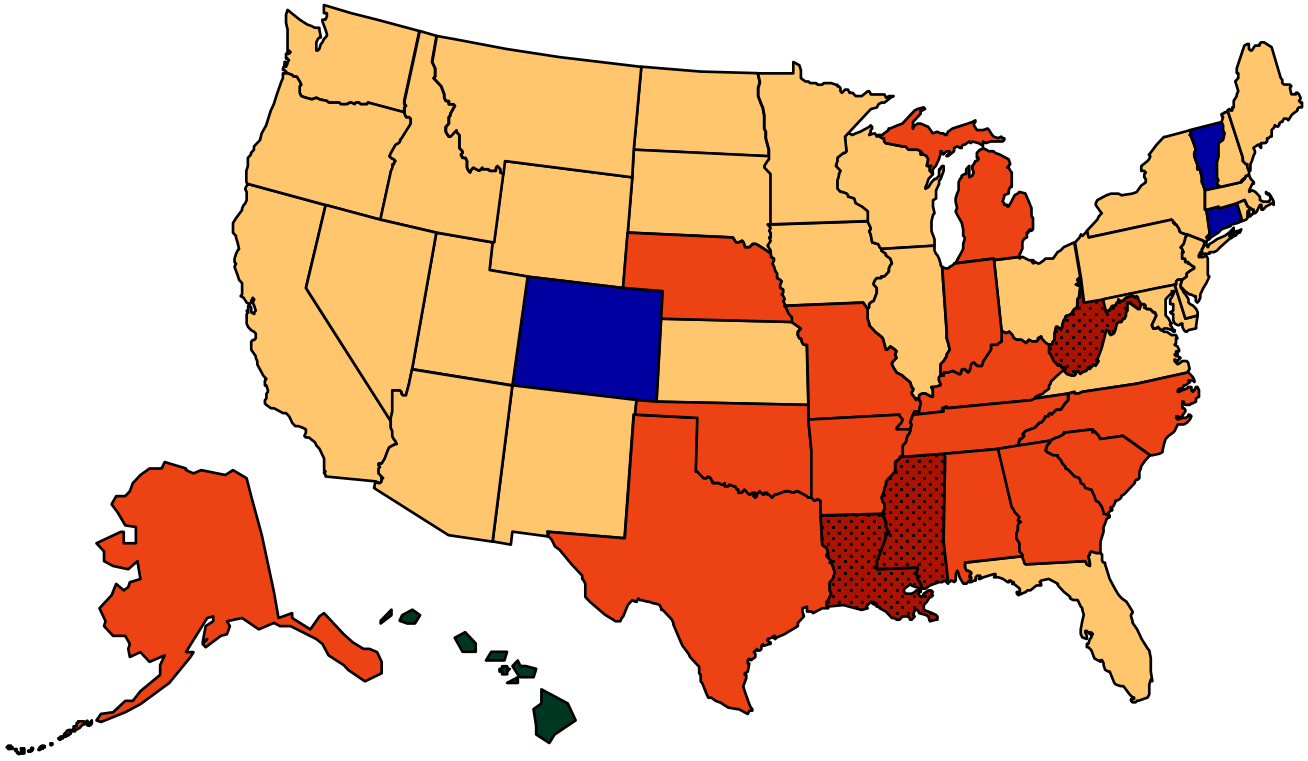
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2005

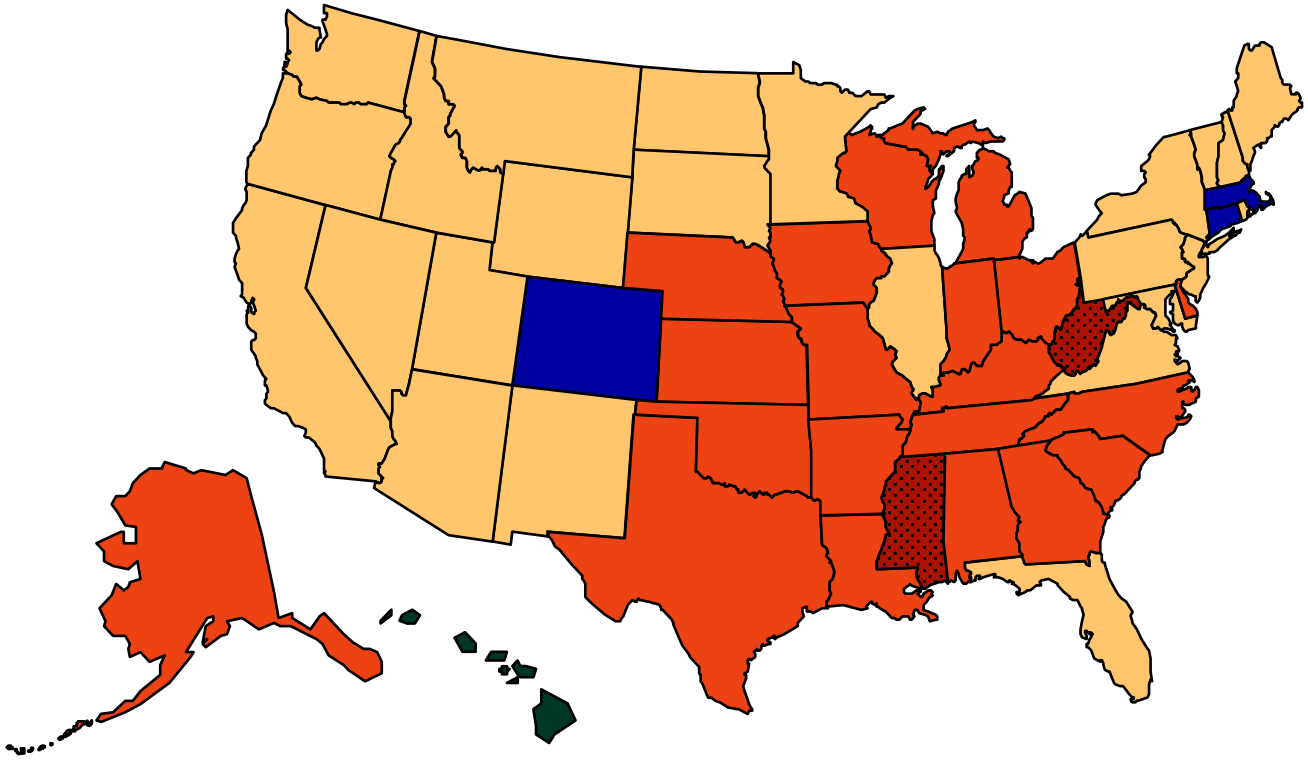
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2006

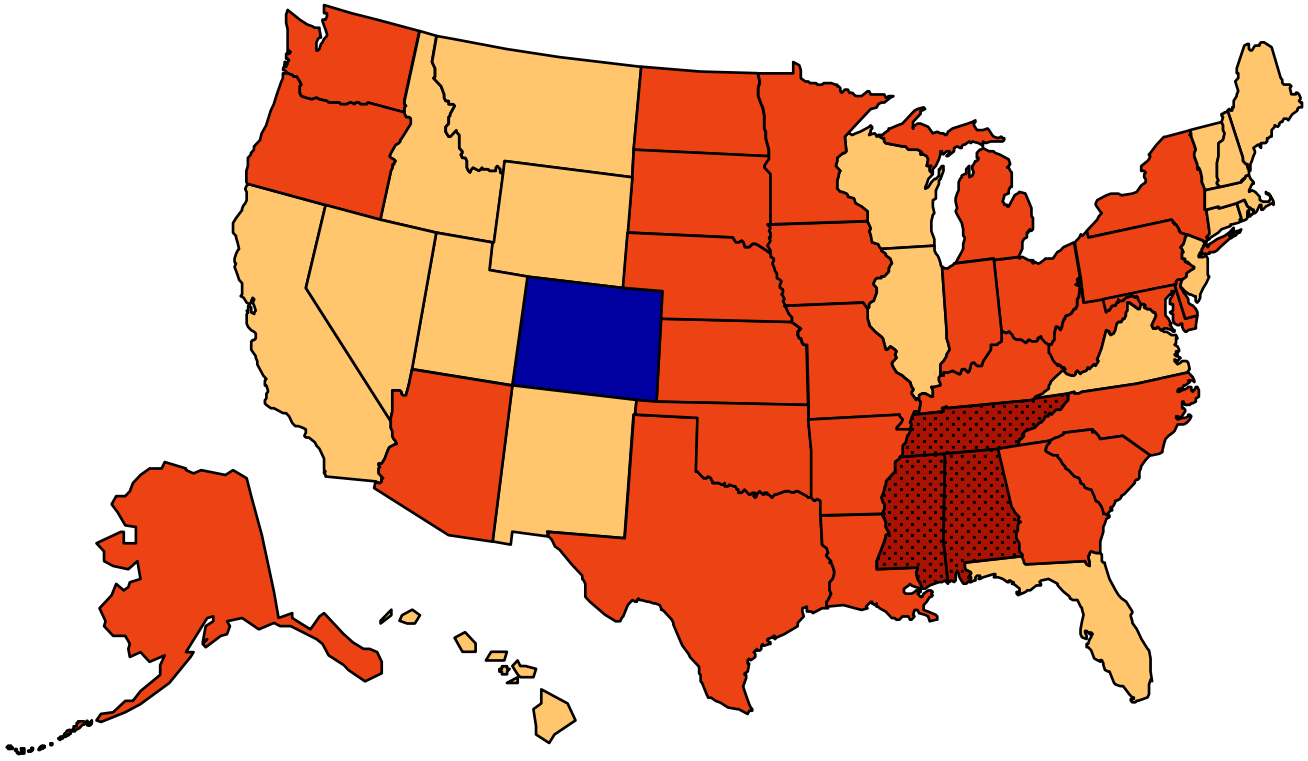
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2007

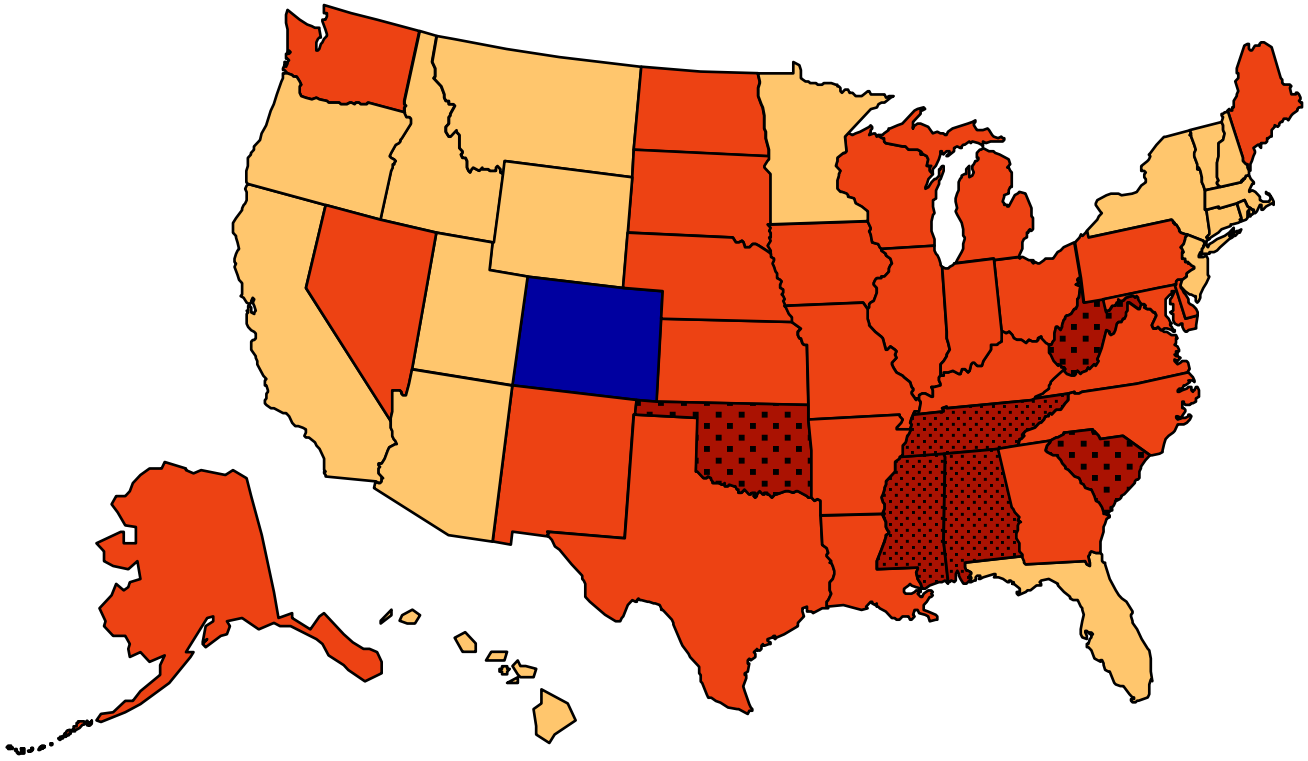
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2008

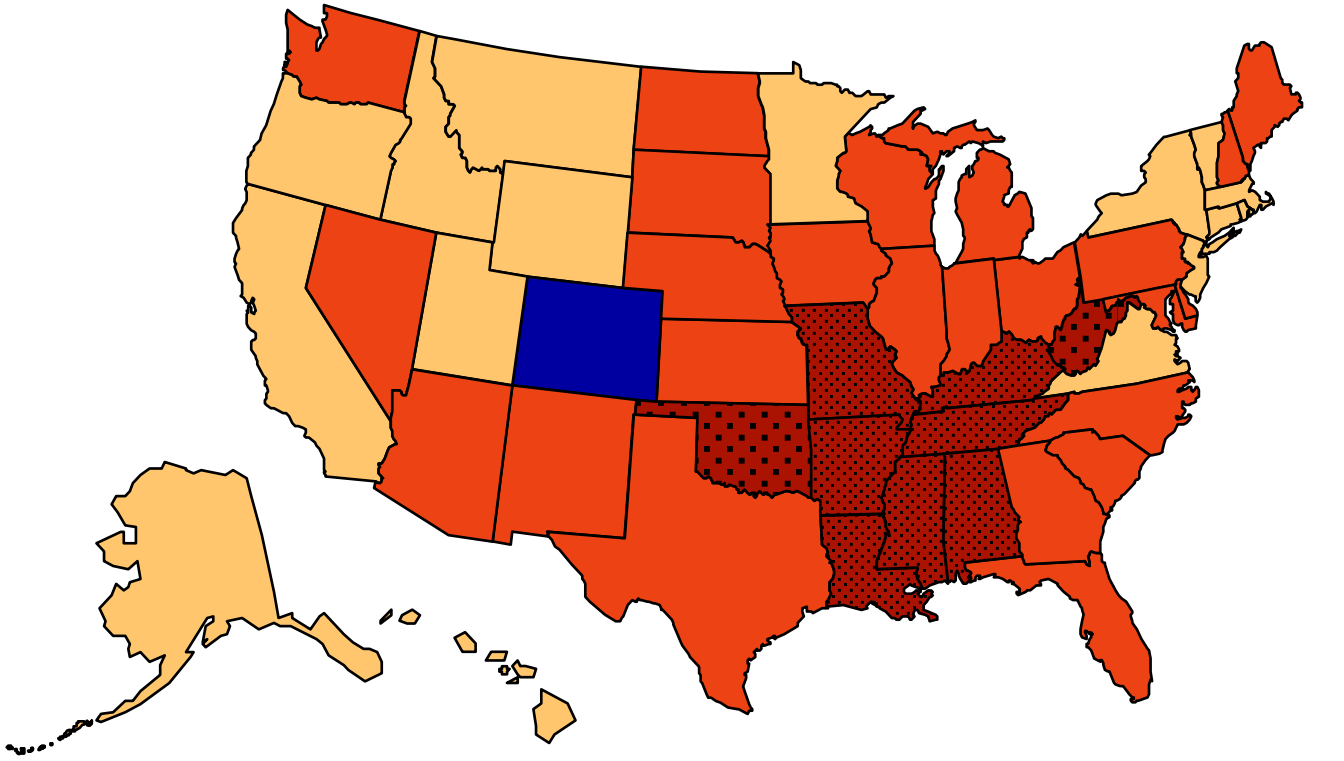
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2009

