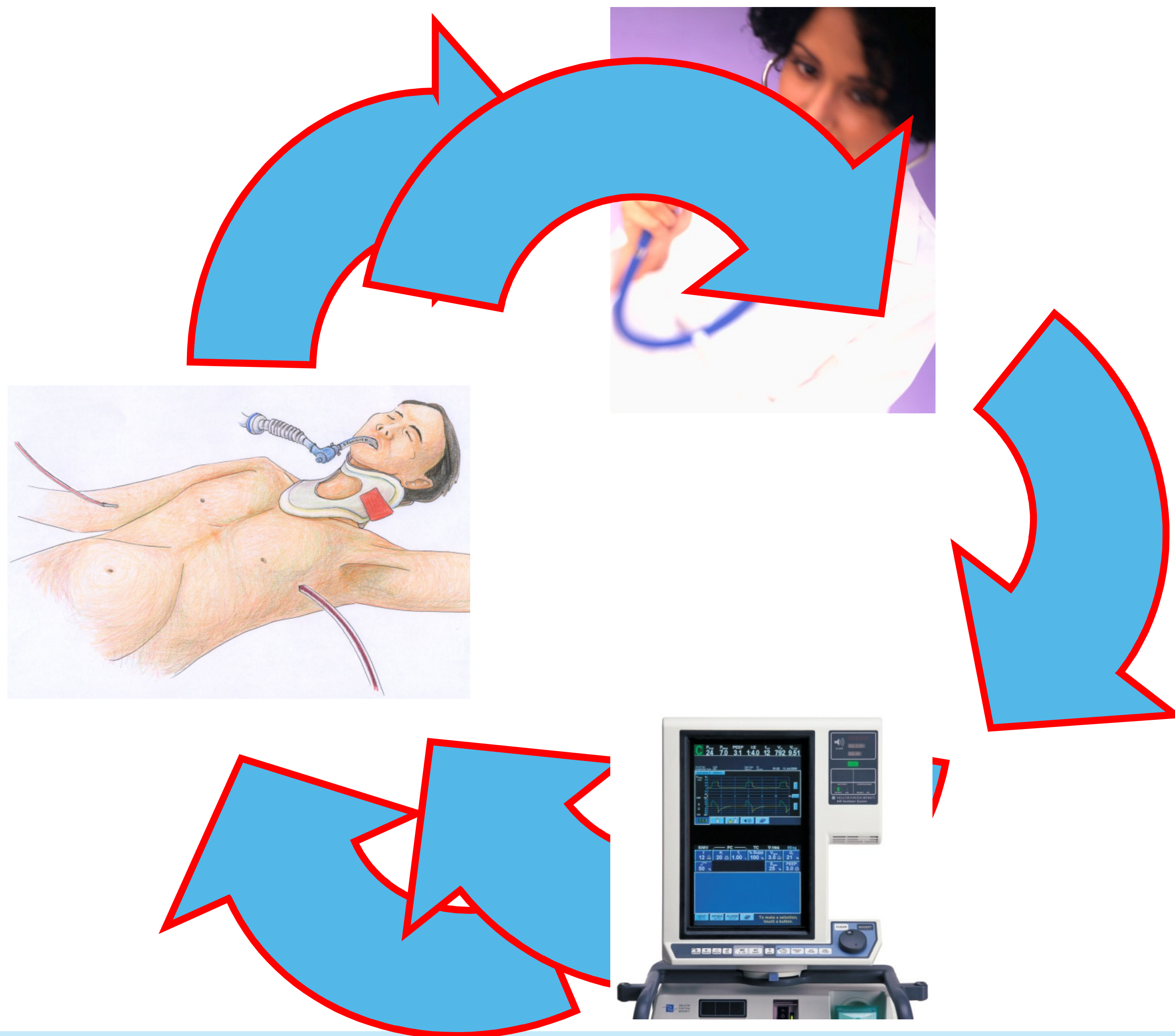
Closing the Loop on Mechanical Ventilation:

COVIDIEN

PAV™+ Software Option Clinical Description



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PAV™+ Software Option Clinical Description

Closed-loop ventilation based on WOB. Now the patient's respiratory center in his brain is in charge of all aspects of ventilatory rate, depth and pattern.

PAV™+ Software Option Clinical Description

WOB comes from…

1. Resistance of the patient's airways.
2. Resistance of the artificial airway.
3. Lung compliance.
4. Chest wall compliance.

