Automated Ventilation for Patient Safety

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Society of Mechanical Ventilation

WHAT ARE WE TALKING ABOUT?

Presentation Outline

- Establish the need for increased Patient Safety
- Describe the risks of mechanical ventilation
- Introduce Automated Ventilation
- Drill down specifics of Automated Ventilation
- Explore quality measures for use of Automated Ventilation for Patient Safety

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- Errors are not tolerated in Commercial Aviation, nor should they be in Medicine.

200,000 Lives Lost Due To Medical Error!

- IOM 1999 “To err is human” reported 98,000 lives lost due to medical error.
- 2007 Journal of Patient Safety reports 210,000 - 440,000
- 2010 OIG DHHS reports 180,000 lives lost in medicare alone
- 2018 John’s Hopkins reports >250,000 lives lost

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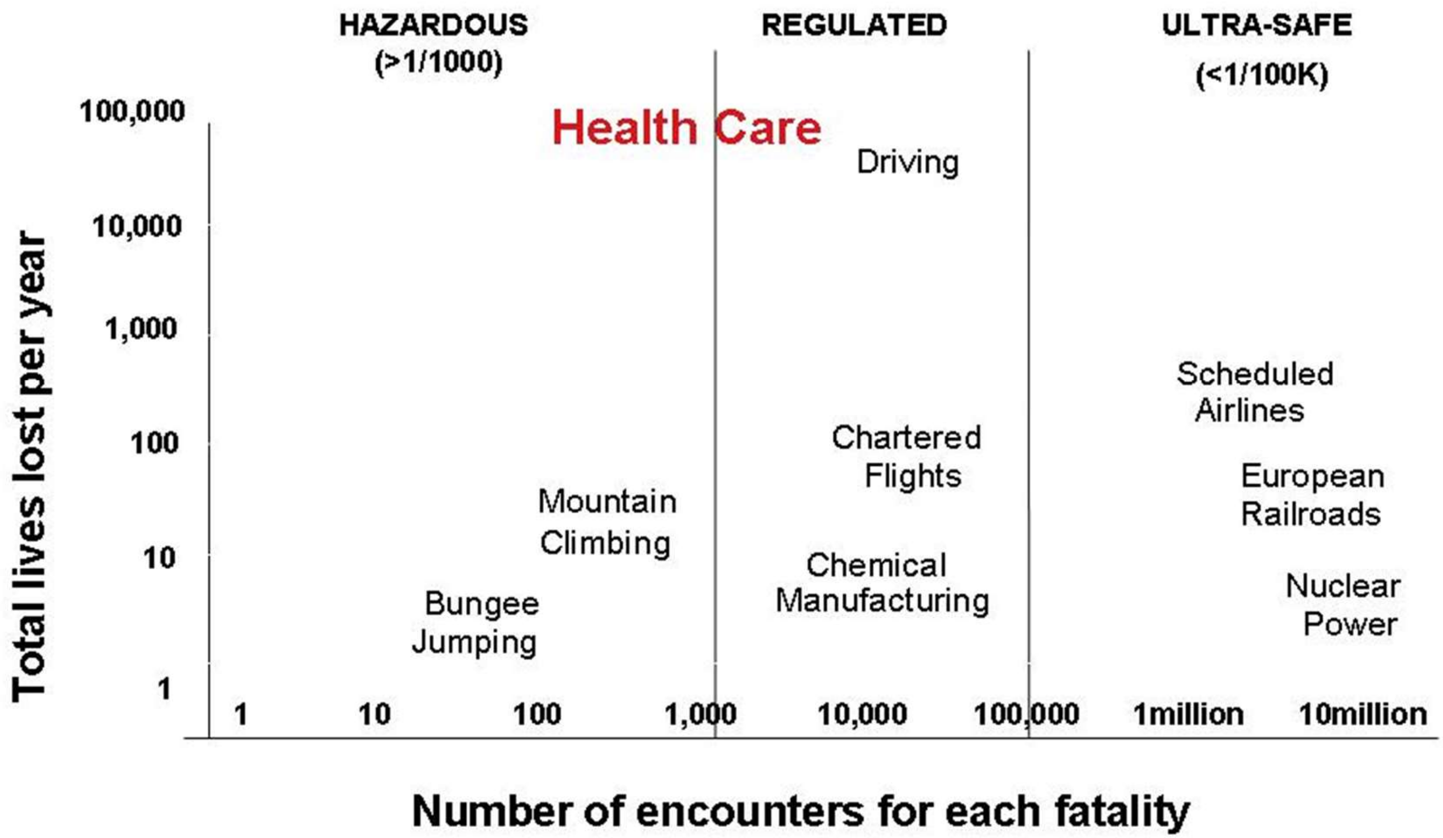
Two 747s going down in the U.S.A. everyday!
= 182,000/year


Healthcare is hazardous



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Evaluation of User-Interface Simplicity and Human Errors in Modern Generation Mechanical Ventilators

using (PB840, Servo*i*, Evita XL and Newport e500)

When given ventilator setup, vent changes and alarm response tasks:

experienced operators made 11% errors

Newly trained operators made 23% errors

Uzawa Y et al. Respir Care 2008;53(3):329-337

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We have been working very hard to save lives.

ARDS Mortality reported by:

Diamond	2020	27 – 45%
Charalampos	2012	41 - 46%
ARDS Network	2009	26 – 35%
ARDS Net	2000	31 - 46%
Brochard	1998	38 – 47%
Montgomery	1985	68%
Downs/Kirby	1975	19 – 39%

But we haven't made much progress in 45 years

Risks of Mechanical Ventilation

Barotrauma
Atelectrauma
Volutrauma
Pneumothorax
Absorption atelectasis
Oxygen toxicity
Alveolar distention
Aspiration
Near-drowning
ICU delirium, PTSD
Hypercapnia
Hypocapnia
Hypoxia
Suffocation
Death

Pressure necrosis (oral, facial or tracheal)
Vocal cord paralysis
Trauma (due to intubation or suction)
Infection
Decreased blood pressure
Reduced cerebral blood flow
Fluid overload
Decreased cardiac output
Decreased coronary vessel perfusion
Decreased cerebral perfusion pressure
Decreased renal perfusion
Decreased urine output
Tracheomalacia
Over sedation

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Most Powerful Ventilator Safety Intervention:

Get the Patient off the ventilator!

Reduce Ventilator Length of Stay

Reduce Risk of injury or death:
Highest Risk at ventilator initiation
High Risk intra-hospital transport
Beyond that it is high risk all the time

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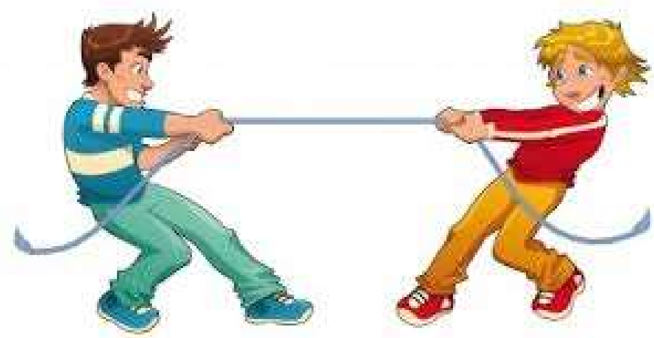
Forces driving ICU ventilator care

- Patient survival
- Patient safety (alarms, OVP, monitoring, etc.)
- Ventilator/Patient Protocols
- Financial pressure
- Professional staff stressors
- Patient/Family Psychosocial influences
- Ventilator Associated Event (VAE) prevention
- Extremely complex modality
- Same old processes, habits….inertia?…………………



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It is the process, not the people.

Systems Approach to Error Reduction

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Are you sure about that?

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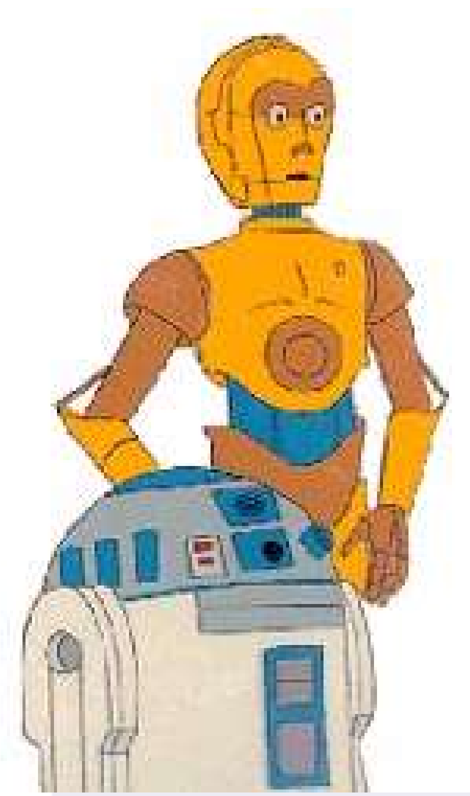
How Can Automated Ventilation Increase Patient Safety?

What is “Automation”?



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Types of Closed Loop Automation

1. Set point and adaptive **dual control modes** – good first step (Car cruise control
   Automated heated wire circuit)

2. Automated **initialization of CMV**

3. Optimal dual control mode with **multivariate feedback – long term solution**

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Simple Closed Loop Ventilator Systems

Simple control options available on the market:
VAPS, PRVC, APV ETC………………..

Monitor: One or two parameters
(Tidal Volume, minute volume)

Change: One or two parameters
(Inspiratory pressure, frequency)

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Automation in Initiation of CMV

Why?