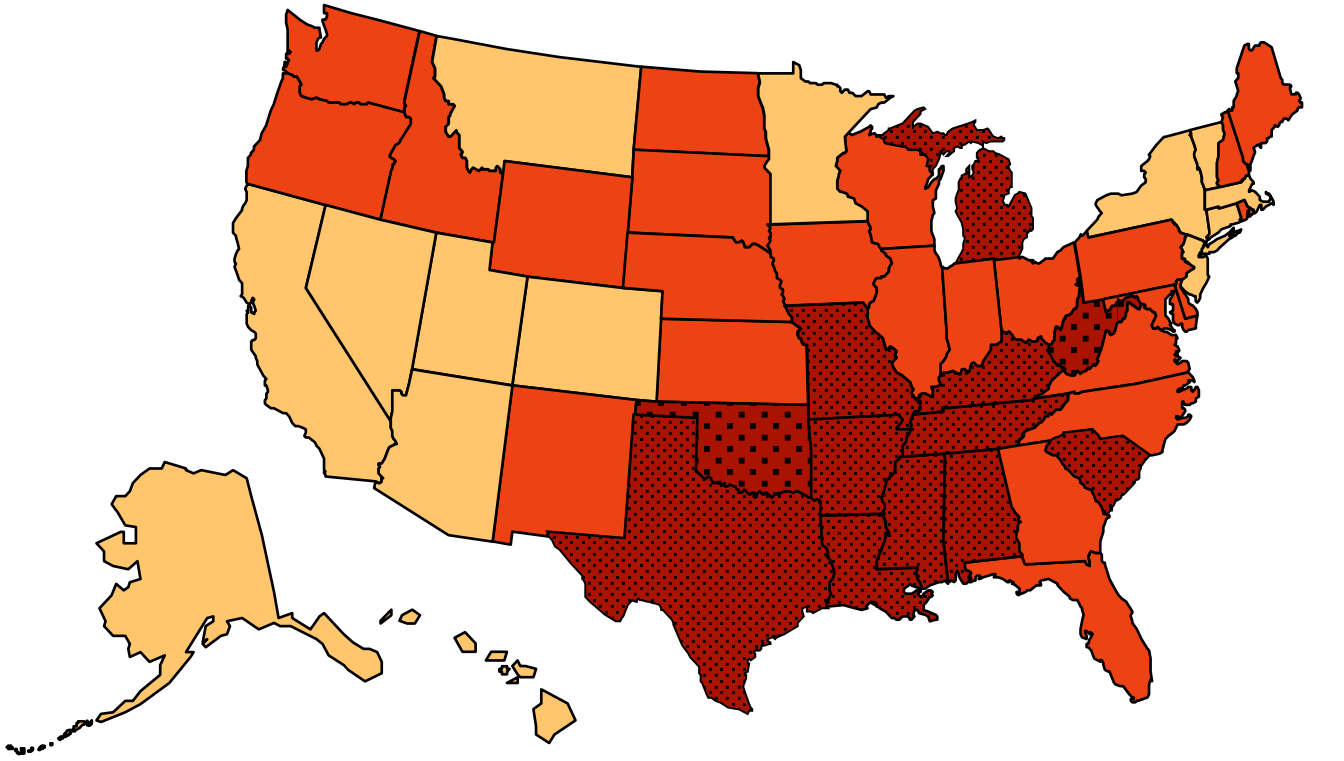
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Obesity Trends* Among U.S. Adults

BRFSS, 2010

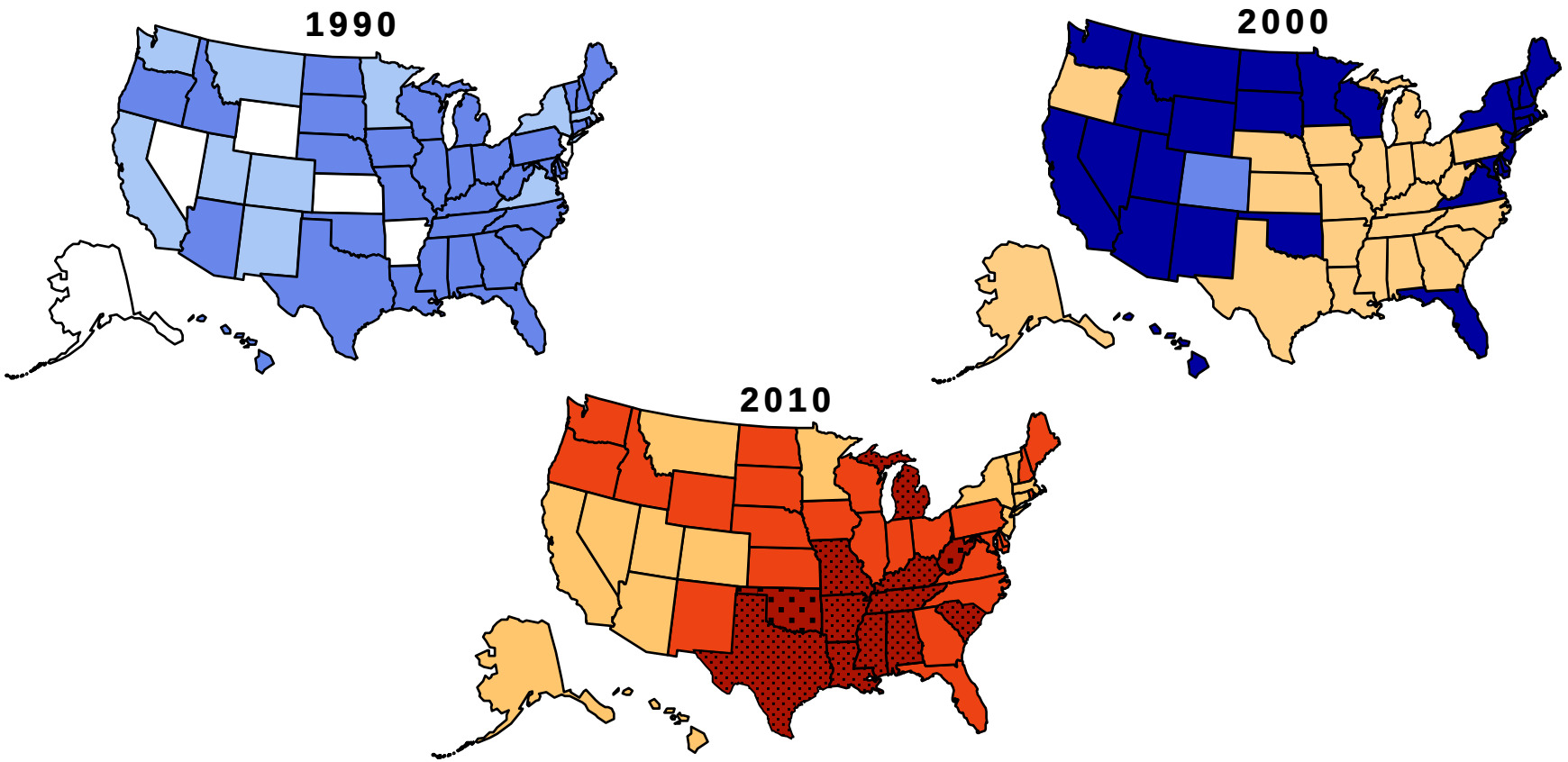
(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



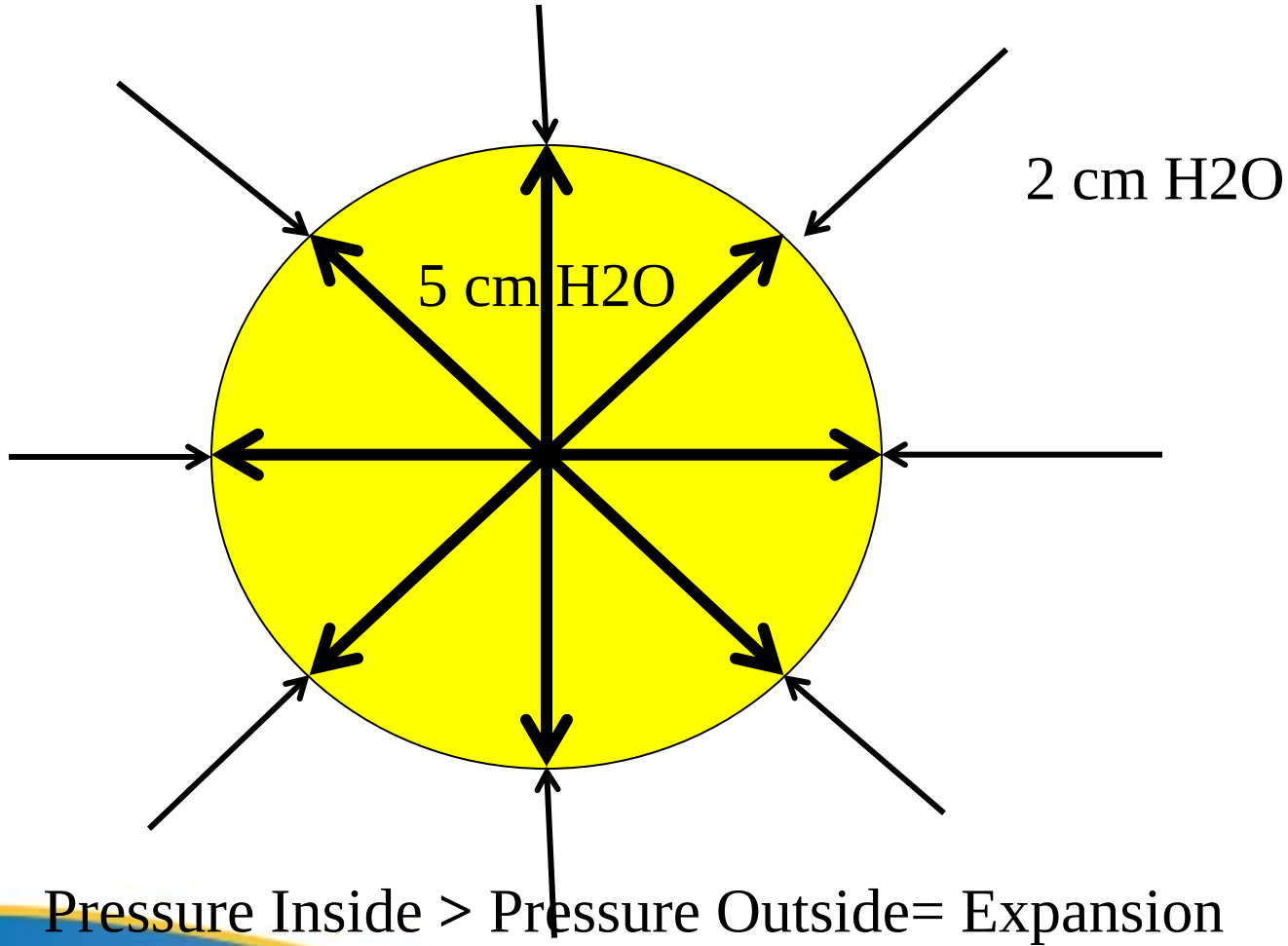
Obesity Trends* Among U.S. Adults

BRFSS, 1990, 2000, 2010

(*BMI ≥30, or about 30 lbs. overweight for 5'4" person)

