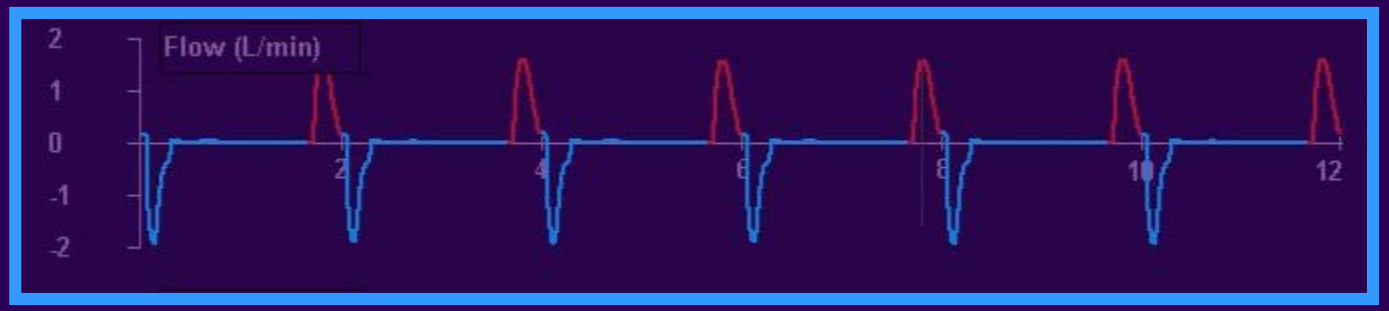
Neonatal Pulmonary Graphics: Every Breath You Take…



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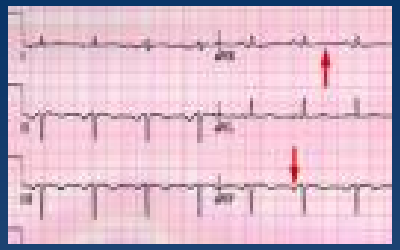
University of Michigan Health System



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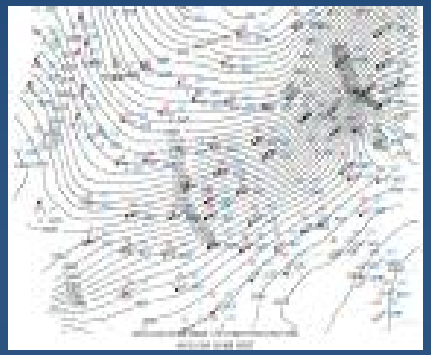
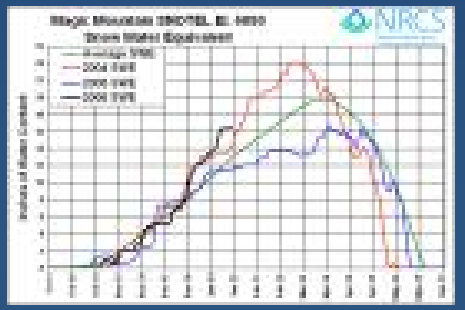
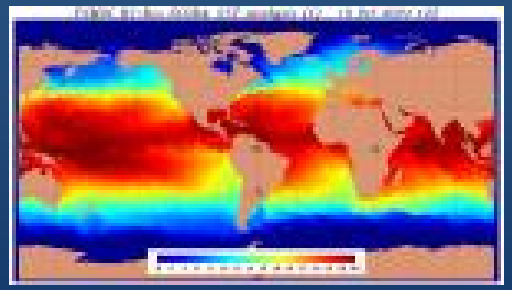
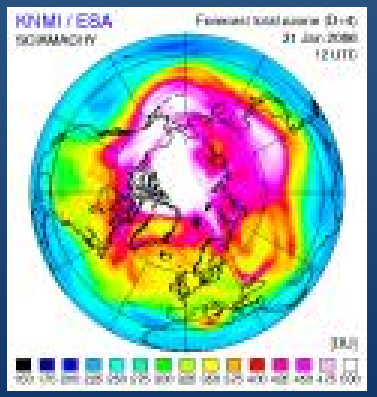
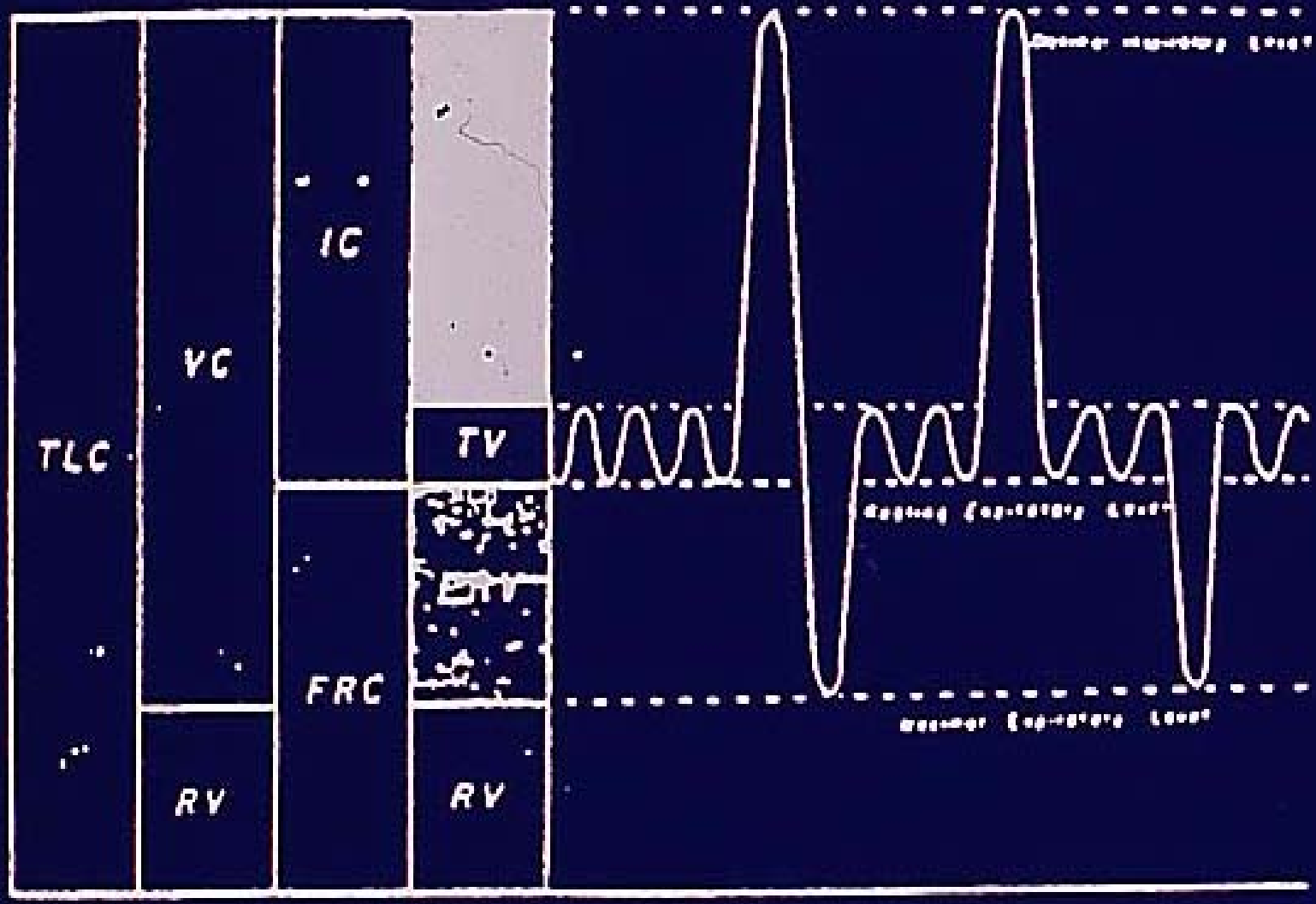




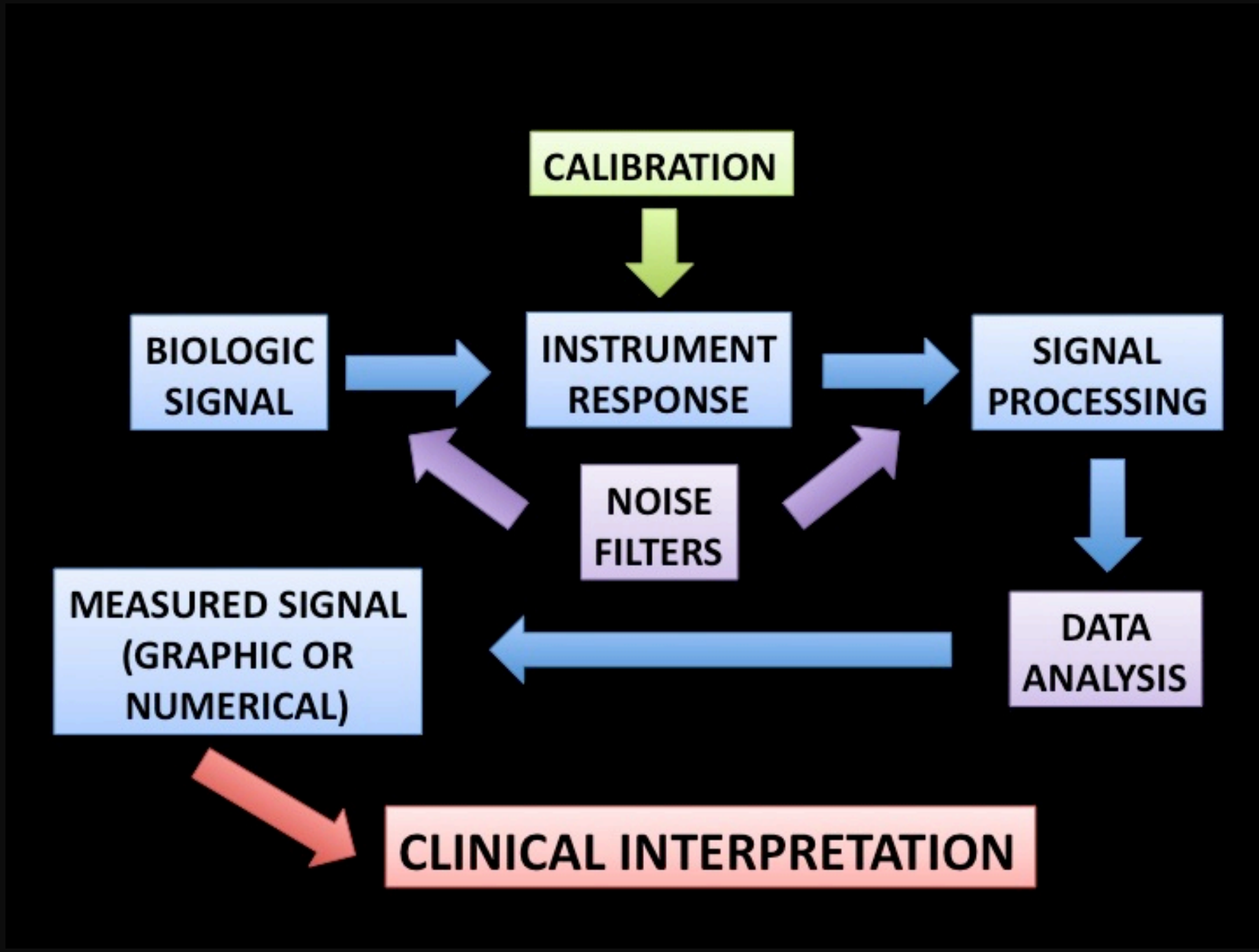





foro
tempio di Giove
archivi del foro
mensa ponderaria
basilica
edifici amministrazione pubblica



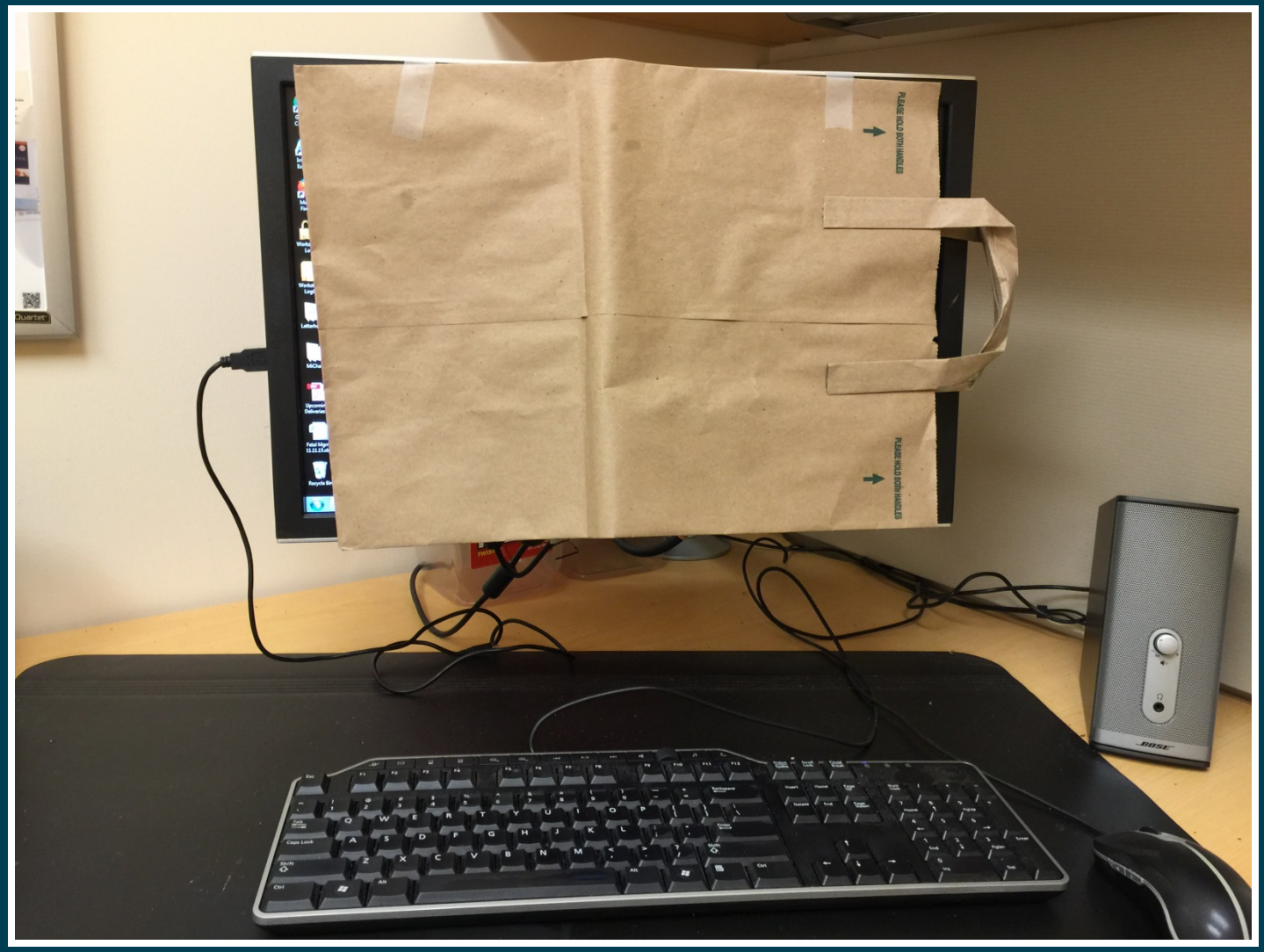
Lung volumes


CALIBRATION
BIOLOGIC SIGNAL
INSTRUMENT RESPONSE
SIGNAL PROCESSING
NOISE FILTERS
DATA ANALYSIS
MEASURED SIGNAL (GRAPHIC OR NUMERICAL)
CLINICAL INTERPRETATION

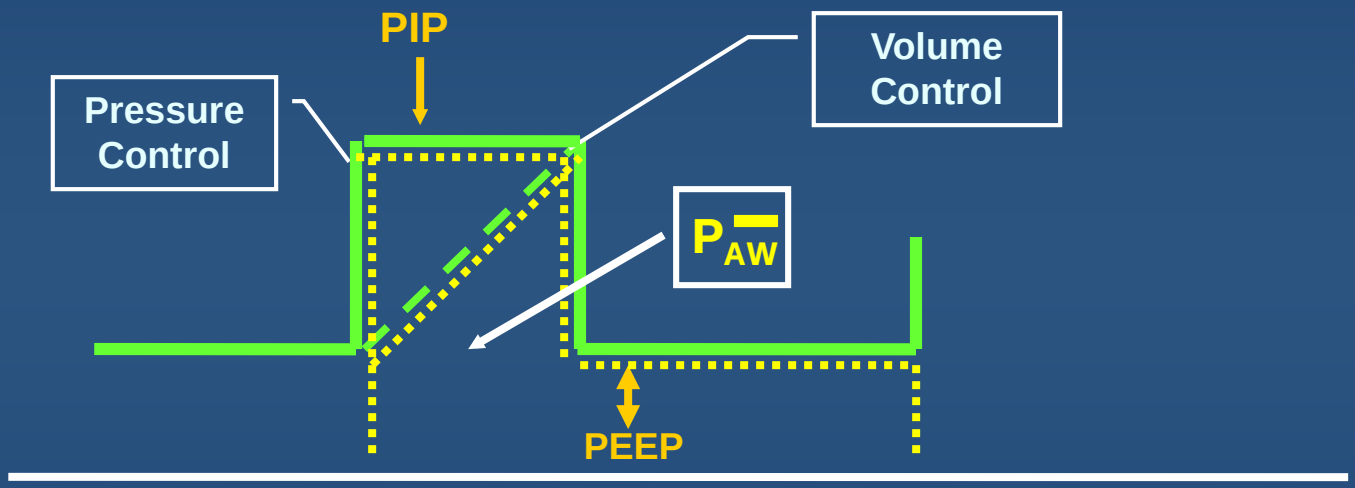

TO PT.