- Mass Casualty
- Flu Pandemic increased ICU capacity

- iVent
- LTV-1200
- Uni-vent Eagle

Multi-variable Closed Loop
"Embedded Ventilator Protocols"

- **Hamilton Galileo, G-5, T1, C1, C2, C3, MR1 & S-1** Adaptive Support Ventilation (Apnea to extubation)
- **Drager Evita** – " Smart Care" (Spontaneous ventilation to extubation)
- **Covidien/PB 840, 980** Proportional Assist+ (Spontaneous ventilation to extubation)
- **Maquet Servo *I*,** Neurally Adjusted Ventilatory Assist (NAVA) (Spontaneous ventilation to extubation)

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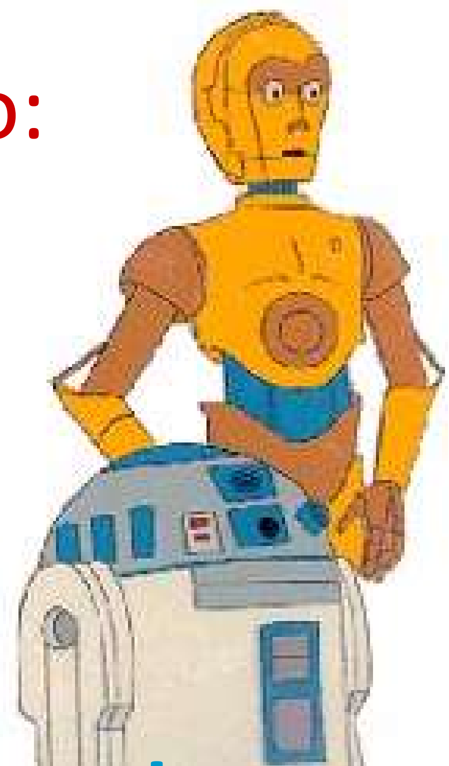
Adaptive Support Ventilation

- Intelligent Ventilation
- Available in Europe 1990s
- Available in USA 1998

Automation is an assistant who:



- **Monitors the patient every breath**
- **Watches the important parameters**
- **Responds appropriately to every change**
- **Never becomes tired or bored**
- **Saves MD/RT/Nurse much time and trouble**

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Imagine

- **Your best practitioner at the bedside making appropriate changes every time.**
- **Never distracted**
- **Never takes a break**
- **Always follows correct protocol**

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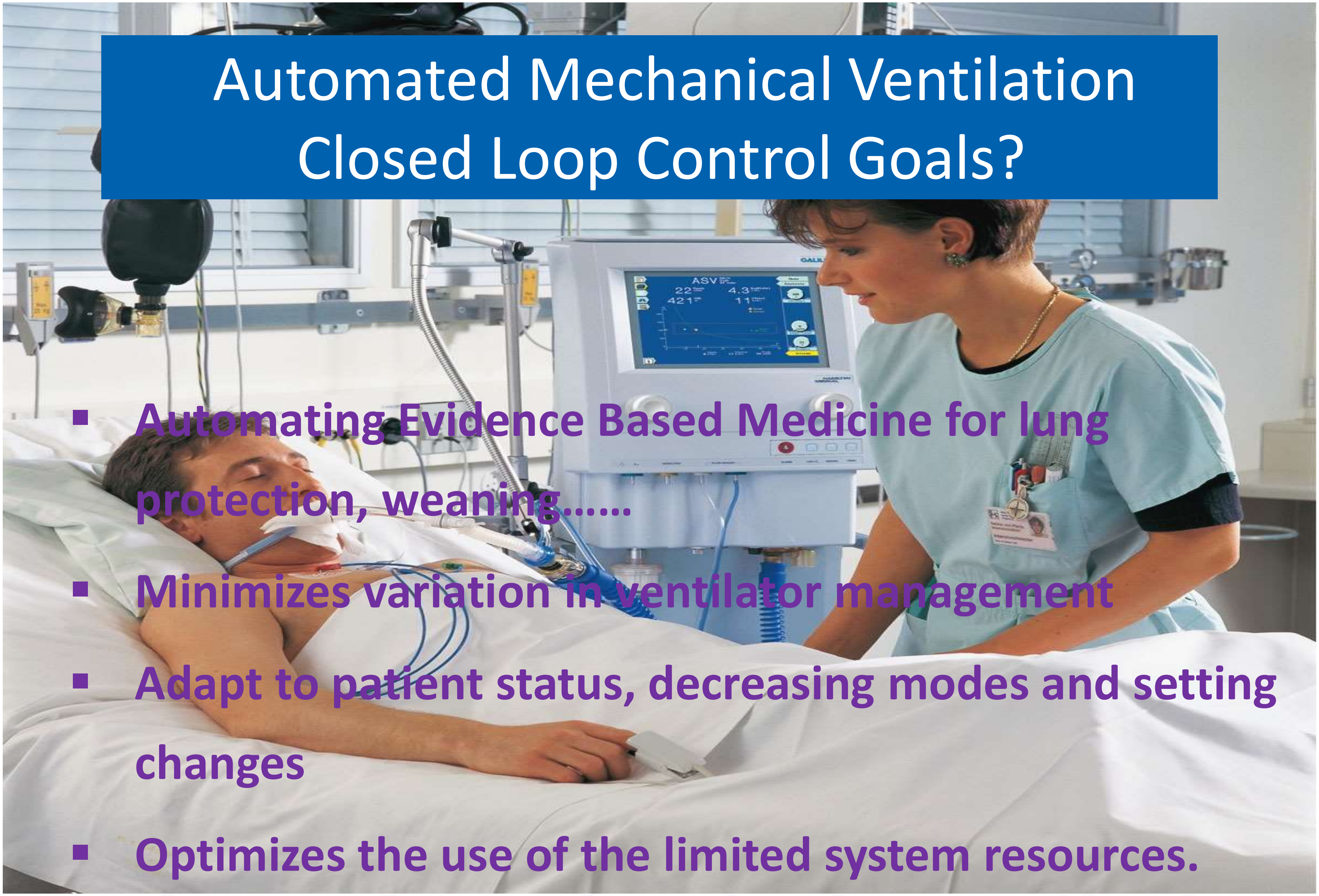
Automated Mechanical Ventilation Closed Loop Control Goals?



- **Automating Evidence Based Medicine for lung protection, weaning……**
- **Minimizes variation in ventilator management**
- **Adapt to patient status, decreasing modes and setting changes**
- **Optimizes the use of the limited system resources.**

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Intelligent Ventilation

- Suitable for all phases of ventilation, including weaning
- A NON-MODE that adapts ‘mode’ to patient needs
- Automatic selection of tidal volumes – even in ARDS
- Automatic weaning, only when appropriate
- Automatic adaptation to all patients

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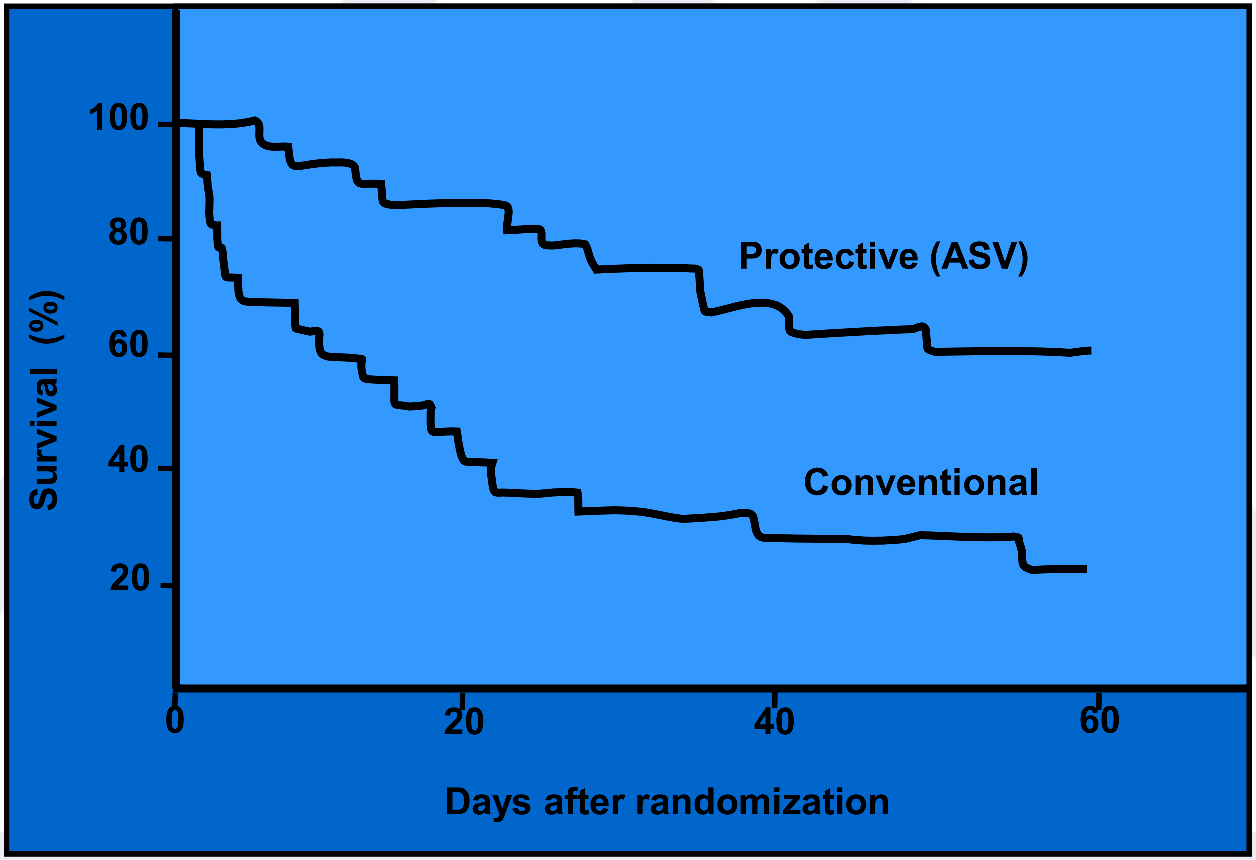
Automated Lung Protective Ventilation SAVES LIVES



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Amato et al.; N England J Med. 1998; 338:347-54

Adoption of Automation at Castle Medical Center 2003-2008

(1271 total vent patients)
n = all patients (non-random)

Three Categories of Patients:

577 ASV only (start to finish)
135 Switched to ASV
526 Conventional ventilation

Patient's average age = 66 y.o ; 54% female

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ASV experience at Castle Medical Center (A Case Report Series)

#Pt	Method	Year	%of total	Vent. LOS (Days)
36	ASV only	2003	23 %	2.5
93	No ASV	2003	50 %	4.2
170	ASV only	2008	84%	3.6
23	No ASV	2008	11%	7.9

(2003 n = 159, 2008 n = 203)

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ASV experience at Castle Medical Center

We use ASV on any:

- Post-operative patient
- Emergency room patient
- Acute Respiratory Failure
- ARDS
- Asthma
- COPD
- Neurological patient
- Drug overdose

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ASV experience at Castle Medical Center

ASV may be used safely.

ASV can move patient from full support
to extubation without any changes.

ASV preferred by respiratory therapists,
ICU nurses and most physicians.

ASV more patient comfort and less alarms.

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G-5

T-1

Automated Ventilation
Closed-Loop
Intelligent Ventilation
Adaptive Support Ventilation

Hamilton Medical Ventilators

C-6

Galileo

echanical Ventilation

Respiratory Failure

Two Problems:

- Ventilation (ASV is a solution)
- Oxygenation ($PEEP$ & F_IO_2)

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Ventilatory Failure

Only Four Problems…..?