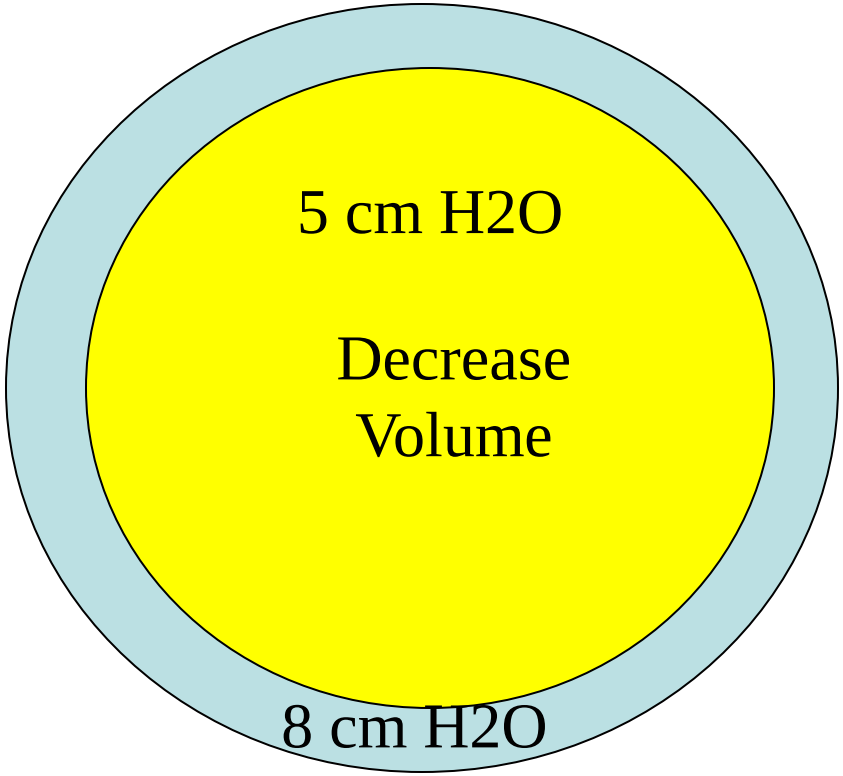


Distendability



Pressure Inside > Pressure Outside= Expansion

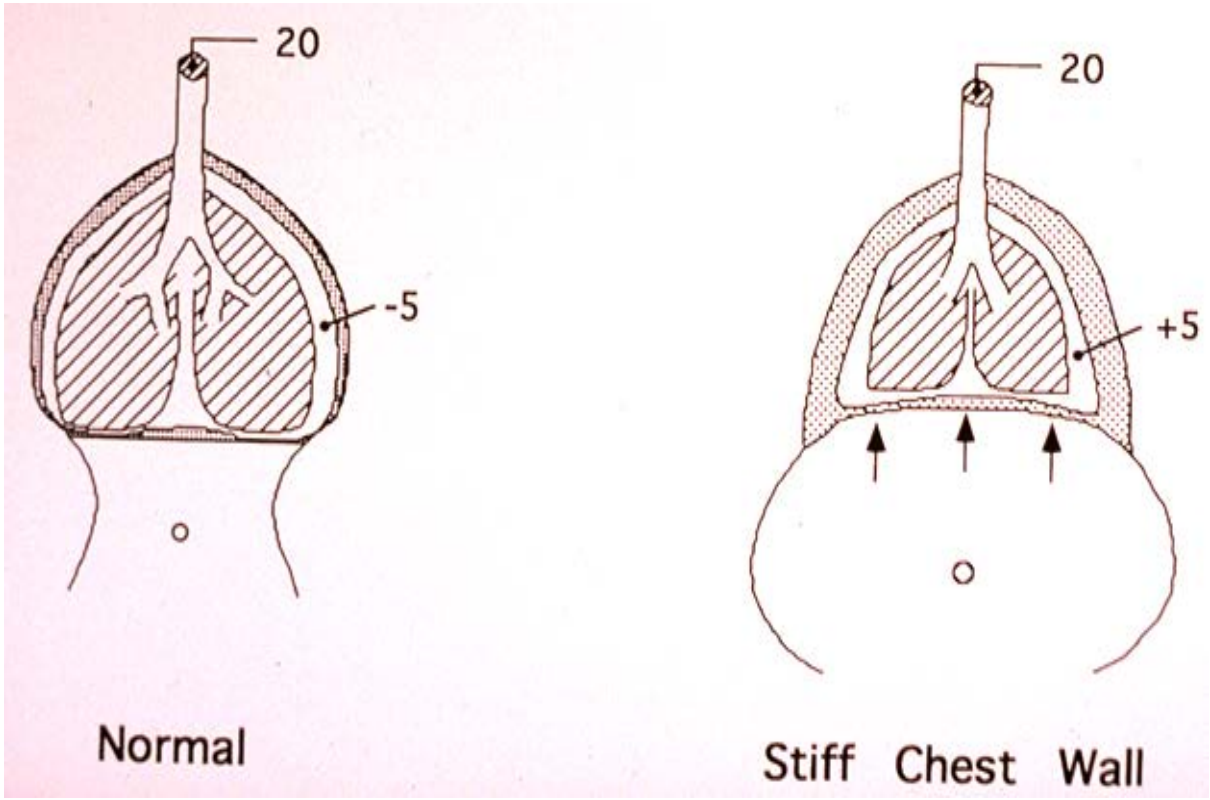
Distendability



2 cm H2O

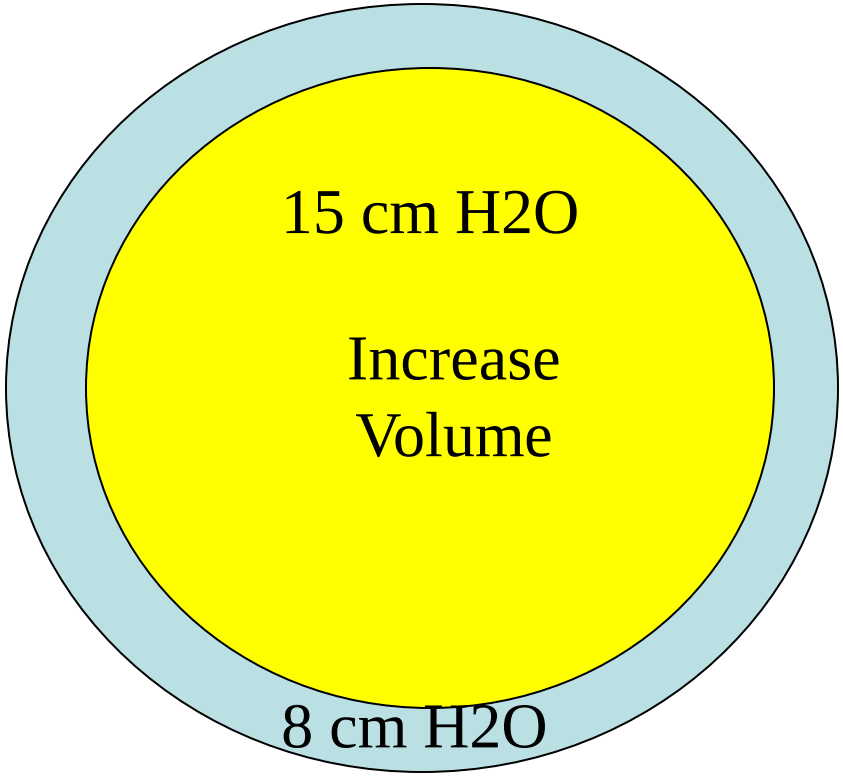
Pressure Inside < Pressure Outside= Collapse

Partitioning of Alveolar Pressure is a Function of Lung and Chest Wall Compliances

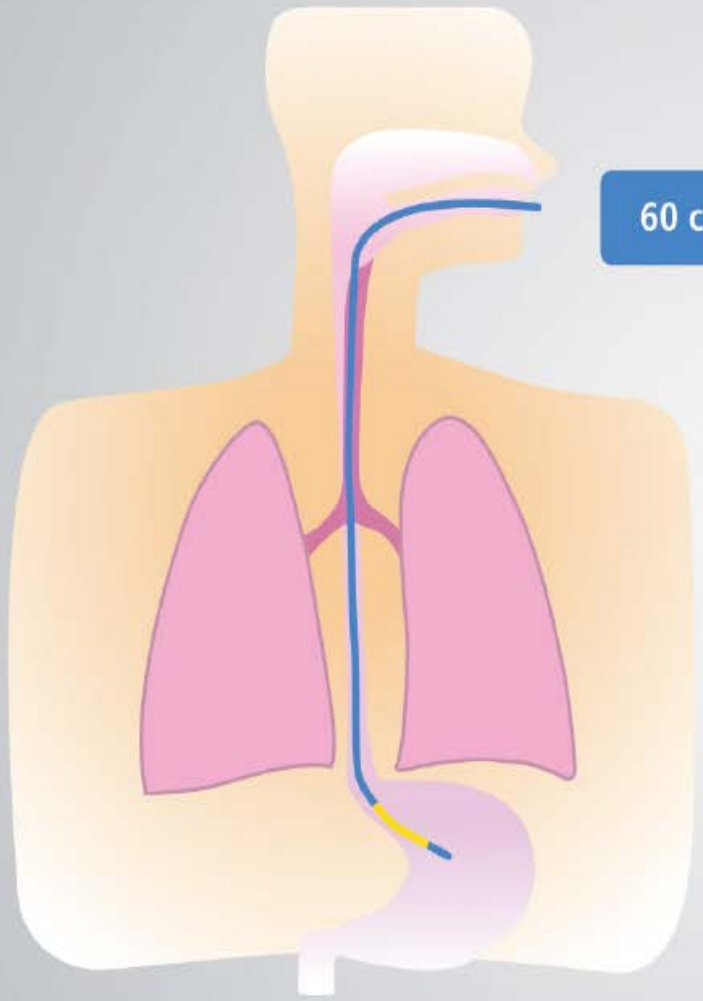


Ptpt (transpulmonary) =

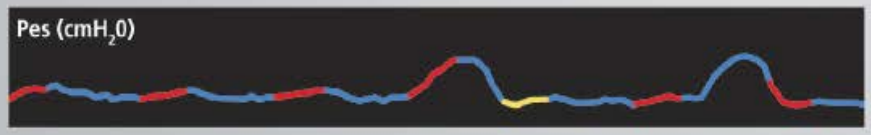
Distendability

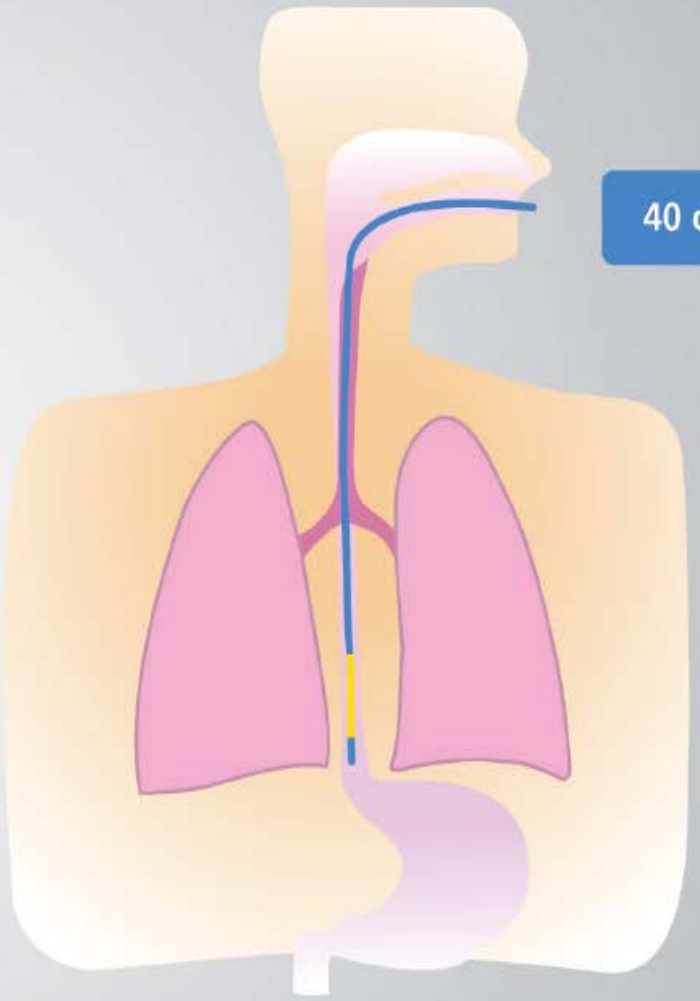


2 cm H2O

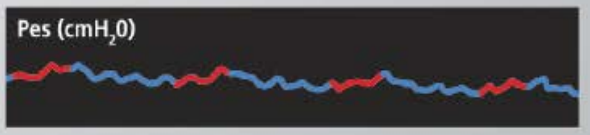


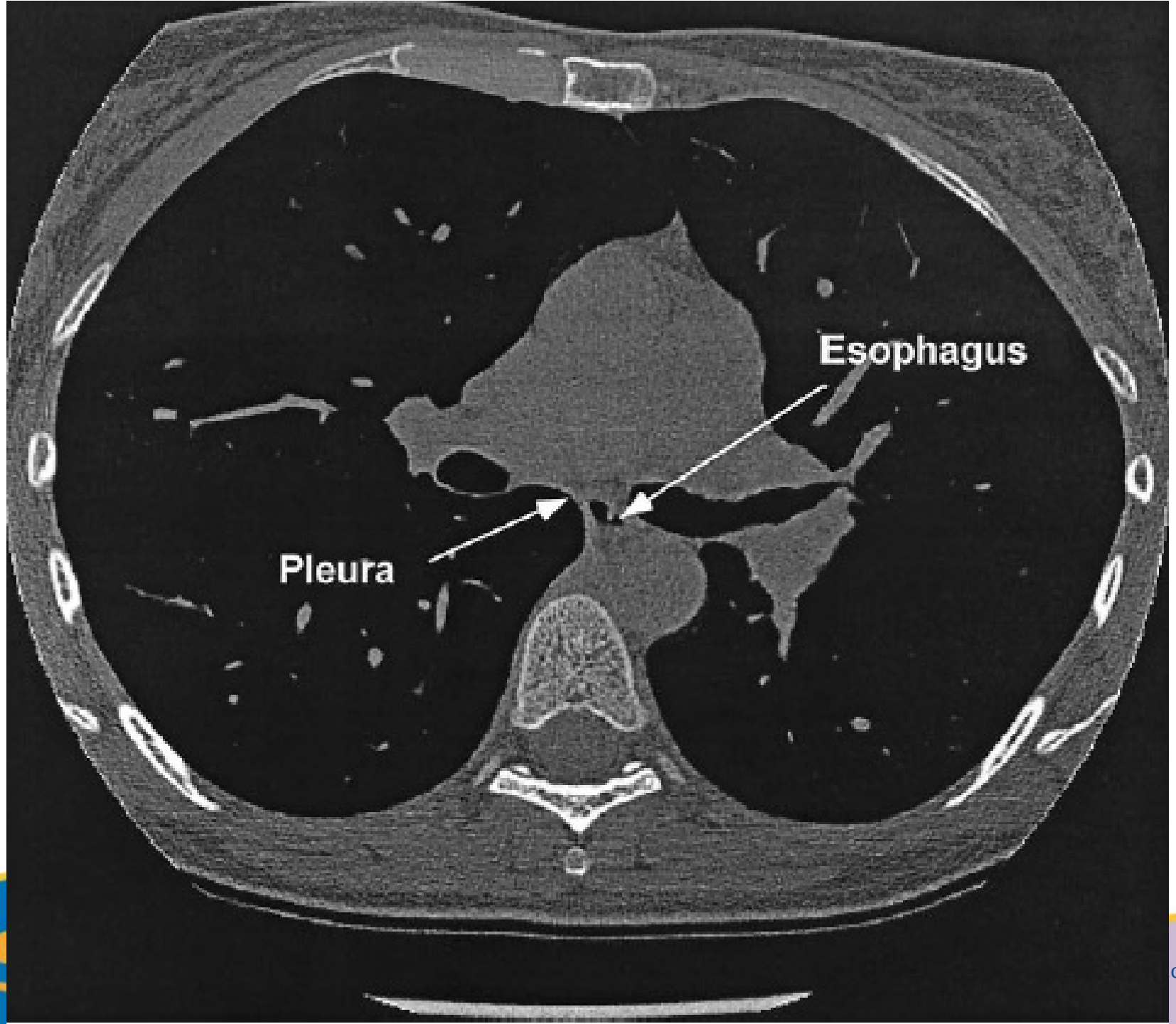
Gentle compression of the abdomen to confirm placement