MAGIC Etch A Sketch SCREEN
DONN'S GRAPHIC MONITOR
USE WITH CARE

The Importance of Graphics

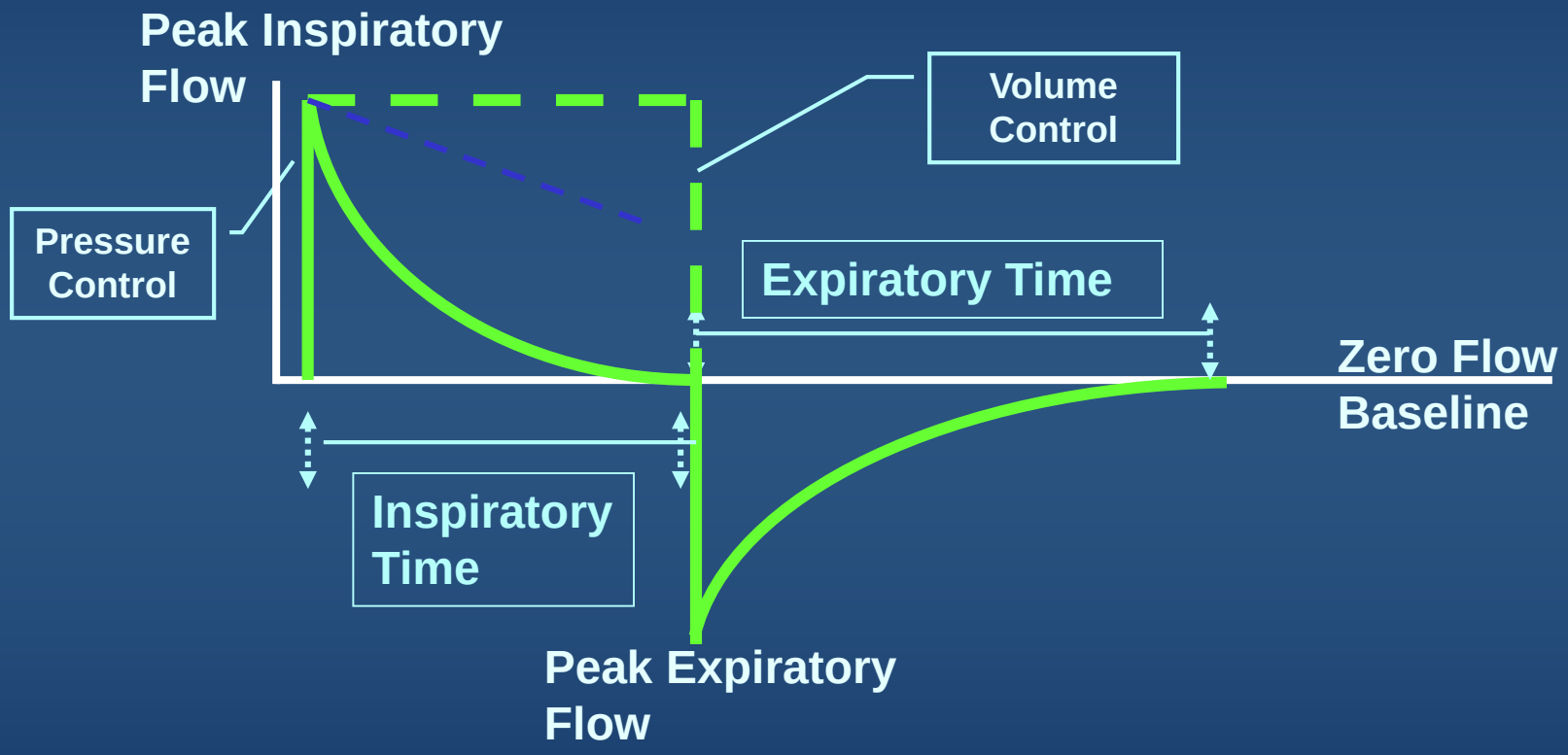


Anatomy of a Pressure Waveform



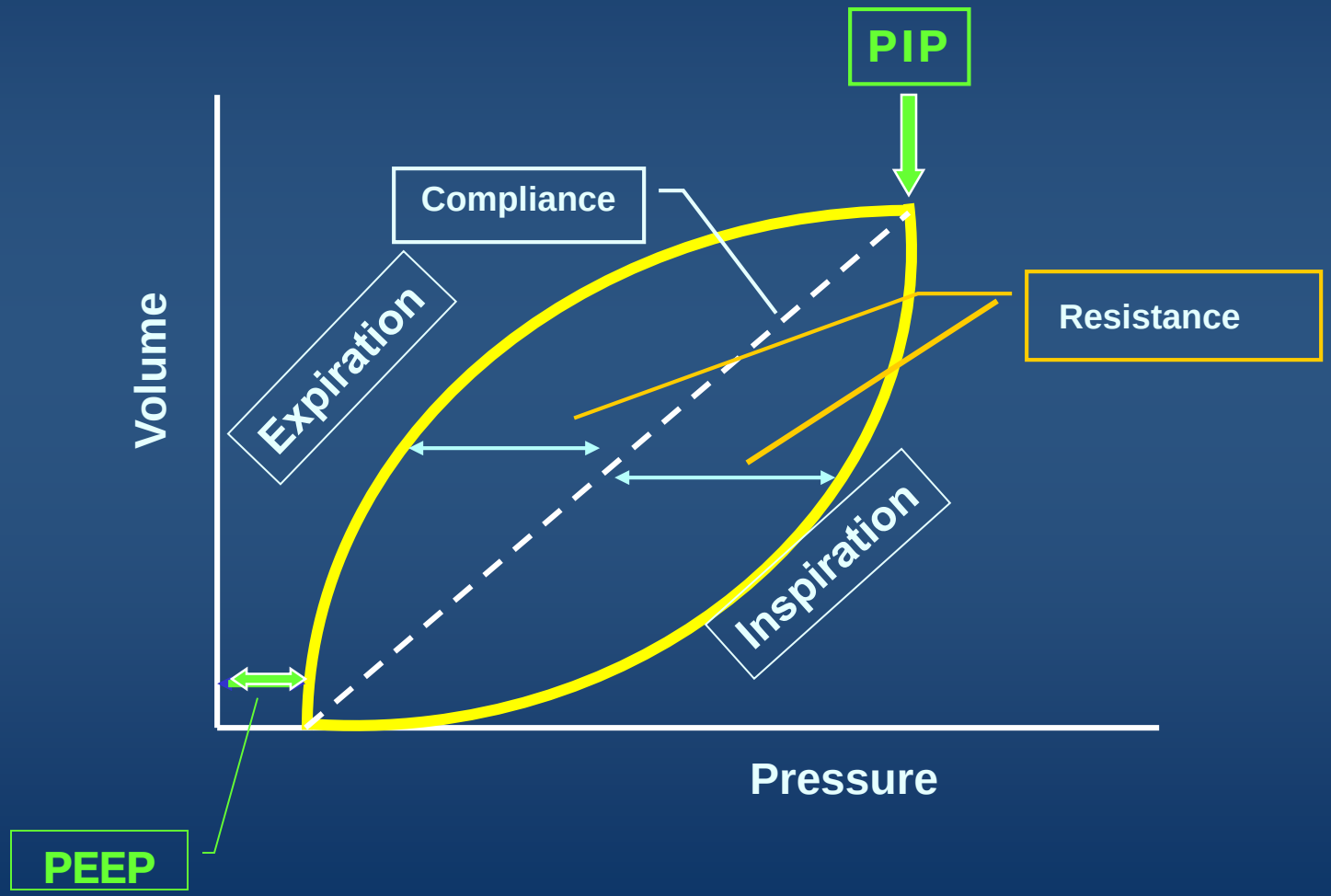
- ✓ Volume Control Ventilation – Triangular Pressure Waveform
- ✓ Pressure Control Ventilation – Square Pressure Waveform

Anatomy of a Flow Waveform

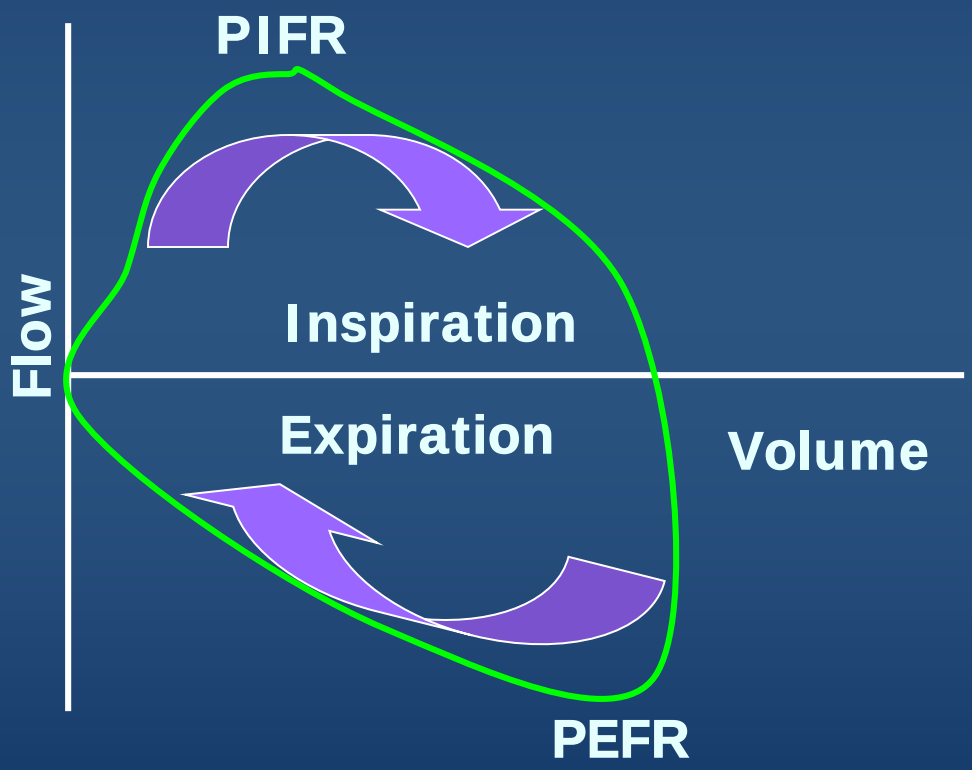


- ✓ Volume Control Ventilation – Constant Square or Deceleration Flow
- ✓ Pressure Control Ventilation – Variable Decelerating Flow