- Airway Resistance — ASV is a solution
- Lung/Thorax Compliance — ASV is a solution
- Respiratory Drive — ASV is a solution
- Work of Breathing — ASV is a solution

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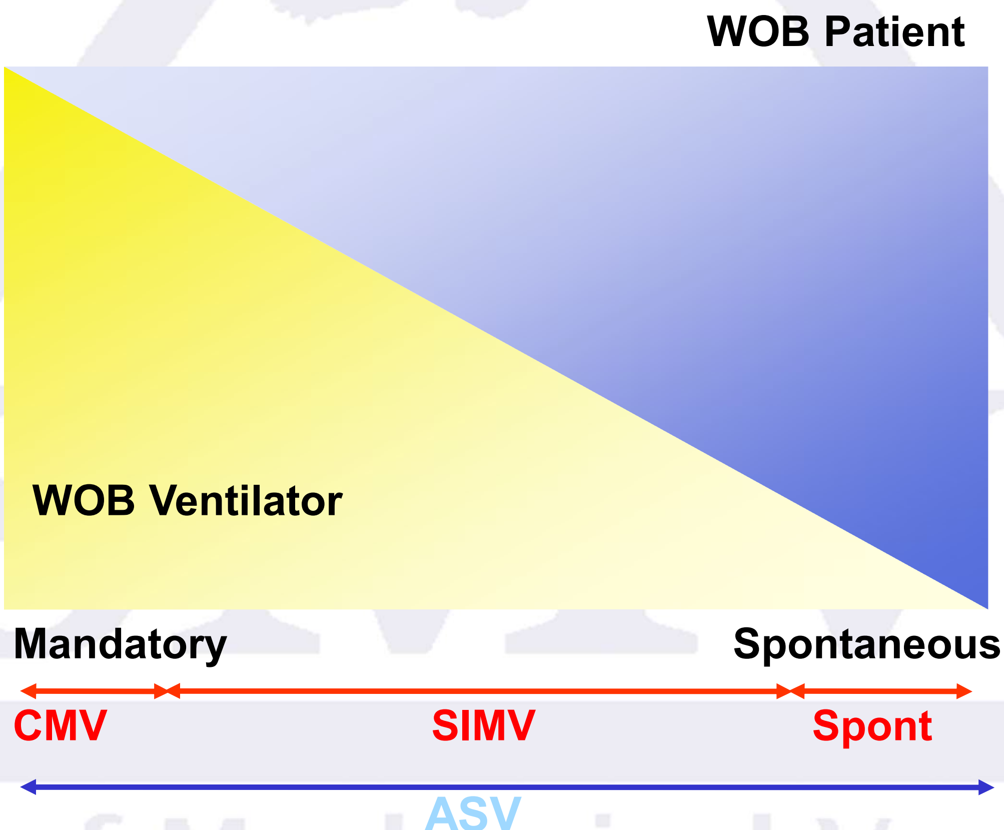
Adaptive Support Ventilation

No manual mode change. ASV adapts automatically to the needs and capabilities of the patient



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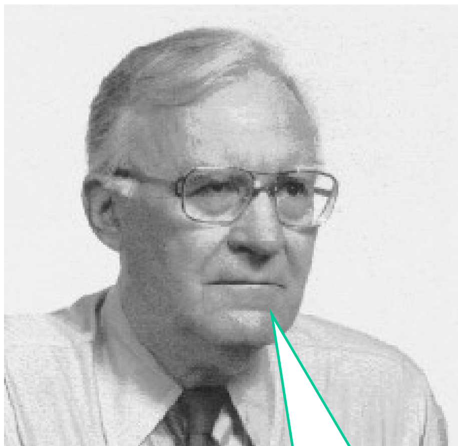
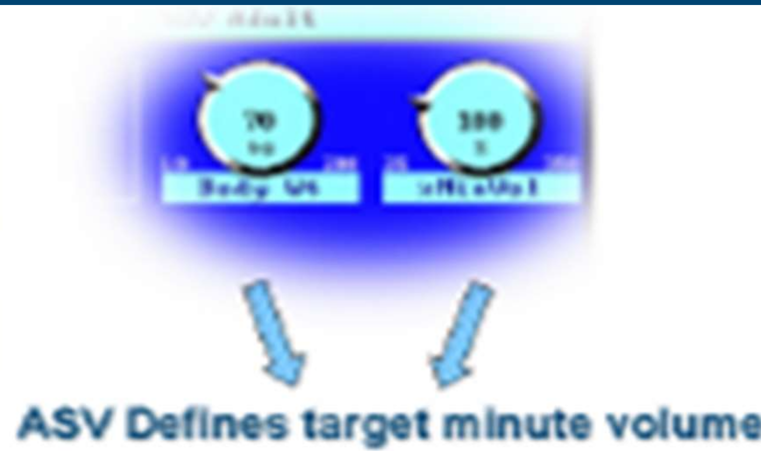
How does PATIENT ORIENTED Intelligent Ventilation work?



Dr. A.B. Otis



$$f\text{-target} = \frac{\sqrt{1+2a*RCexp*(MV-V'D)/VD}-1}{a*RCexp}$$

For any combination of resistance, compliance, V' a and Vd, there is a respiratory rate where WOB is minimal

Otis AB, Fenn WO, Rahn H, Mechanics of breathing in man, JAP 1950; 2: 592-607

Automated Ventilator System

Hamilton G-5: ASV

Monitors & Reports to Microprocessor:

- Minute volume
- Tidal volume
- Expiratory Resistance
- Lung/Thorax Compliance
- Frequency, control
- Frequency, spontaneous
- Peak inspiratory pressure

(Expiratory Resistance and Lung/Thorax Compliance → Expiratory Time Constant)

Computer - Changes:

- Mode of ventilation
- Inspiratory pressure
- Inspiratory time
- Respiratory frequency

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5 Test Breaths…..

(example)

1. SIMV = 15/minute
2. PCV = 15 cmH_2O
3. Insp. Time = 1 second

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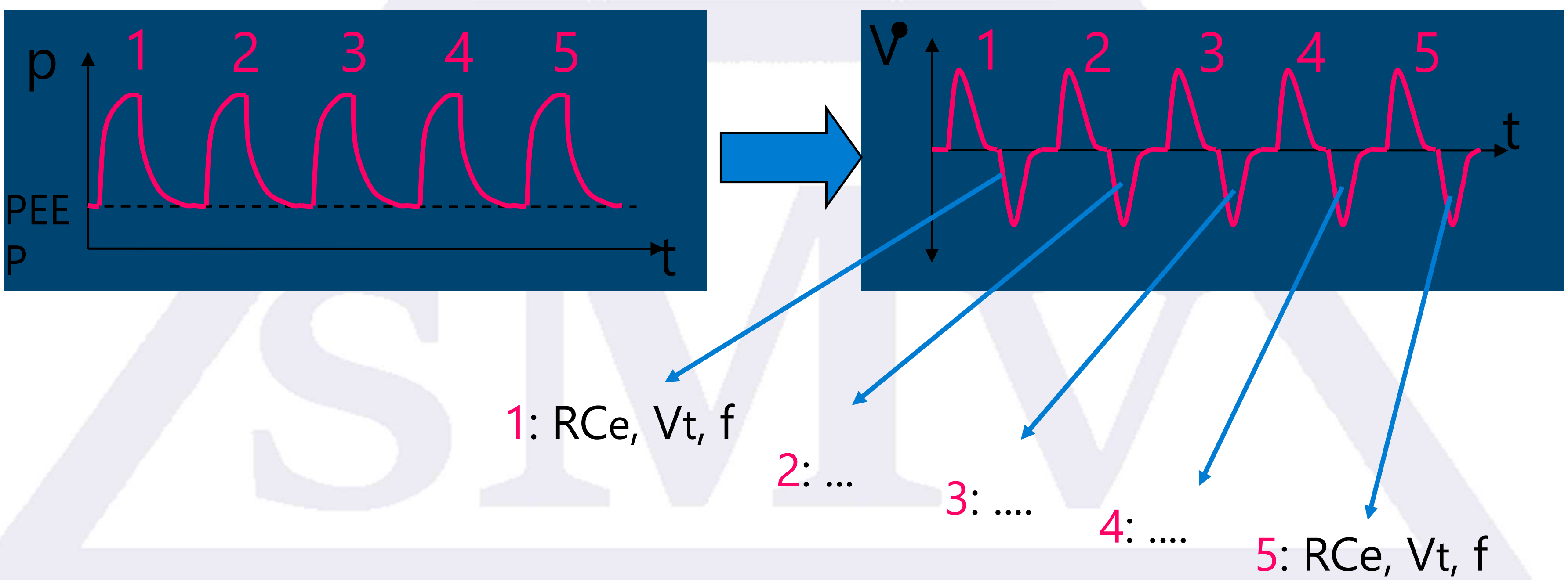
The microprocessor
Assesses patient: 5 test breaths

Pressure x time causes Flow



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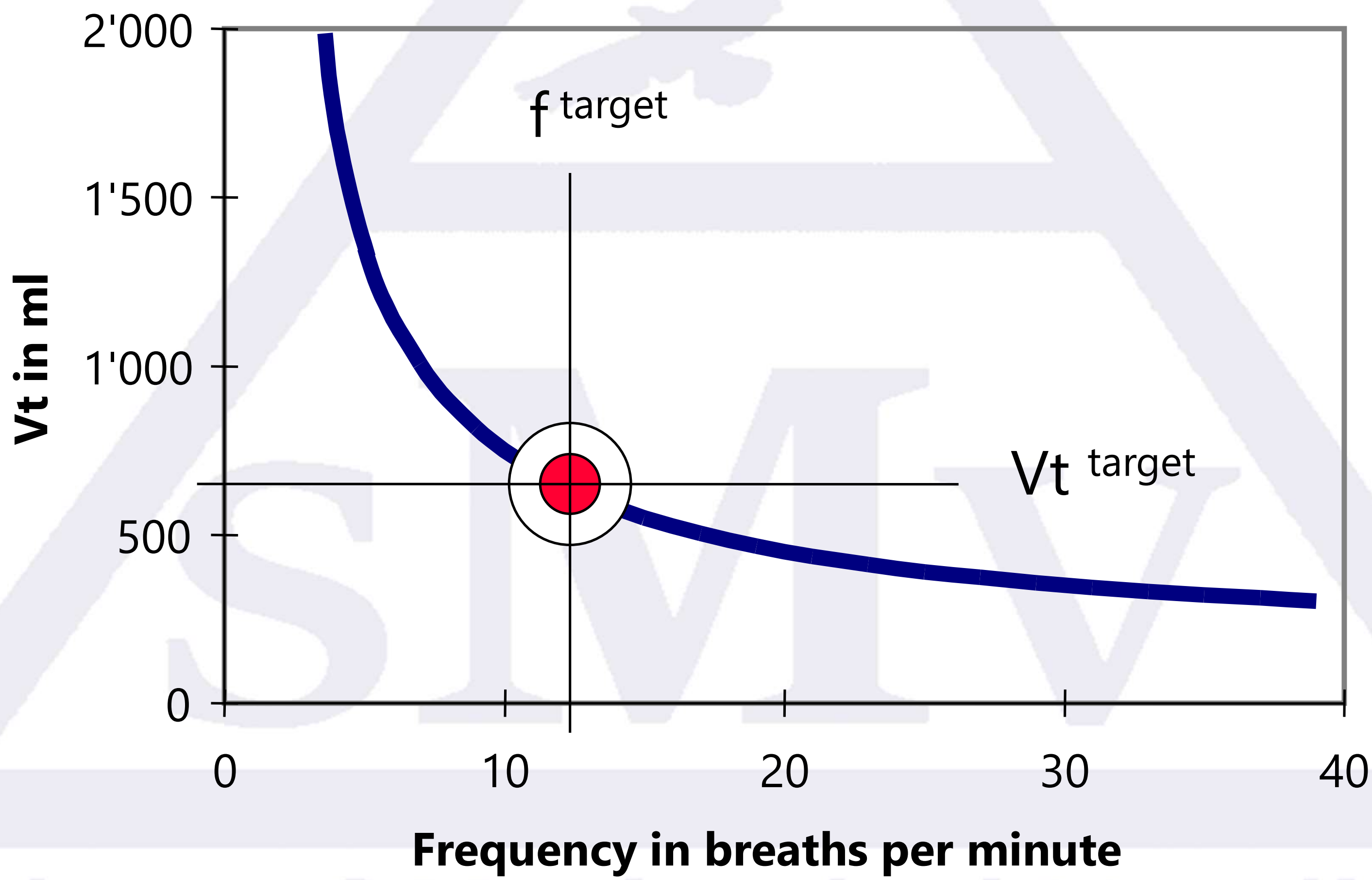
Calculate optimal breath pattern: Calculate V_T