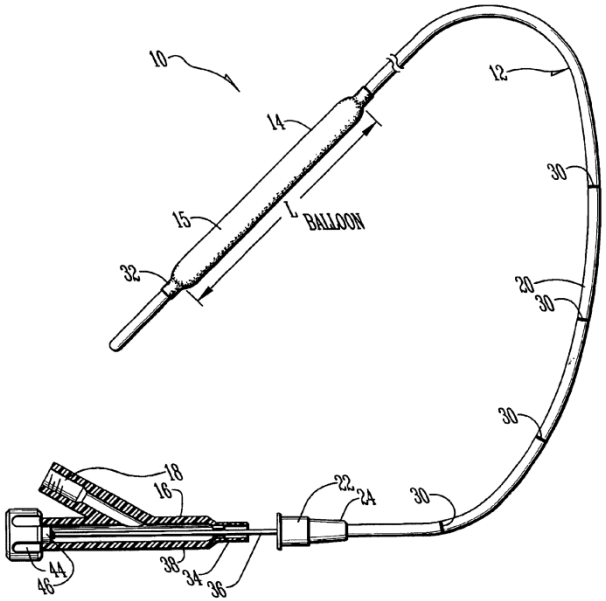
Look for cardiac oscillations

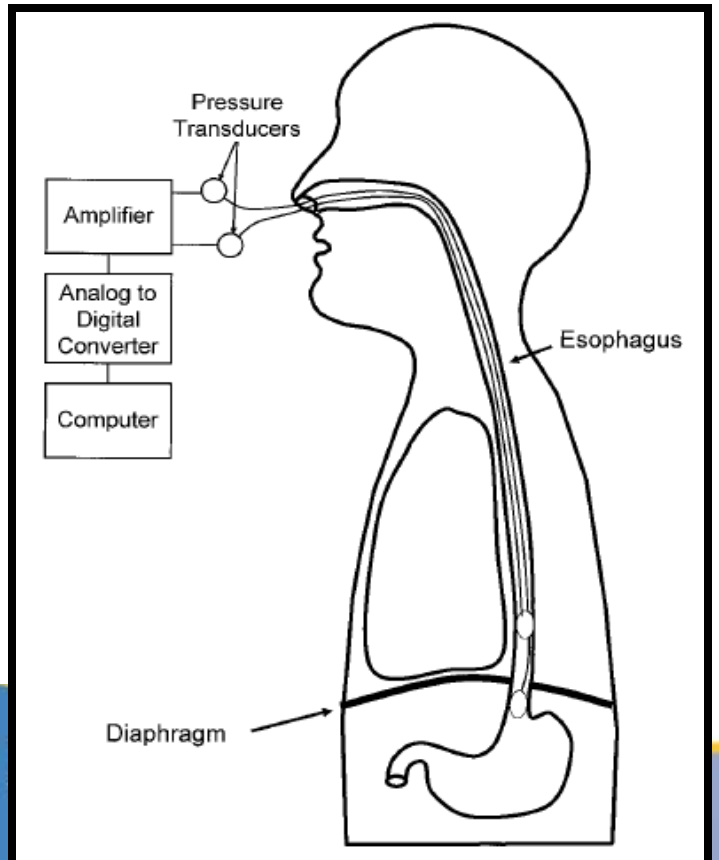


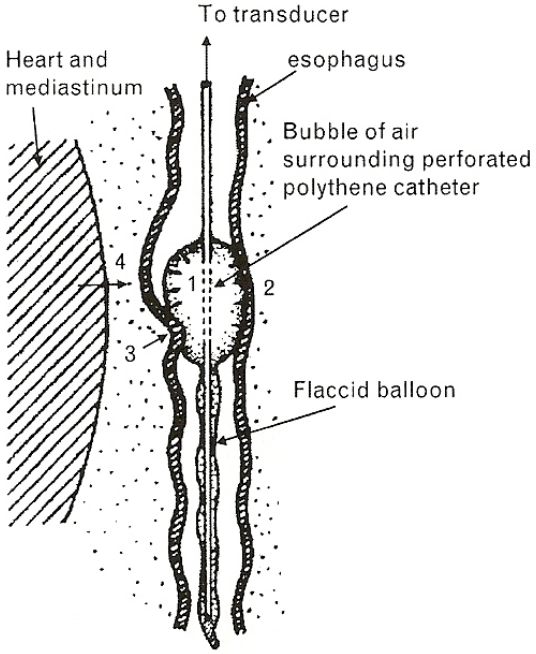


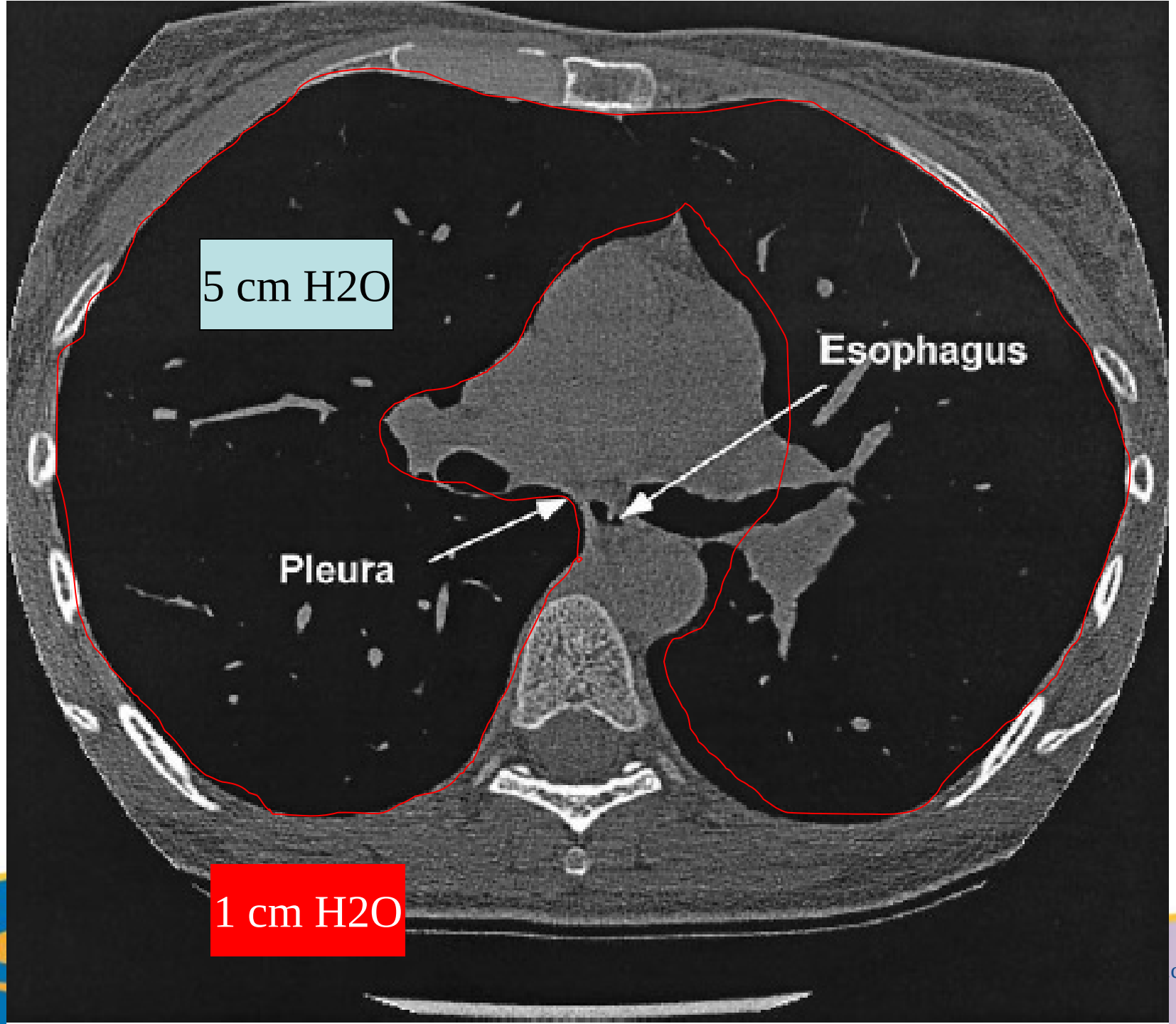
Esophageal Pressure Guided PEEP

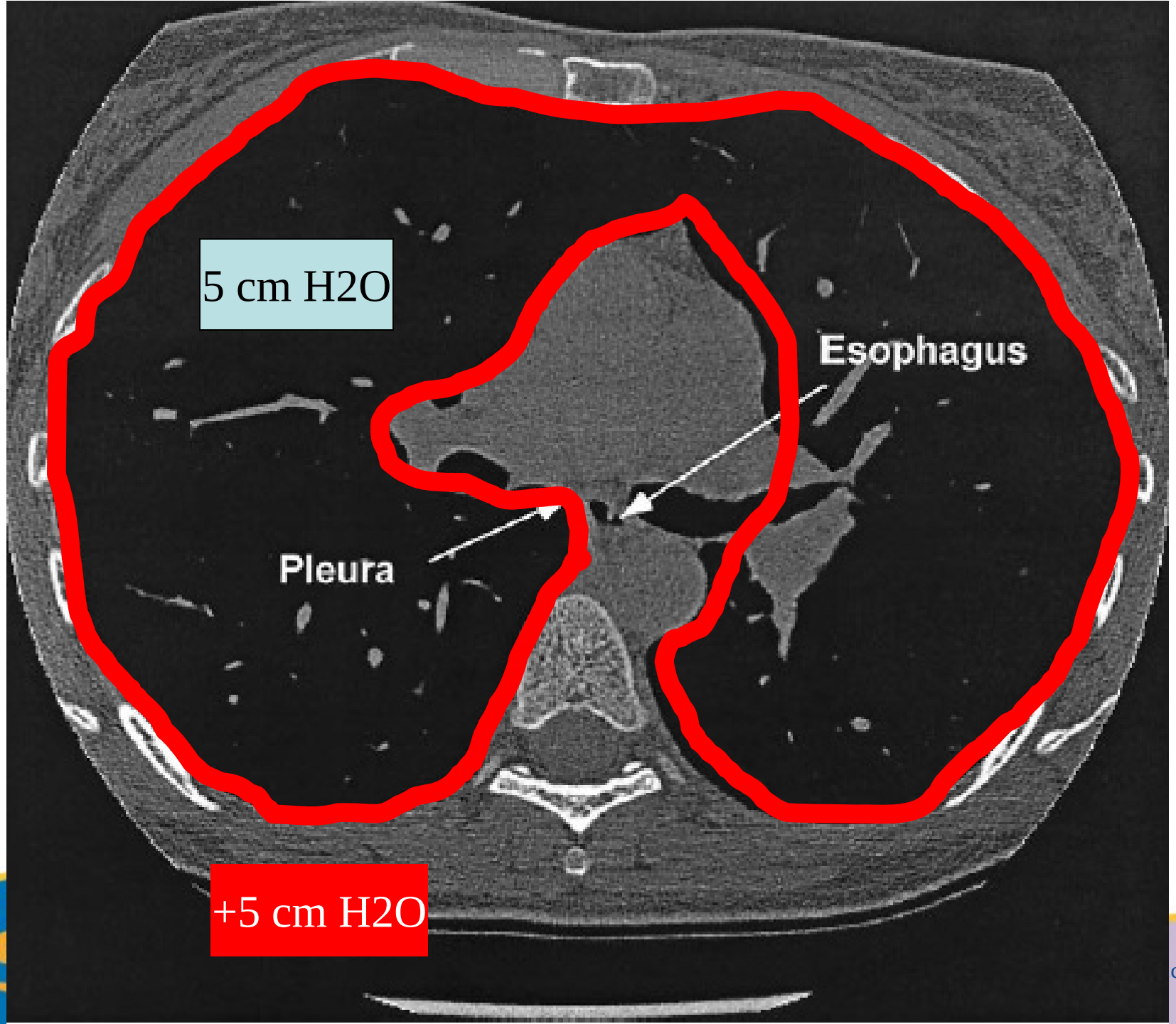
Esophageal Balloon

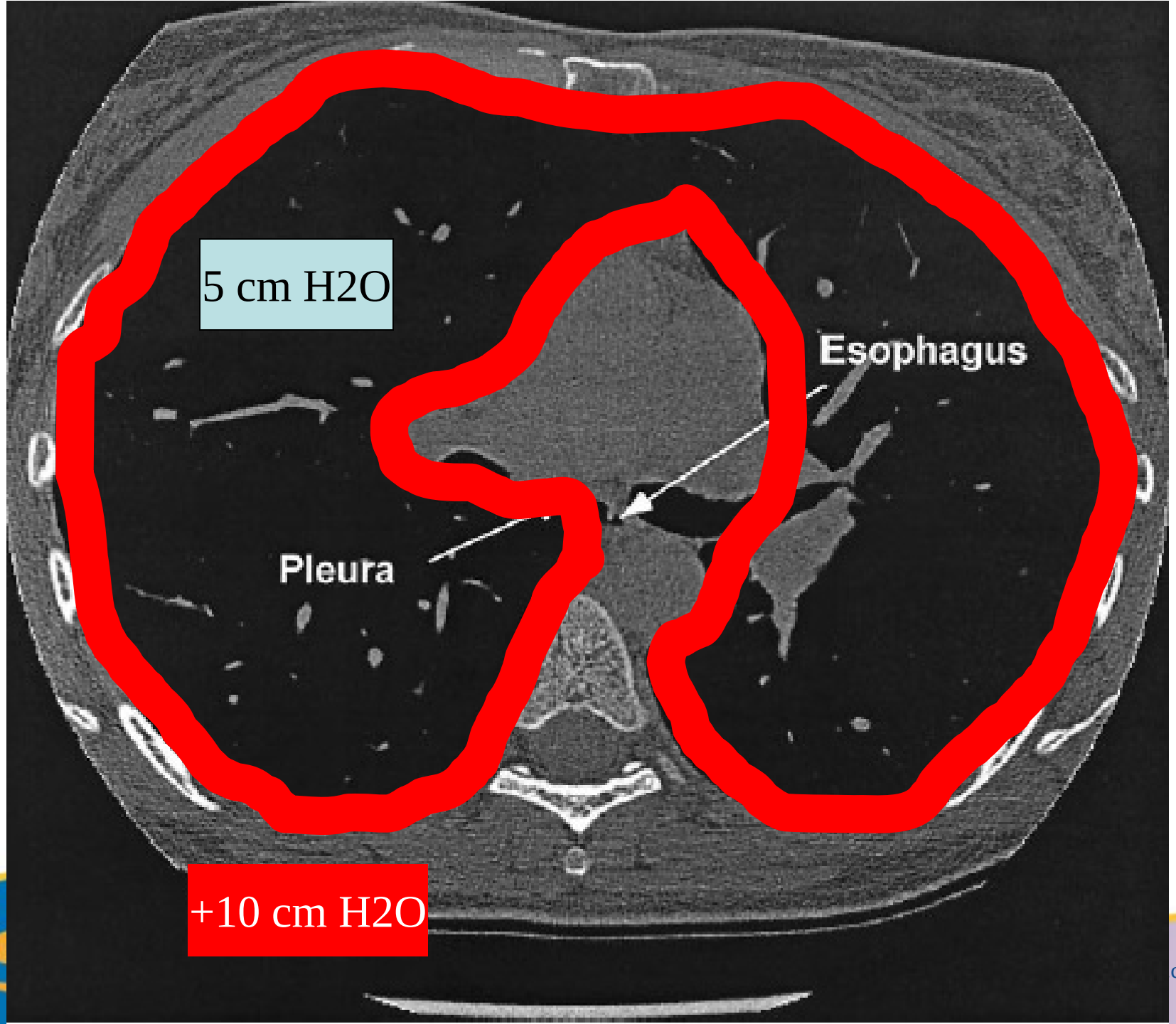


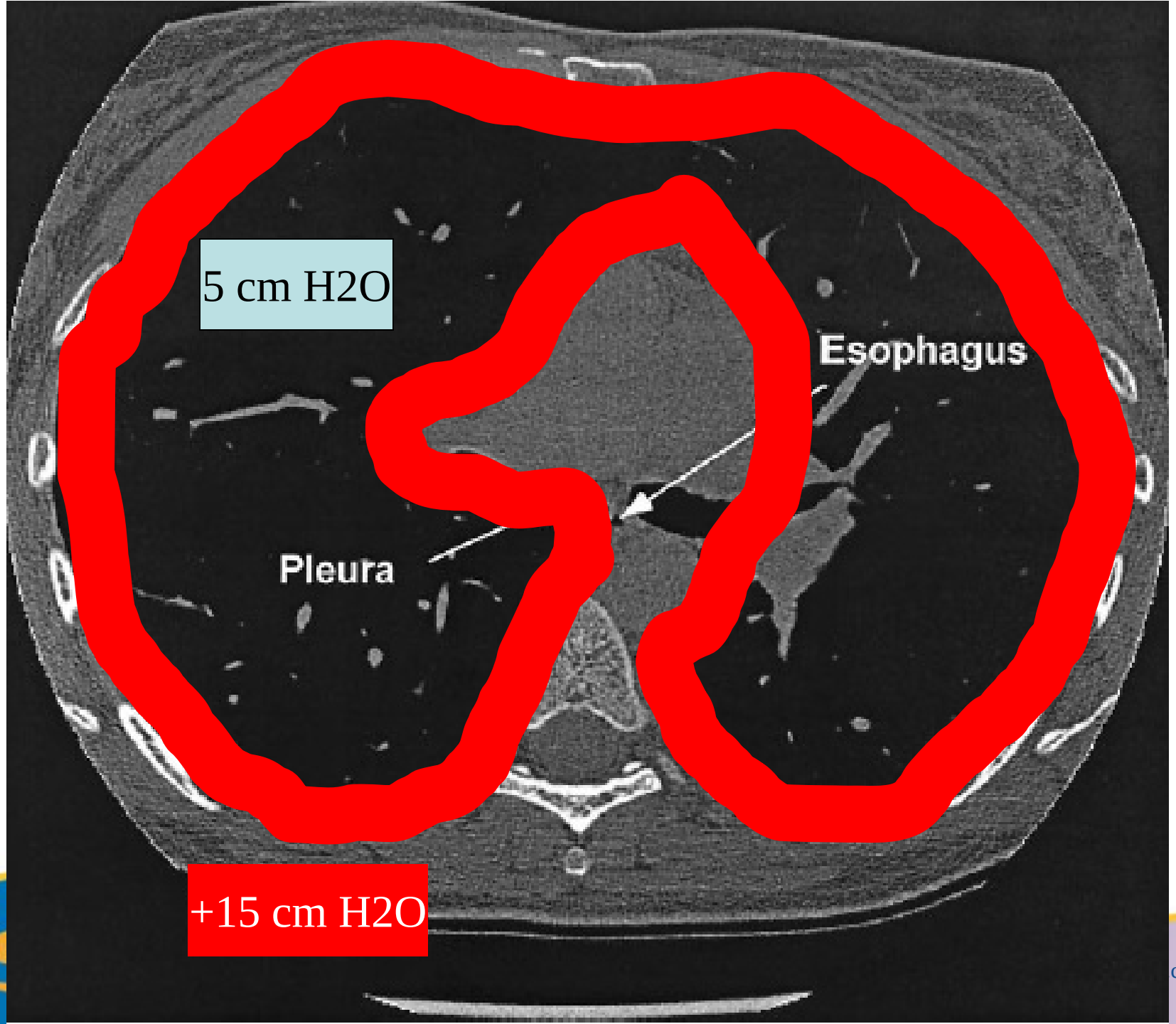


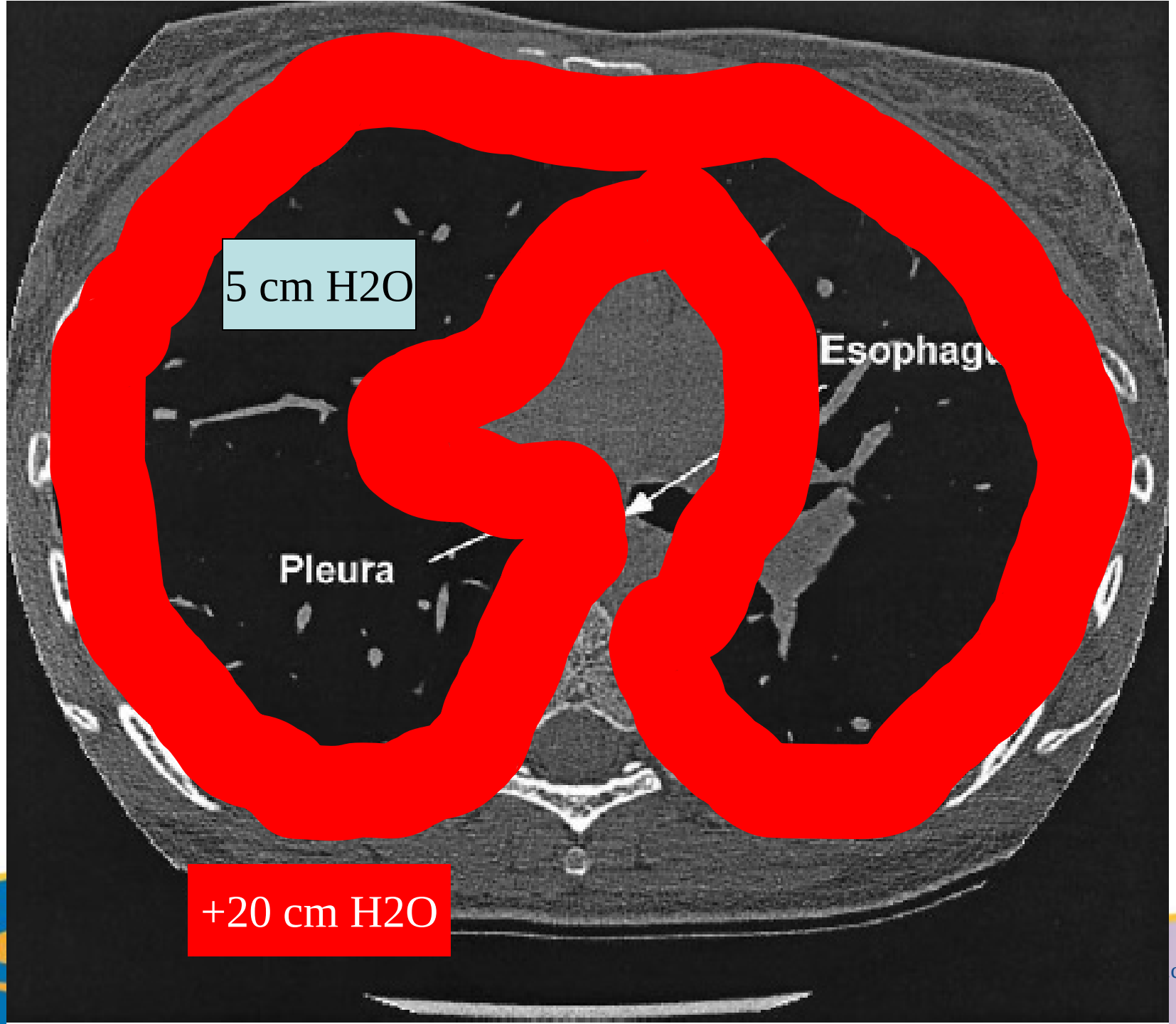





5 cm H2O
Esophagus
Pleura
+5 cm H2O


5 cm H2O
Esophagus
Pleura
+10 cm H2O

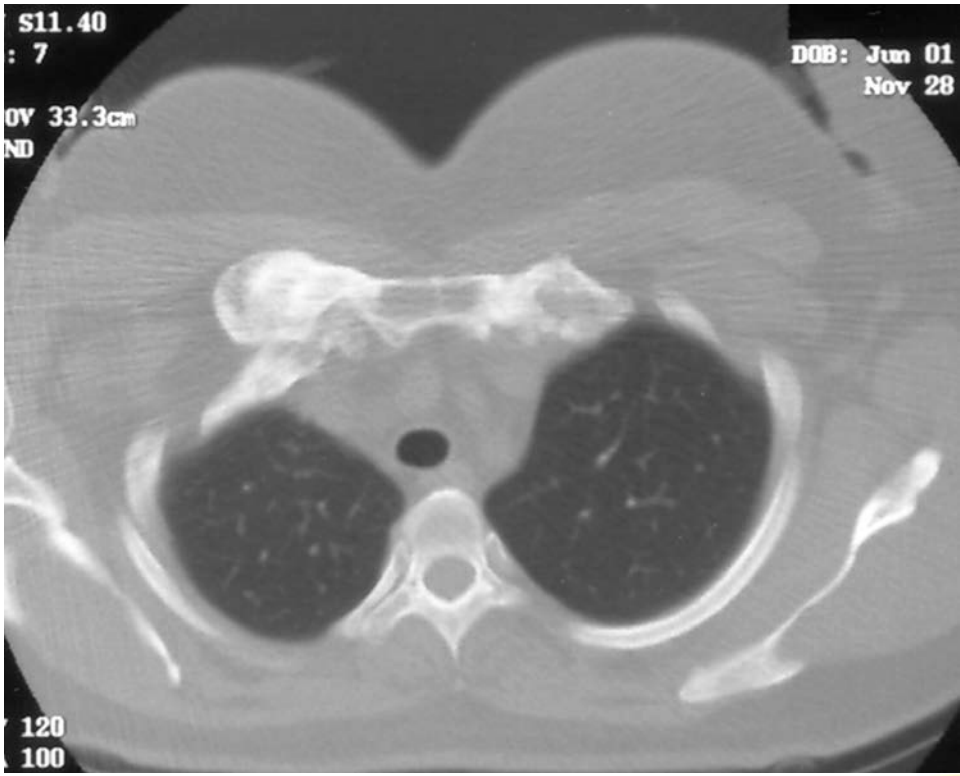

5 cm H2O
Esophagus
Pleura