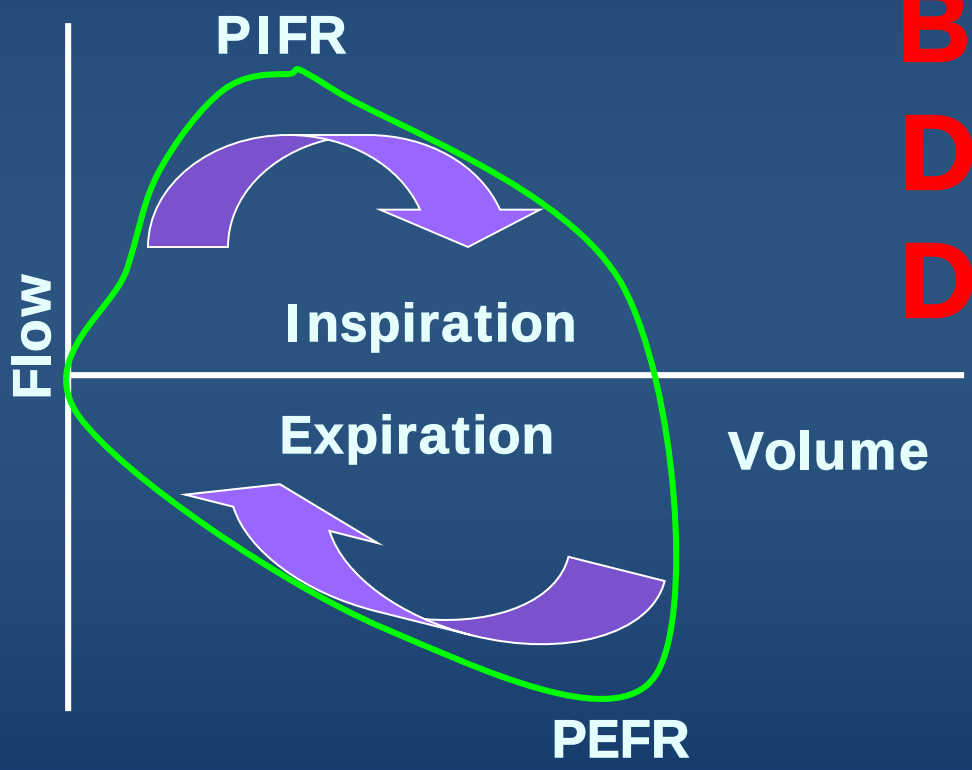
Anatomy of a Pressure-Volume Loop



Anatomy of a Flow-Volume Loop



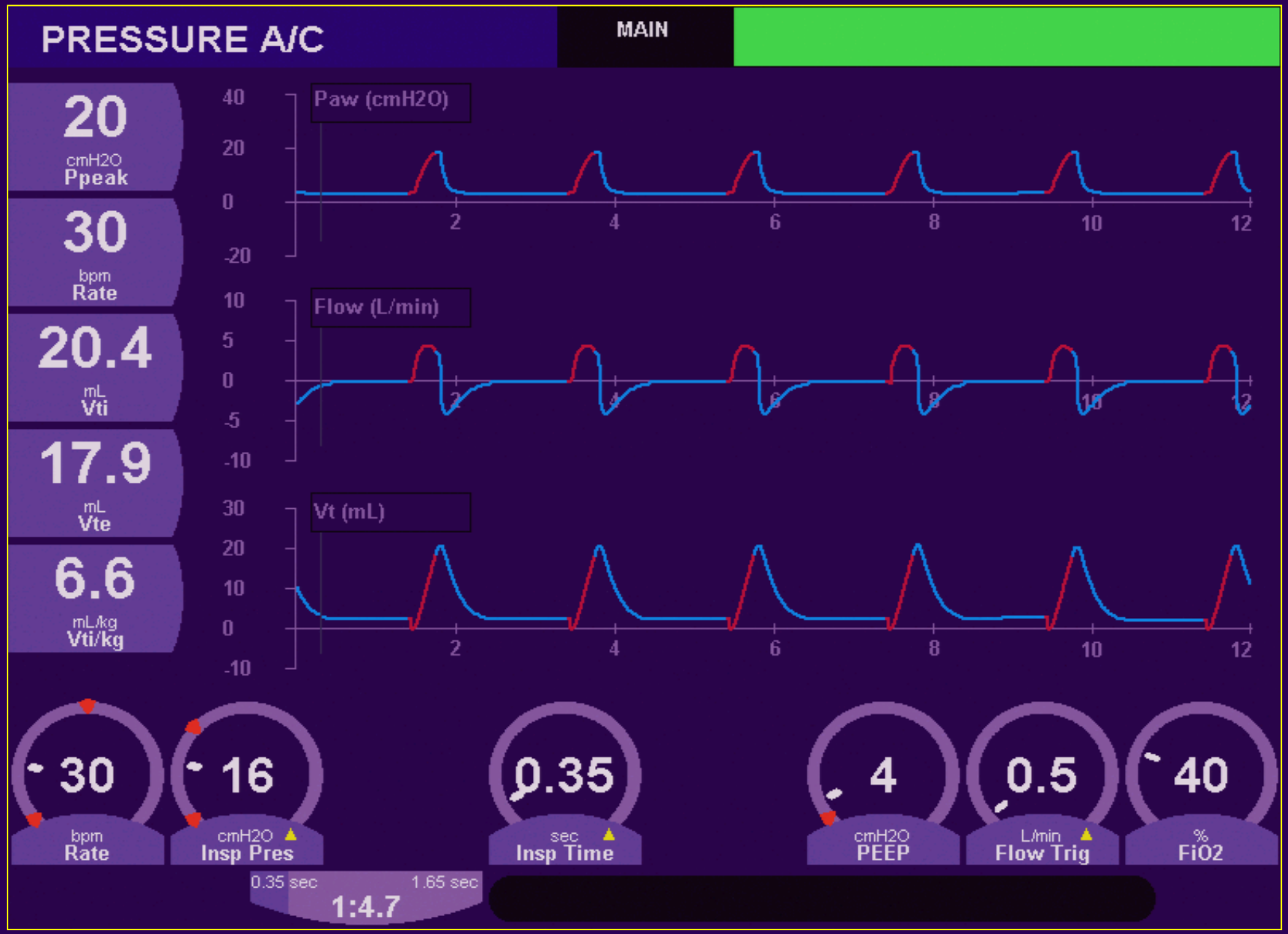
Anatomy of a Flow-Volume Loop

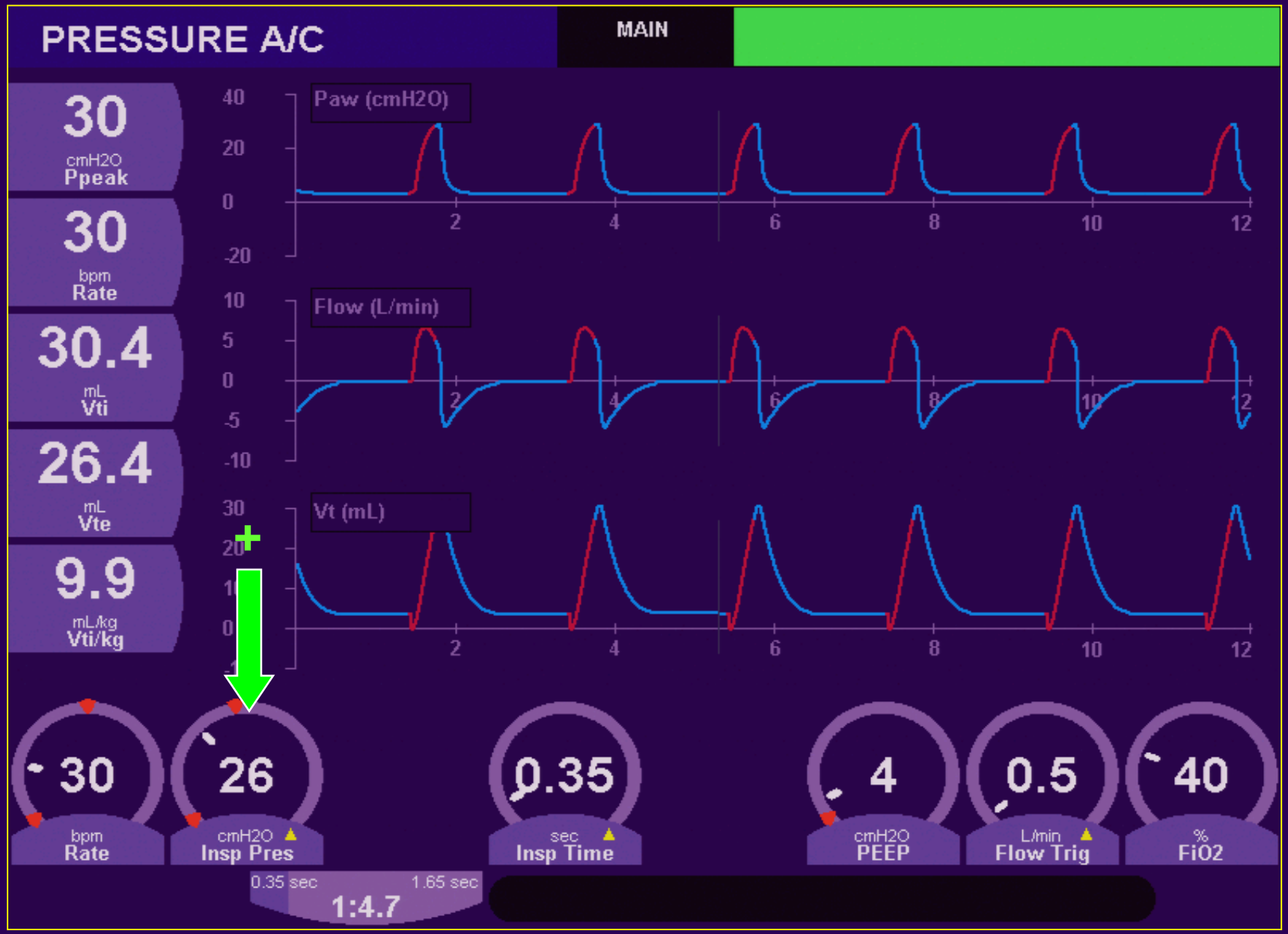


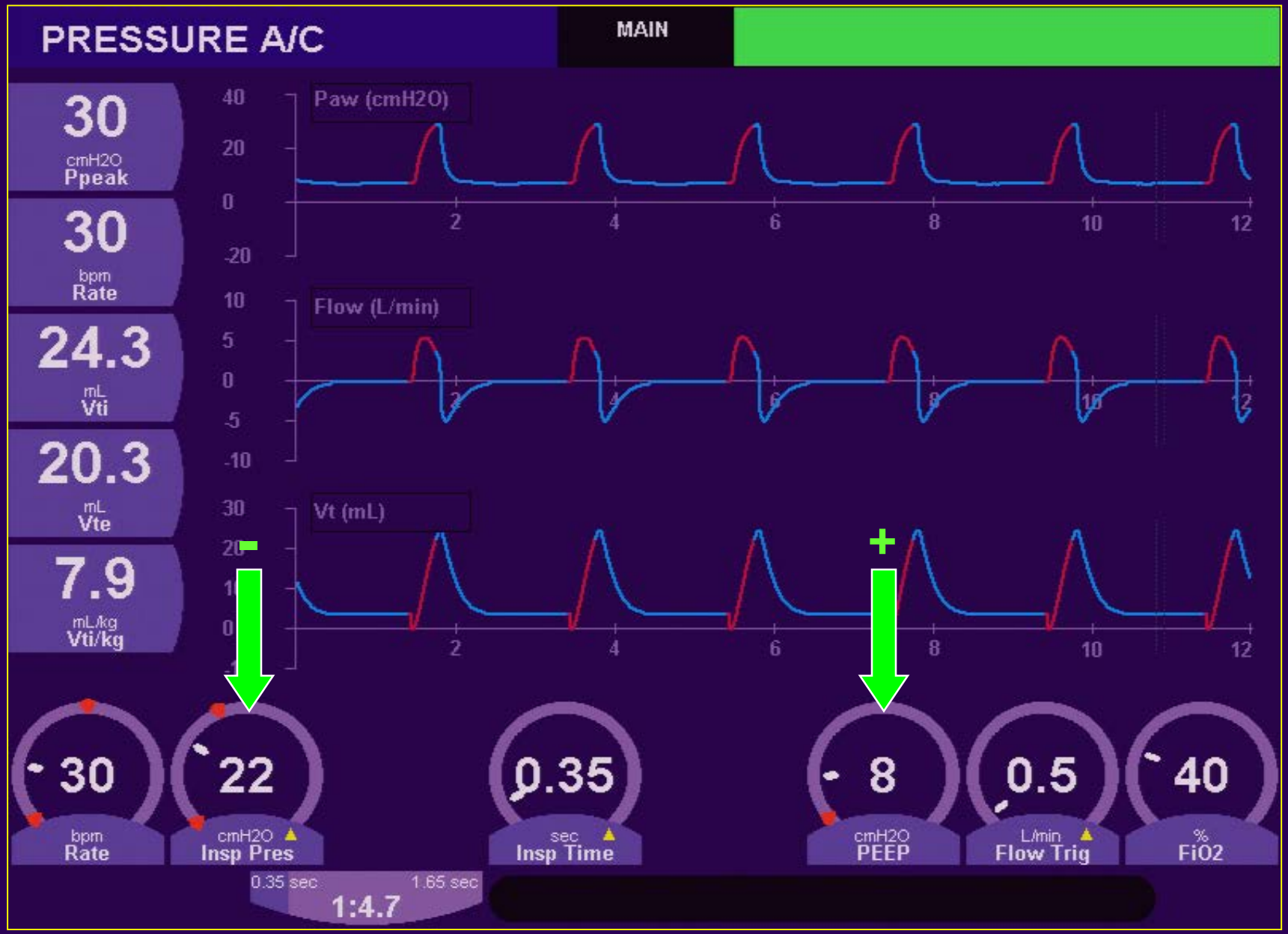
BEWARE OF DEVICE DIFFERENCES!