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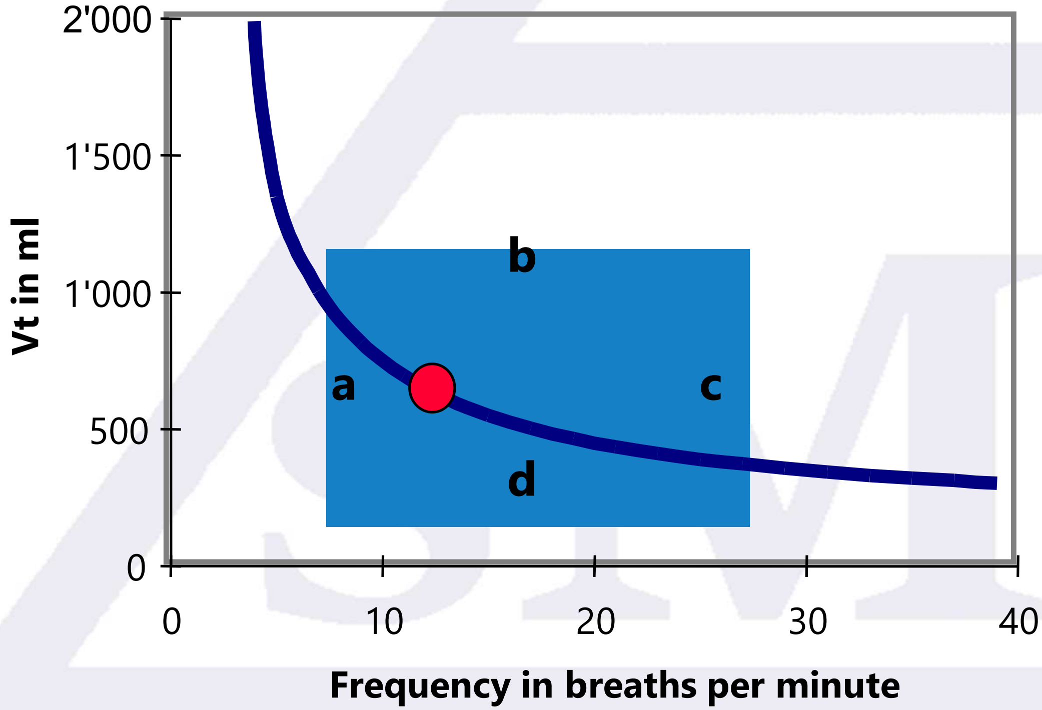
Calculate - optimal breath pattern: Lung protective strategy



Avoid:

a: apnea

b: volu/barotrauma

c: AutoPEEP

d: excessive V'_D/tachypnea

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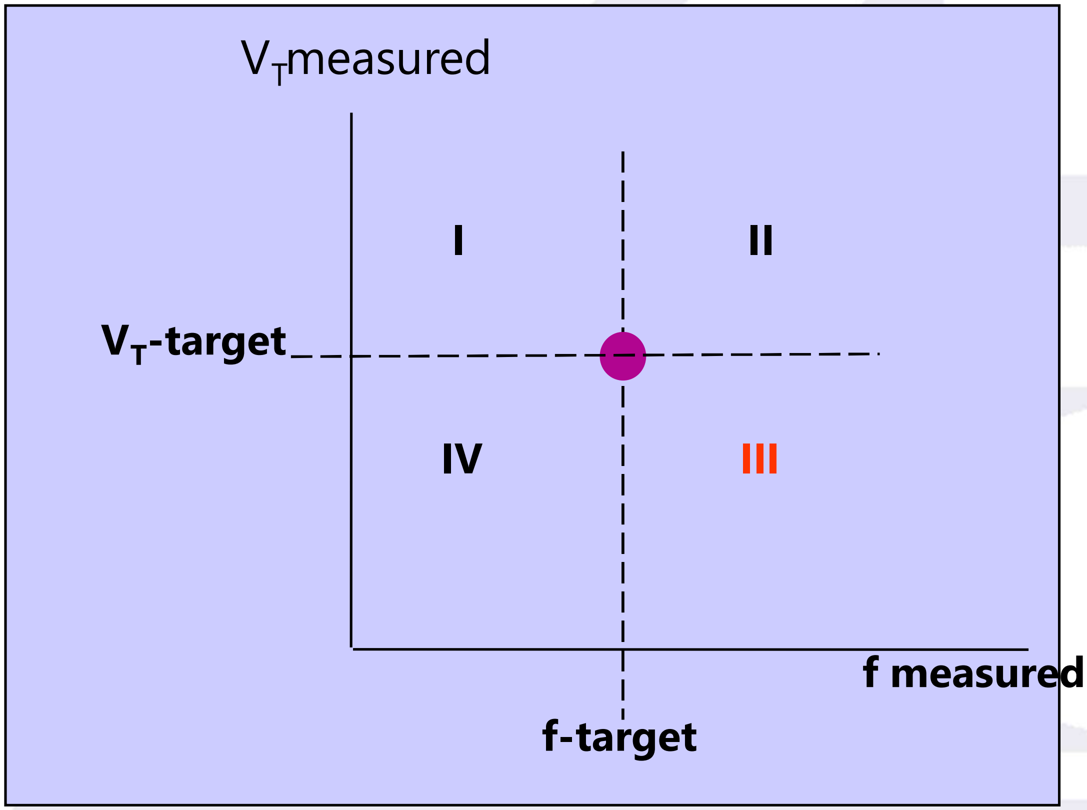
Adjust Pinsp and mand. Rate to meet targets: Principle



Quadr.	Pinsp	mand.rate
I	□	□
II	□	□
III	□	□
IV	□	□

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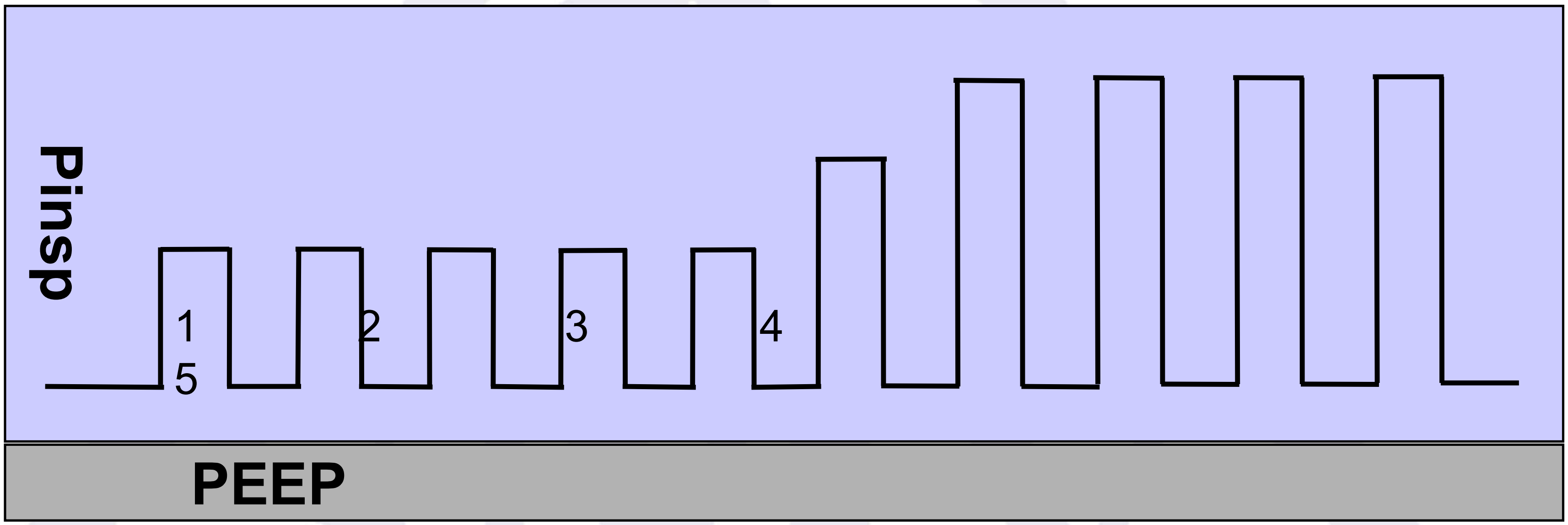
Adjust Pinsp and mandatory rate to meet targets: Dynamics



less than 60 sec

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Maintain optimal breath pattern

Re-assess patient breath-by-breath (RC_e, V_T, f)

Re-calculate optimal breath pattern (V_{Target}, f_{Target})

Adjust P_{insp} & mand.rate to meet target (P_{insp}, f_{mand}, I:E ratio)

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Control breaths are “PCV-SIMV”

Spontaneous breaths are “PSV”