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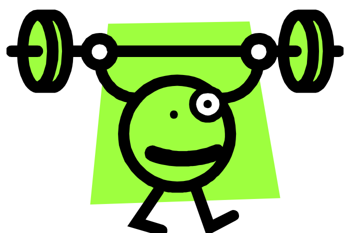
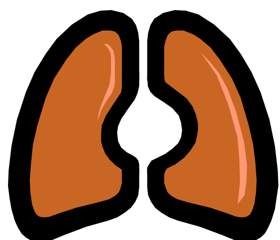
PAV™+ Software Option Clinical Description





The ventilator now has the ability to continuously assess the total work of breathing (WOB) and uses this information to determine how much support is needed.

The ventilator achieves this by measuring compliance and resistance every 4 to 10 breaths randomly.

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PAV™+ Software Option Clinical Description

The clinician will NOT set a rate, tidal volume, flow or target pressure. Instead, the clinician will simply set the percentage of *work* that the ventilator should do.

f ✗ V_t ✗ $\dot{V}$ ✗ P_i ✗ %Supp

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PAV™+ Software Option Clinical Description

SPONT

VC
Manual Insp only

PA

$\dot{V}$-TRIG

50 kg

V_T 510 mL

$\dot{V}_{MAX}$ 56 L/min

% Supp 75 %

$\dot{V}_{SENS}$ 3.0 L/min

O_2 21 %

T_{PL} 0.0 s

RAMP

E_{SENS} 3 %

PEEP 3.0 cm H_2O

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PAV™+ Software Option Clinical Description

Q. How does the clinician know where to set the *%Support*?

1. Sound clinical assessment

2. Work of Breathing (WOB) bar

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PAV™+ Software Option Clinical Description

Sound Clinical Assessment.

Vital signs

ABG

Signs of respiratory distress

- Respiratory rate > 40 breaths/minute
- Marked use of accessory muscles
- Diaphoresis
- Abdominal paradox
- Marked complaint of dyspnea

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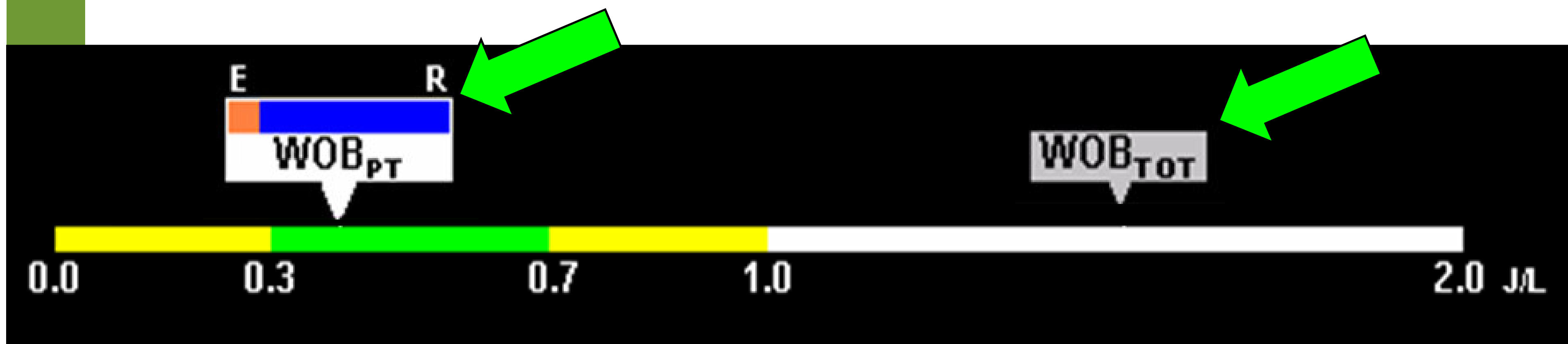
PAV™+ Software Option Clinical Description

Real-time assessment of WOB.



Pt=25% of work

Vent=75% of work

Effort is *amplified* by a factor of **4** with a *proportionality* ratio of **3:1**