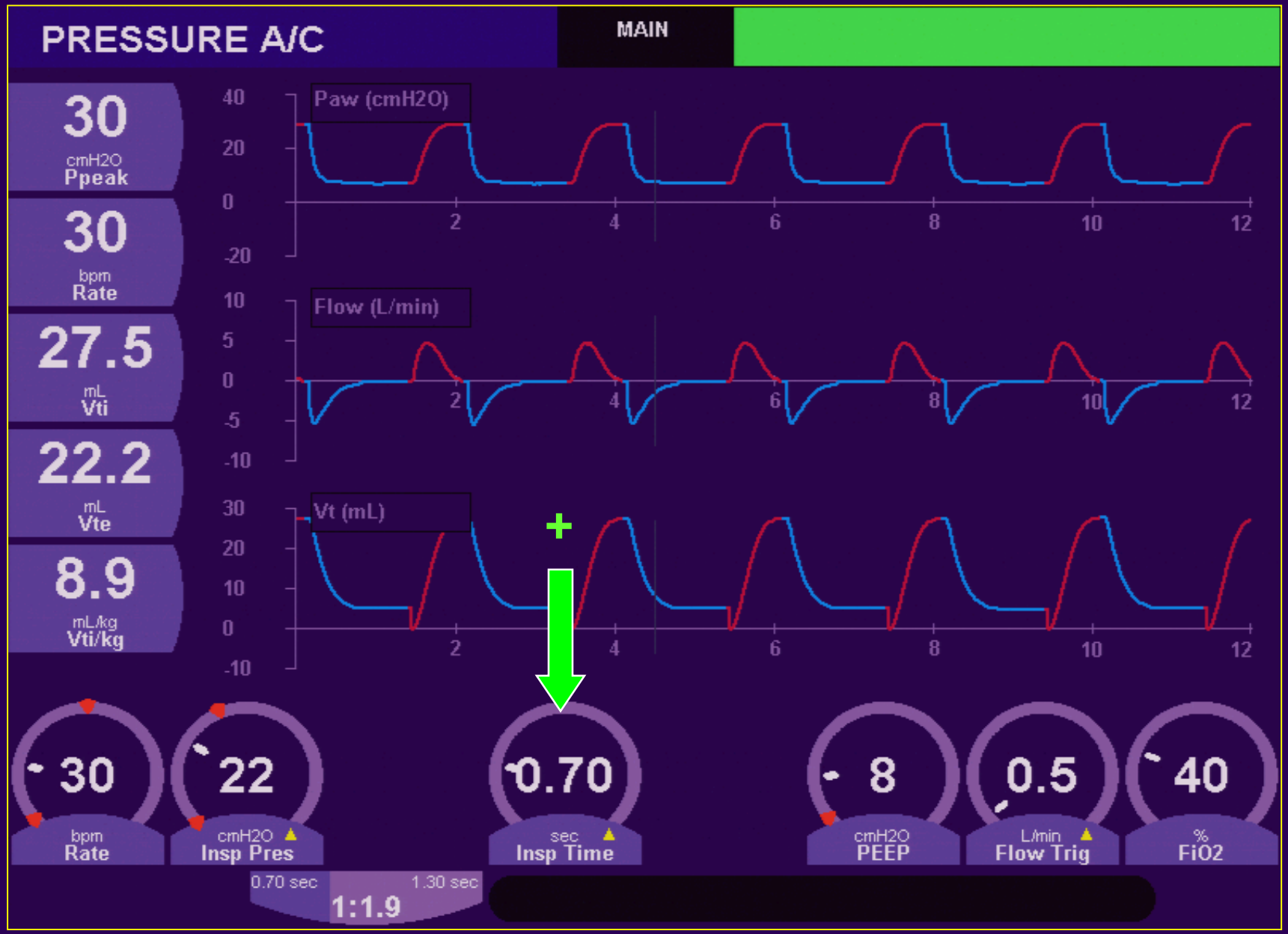
Effect of Pressure Changes

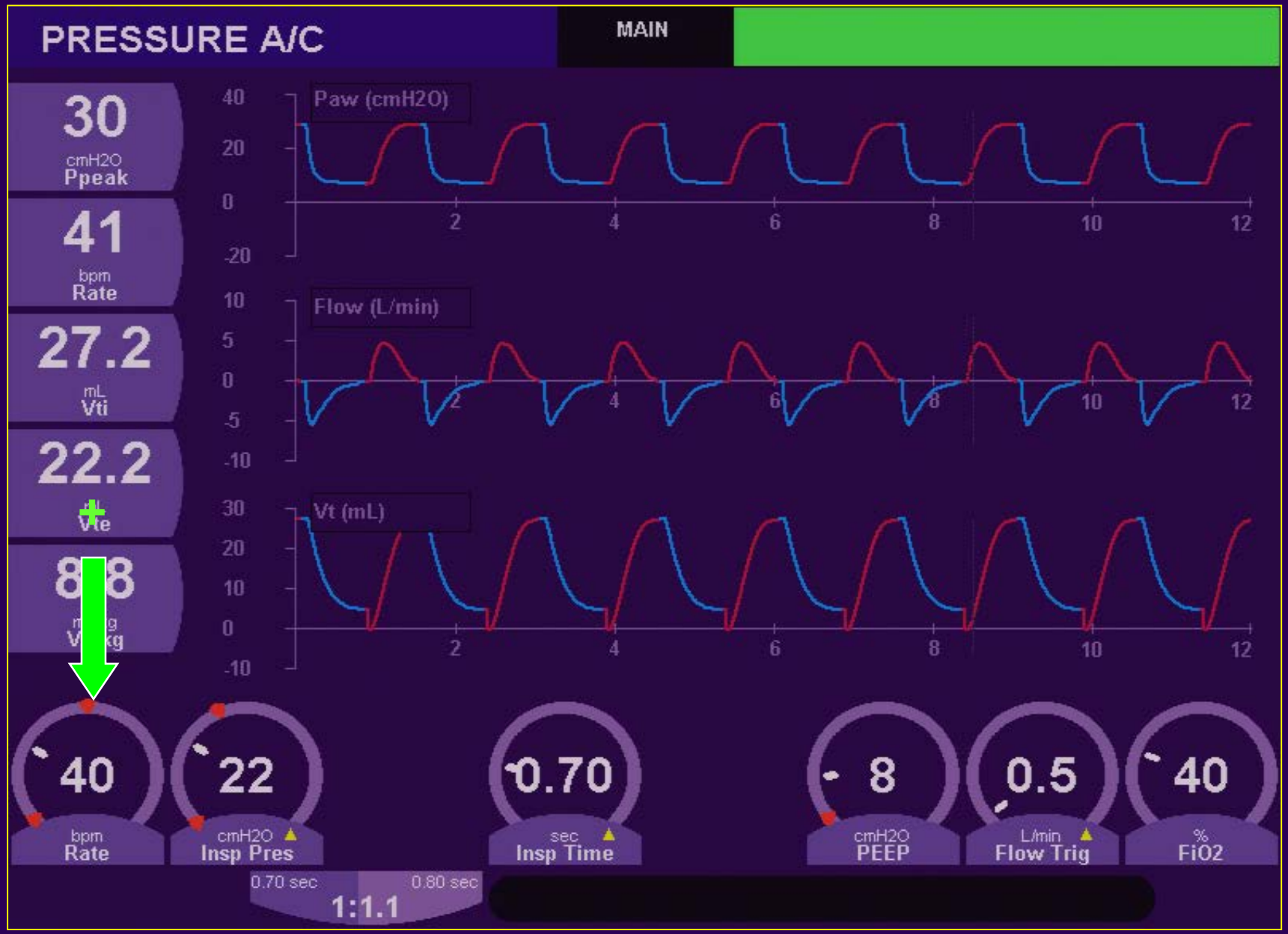
- Oxygenation is proportional to mean Paw
  - PIP
  - PEEP
  - Ti
- Ventilation is proportional to amplitude
  - PIP – PEEP
  - Te

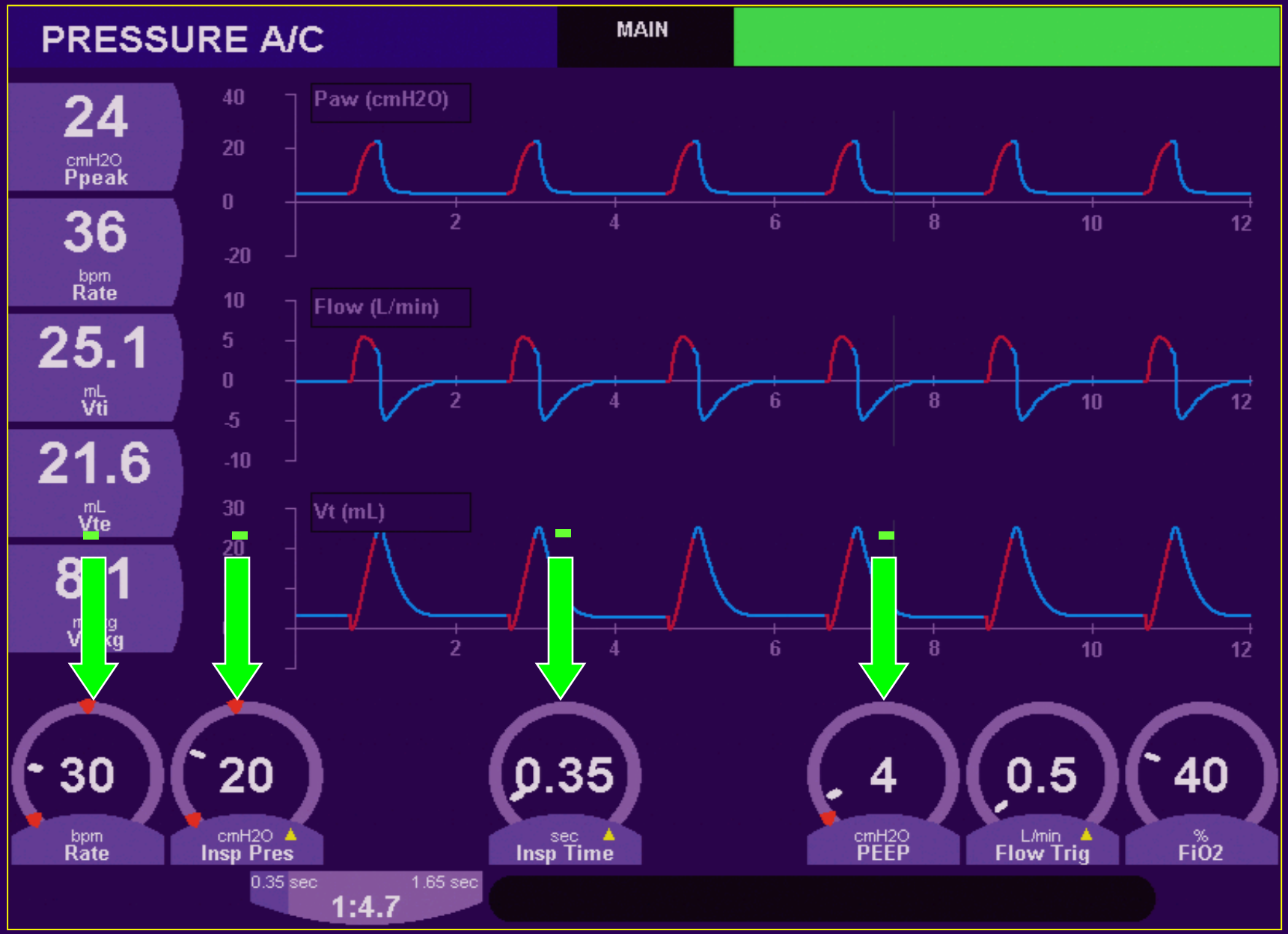

PRESSURE A/C
MAIN
20
cmH2O
Ppeak
30
bpm
Rate
20.4
mL
Vti
17.9
mL
Vte
6.6
mL/kg
Vti/kg
Paw (cmH2O)
40
20
0
-20
2
4
6
8
10
12
Flow (L/min)
10
5
0
-5
-10
Vt (mL)
30
20
10
0
-10
30
bpm
Rate
16
cmH2O
Insp Pres
0.35
sec
Insp Time
4
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.35 sec
1.65 sec
1:4.7

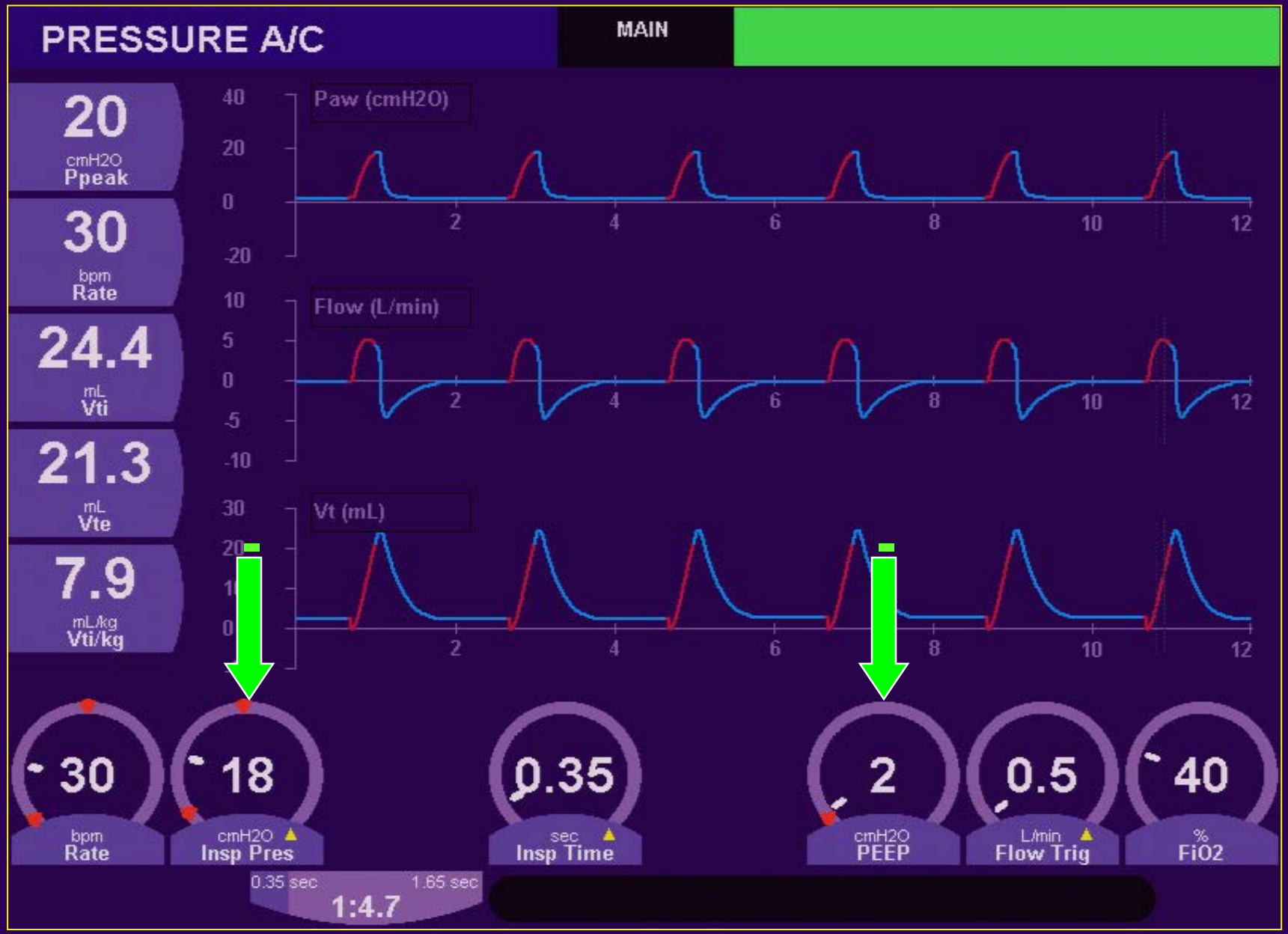

PRESSURE A/C
MAIN
30
cmH2O
Ppeak
30
bpm
Rate
30.4
mL
Vti
26.4
mL
Vte
9.9
mL/kg
Vti/kg
Paw (cmH2O)
Flow (L/min)
Vt (mL)
30
bpm
Rate
26
cmH2O
Insp Pres
0.35
sec
Insp Time
4
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.35 sec
1.65 sec
1:4.7


PRESSURE A/C
MAIN
30
cmH2O
Ppeak
30
bpm
Rate
24.3
mL
Vti
20.3
mL
Vte
7.9
mL/kg
Vti/kg
Paw (cmH2O)
Flow (L/min)
Vt (mL)
30
bpm
Rate
22
cmH2O
Insp Pres
0.35
sec
Insp Time
8
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.35 sec
1.65 sec
1:4.7


PRESSURE A/C
MAIN
30
cmH2O
Ppeak
30
bpm
Rate
27.5
mL
Vti
22.2
mL
Vte
8.9
mL/kg
Vti/kg
Paw (cmH2O)
Flow (L/min)
Vt (mL)
30
bpm
Rate
22
cmH2O
Insp Pres
0.70
sec
Insp Time
8
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.70 sec
1.30 sec
1:1.9

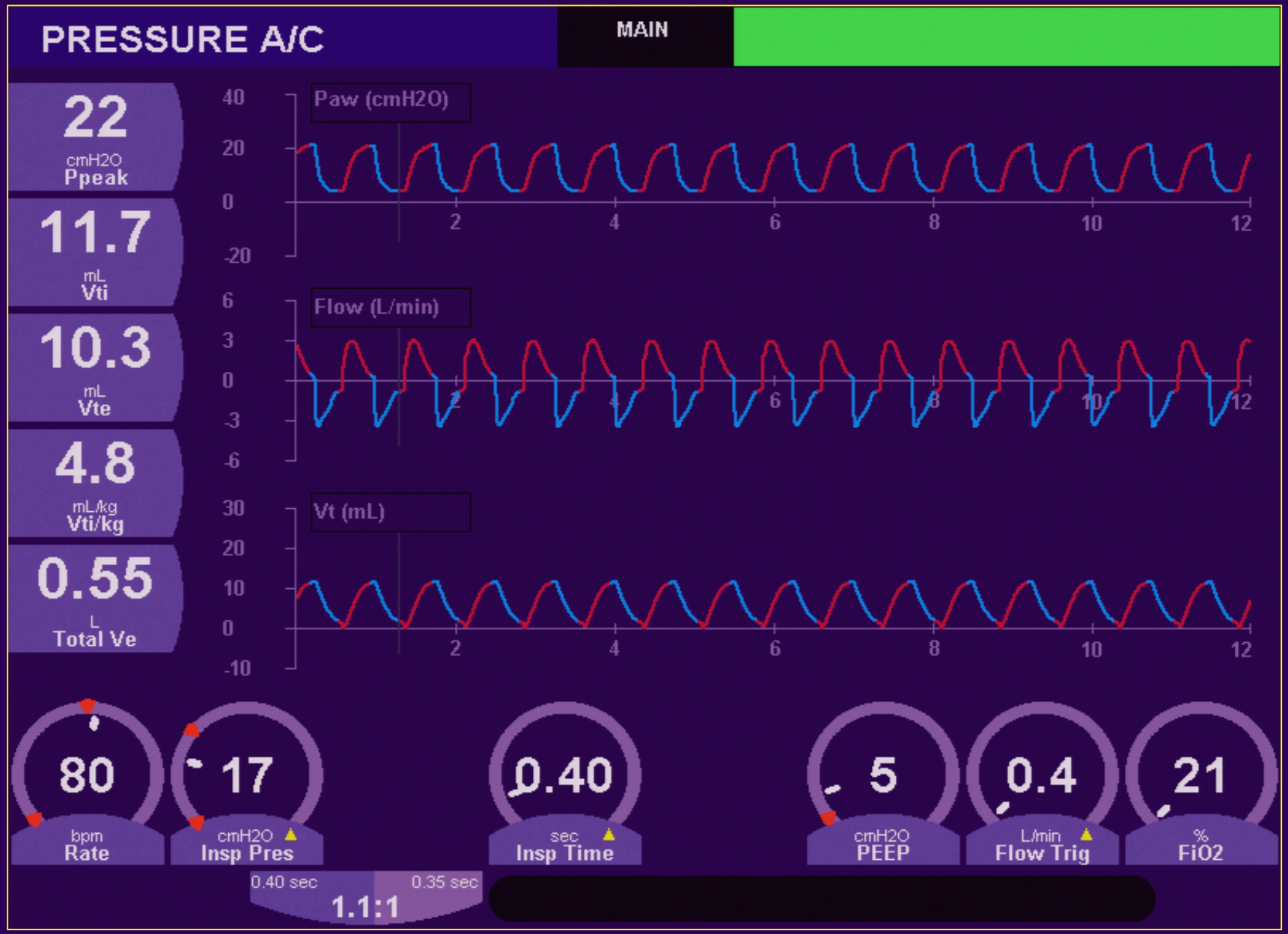

PRESSURE A/C
MAIN
30
cmH2O
Ppeak
41
bpm
Rate
27.2
mL
Vti
22.2
Vte
Paw (cmH2O)
Flow (L/min)
Vt (mL)
40
bpm
Rate
22
cmH2O
Insp Pres
0.70
sec
Insp Time
8
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.70 sec
0.80 sec
1:1.1