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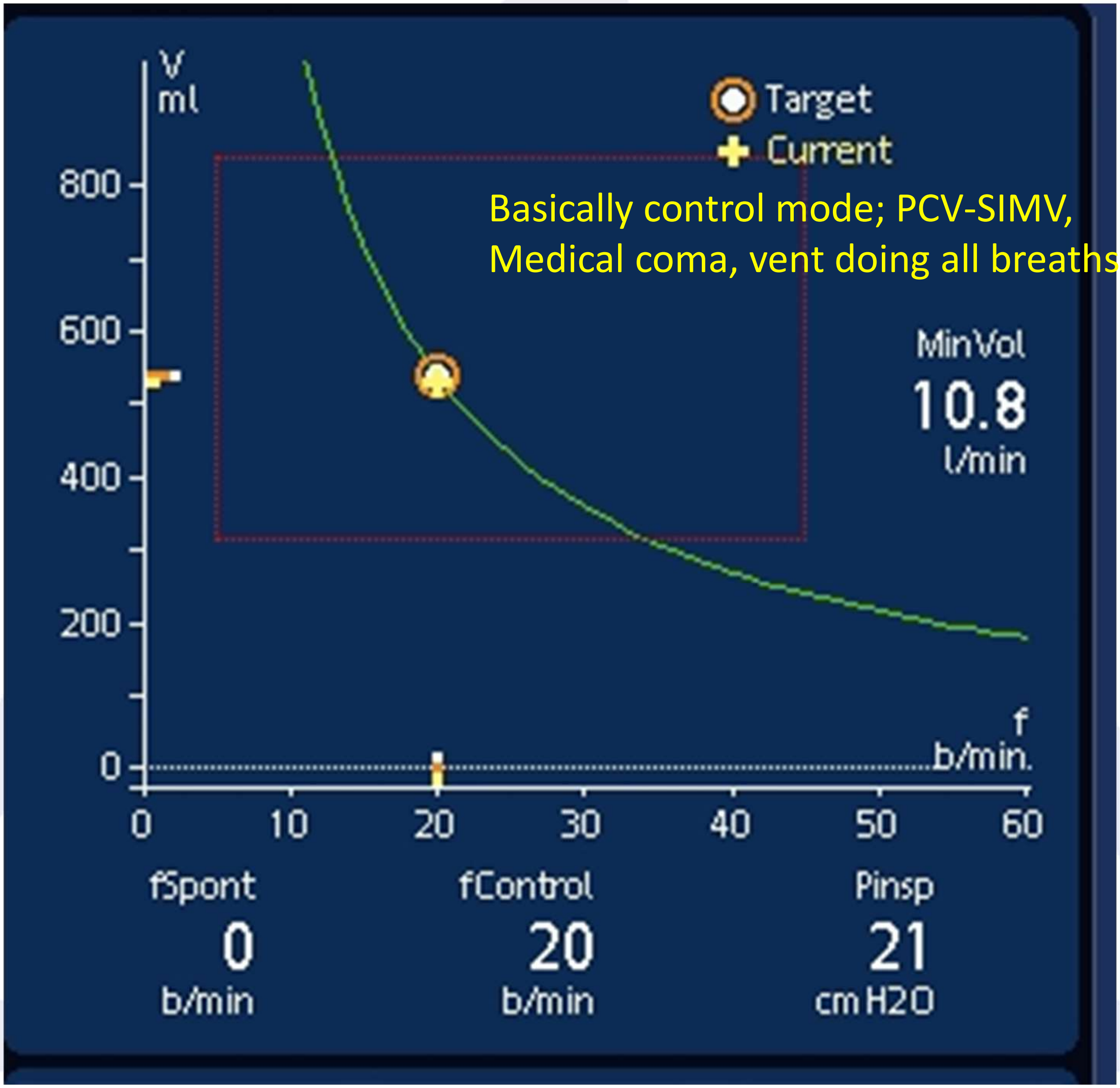

Basically control mode; PCV-SIMV,
Medical coma, vent doing all breaths

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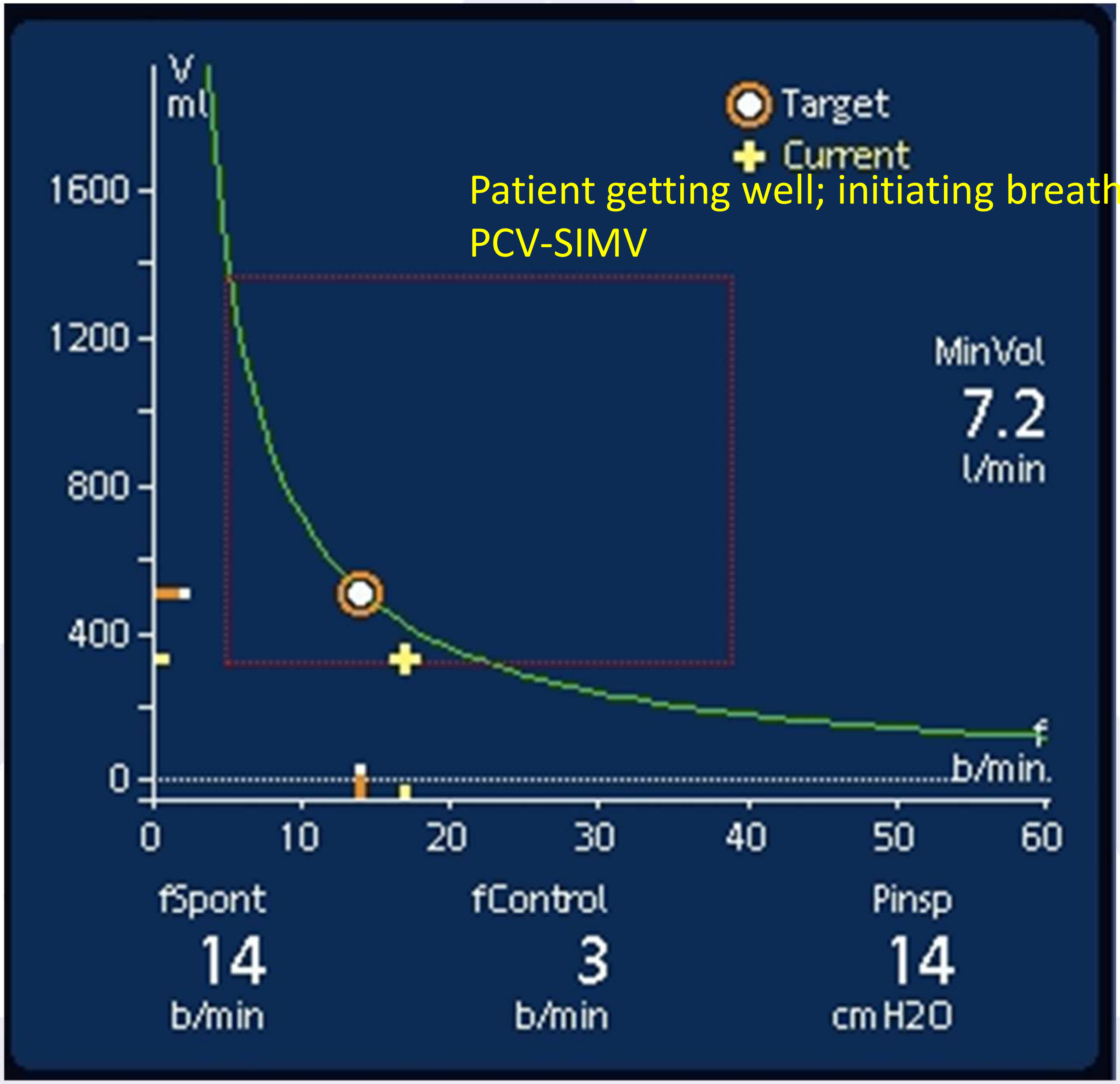
Patient getting well; initiating breaths, PCV-SIMV



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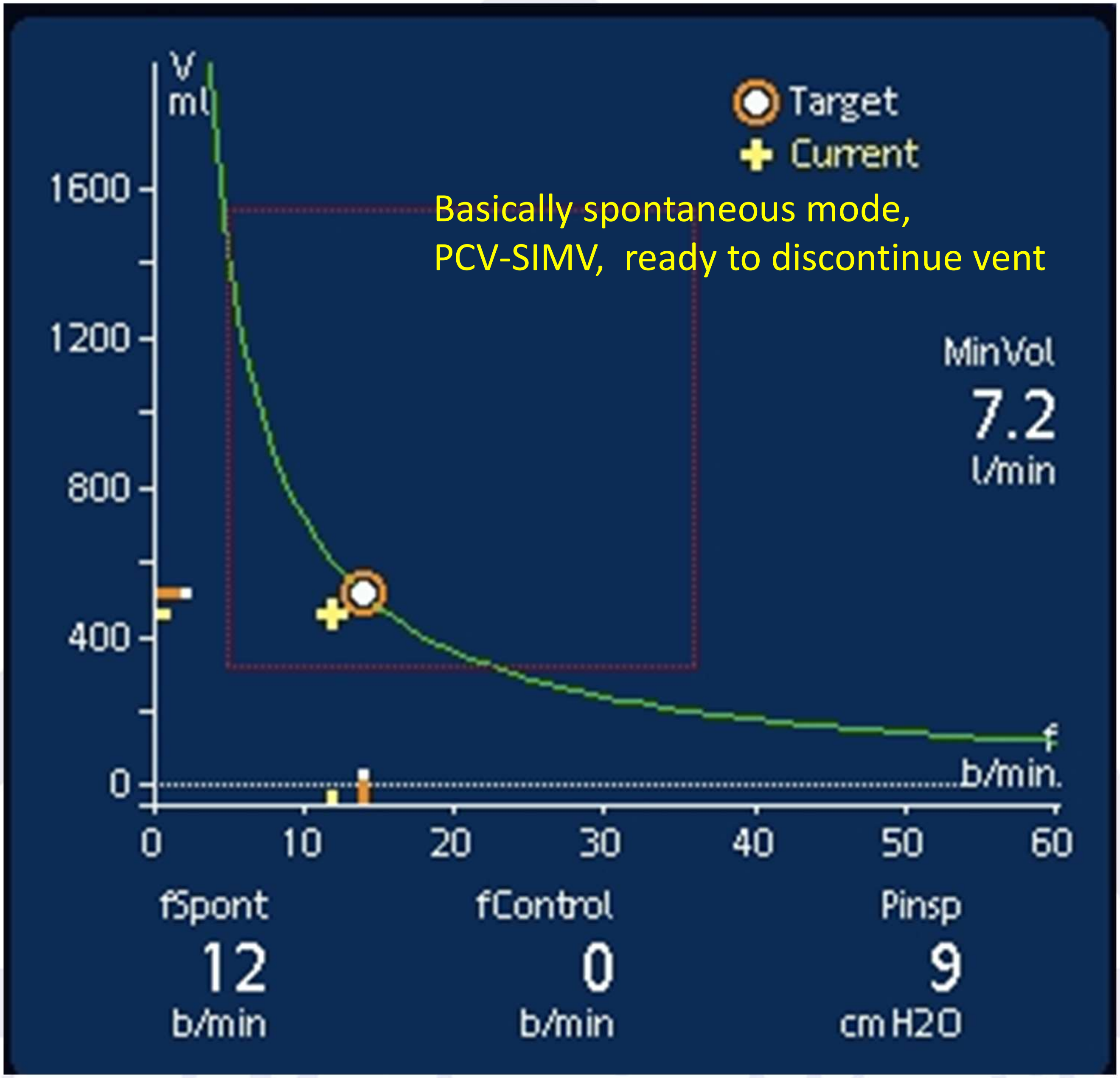