% Supp 75 %

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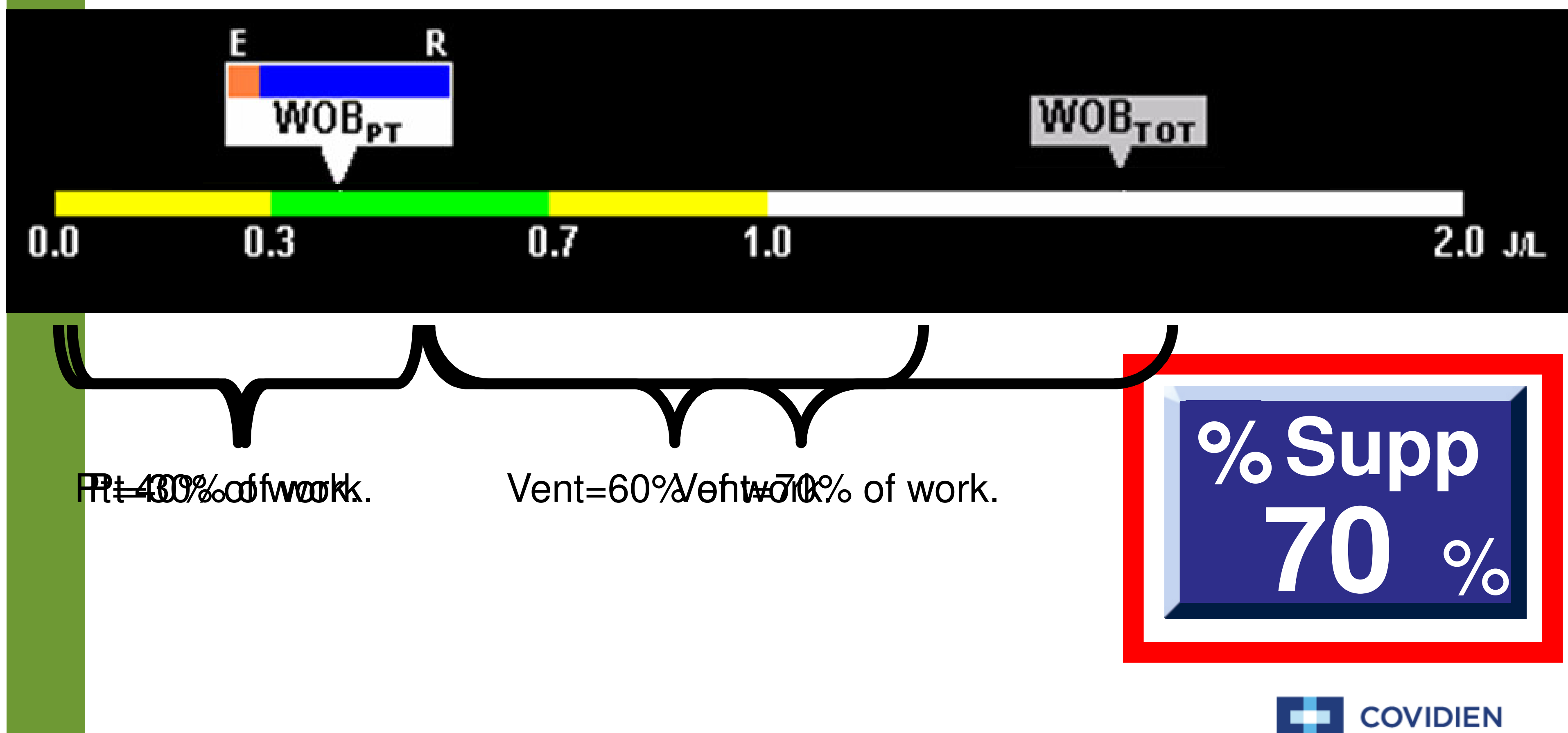
PAV™+ Software Option Clinical Description

Suppose there is an improvement in compliance.

Suppose there is an increase in airway resistance.