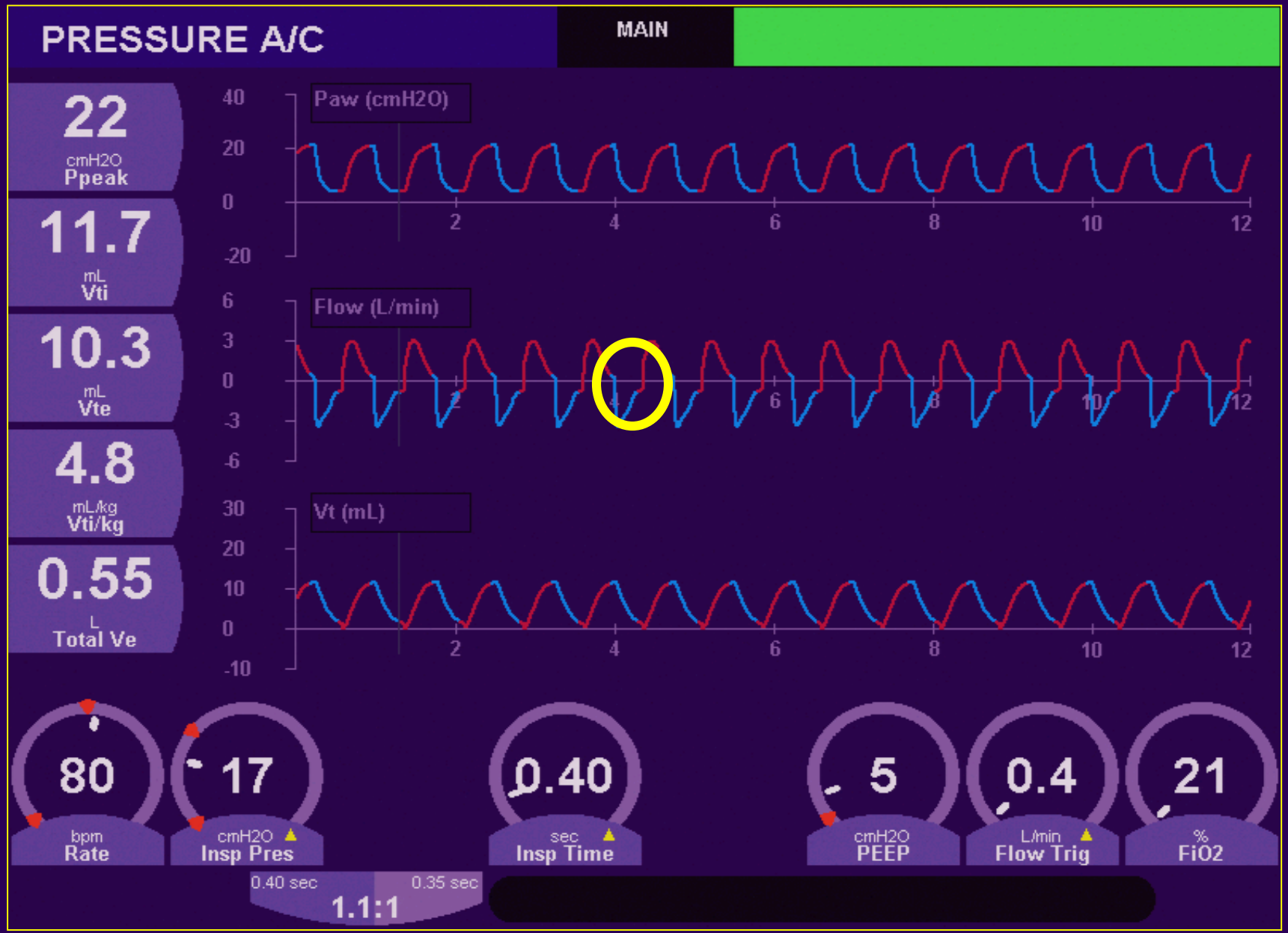

PRESSURE A/C
MAIN
24
cmH2O
Ppeak
36
bpm
Rate
25.1
mL
Vti
21.6
mL
Vte
Paw (cmH2O)
Flow (L/min)
Vt (mL)
30
bpm
Rate
20
cmH2O
Insp Pres
0.35
sec
Insp Time
4
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.35 sec
1.65 sec
1:4.7


PRESSURE A/C
MAIN
20
cmH2O
Ppeak
30
bpm
Rate
24.4
mL
Vti
21.3
mL
Vte
7.9
mL/kg
Vti/kg
Paw (cmH2O)
Flow (L/min)
Vt (mL)
30
bpm
Rate
18
cmH2O
Insp Pres
0.35
sec
Insp Time
2
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.35 sec
1.65 sec
1:4.7

Gas Trapping

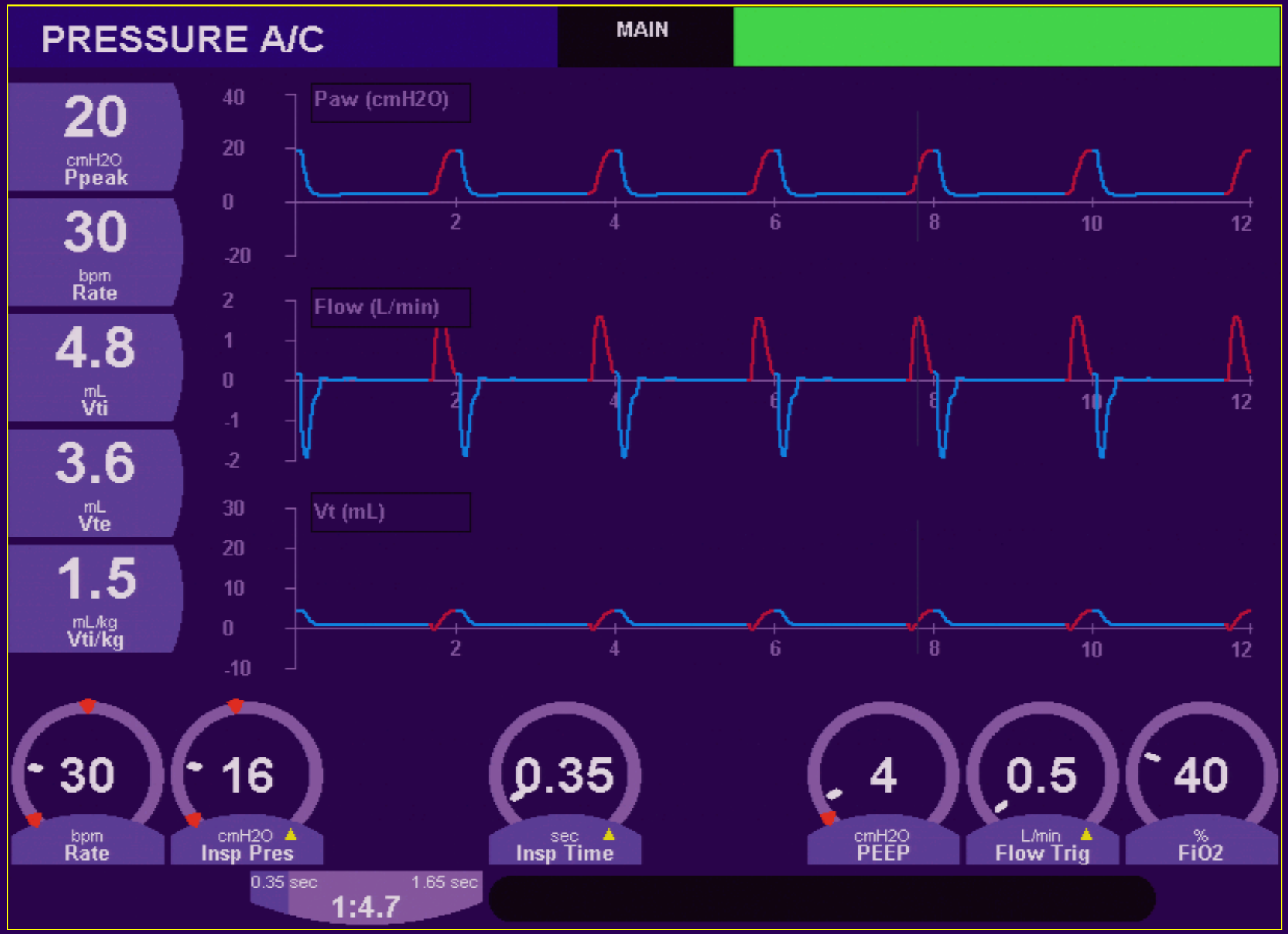
- Expiratory flow waveform does not return to baseline
- No zero flow state at end expiration
- More gas enters than leaves
- Adjustments:
  - Decrease rate
  - Increase Te
  - Decrease flow
  - Consider increase in PEEP


PRESSURE A/C
MAIN
22
cmH2O
Ppeak
11.7
mL
Vti
10.3
mL
Vte
4.8
mL/kg
Vti/kg
0.55
L
Total Ve
Paw (cmH2O)
40
20
0
-20
2
4
6
8
10
12
Flow (L/min)
6
3
0
-3
-6
Vt (mL)
30
20
10
0
-10
80
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
0.35 sec
1.1:1


PRESSURE A/C
MAIN
22
cmH2O
Ppeak
11.7
mL
Vti
10.3
mL
Vte
4.8
mL/kg
Vti/kg
0.55
L
Total Ve
Paw (cmH2O)
40
20
0
-20
2
4
6
8
10
12
Flow (L/min)
6
3
0
-3
-6
Vt (mL)
30
20
10
0
-10
80
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
0.35 sec
1.1:1

Flow Delivery

- Gas flow during pressure-targeted ventilation generates a sinusoidal wave and in some devices adjusted by rise time
- Gas flow during volume-targeted ventilation generates a square wave and in some devices can be adjusted to decelerate

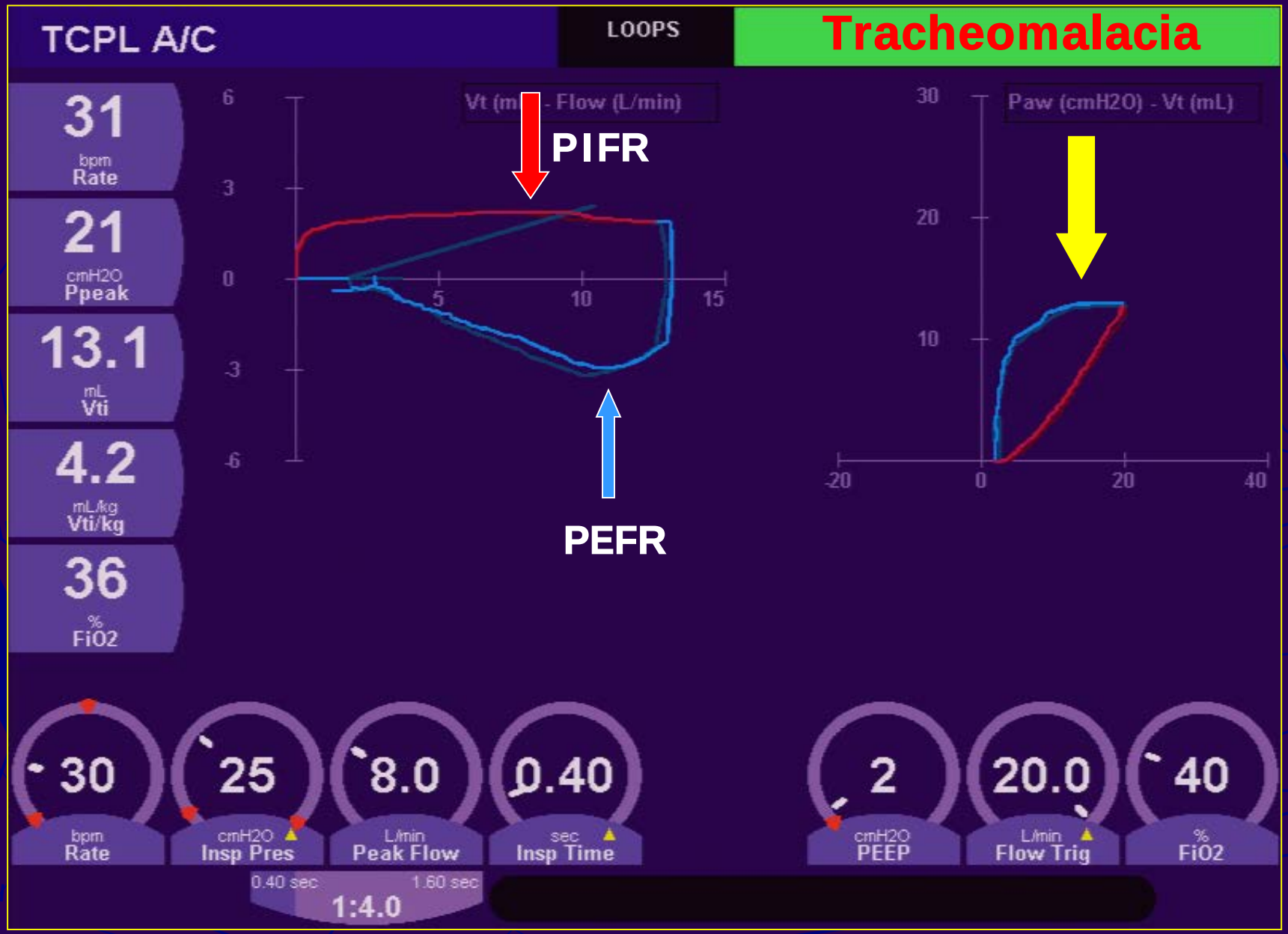

PRESSURE A/C
MAIN
20
cmH2O
Ppeak
30
bpm
Rate
4.8
mL
Vti
3.6
mL
Vte
1.5
mL/kg
Vti/kg
Paw (cmH2O)
40
20
0
-20
2
4
6
8
10
12
Flow (L/min)
2
1
0
-1
-2
Vt (mL)
30
20
10
0
-10
30
bpm
Rate
16
cmH2O
Insp Pres
0.35
sec
Insp Time
4
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.35 sec
1.65 sec
1:4.7