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"Vent monitor with ventilation goals"

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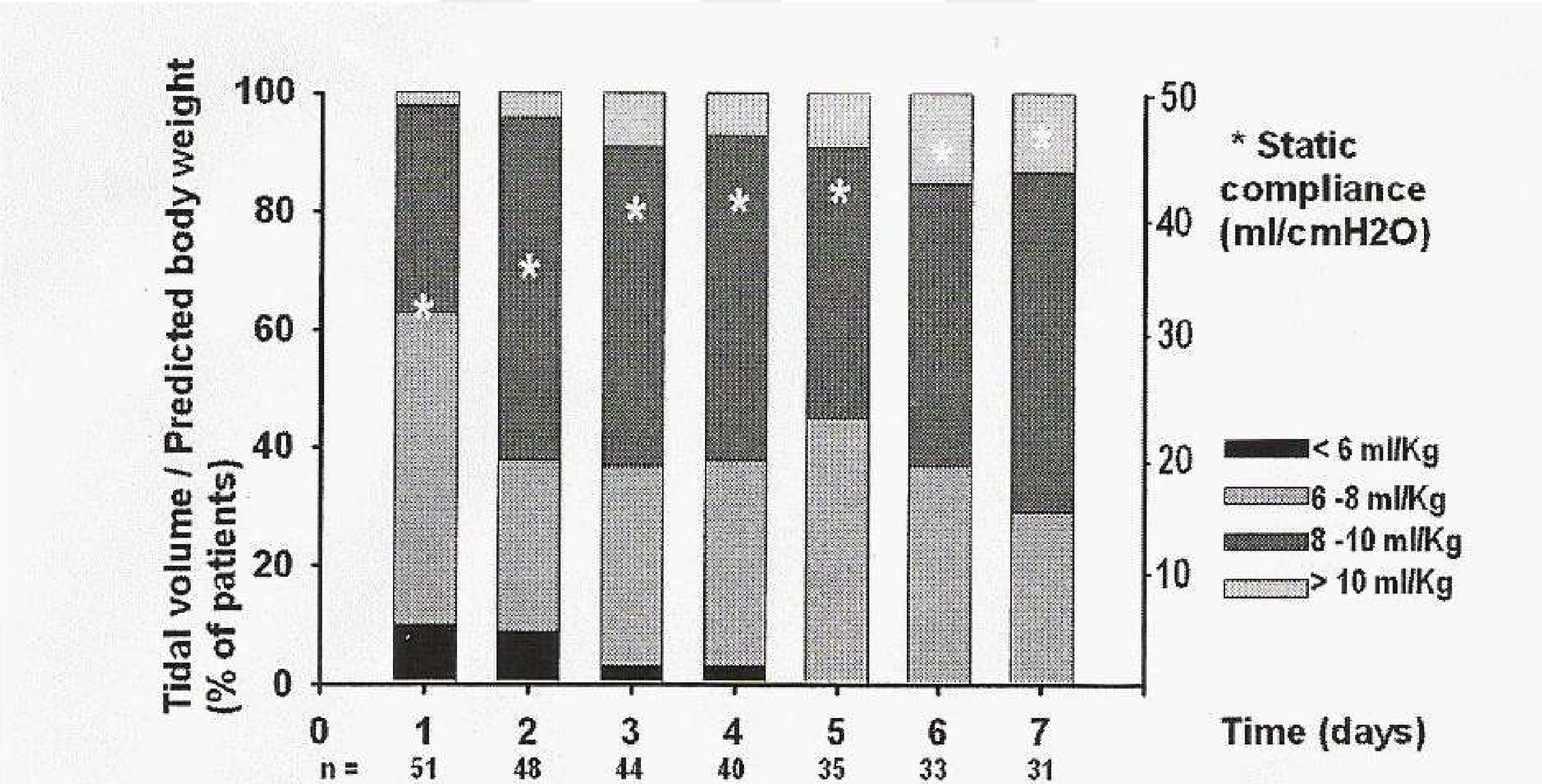
ASV uses low V_T strategy

V_T typically 5 - 7 ml/Kg
for ARDS patients

Lower V_T similar to report from
NEJM, 342:18, 1301- 08, May 4, 2000

Adaptive Support Ventilation (ASV®) automatically adapts a protective ventilation in ARDS patients.

Arnal JM, Wysocki M, Garcin F, Donati SY, Granier I, Durand-Gasselin J.



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Intelligent Ventilation/ASV

Improved Patient Outcomes

- **ASV reduces weaning time.**

  Sulzer CF, Chiolero R, Chassot PG, Mueller XM, Revelly JP: Anesthesiology. 2001 Dec;95(6):1339-45

- **ASV automatically selects a breathing pattern that fits the patient' s pathology.**

Bellatio M Maggio M. Neri S., Via G. Fusilli N., Olivie M. Iotti G., Braschi A., Intensive Care Med 2000 Vol

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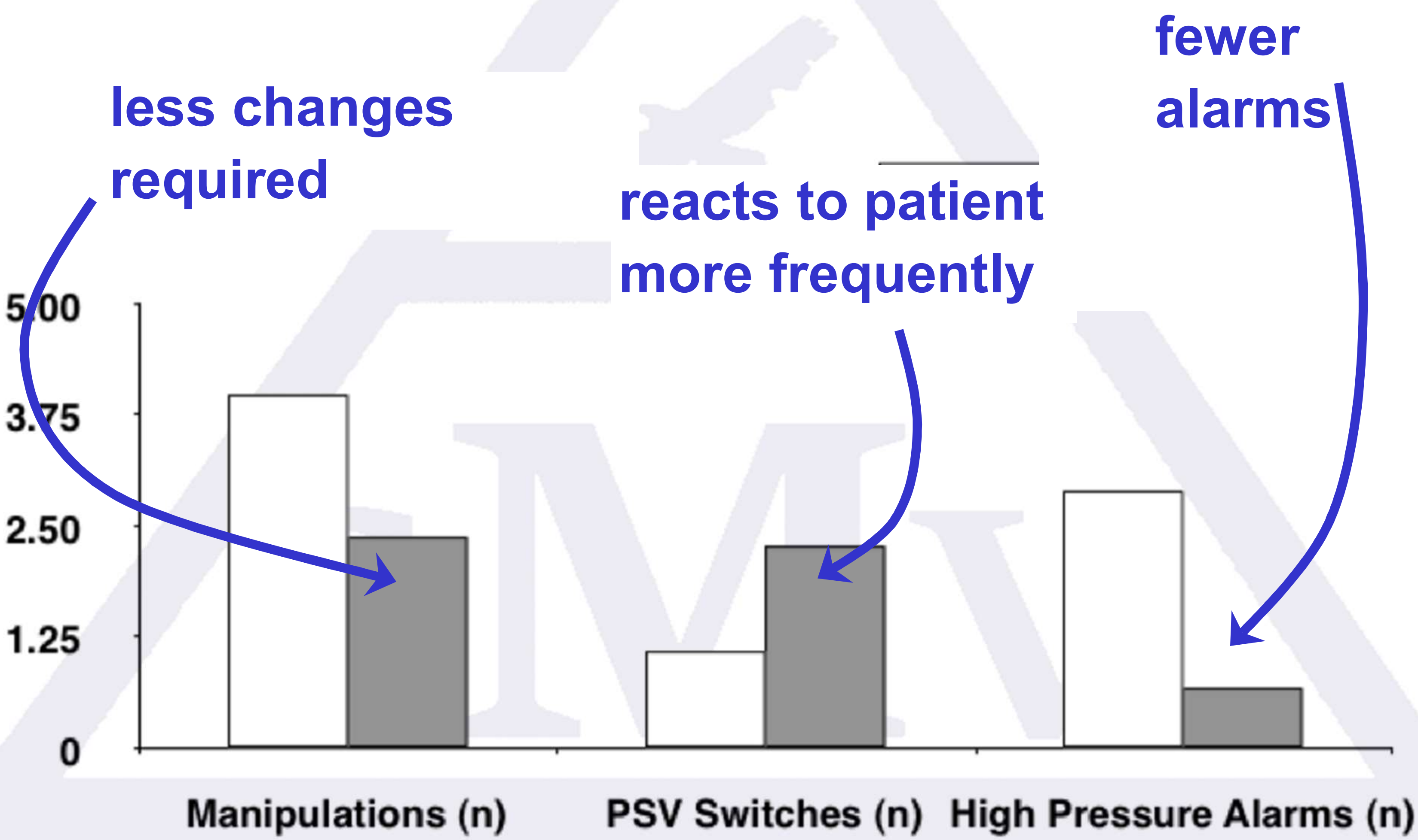
Intelligent Ventilation- Operator/ventilator reactivity



Sulzer, Anesthesiology, 2001

Petter, Anesth Analgesia, 2003

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ASV meets clinician set goals in one to three minutes.

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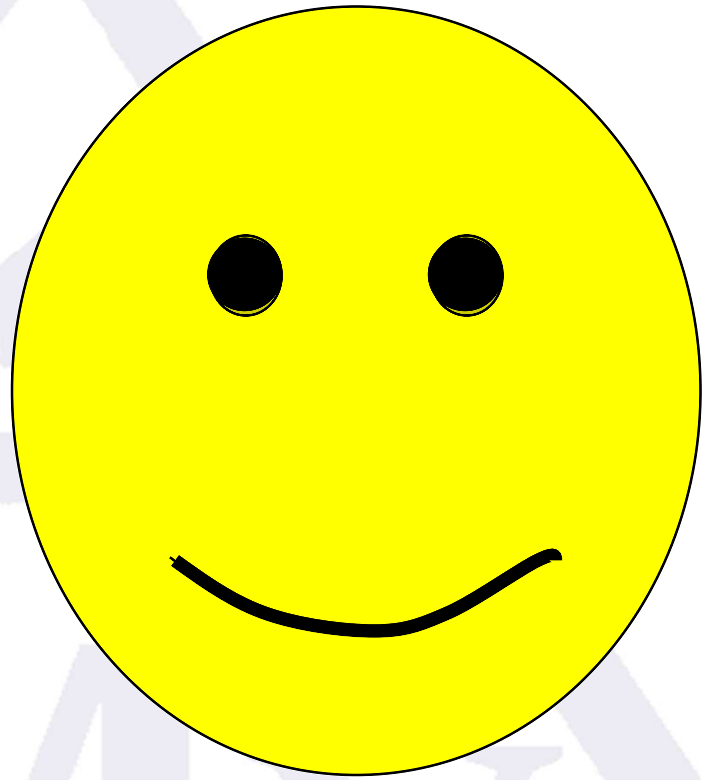

Patient feels relief almost immediately.