+15 cm H2O



com

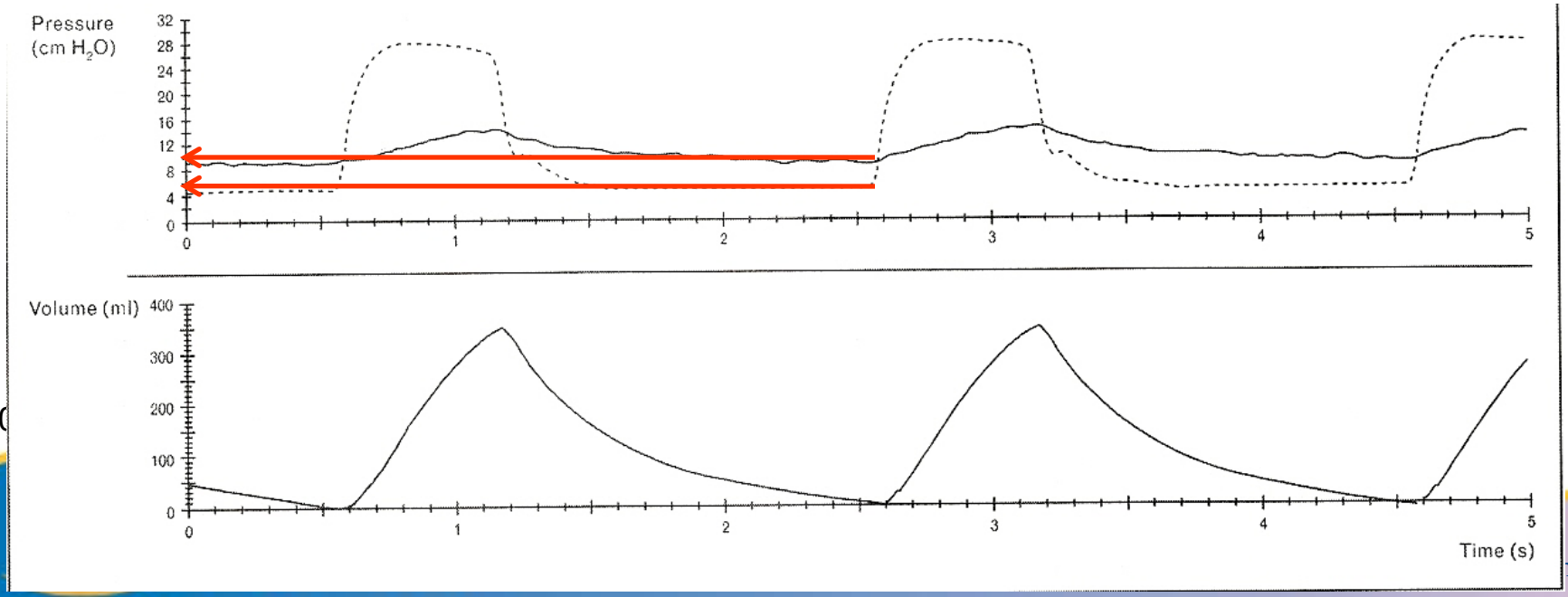
com

Normal Chest Wall Vs. Increased Chest Wall



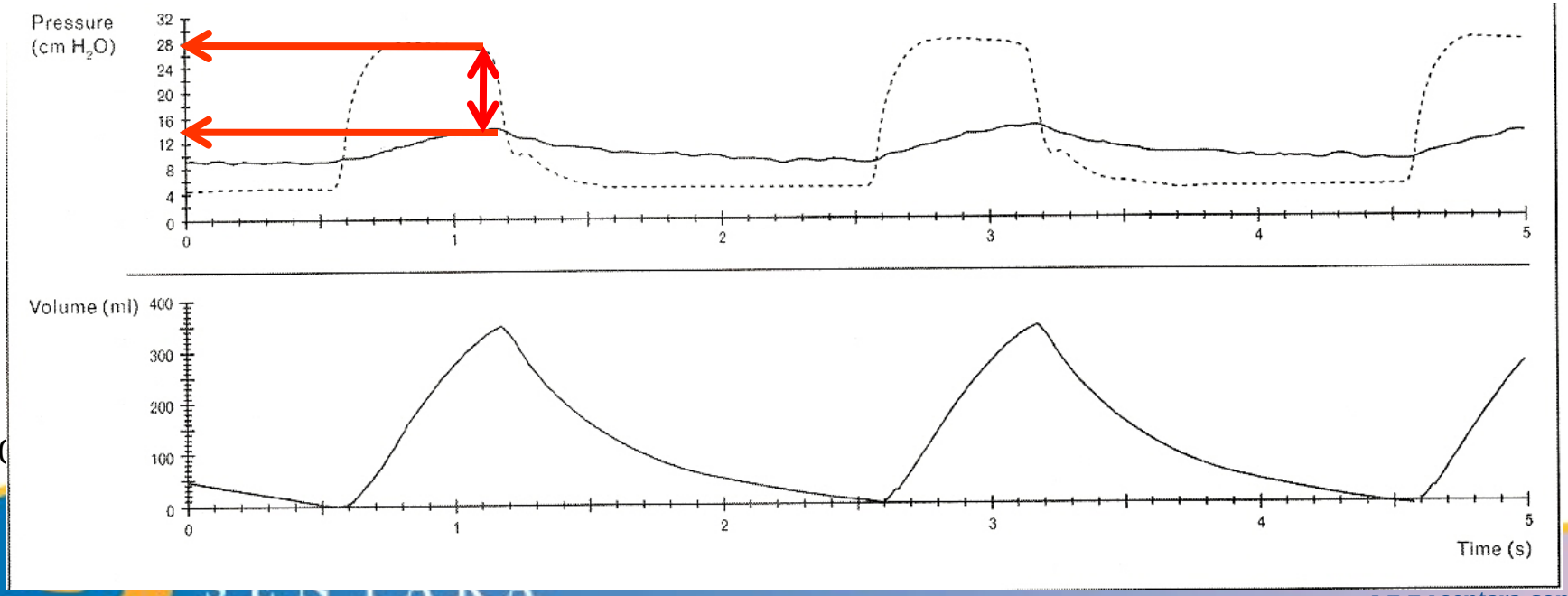
Measurement of End Expiratory Transpulmonary pressure “EETP”

- Transpulmonary Pressure =Alveolar pressure – pleural pressure
- Palv-Pplp=Ptp
- 4 – 9 = -5 cm H2O
- Where should PEEP be set to have a EETP of 0- +1?
- 9-10 cm H2O



Measurement of Transpulmonary pressure End Inspiratory

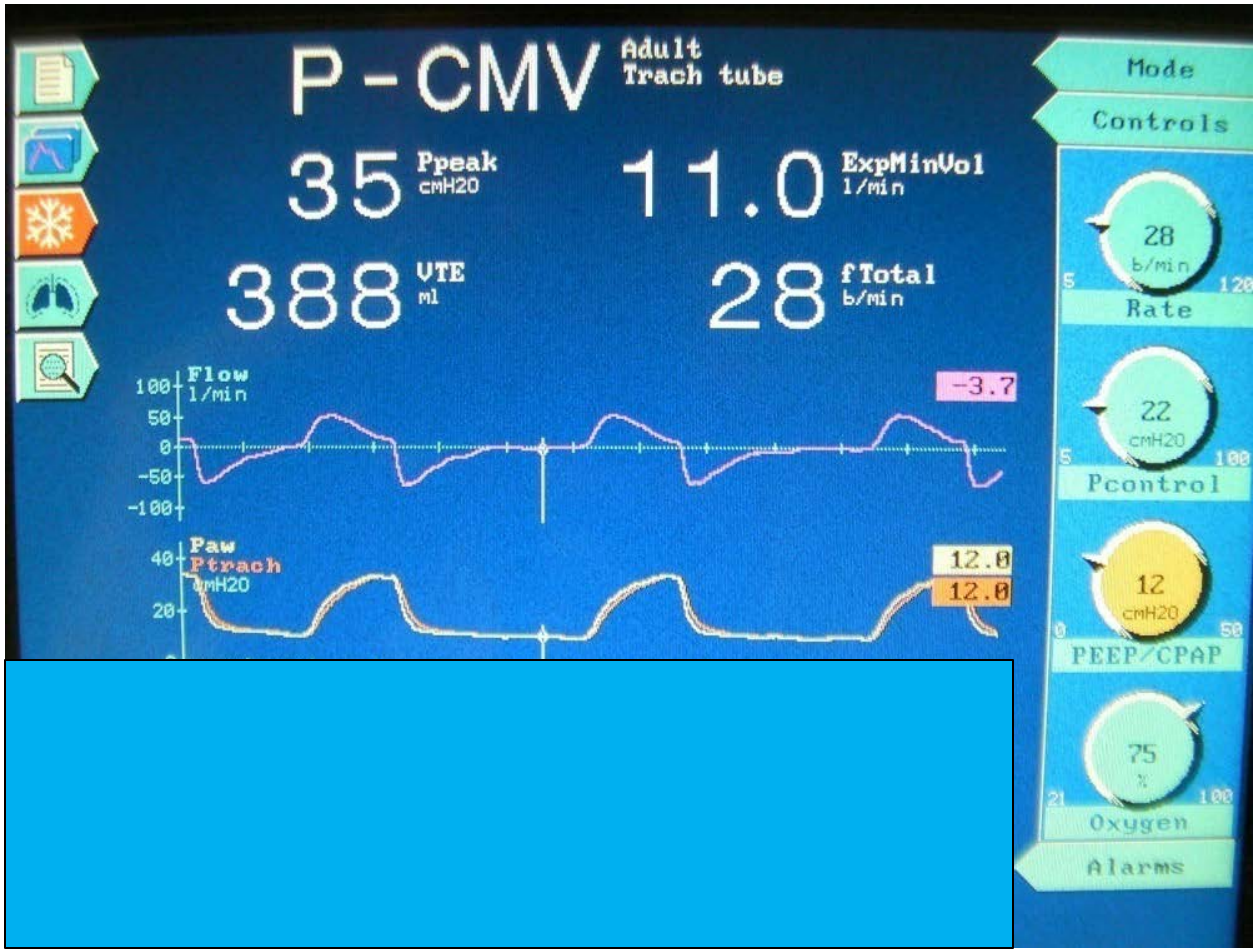
- Transpulmonary Pressure =Alveolar pressure – pleural pressure
- Palv-Pplp=Ptp
- 28 – 14 = +14