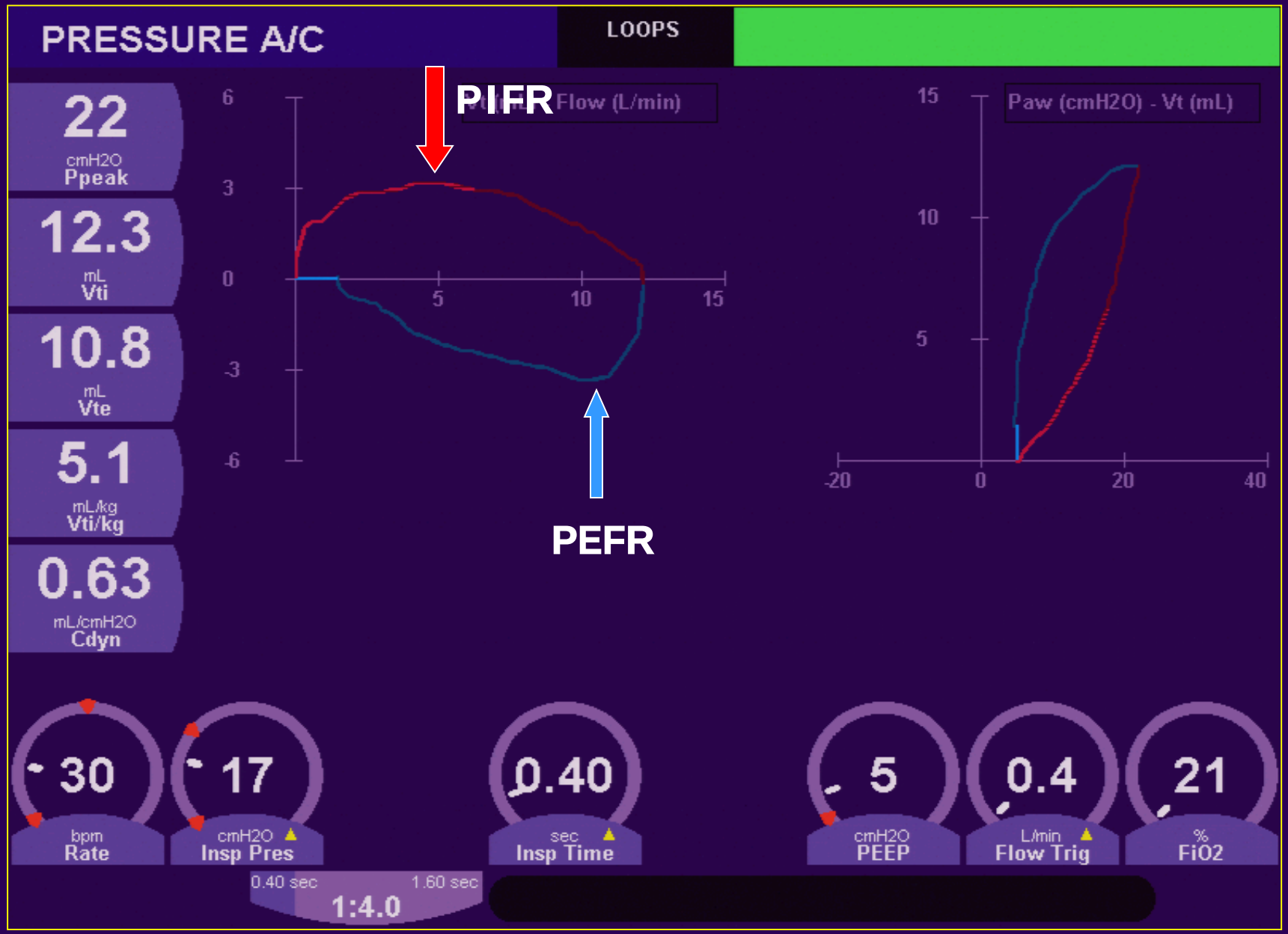

VOLUME A/C
MAIN
22
cmH2O
Ppeak
30
bpm
Rate
5.6
mL
Vti
4.4
mL
Vte
1.8
mL/kg
Vti/kg
Paw (cmH2O)
40
20
0
-20
Flow (L/min)
2
1
0
-1
-2
Vt (mL)
6
4
2
0
-2
2
4
6
8
10
12
30
bpm
Rate
40.1
mL
Volume
9.2
L/min
Peak Flow
0.00
sec
Insp Pause
4
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
Calc Ve
L
1.20
0.26 sec
1.74 sec
1:6.6


VOLUME A/C
MAIN
20
cmH2O
Ppeak
30
bpm
Rate
5.4
mL
Vti
4.2
mL
Vte
1.8
mL/kg
Vti/kg
Paw (cmH2O)
Flow (L/min)
Vt (mL)
30
bpm
Rate
40.1
mL
Volume
9.2
L/min
Peak Flow
0.00
sec
Insp Pause
4
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
Calc Ve
L
1.20
0.35 sec
1.65 sec
1:4.7

Elevated Resistance

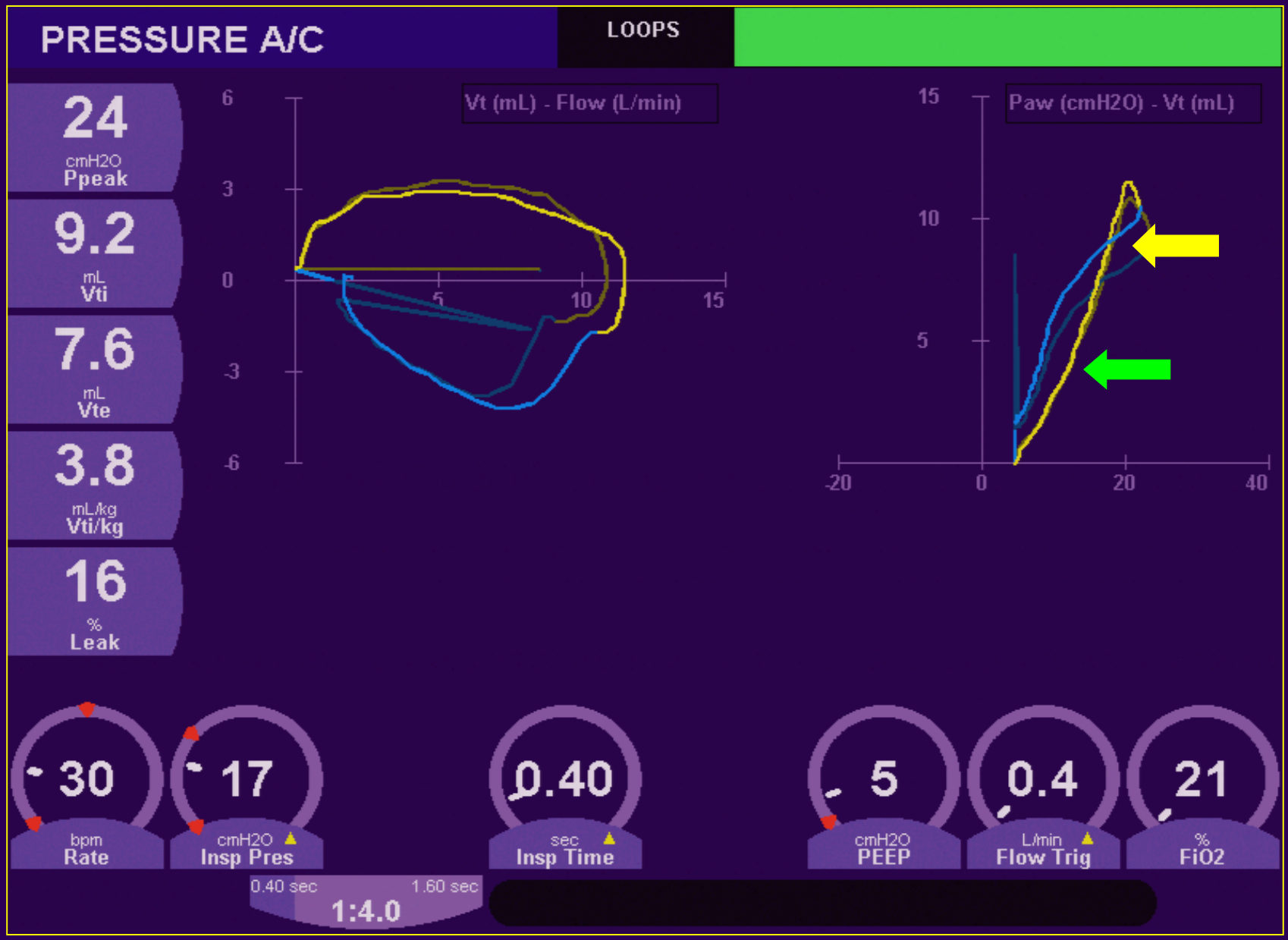
- Diminished inspiratory and expiratory flow rates
- Note decreased peak flows
- P-V loop also shows some degree of hyperinflation


TCPL A/C
LOOPS
Tracheomalacia
31
bpm
Rate
21
cmH2O
Ppeak
13.1
mL
Vti
4.2
mL/kg
Vti/kg
36
%
FiO2
Vt (mL) - Flow (L/min)
PIFR
PEFR
Paw (cmH2O) - Vt (mL)
30
bpm
Rate
25
cmH2O
Insp Pres
8.0
L/min
Peak Flow
0.40
sec
Insp Time
2
cmH2O
PEEP
20.0
L/min
Flow Trig
40
%
FiO2
0.40 sec
1.60 sec
1:4.0


PRESSURE A/C
LOOPS
22
cmH2O
Ppeak
12.3
mL
Vti
10.8
mL
Vte
5.1
mL/kg
Vti/kg
0.63
mL/cmH2O
Cdyn
Flow (L/min)
6
3
0
-3
-6
5
10
15
PIFR
PEFR
Paw (cmH2O) - Vt (mL)
15
10
5
-20
0
20
40
30
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
1.60 sec
1:4.0

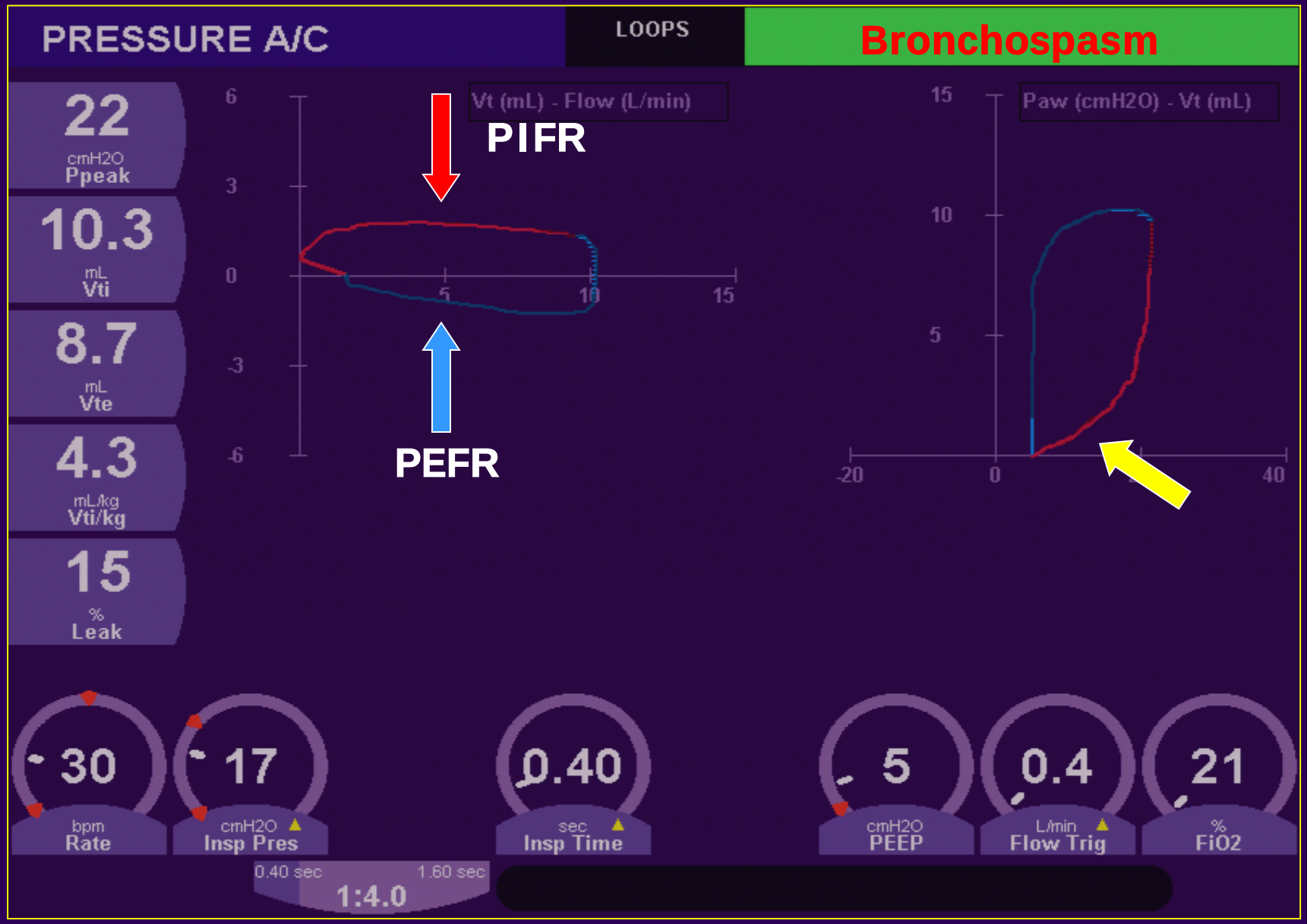
Air Hunger

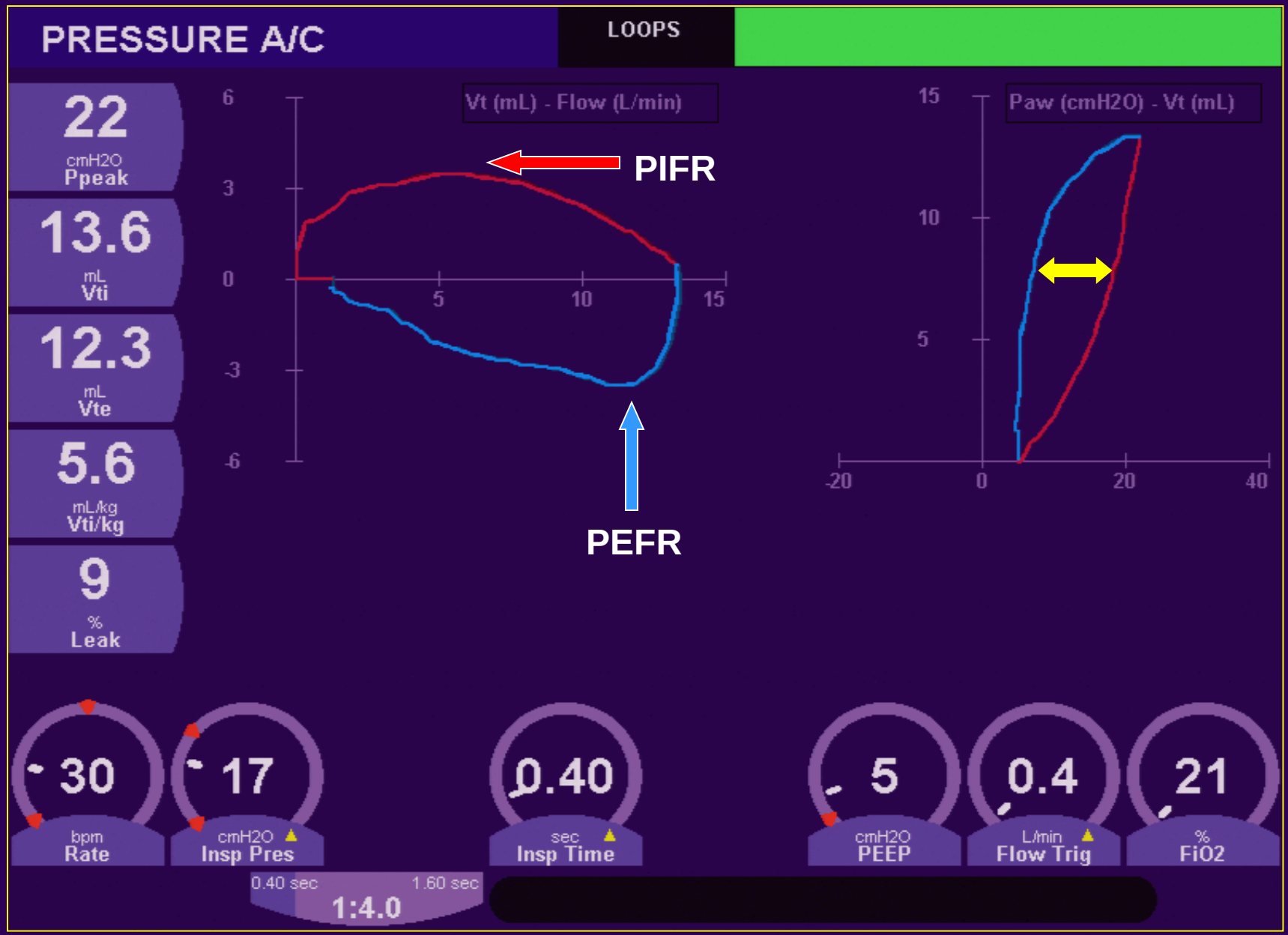
- Inadequate hysteresis
- Little separation between inflation and deflation limbs of P-V loop
- “Figure Eight” appearance at end-inspiration
- Adjustments:
  - Inspiratory flow
  - Rise time
  - Ti