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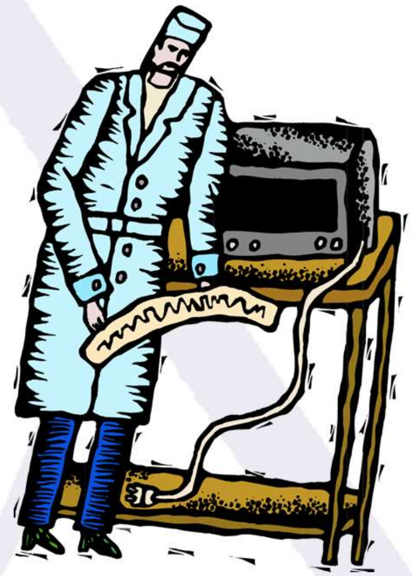
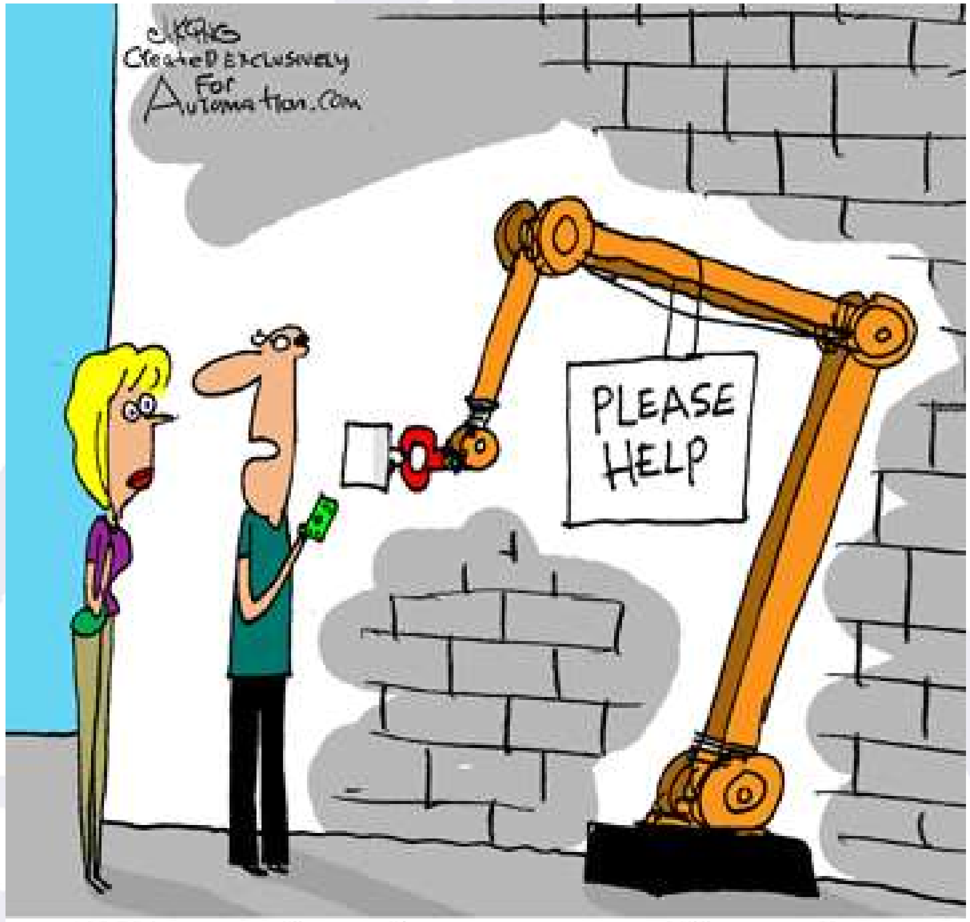
We still need physicians, nurses and respiratory therapists.



ASV cannot make clinical decisions.



"Yesterday there was a homeless person here. I told you automation can replace anybody."

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rager Evita XL

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SmartCare/PS™ classification of patient ventilation

The 3 Monitored parameters:

- f_{spont}
- V_T
- $etCO_2$

8 Classifications

1. Normal Ventilation
2. Insufficient Ventilation
3. Hypoventilation
4. Central Hypoventilation
5. Tachypnea
6. Severe Tachypnea
7. Unexplained Hyperventilation
8. Hyperventilation

The Hypoventilation

- Tachypnea
- Severe Tachypnea
- Unexplained Hyperventilation
- Hyperventilation

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Diagnosis	fspn	VT	etCO2	SC response
Normal ventilation	OK	OK	OK	↓ PS by 2 or 4
Insufficient ventilation	OK	↓	OK	↑ PS by 2 or 4
	OK	OK	↑	
Hypoventilation	↓	OK	↑	↑ PS by 4
Central Hypoventilation	↓	↓	↑	ALARM
Tachypnea	↑	OK	OK	↑ PS by 2 or 4
	if 3 X			ALARM
Severe Tachypnea	↑ ↑	OK	OK	↑ PS by 4
	if 3 X			ALARM
Hyperventilation	↓	OK	OK	↓ PS by 4
Unexplained Hyperventilation	↑	OK	↓	ALARM

Overview of patient classifications and SmartCare response.

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SmartCare/PS™ the clinical evidence

TABLE 2. COMPARISON OF THE OUTCOMES IN THE TWO GROUPS

OUTCOME median no. of days (interquartile range)	CDW group (N = 74)	Usual weaning group (N = 70)	P Value
Time to first extubation[†]	2.00 (1.75-6.25)	4.00 (2.00-8.25)	0.02
Duration of mechanical ventilation until first extubation[†]	6.50 (3.00-12.25)	9.00 (5.75-16.00)	0.03
Time to successful extubation *	3.00 (2.00-8.00)	5.00 (2.00-12.00)	0.01
Total duration of mechanical ventilation *	7.50 (4.00-16.00)	12.00 (7.00-26.00)	0.003
Intensive care length of stay	12.00 (6.00-22.00)	15.50 (9.00-33.00)	0.02
Hospital length of stay	30.00 (17.00-54.75)	35.00 (21.00-60.25)	0.22

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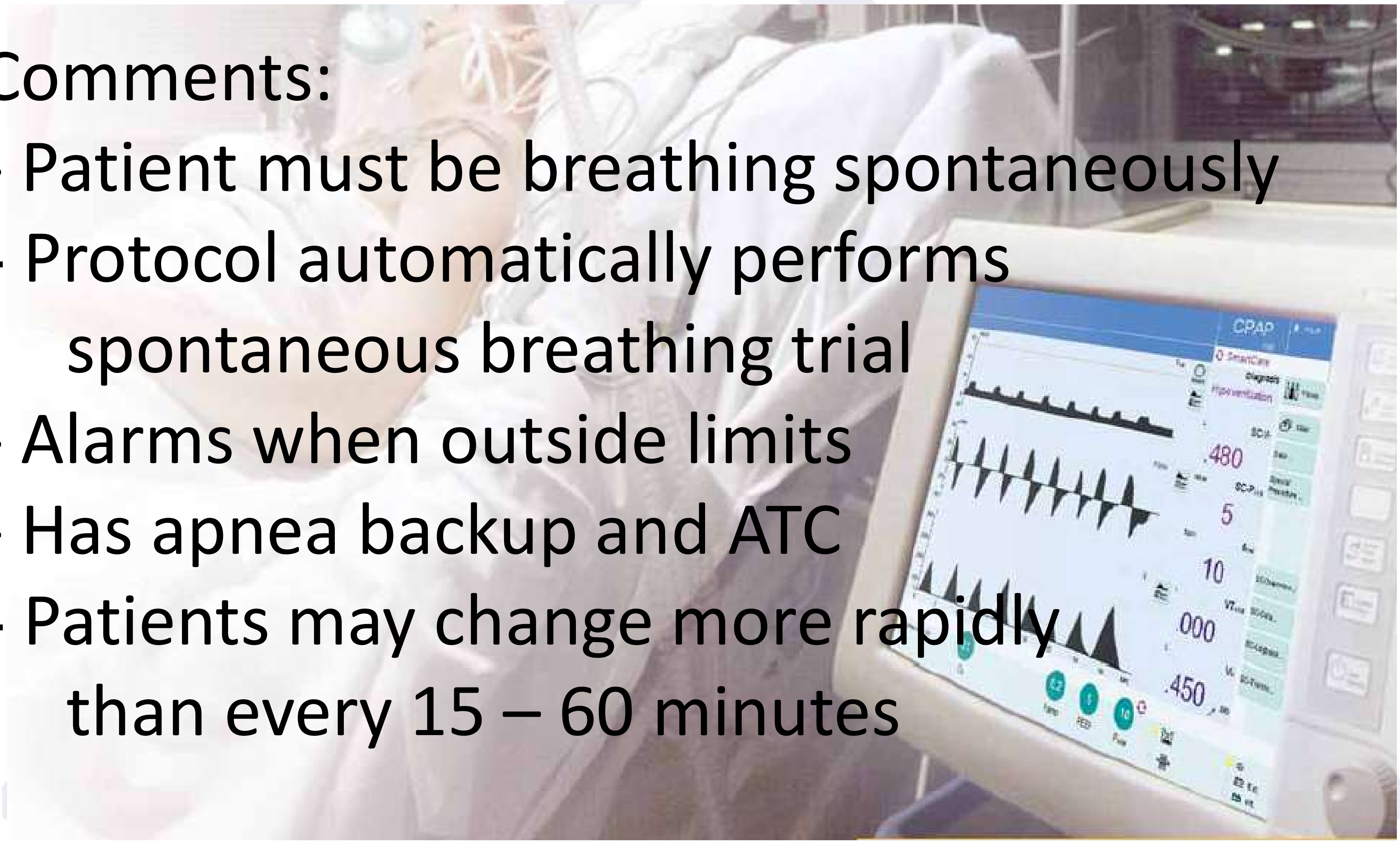
Lellouche F, Mancebo J, Jolliet P, *et al.* A multicenter randomized trial of computer- driven protocolized weaning from mechanical ventilation. *Amer J Respir Crit Care* 2006; 174: 894- 900.

Drager Evita – Smart Care



Comments:

- Patient must be breathing spontaneously
- Protocol automatically performs spontaneous breathing trial
- Alarms when outside limits
- Has apnea backup and ATC
- Patients may change more rapidly than every 15 – 60 minutes

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Maquet – Servo-*I*

NAVA

Neurally Adjusted Ventilatory Assist

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NAVA senses activity in the diaphragm and responds by providing the requested level of ventilatory assist. The Edi signal is obtained by an electrode array mounted close to the distal tip of the Edi catheter. This catheter can also serve as a conventional nasogastric feeding tube.