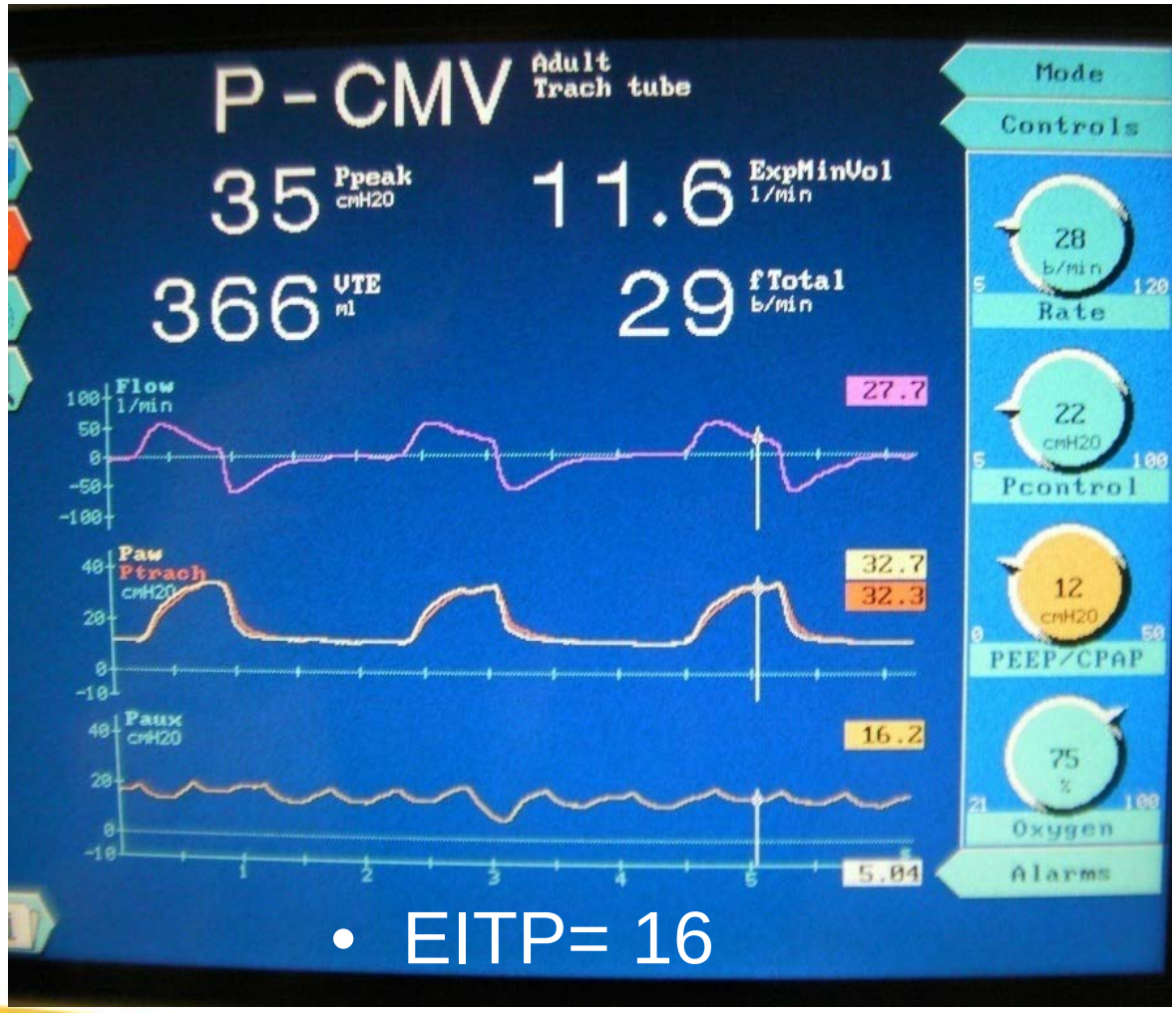
Case Report

- 62 year old man with ETOH abuse presented to OBX hospital for c/o nausea/vomitting X3 days.
- Admitted for having melena, but no rectal hematochezia or hematemesis.
- Hgb of 4.8 and transfused with 3 units PRBC and transferred to SNGH.
- 1994 & 2006 CABG and cardiac valve replaced X2.
- Hypoinflation, bilateral diffuse infiltrates, underlying pulmonary congestion, pneumonia.
- Trached and future problems with oxygenation prompted use of esophageal balloon.

Case Report

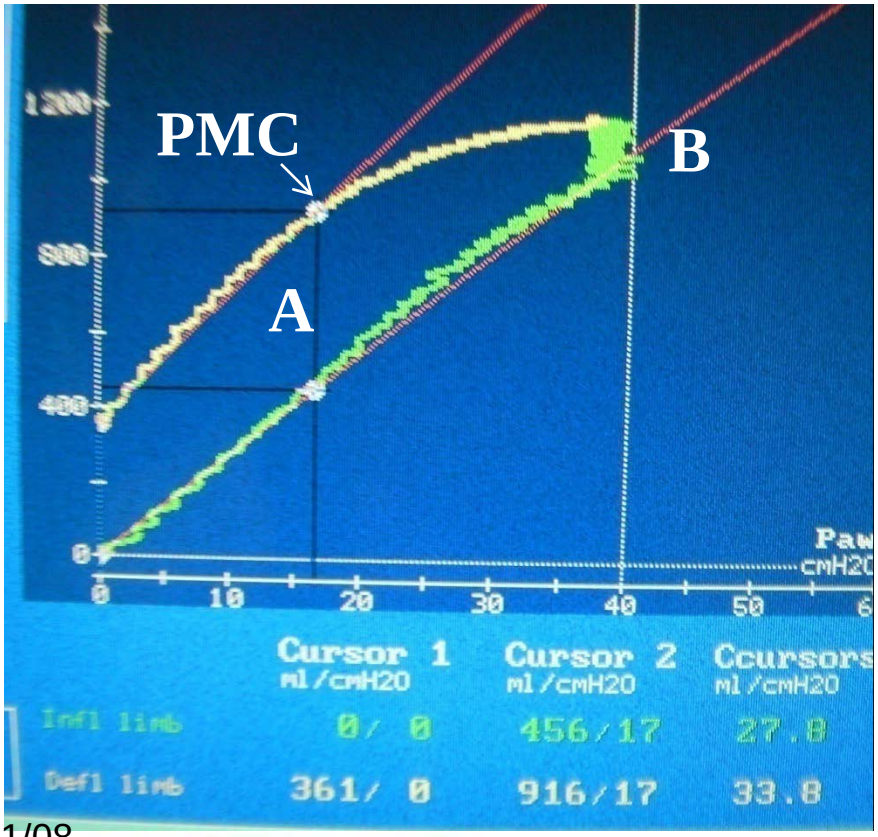


Case Report



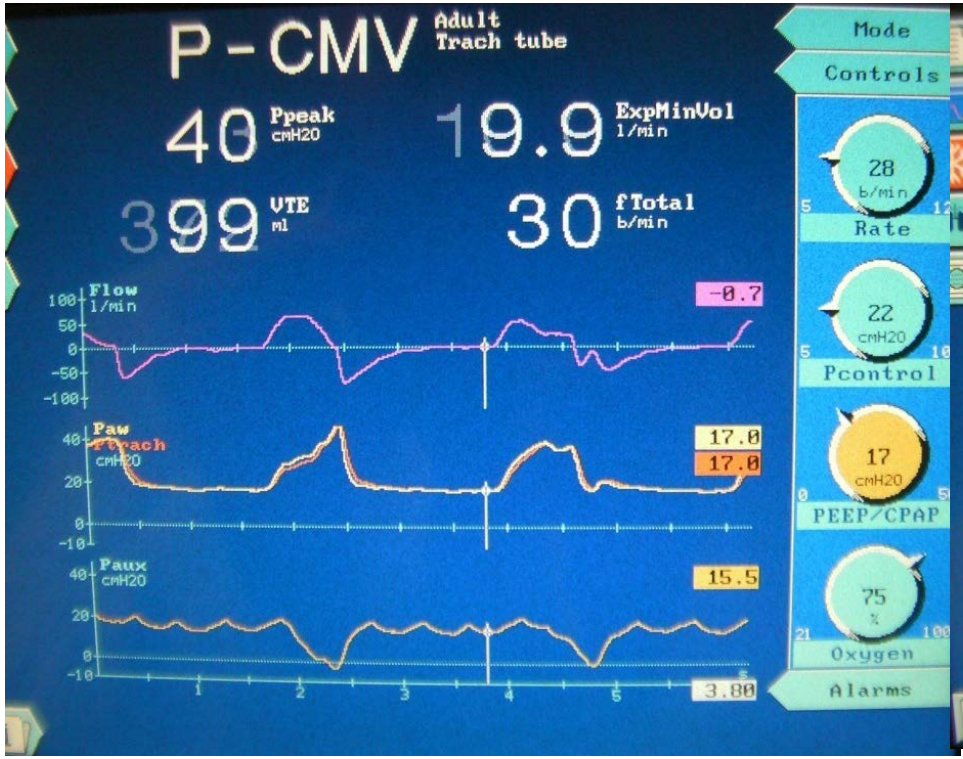
- EITP= 16

Case Report

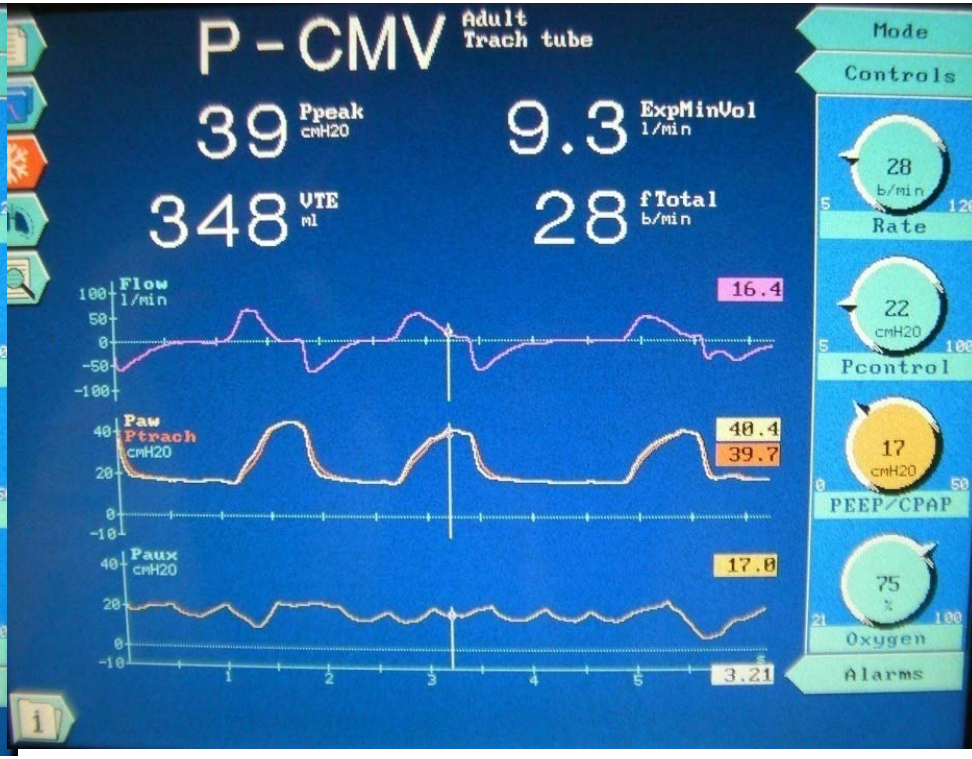


- PV curve performed to assess lung recruitability.
- PV Curve Hysteresis (A) & Volume of Recruitment (B) both indicate recruitability.
- PMC &PVH largest at 17cmH2O.