S

P_{PEAK}	P_{MEAN}	PEEP	I:E	f_{TOT}	V_{TE}	$\dot{V}_{E\,TOT}$
24	5.6	3.0	1:7.0	4.9	388	2.14

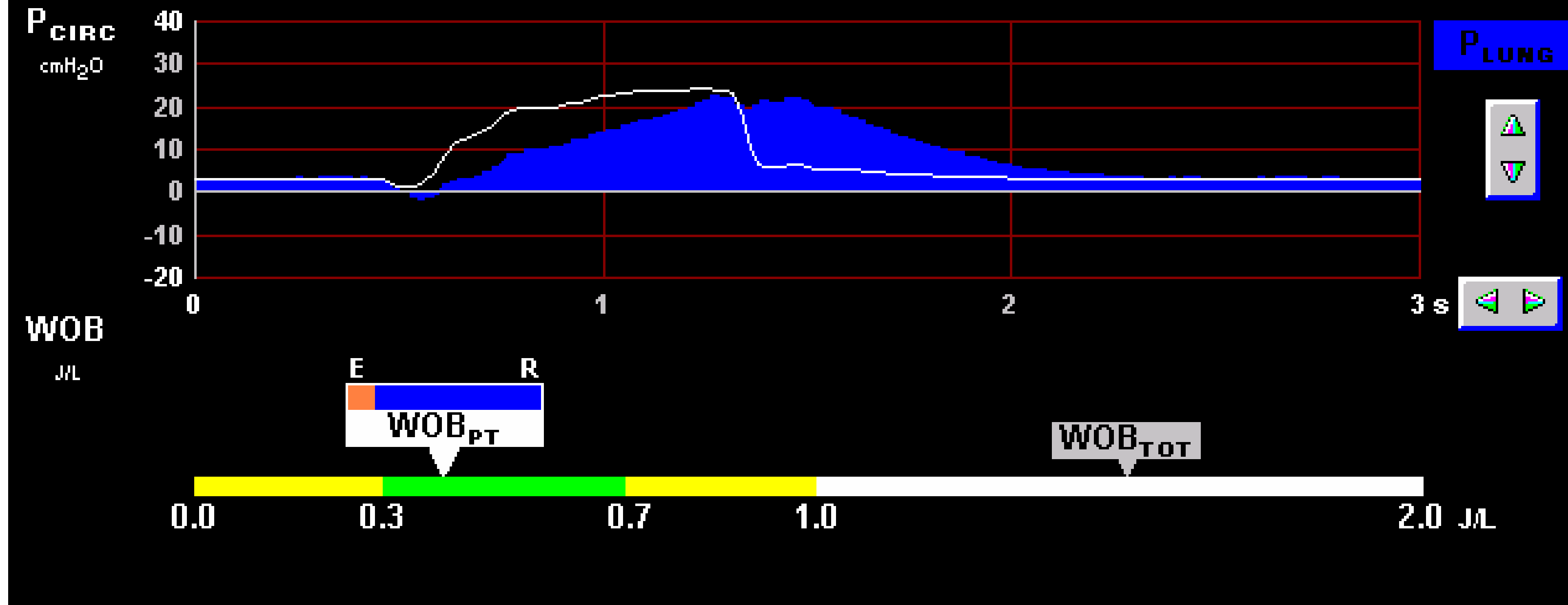
Circuit Type: Adult
Humidification Type: HME

Tube Type: ET
Tube I.D.: 10.0 mm

14:59 05 Aug 2003

PLOT SETUP UNFREEZE

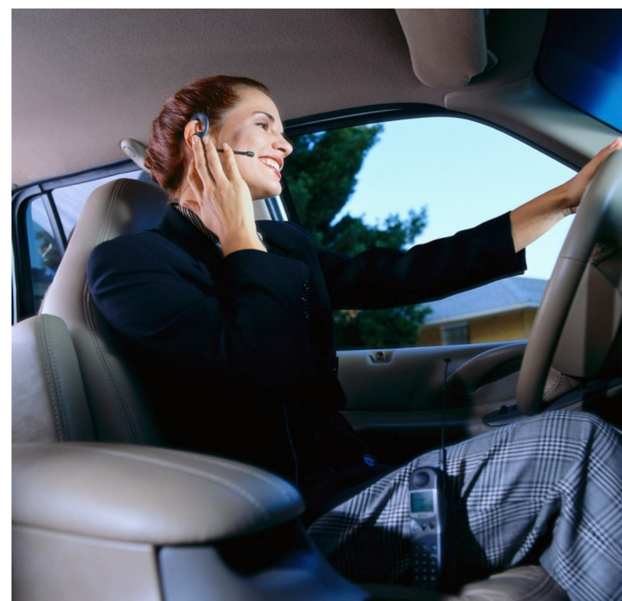
C_{PAV} 20 $\frac{mL}{cmH_2O}$ R_{PAV} 17 $\frac{cmH_2O}{L/s}$ $PEEP_I$ 0.1 cmH_2O



PAV™+ Software Option Clinical Description

PAV+ software *amplifies* patient effort.

Think about power steering in a car.



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PAV™+ Software Option Clinical Description

$$AMP = \frac{1}{1 - \%Supp}$$

For a setting of 75% support

$$AMP = \frac{1}{1 - 0.75}$$

$$AMP = \frac{1}{0.25}$$

$$AMP = 4$$

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PAV™+ Software Option Clinical Description