PRESSURE A/C
LOOPS
24
cmH2O
Ppeak
9.2
mL
Vti
7.6
mL
Vte
3.8
mL/kg
Vti/kg
16
%
Leak
Vt (mL) - Flow (L/min)
6
3
0
-3
-6
5
10
15
Paw (cmH2O) - Vt (mL)
15
10
5
-20
0
20
40
30
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
1.60 sec
1:4.0

Response to Bronchodilator

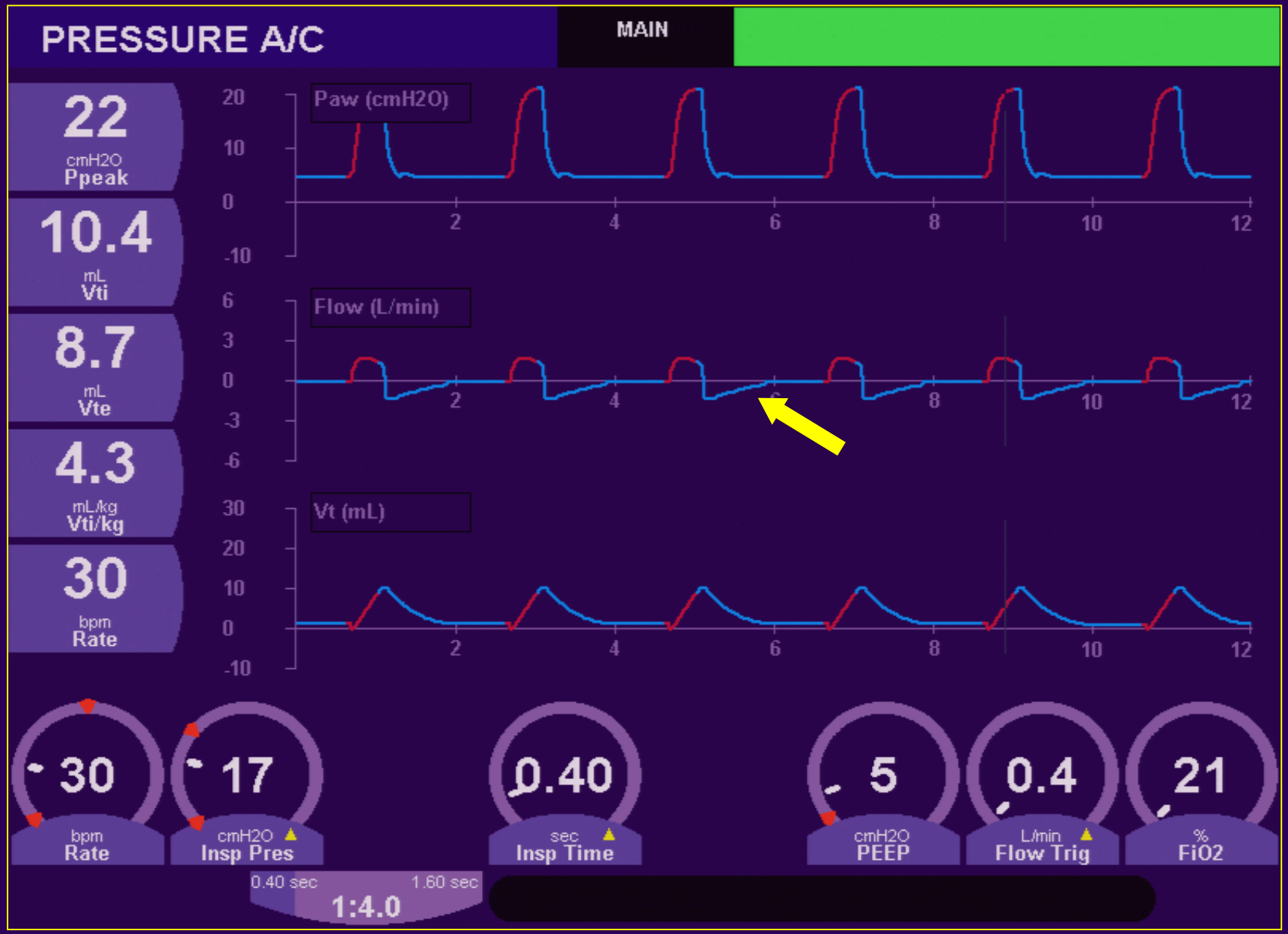
- Improved lung mechanics
- Increased PIFR and PEFR without changing ventilator settings
- Objective evaluation of a therapy with a narrow therapeutic index


PRESSURE A/C
LOOPS
Bronchospasm
22
cmH2O
Ppeak
10.3
mL
Vti
8.7
mL
Vte
4.3
mL/kg
Vti/kg
15
%
Leak
Vt (mL) - Flow (L/min)
PIFR
PEFR
6
3
0
-3
-6
5
10
15
Paw (cmH2O) - Vt (mL)
15
10
5
-20
0
40
30
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
1.60 sec
1:4.0


PRESSURE A/C
LOOPS
22
cmH2O
Ppeak
13.6
mL
Vti
12.3
mL
Vte
5.6
mL/kg
Vti/kg
9
%
Leak
Vt (mL) - Flow (L/min)
6
3
0
-3
-6
5
10
15
PIFR
PEFR
Paw (cmH2O) - Vt (mL)
15
10
5
-20
0
20
40
30
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
1.60 sec
1:4.0

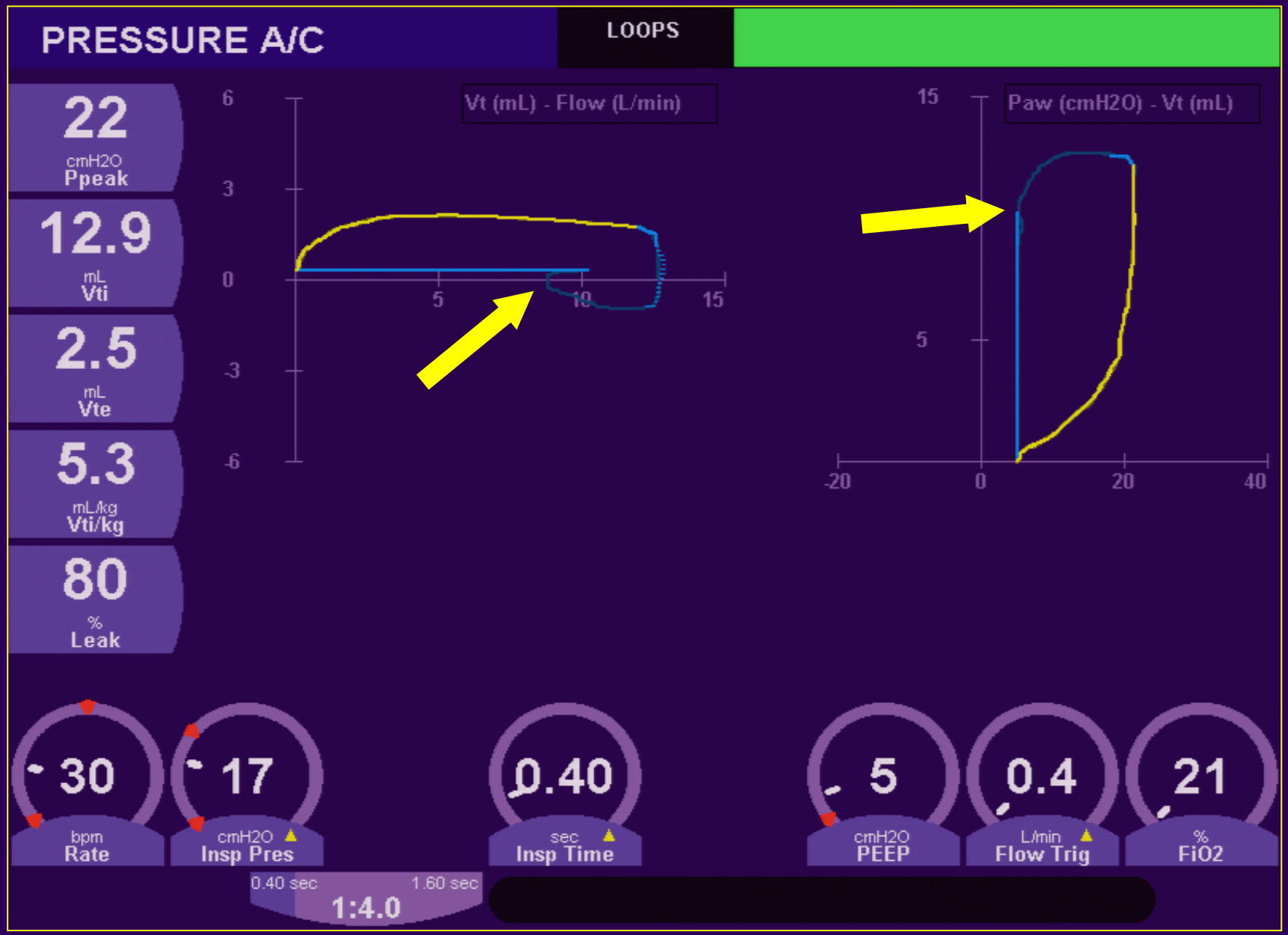
Increased Expiratory Resistance

- Prolonged time for decelerating expiratory waveform to reach baseline
- Adjustments:
  - Increase PEEP (stent airways)
  - Adjust cycle time (↓Ti or ↑Te)
  - Bronchodilator


PRESSURE A/C
MAIN
22
cmH2O
Ppeak
10.4
mL
Vti
8.7
mL
Vte
4.3
mL/kg
Vti/kg
30
bpm
Rate
Paw (cmH2O)
20
10
0
-10
2
4
6
8
10
12
Flow (L/min)
6
3
0
-3
-6
Vt (mL)
30
20
10
0
-10
30
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
1.60 sec
1:4.0

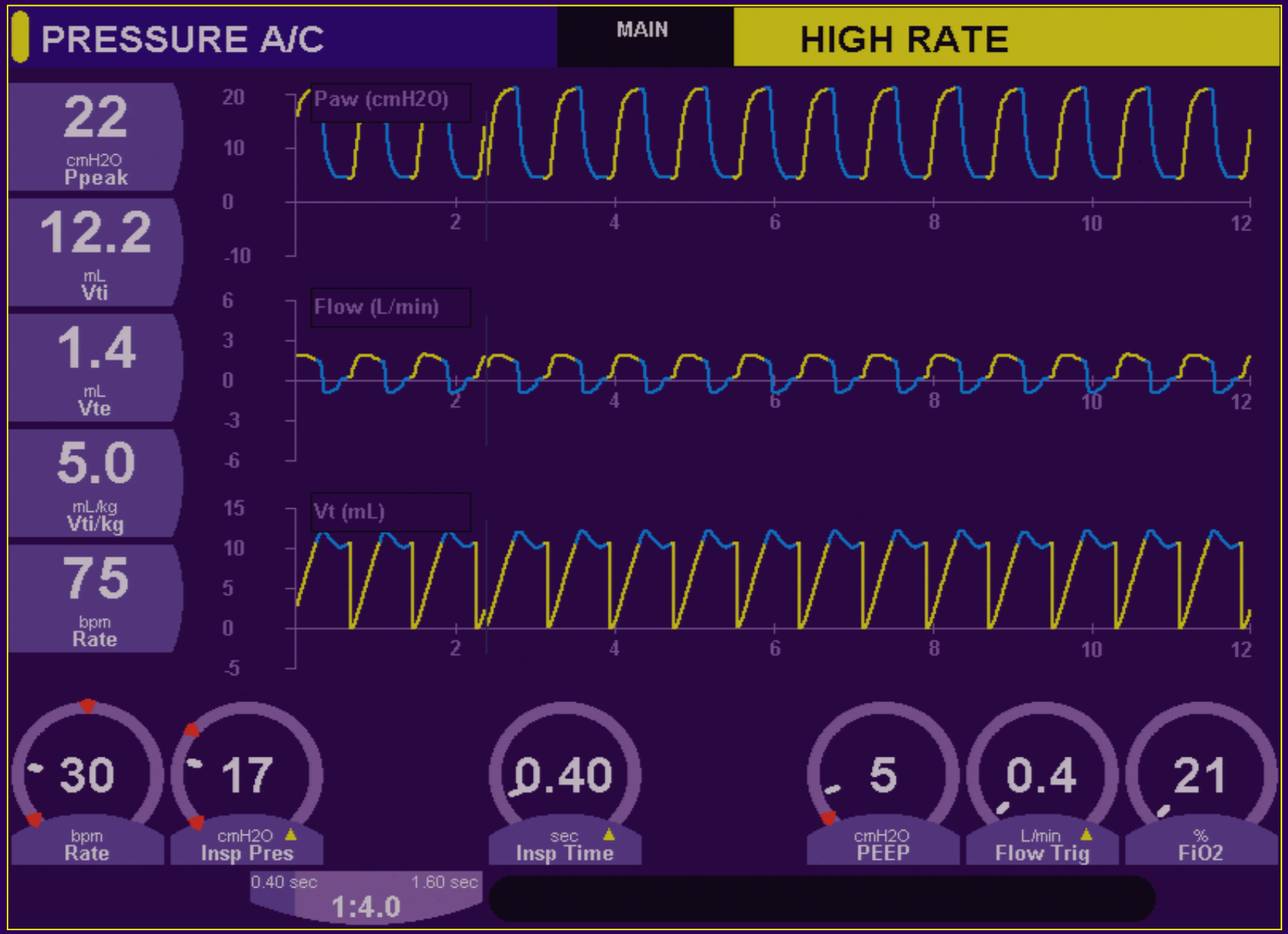
Large ET Tube Leak

- Flow-volume loop does not reach origin
- Pressure-volume loop fails to close
- Tidal volume waveform does not reach baseline at end-expiration
- Adjustments:
  - Change position
  - Consider larger tube


PRESSURE A/C
LOOPS
22
cmH2O
Ppeak
12.9
mL
Vti
2.5
mL
Vte
5.3
mL/kg
Vti/kg
80
%
Leak
Vt (mL) - Flow (L/min)
6
3
0
-3
-6
5
10
15
Paw (cmH2O) - Vt (mL)
15
5
-20
0
20
40
30
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
1.60 sec
1:4.0