PEEP 17 cm H2O

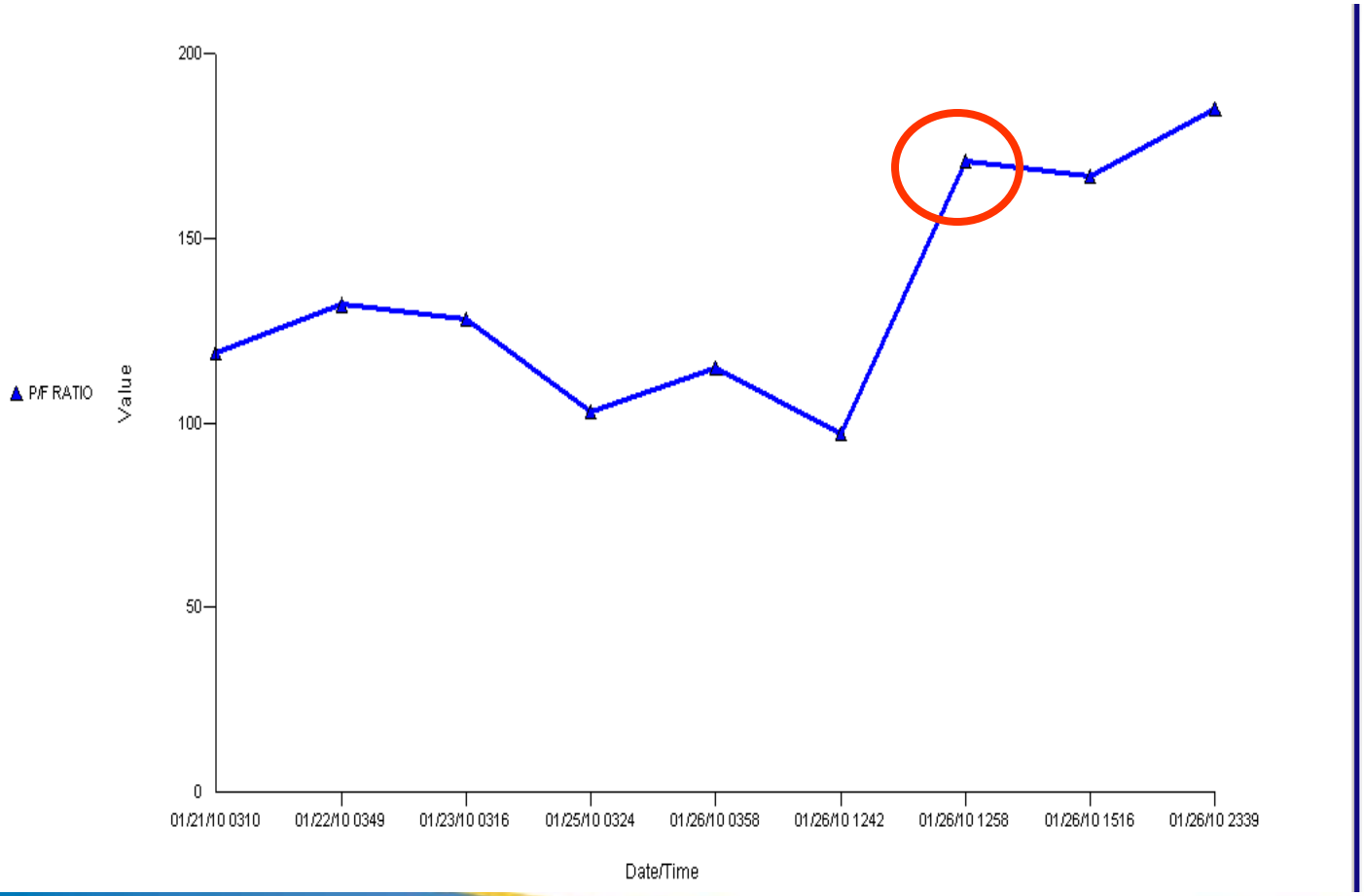


EETP= +1.5



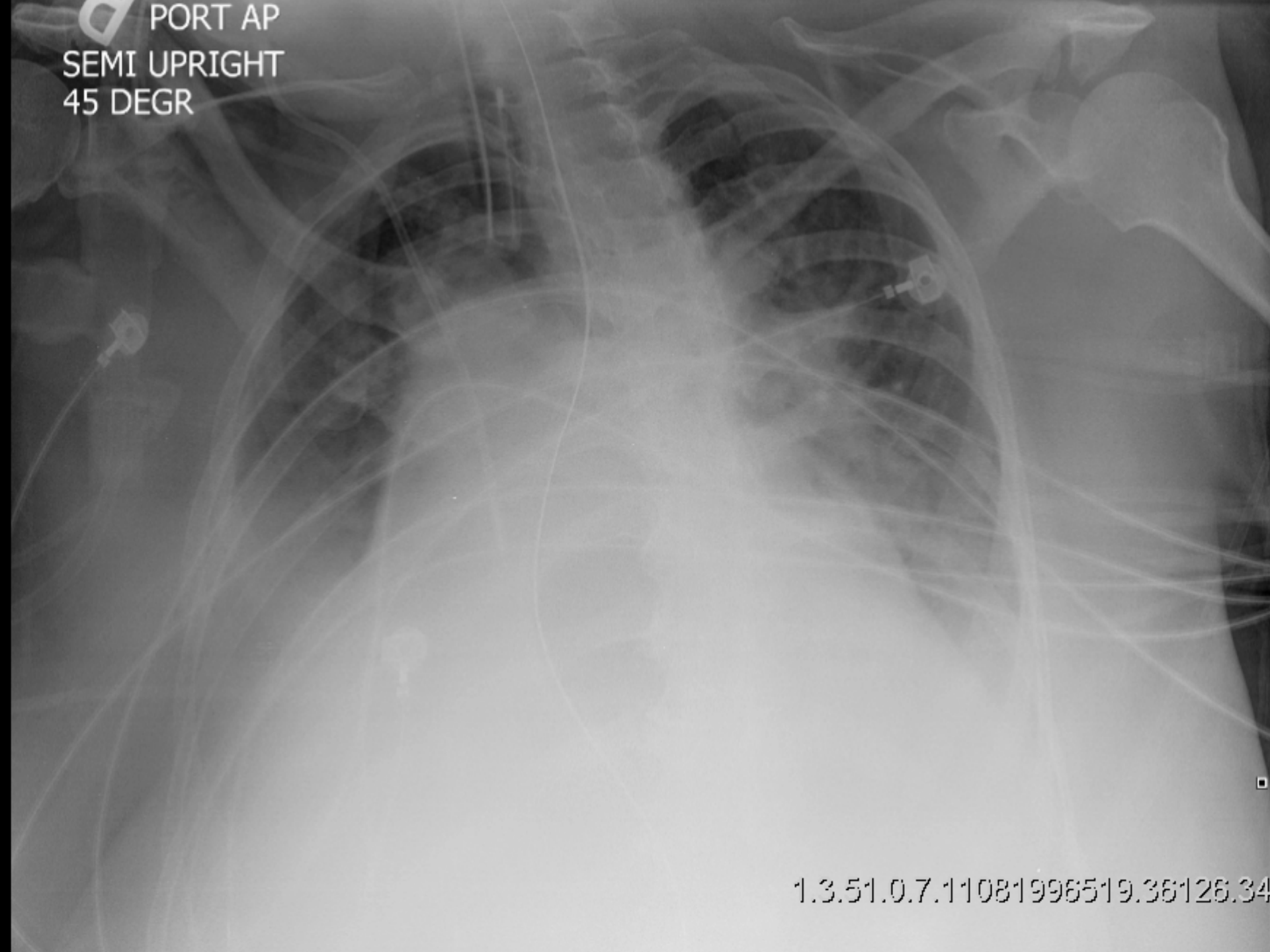
EITP=23

P/F ratio increased due to PEEP increase



Case Study #2

- 48 year old female
- 5'8," 298 lbs= BMI of 45.43Kg/m- (30 is classified as obese)
- post-op (small bowell resection and repair) Para esophageal hernia
- Moderate Pulmonary Hypertension (69 mmHg, normal is 25)
- Sepsis
- Acute renal failure
- Peritonitis
- CAD
- Anemia
- Hx of DVT
- Abdominal pain
- Hypokalemia
- Calcified mediastinal mass
- Diabetes mellitis- Type 2 uncontrolled
- Renal Artery Stenosis
- Leukocytosis
- ARDS


PORT AP
SEMI UPRIGHT
45 DEGR
1.3.51.0.7.11081996519.36126.34

2013-05-07
12:10:43

INTELLiVENT

P-CMV
Adult

Patient | Additions | Modes

Trend

IntelliCuff

40
5
33 Ppeak cmH2O

10
4
7.8 ExpMinVol l/min

750
250
481 VTE ml

23
8
17 fTotal b/min

--- P0.1 cmH2O

41 PetCO2 mmHg

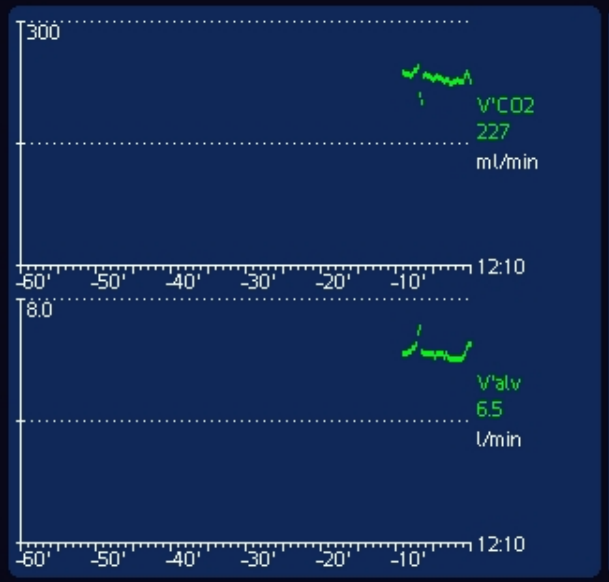
5.8 FetCO2 %

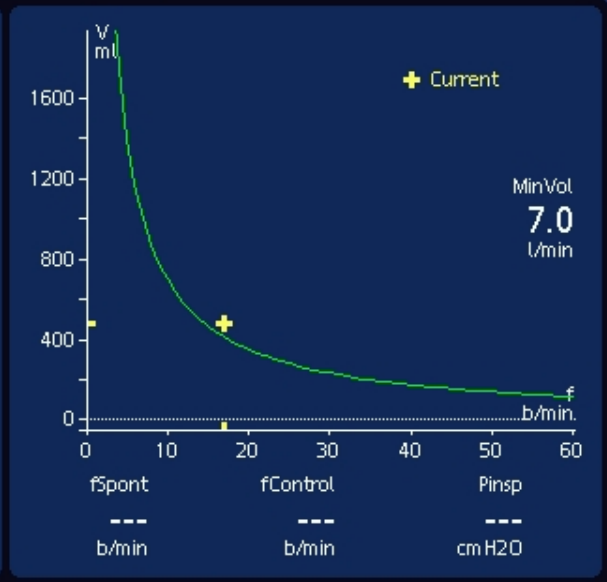
15 VeCO2 ml

1 ViCO2 ml

10 / 10

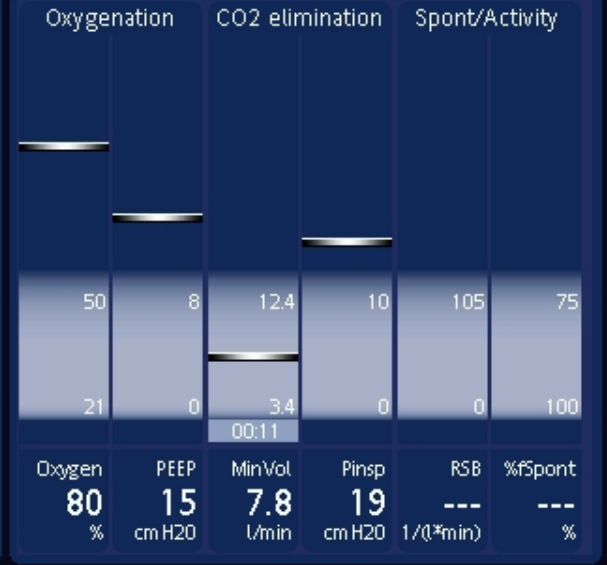
228 V'CO2 ml/min





Adult Male
68 inch
IBW = 69 kg

Rinsp	Cstat	PetCO2
19 cmH2O/l/s	36.4 ml/cmH2O	41 mmHg



16 b/min Rate

19 cmH2O Pcontrol

15 cmH2O PEEP/CPAP

80 % Oxygen

Controls

Alarms

Monitoring | Graphics | Tools | Events | System

USB

INT

AC


2013-05-07
12:30:35
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
40
5
34
Ppeak
cmH2O
10
4
6.9
ExpMinVol
l/min
750
250
464
VTE
ml
23
8
14
fTotal
b/min
P0.1
cmH2O
44
PetCO2
mmHg
6.3
FetCO2
%
17
VeCO2
ml
1
ViCO2
ml
225
V'CO2
ml/min
10 / 10
Paw
cmH2O
14.9
9.42
Paux
cmH2O
26.5
V
ml
1.3
PCO2
mmHg
40.7
Trend
IntelliCuff
16
b/min
Rate
19
cmH2O
Pcontrol
15
cmH2O
PEEP/CPAP
80
%
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC


2013-05-07
12:45:28
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
Trend
IntelliCuff
60
5
40 Ppeak cmH2O
16
4
6.8 ExpMinVol l/min
750
250
426 VTE ml
23
8
16 fTotal b/min
--- P0.1 cmH2O
46 PetCO2 mmHg
6.5 FetCO2 %
15 VeCO2 ml
1 ViCO2 ml
224 V'CO2 ml/min
10 / 10
Paw cmH2O
Paux cmH2O
s
Adult Male
68 inch
IBW = 69 kg
Rinsp 25 cmH2O/l/s
Cstat 37.2 ml/cmH2O
PetCO2 46 mmHg
V'CO2 226 ml/min
V'alv 5.4 l/min
12:45
16 b/min Rate
19 cmH2O Pcontrol
22 cmH2O PEEP/CPAP
80 % Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC


2013-05-07
12:50:02
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
Trend
IntelliCuff
60
5
48
Ppeak
cmH2O
16
4
10.2
ExpMinVol
l/min
750
250
638
VTE
ml
23
8
16
fTotal
b/min
P0.1
cmH2O
40
PetCO2
mmHg
5.6
FetCO2
%
20
VeCO2
ml
1
ViCO2
ml
296
V'CO2
ml/min
10 / 10
Paw
cmH2O
Paux
cmH2O
Adult Male
68 inch
IBW = 69 kg
Rinsp
33
cmH2O/l/s
Cstat
40.7
ml/cmH2O
PetCO2
40
mmHg
V'CO2
299
ml/min
Cstat
40.7
ml/cmH2O
12:49
16
b/min
Rate
30
cmH2O
Pcontrol
20
cmH2O
PEEP/CPAP
70
%
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC


2013-05-07
12:58:30
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
Trend
IntelliCuff
60
5
42
Ppeak
cmH2O
16
4
9.7
ExpMinVol
l/min
750
250
591
VTE
ml
23
8
16
fTotal
b/min
P0.1
cmH2O
37
PetCO2
mmHg
5.2
FetCO2
%
18
VeCO2
ml
1
ViCO2
ml
262
V'CO2
ml/min
10 / 10
Paw
cmH2O
Paux
cmH2O
Adult Male
68 inch
IBW = 69 kg
Rinsp
25
cmH2O/l/s
Cstat
43.6
ml/cmH2O
PetCO2
37
mmHg
V'CO2
270
ml/min
Cstat
44.3
ml/cmH2O
16
b/min
Rate
24
cmH2O
Pcontrol
20
cmH2O
PEEP/CPAP
70
%
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC


2013-05-07
13:00:55
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
Trend
IntelliCuff
60
5
42
Ppeak
cmH2O
16
4
9.4
ExpMinVol
l/min
750
250
587
VTE
ml
23
8
16
fTotal
b/min
P0.1
cmH2O
37
PetCO2
mmHg
5.2
FetCO2
%
17
VeCO2
ml
1
ViCO2
ml
258
V'CO2
ml/min
10 / 10
Paw
cmH2O
Paux
cmH2O
Adult Male
68 inch
IBW = 69 kg
Rinsp
25
cmH2O/l/s
Cstat
42.8
ml/cmH2O
PetCO2
37
mmHg
V'CO2
258
ml/min
Cstat
43.4
ml/cmH2O
16
b/min
Rate
24
cmH2O
Pcontrol
20
cmH2O
PEEP/CPAP
60
%
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC


2013-05-07
13:02:07
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
Trend
IntelliCuff
60
5
42
Ppeak
cmH2O
16
4
9.4
ExpMinVol
l/min
750
250
578
VTE
ml
23
8
16
fTotal
b/min
P0.1
cmH2O
38
PetCO2
mmHg
5.3
FetCO2
%
17
VeCO2
ml
1
ViCO2
ml
261
V'CO2
ml/min
10 / 10
Paw
cmH2O
Paux
cmH2O
Adult Male
68 inch
IBW = 69 kg
Rinsp
25
cmH2O/l/s
Cstat
40.6
ml/cmH2O
PetCO2
38
mmHg
V'CO2
260
ml/min
Cstat
42.5
ml/cmH2O
16
b/min
Rate
24
cmH2O
Pcontrol
20
cmH2O
PEEP/CPAP
60
%
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC


2013-05-07
13:05:30
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
Trend
IntelliCuff
60
5
49
Ppeak
cmH2O
16
4
10.9
ExpMinVol
l/min
750
250
693
VTE
ml
23
8
16
fTotal
b/min
P0.1
cmH2O
36
PetCO2
mmHg
5.1
FetCO2
%
19
VeCO2
ml
1
ViCO2
ml
286
V'CO2
ml/min
10 / 10
Paw
cmH2O
Paux
cmH2O
Adult Male
68 inch
IBW = 69 kg
Rinsp
28
cmH2O/l/s
Cstat
43.5
ml/cmH2O
PetCO2
36
mmHg
V'CO2
280
ml/min
Cstat
42.6
ml/cmH2O
16
b/min
Rate
30
cmH2O
Pcontrol
20
cmH2O
PEEP/CPAP
60
%
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC