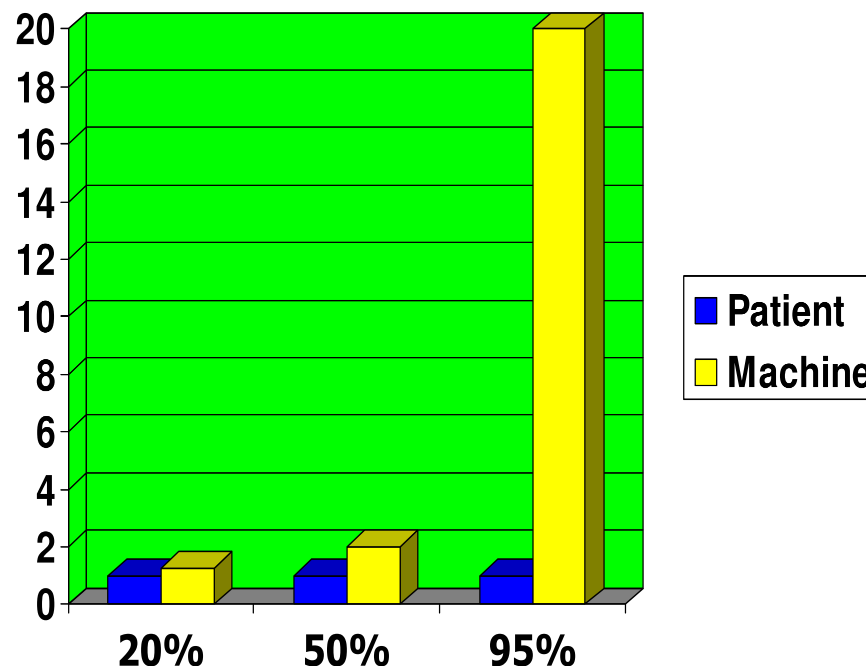
Amplification of Patient Effort

Small at low levels and high at high levels

20% Support 1.25:1

50% Support 2:1

95% Support 20:1



$$AMP = \frac{1}{1 - \%Supp}$$

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PAV™+ Software Option Clinical Description

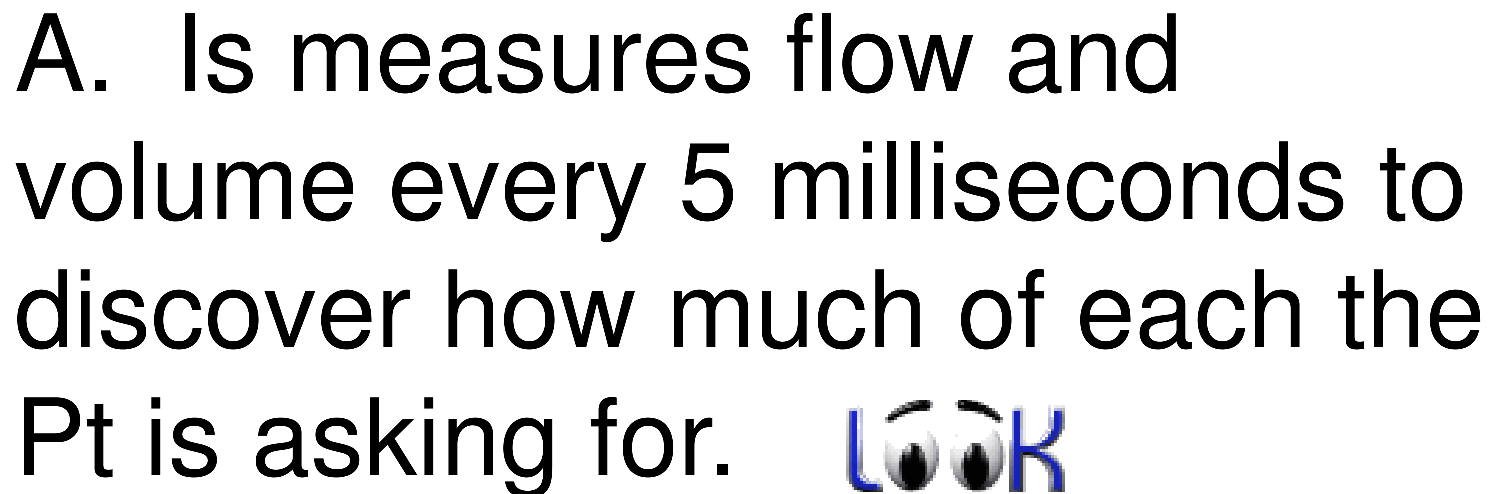
Proportionality vs. Amplification

% Support	Pt Contribution	Proportionality	Amplification
25	75	1:3	1.3
50	50	1:1	2.0
75	25	3:1	4.0
90	10	9:1	10.0