NAVA

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Maquet – Servo-I NAVA

Improved synchrony: the ventilator is cycled-on as soon as neural inspiration starts.

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Beck J, Sinderby C, Lindström L, Grassino A. Crural Diaphragm activation during dynamic contractions at various inspiratory flow rates. J Appl Physiol 1998;85:451-8.

Maquet – Servo-I NAVA

- **Lung protection:** With NAVA avoid over or under assistance of the patient.
- **Unique monitoring capability:** in all ventilation modes, providing information on Respiratory Drive, Volume requirements and the effect of the ventilator settings, and to gain indications for sedation and weaning

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Maquet – Servo-I NAVA

Patient comfort: The delivered assistance is matched to neural demands to minimize patient discomfort and promoting spontaneous breathing.

Decision support for unloading and extubation: As the patient's condition improves, Edi amplitude decreases, resulting in reduction in ventilator-delivered pressure. This pressure drop is an indicator to consider weaning and extubation

Sinderby C, Beck J, Spahija J, DeMarchie M, Lacroix J, Navalesi P, Slutsky AS. Inspiratory Muscle Unloading by Neurally Adjusted Ventilatory Assist during Maximal Inspiratory Efforts in Healthy Subjects. Chest. In press, Sept 2006

Maquet – Servo-*I* *NAVA*

Comments:

- Patient must be breathing spontaneously
- Protocol automatically performs spontaneous breathing trial
- Alarms when outside limits
- NG tube is a little difficult

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Covidien
PB 980

PAV+

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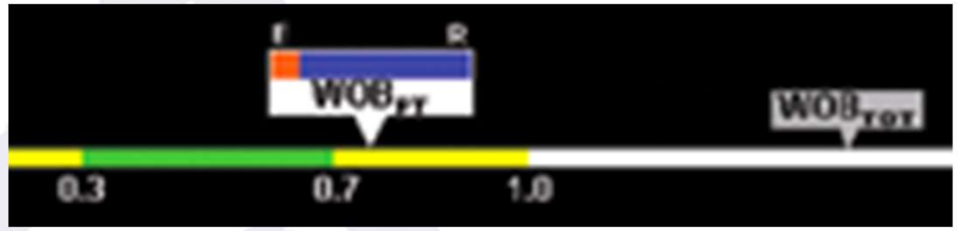
PAV+



- The WOB bar displays total (WOBtot) and the patient (WOBpt).

Work of breathing calculated using the equation of motion.

- When R and E are known, it's possible to calculate (Pmusc) &WOB
  PMUSC + PVENT = (flow x resistance) + (volume x elastance)

- PAV+ measures resistance and compliance every 4-10 breaths.
- Once %Support is set, clinicians use (WOB) bar for feedback on
  pt WOB vs. vent WOB

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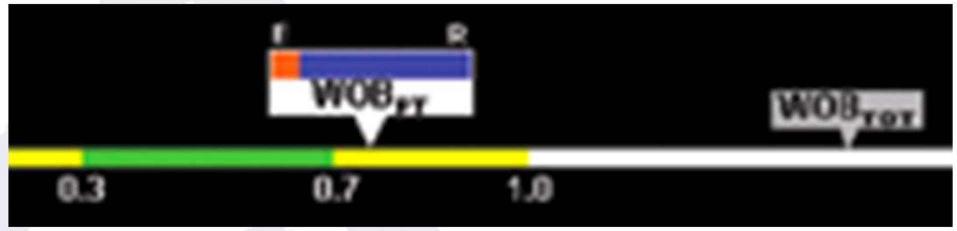
PAV+



Fatigue values for work of breathing are shown as being outside the green zone.

WOB bar and clinical assessment, determine level of ventilator support.

WOB feedback keeps the patient at a sustainable level of work—reducing respiratory muscle atrophy, but off-loading enough work to avoid fatigue.

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Covidien –
PB840 & PB980

PAV+

Comments:

- Patient must be breathing spontaneously
- Focuses on WOB
- Alarms when outside limits

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Other Automation

- Open Lung Maneuvers (Recruitment)
- Ramping up pressure or volumes
- ET tube compensation
- Oxygenation - changing PEEP & F_IO_2
- Monitoring weaning goals and reporting

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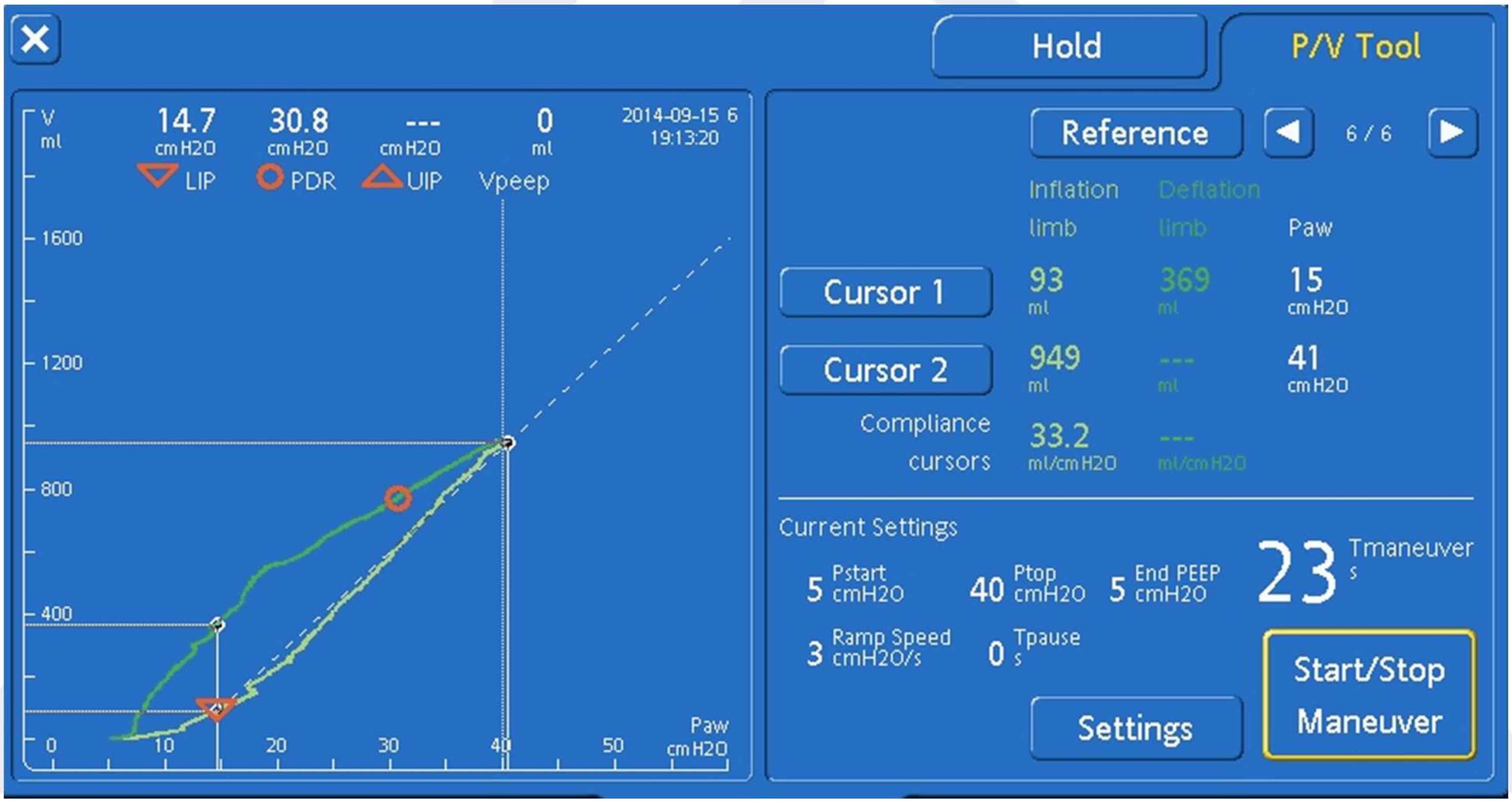
Automated Recruitment Maneuver and Inflection Points



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How do We Know if We are doing Better?
What is the Quality Measure for Ventilator Patient Safety?

Ventilator Length of Stay (VLOS)

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What Contributes to Ventilator LOS?

Conventional Wisdom: The ventilator LOS is a function of the patient's disease process.

(just reverse the pathology and wean the patient)

- ↓ Expiratory Resistance
- ↑ Lung/thoracic compliance
- ↑ Respiratory drive
- ↑ Respiratory muscle strength
- Improve oxygenation

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What Contributes to Ventilator LOS?

- Critical thinking – ventilator LOS is a function of many factors in addition to the patient's underlying pathology
  - Correct diagnosis and treatment
  - Decision to intubate and ventilate
  - Patient/family attitudes and wishes
  - Physician's ventilator management style
  - ICU teamwork
  - …………………………………………….

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Why is Ventilator LOS Important?

Patient safety

Quality of care

Cost to the hospital

Cost to payors

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What is the Ventilator LOS in Your Medical Center?

- Do you know it?
- How is it measured?

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Assess Patient safety Using Ventilator LOS

- Each unnecessary day on a ventilator in ICU exposes the patient to increased chance of healthcare related infections, injury, and death.

- Your worst nightmare? My worst nightmare……. being on a ventilator!

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Assess Quality of Care Using Ventilator LOS

Ability to implement ventilator care improvement tactics and measure outcomes

- New equipment
- New techniques
- New processes and/or protocol
- Changes in staffing

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Assess Cost to the Hospital Using Ventilator LOS

- Reduced ventilator LOS has been clearly correlated with reduced ICU LOS and hospital LOS
- This “thru put” increases opportunity for reimbursement

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Ventilator Discontinuation

Controversies:

T-piece trial vs

SIMV vs

Pressure support

Spontaneous Breathing Trial (SBT) either
T-piece or low level pressure support (PS)

Eur Respir J 2007; 29: 1033–1056

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Ventilator Management
Standard of Care

- There is no clear standard of care
- Physician specific management styles
- Hospital standards vary
- Community standards vary
- State – no standards
- National – few standards
- International –few standards

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Use of Ventilator Protocols

- Patient driven
- Therapist driven
- Nursing protocols
- Microprocessor embedded

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If you don’t measure it; you can’t assess interventions

Improve our end-of-life conversations

Palliative care
Futile care
Comfort measures
Code Status

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Summary

Take home message:

1. Appreciate Importance of Patient Safety
2. Embrace Increased use of Automation
3. Learn how to measure ventilator length of stay accurately

"If you can't measure it;

it doesn't count"

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THE END