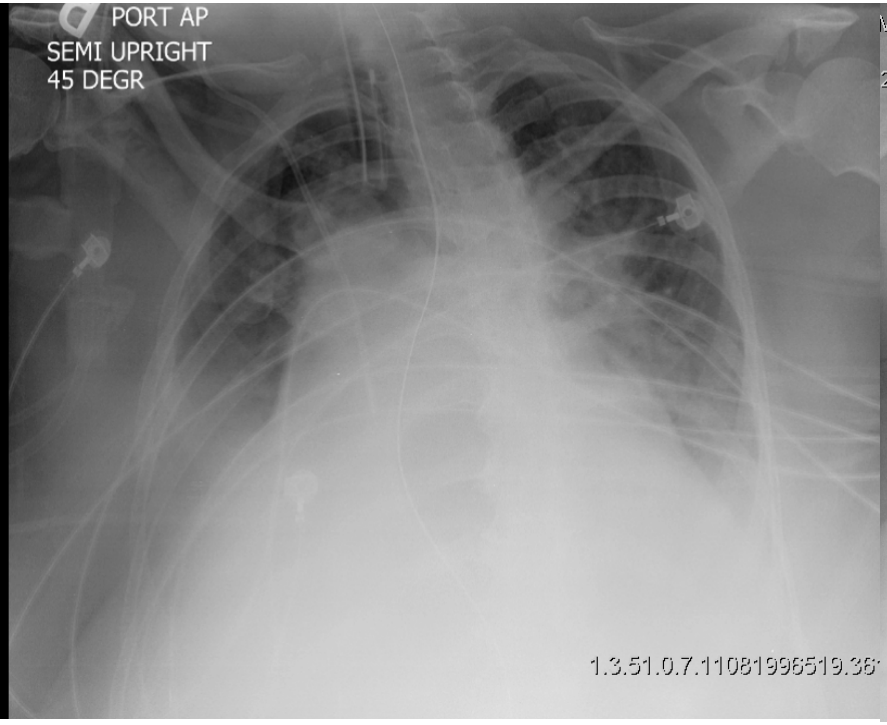

2013-05-07
13:06:01
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
Trend
IntelliCuff
60
5
49
Ppeak
cmH2O
16
4
11.0
ExpMinVol
l/min
750
250
682
VTE
ml
23
8
16
fTotal
b/min
P0.1
cmH2O
36
PetCO2
mmHg
5.1
FetCO2
%
19
VeCO2
ml
1
ViCO2
ml
285
V'CO2
ml/min
10 / 10
Paw
cmH2O
80
40
0
-10
1
2
3
4
5
6
7
8
9
10
s
Flow
l/min
100
50
0
-50
-100
Adult Male
68 inch
IBW = 69 kg
Rinsp
29
cmH2O/l/s
Cstat
43.2
ml/cmH2O
PetCO2
36
mmHg
400
V'CO2
288
ml/min
13:05
-60'
-50'
-40'
-30'
-20'
-10'
60.0
Cstat
44.3
ml/cmH2O
16
b/min
Rate
30
cmH2O
Pcontrol
20
cmH2O
PEEP/CPAP
60
%
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC

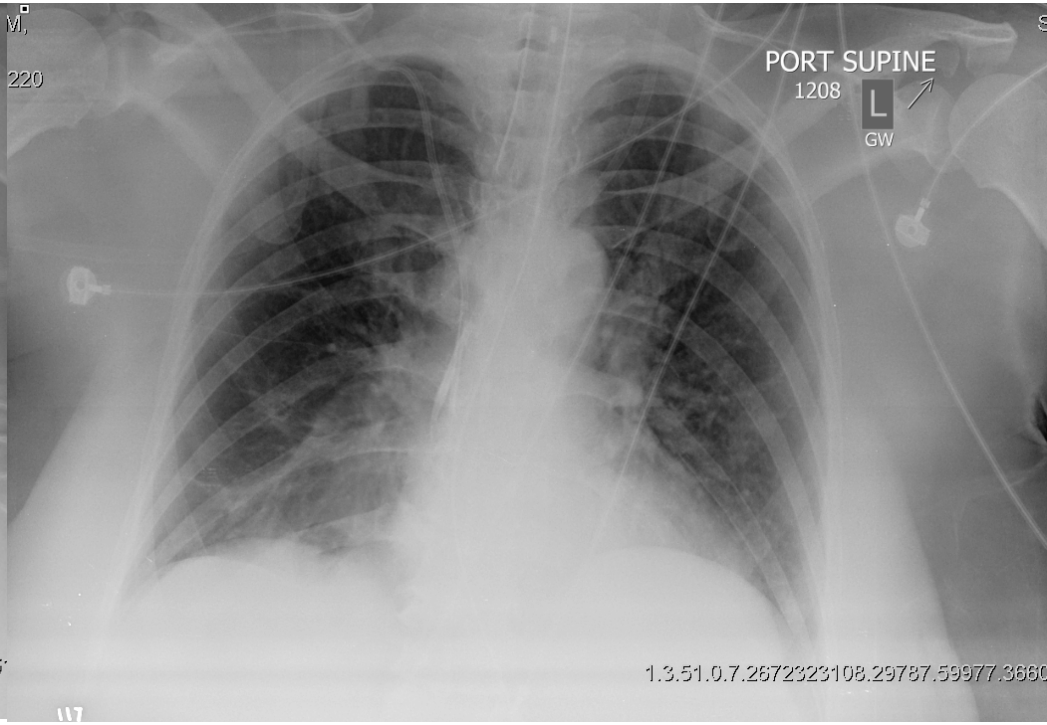

2013-05-08
07:26:30
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
Trend
IntelliCuff
50
20
36
Ppeak
cmH2O
15
4
7.1
ExpMinVol
l/min
750
250
588
VTE
ml
35
8
12
fTotal
b/min
P0.1
cmH2O
33
PetCO2
mmHg
4.7
FetCO2
%
15
VeCO2
ml
1
ViCO2
ml
180
V'CO2
ml/min
10 / 10
Paw
cmH2O
Flow
l/min
s
Adult Male
68 inch
IBW = 69 kg
Rinsp
18
cmH2O/l/s
Cstat
41.1
ml/cmH2O
PetCO2
33
mmHg
V'CO2
180
ml/min
07:26
Cstat
42.9
ml/cmH2O
12
b/min
Rate
20
cmH2O
Pcontrol
18
cmH2O
PEEP/CPAP
45
%
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC


2013-05-08
07:27:17
INTELLiVENT
P-CMV
Adult
Patient
Additions
Modes
Trend
IntelliCuff
50
20
36
Ppeak
cmH2O
15
4
7.1
ExpMinVol
l/min
750
250
583
VTE
ml
35
8
12
fTotal
b/min

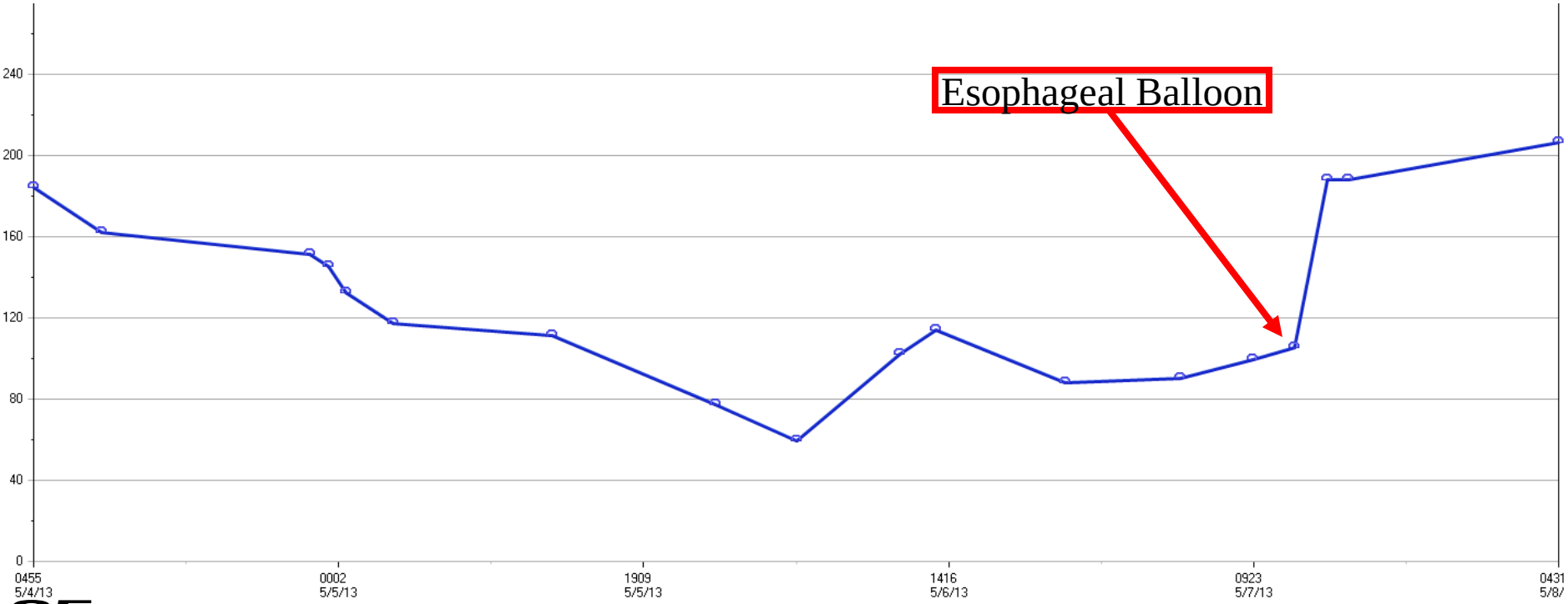
P0.1
cmH2O
34
PetCO2
mmHg
4.7
FetCO2
%
16
VeCO2
ml
0
ViCO2
ml
181
V'CO2
ml/min
10 / 10
Paw
cmH2O
Flow
l/min
s
Adult Male
68 inch
IBW = 69 kg
Rinsp
19
cmH2O/l/s
Cstat
40.9
ml/cmH2O
PetCO2
34
mmHg
V'CO2
181
ml/min
07:27
V'alv
6.0
l/min
12
b/min
Rate
20
cmH2O
Pcontrol
18
cmH2O
PEEP/CPAP
45
%
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
USB
INT
AC

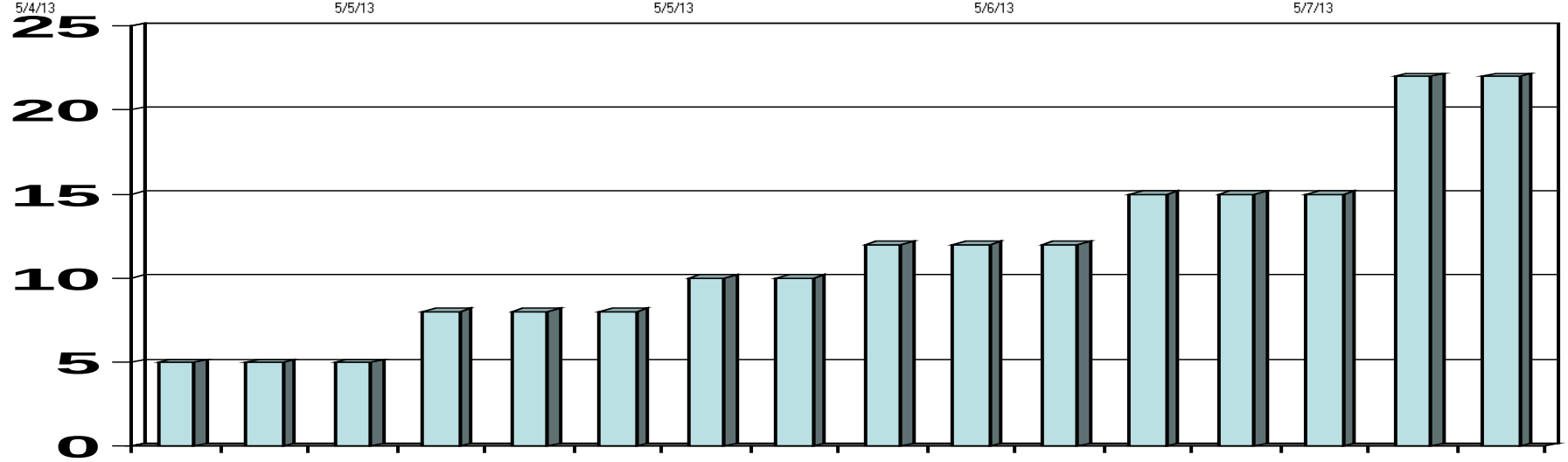
Chest X-ray Pre/Post Ventilator adjustments

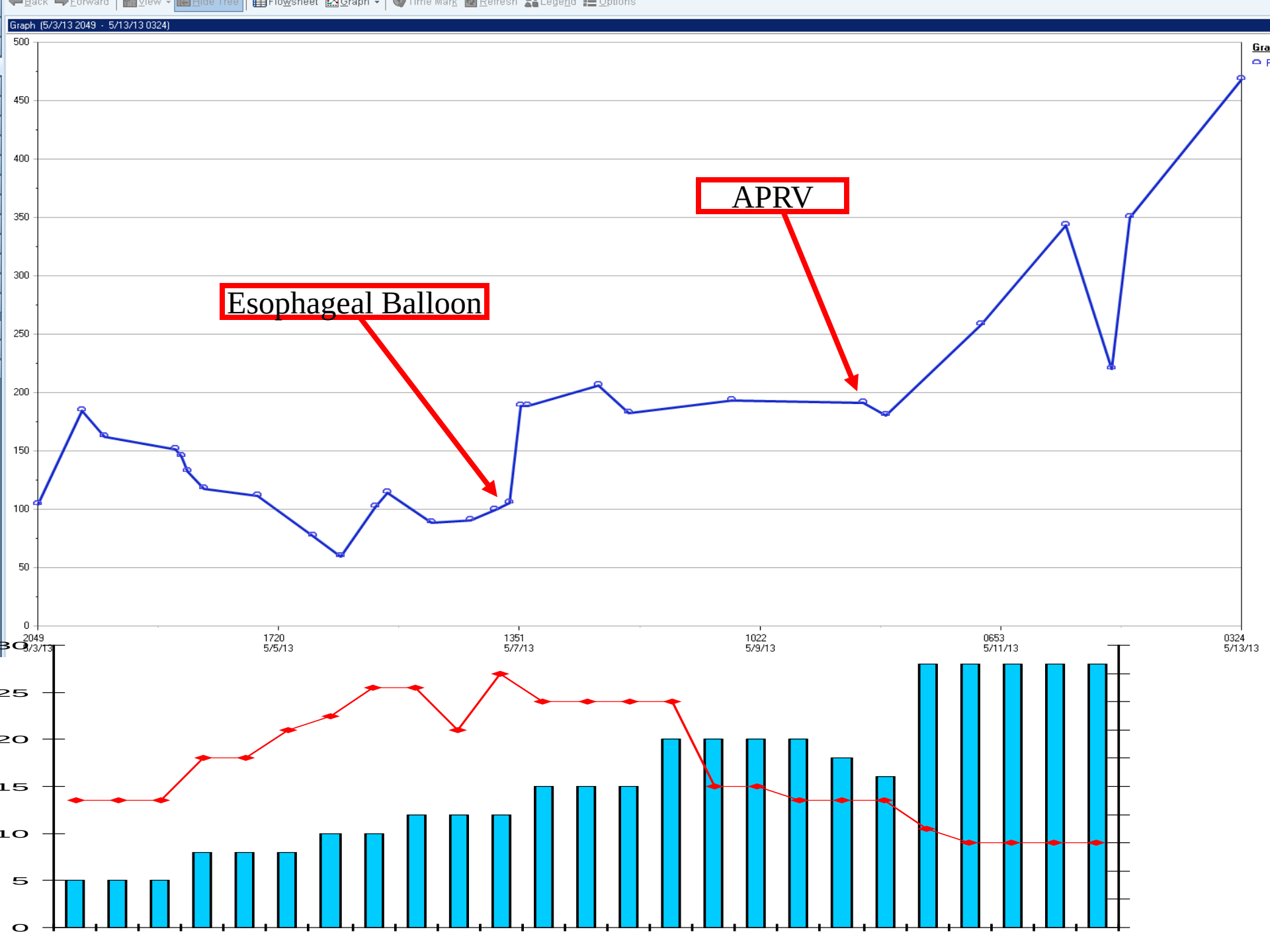




Oxygenation Trends despite PEEP increases






Graph (5/3/13 2049 - 5/13/13 0324)
Esophageal Balloon
APRV
500
450
400
350
300
250
200
150
100
50
0
2049
5/3/13
1720
5/5/13
1351
5/7/13
1022
5/9/13
0653
5/11/13
0324
5/13/13
30
25
20
15
10
5
0

Summary

- “However does it make sense not to use a novel (or not so novel) therapeutic strategy that has a strong physiological rationale, demonstrates a strong positive trend in an important clinical outcome has an acceptable adverse effect profile & is inexpensive.”

  – Dr. Arthur Slutsky. Improving Outcomes in Critically Ill Patients: The Seduction of Physiology. JAMA 2010;302(18):2030-2032.

Distendability at its finest

Thank you!

dxgrooms@sentara.com