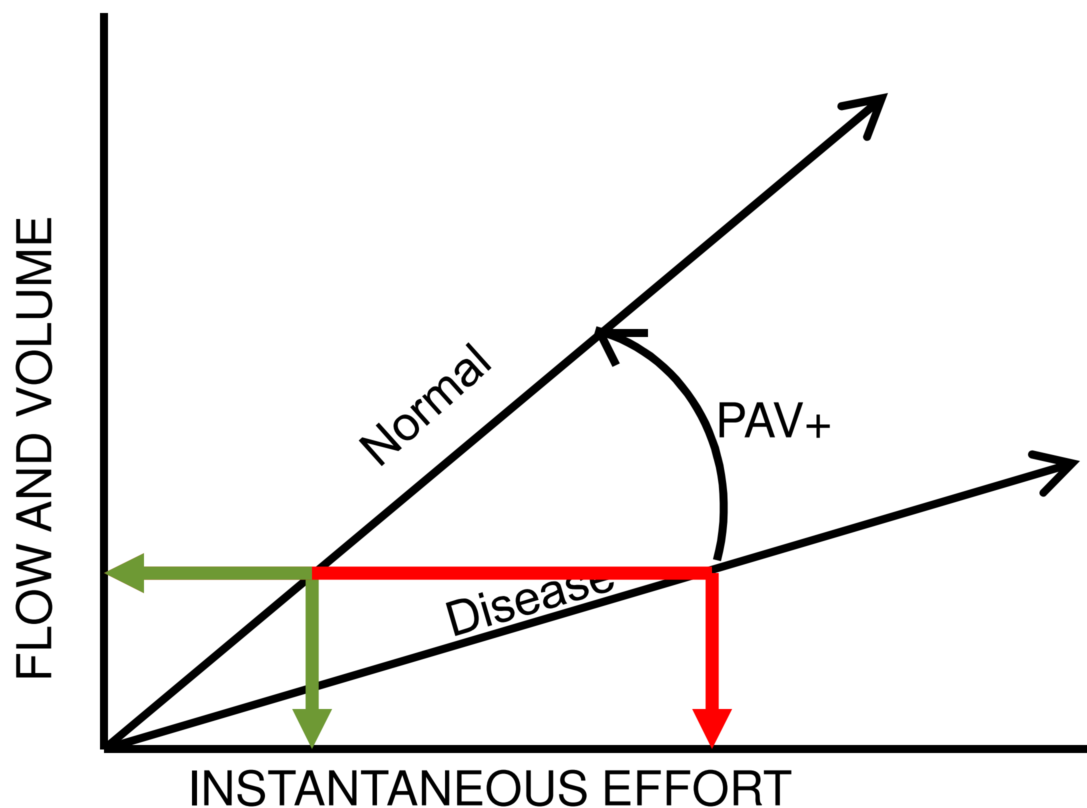
PAV™+ Software Option Clinical Description

Q. How does the ventilator assess the patients effort?

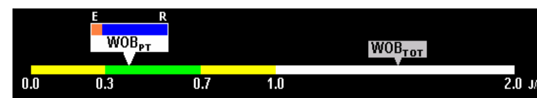
A. Is measures flow and volume every 5 milliseconds to discover how much of each the Pt is asking for.



PAV™+ Software Option Clinical Description



"Normal" is the GREEN ZONE



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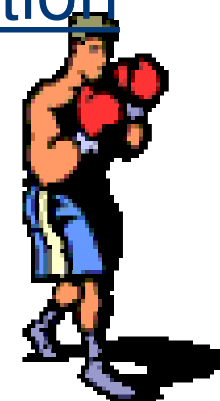
PAV™+ Software Option Clinical Description



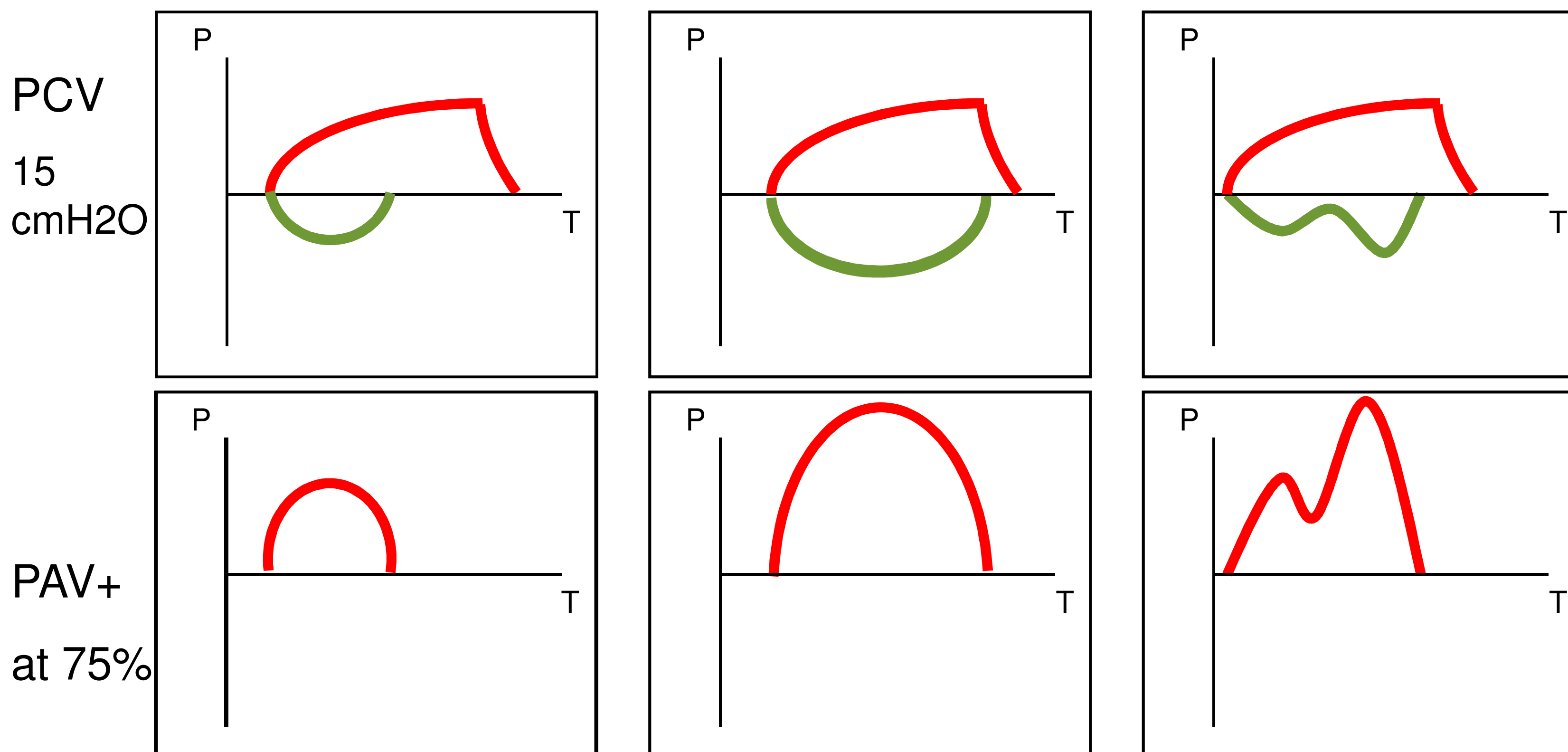
PAV+ uses the compliance and resistance information collected every 4-10 breaths to know what it's *fighting against*.

PAV+ uses the flow and volume information collected every 5 milliseconds to know what the *patient wants.*

PAV+ combines this data with the %Supp information input by the clinician to determine *how much pressure* to supply to the system.

PAV™+ Software Option Clinical Description

Compared to PCV, the PAV+ mode better matches effort to ventilator output.



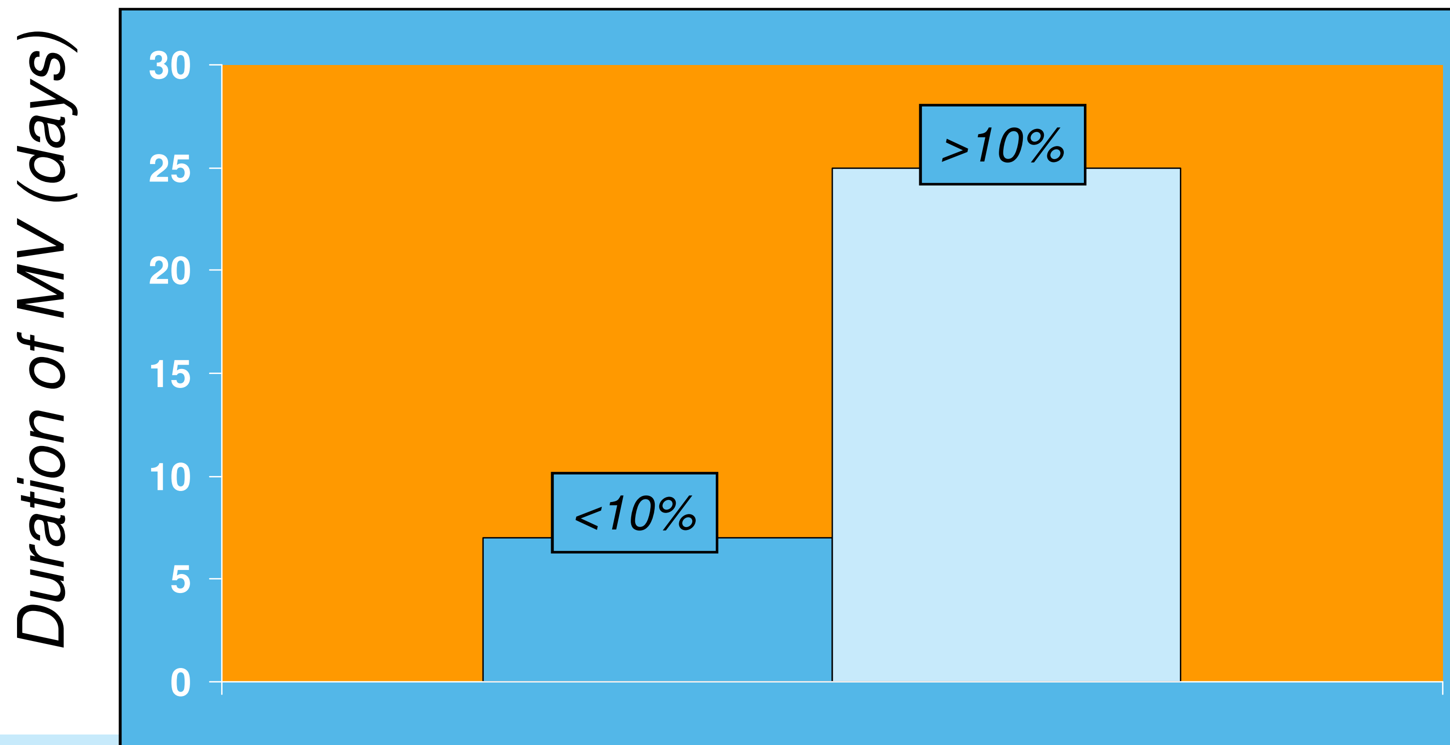
PAV™+ Software Option Support and Literature

Arnaud W. Thille
Pablo Rodriguez
Belen Cabello
François Lellouche
Laurent Brochard

Patient-ventilator asynchrony during assisted mechanical ventilation

Intensive Care Med. 2006;32:1512

24% of mechanically ventilated patients exhibit patient-ventilator asynchrony in > 10% of their respiratory efforts during AVC and PS ventilation (ineffective triggering and double triggering).



PAV™+ Software Option Support and Literature

Cost of an Intensive Care Unit Day: The Contribution of Mechanical Ventilation

- Setting: 253 diverse US hospitals
- Sample: 51,000 patients
- 36% of patients were ventilated at some point
- Average cost for a ventilated ICU patient = $3,968

Dasta J et al. *Crit Care Med.* 2005;33:1266-1271.

PAV™+ Software Option Support and Literature

The Cost of Asynchrony Adds Up

Asynchronous patients require an additional 18 days on average to ventilate[1]

The average daily cost of a ventilated patient is about $4,000[2]
One asynchronous patient can cost:

18 days x $4,000 = $72,000

1. Thille AW et al. Patient-ventilator asynchrony during assisted mechanical ventilation. *Intensive Care Med.* 2006;32:1512.

2. Dasta J et al. *Crit Care Med.* 2005;33:1266-1271.

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PAV™+ Software Option Clinical Description

PAV Potential Benefits

1. Comfort.
2. Lower peak airway pressure.
3. Less need for paralysis and/or sedation.
4. Less likelihood for over ventilation.
5. Preservation and enhancement of patient's own control mechanisms such as metabolic ABG control and Hering-Breuer reflex.
6. Improved efficiency of negative pressure ventilation.

M Younes. Proportional Assist Ventilation, A New Approach to Ventilatory Support. Theory. *Am Rev Respir Dis* 1992;145:114-120.

COVIDIEN

PAV™+ Software Option Clinical Description

PAV+ is NOT recommended for…

1. Low drive due to meds.
2. Abnormal breathing pattern.
3. Extreme air trapping.
4. Large mechanical leaks (TEF).

PAV™+ Software Technical Description

Algorithm

- Four breath start-up.
- Each includes an end-inspiratory maneuver that yields patient's compliance and resistance.
- First breath is delivered using the predicted resistance for the artificial airway and a conservative estimate for a patient's resistance and compliance based on IBW. NOTE: IBW must be correct!
- Each valid measurement is then factored in until the fifth breath, which is the first *PAV+* breath.
- Measurements for compliance and resistance are then taken randomly every 4-10 breaths.
- Flow and volume is assessed every 5 milliseconds.

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PAV™+ Software Option Support and Literature

PAV

No C and R

PAV +

Updates Compliance and Resistance every 4–10 breaths.

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