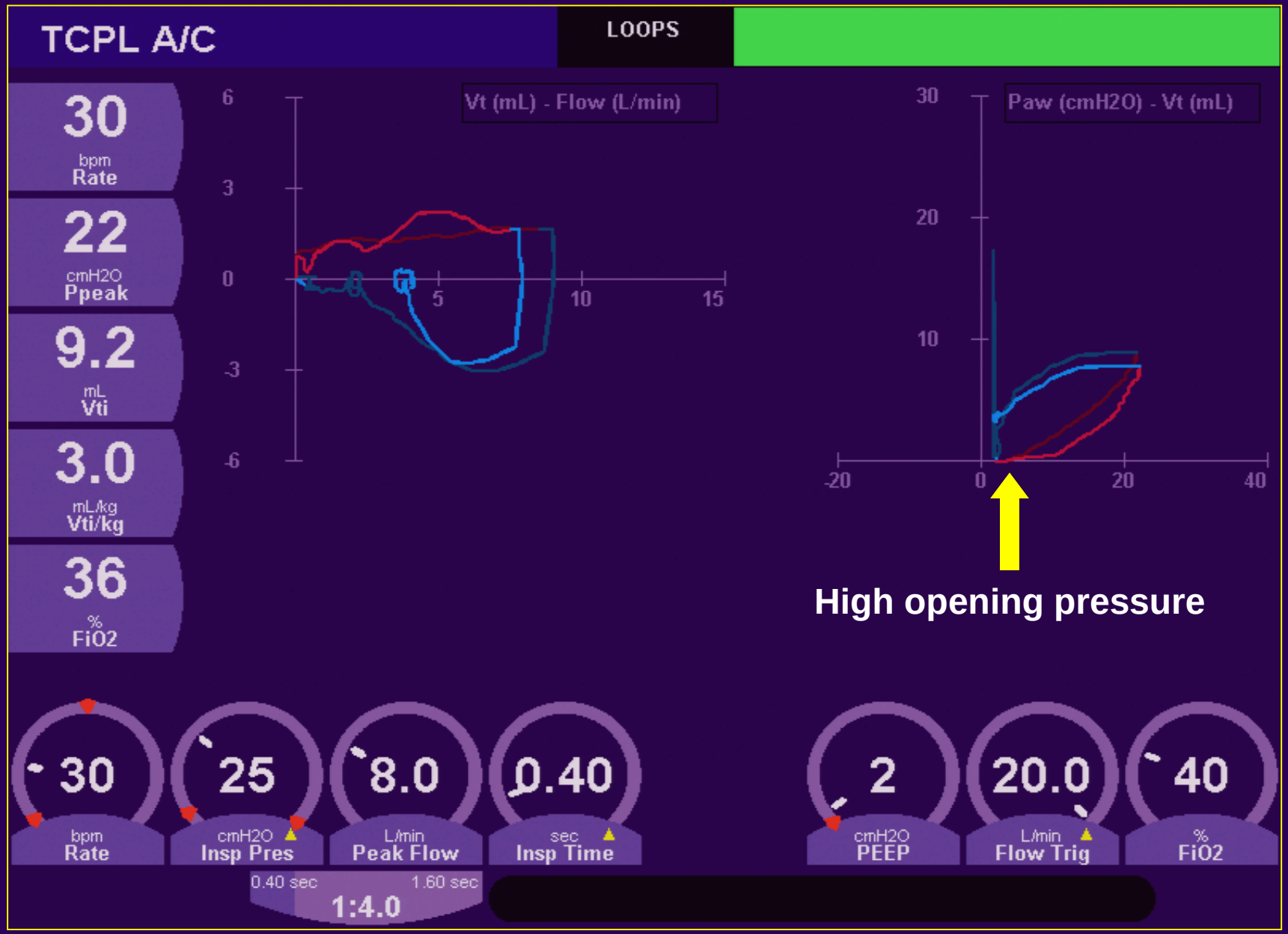
Auto-Cycling

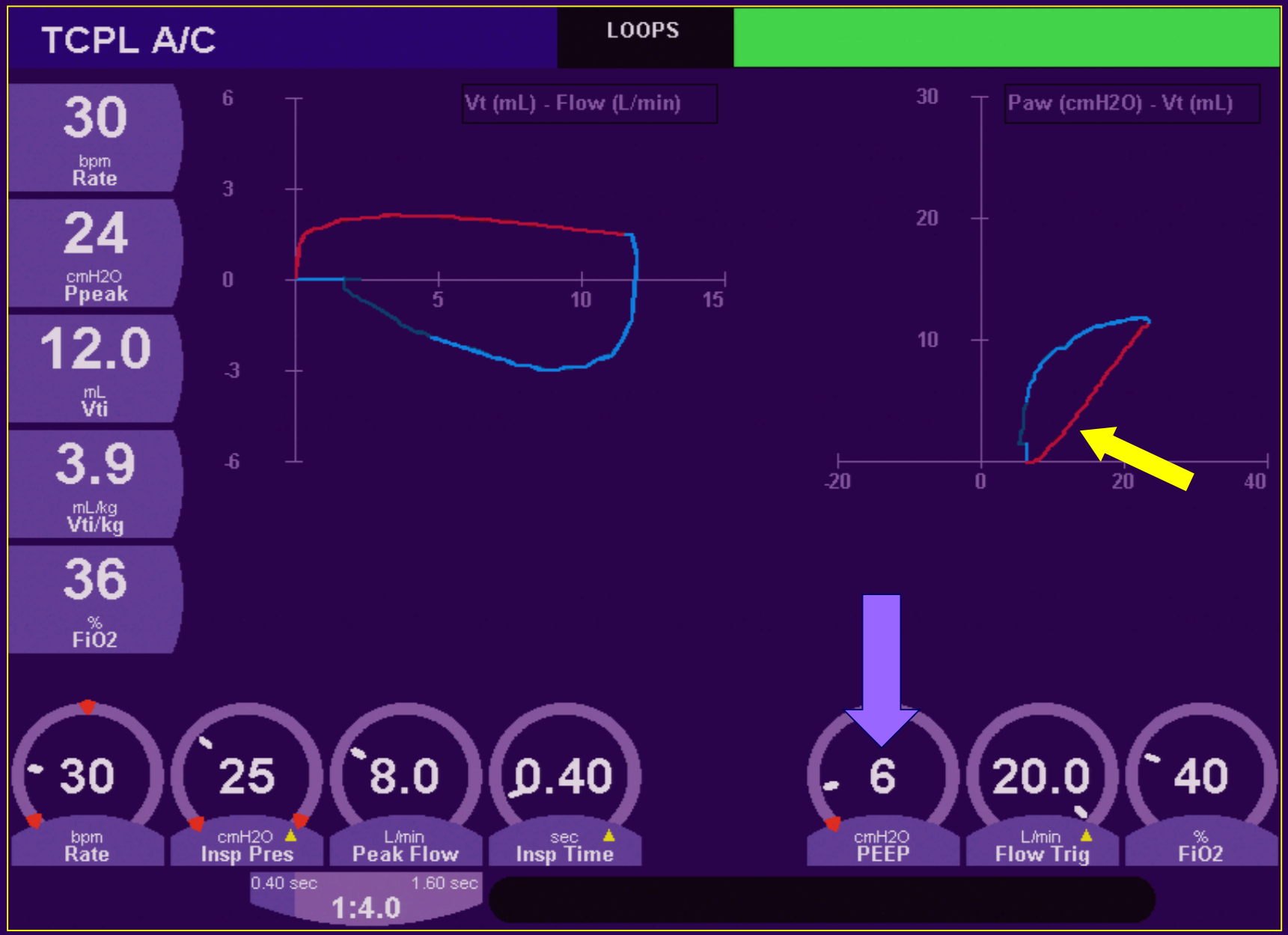
- Trigger misreads a flow leak as patient effort and initiates a mechanical breath
- This results in rhythmic breaths without a pause
- May also be caused by excessive condensation in circuit resulting in flow changes
- Adjustments:
  - Stop leak
  - Remove rain-out and avoid recurrence
  - Increase trigger sensitivity above measured leak


PRESSURE A/C
MAIN
HIGH RATE
22
cmH2O
Ppeak
12.2
mL
Vti
1.4
mL
Vte
5.0
mL/kg
Vti/kg
75
bpm
Rate
Paw (cmH2O)
Flow (L/min)
Vt (mL)
30
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
1.60 sec
1:4.0

Best PEEP Analysis

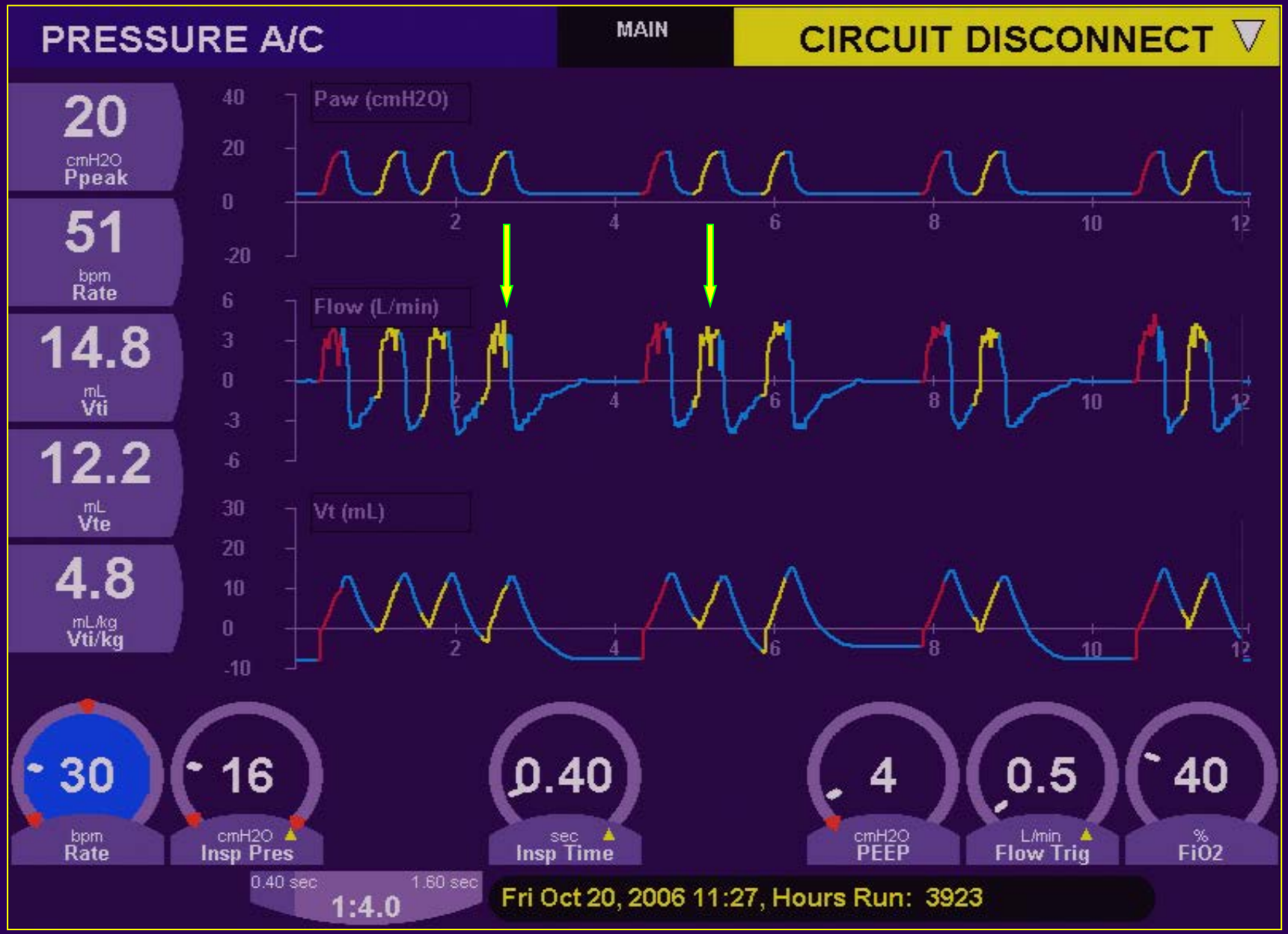
- Examine shape of inspiratory limb of P-V loop for early slope
- Sub-optimal PEEP results in “box-like” shape-- prolonged inflation without concomitant recruitment of lung volume
- Adjustments:
  - Increase PEEP
  - May need similar increase in PIP

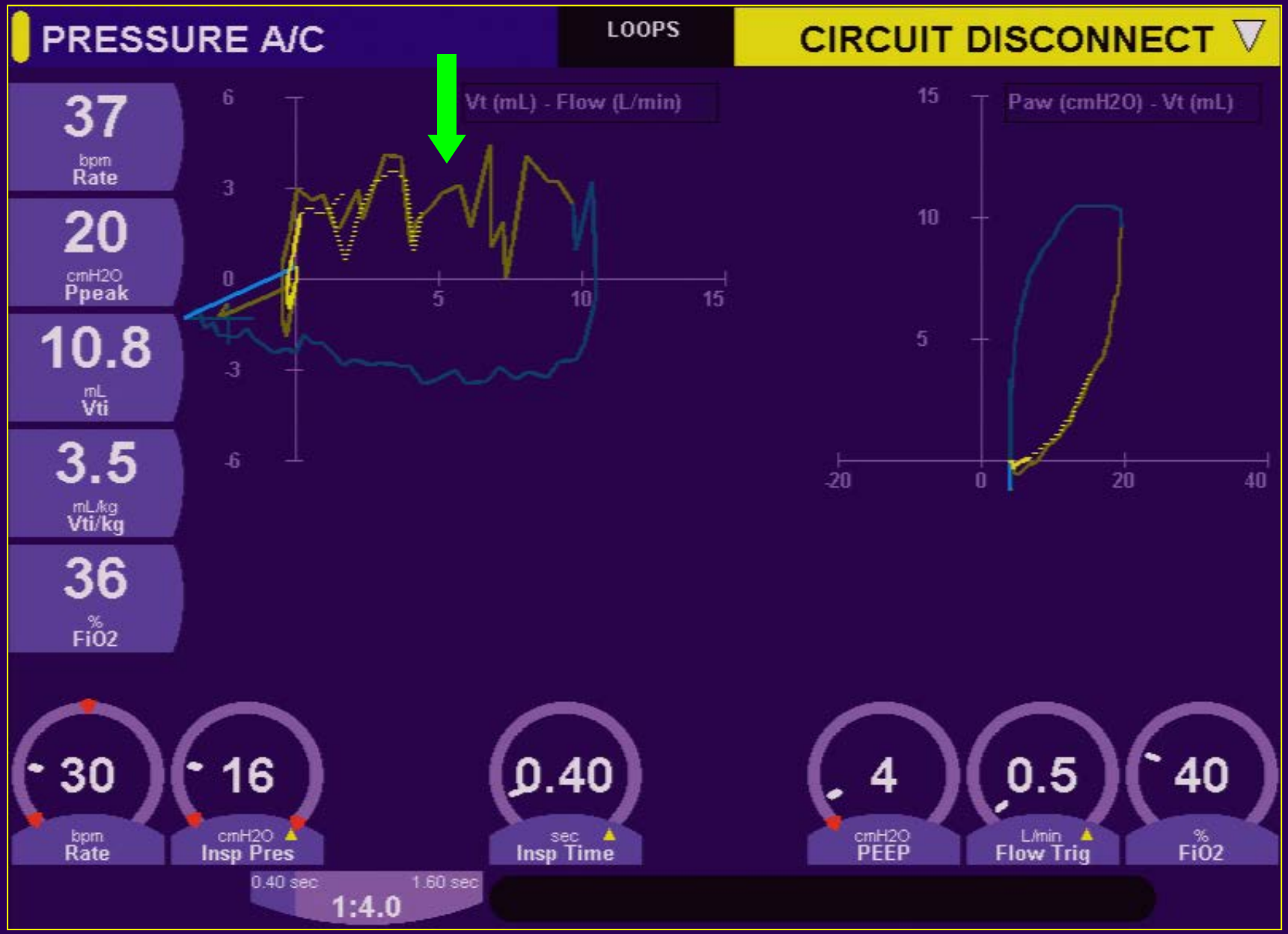

TCPL A/C
LOOPS
30
bpm
Rate
22
cmH2O
Ppeak
9.2
mL
Vti
3.0
mL/kg
Vti/kg
36
%
FiO2
Vt (mL) - Flow (L/min)
6
3
0
-3
-6
5
10
15
Paw (cmH2O) - Vt (mL)
30
20
10
-20
0
20
40
High opening pressure
30
bpm
Rate
25
cmH2O
Insp Pres
8.0
L/min
Peak Flow
0.40
sec
Insp Time
2
cmH2O
PEEP
20.0
L/min
Flow Trig
40
%
FiO2
0.40 sec
1.60 sec
1:4.0


TCPL A/C
LOOPS
30
bpm
Rate
24
cmH2O
Ppeak
12.0
mL
Vti
3.9
mL/kg
Vti/kg
36
%
FiO2
Vt (mL) - Flow (L/min)
6
3
0
-3
-6
5
10
15
Paw (cmH2O) - Vt (mL)
30
20
10
-20
0
20
40
30
bpm
Rate
25
cmH2O
Insp Pres
8.0
L/min
Peak Flow
0.40
sec
Insp Time
6
cmH2O
PEEP
20.0
L/min
Flow Trig
40
%
FiO2
0.40 sec
1.60 sec
1:4.0

Turbulence

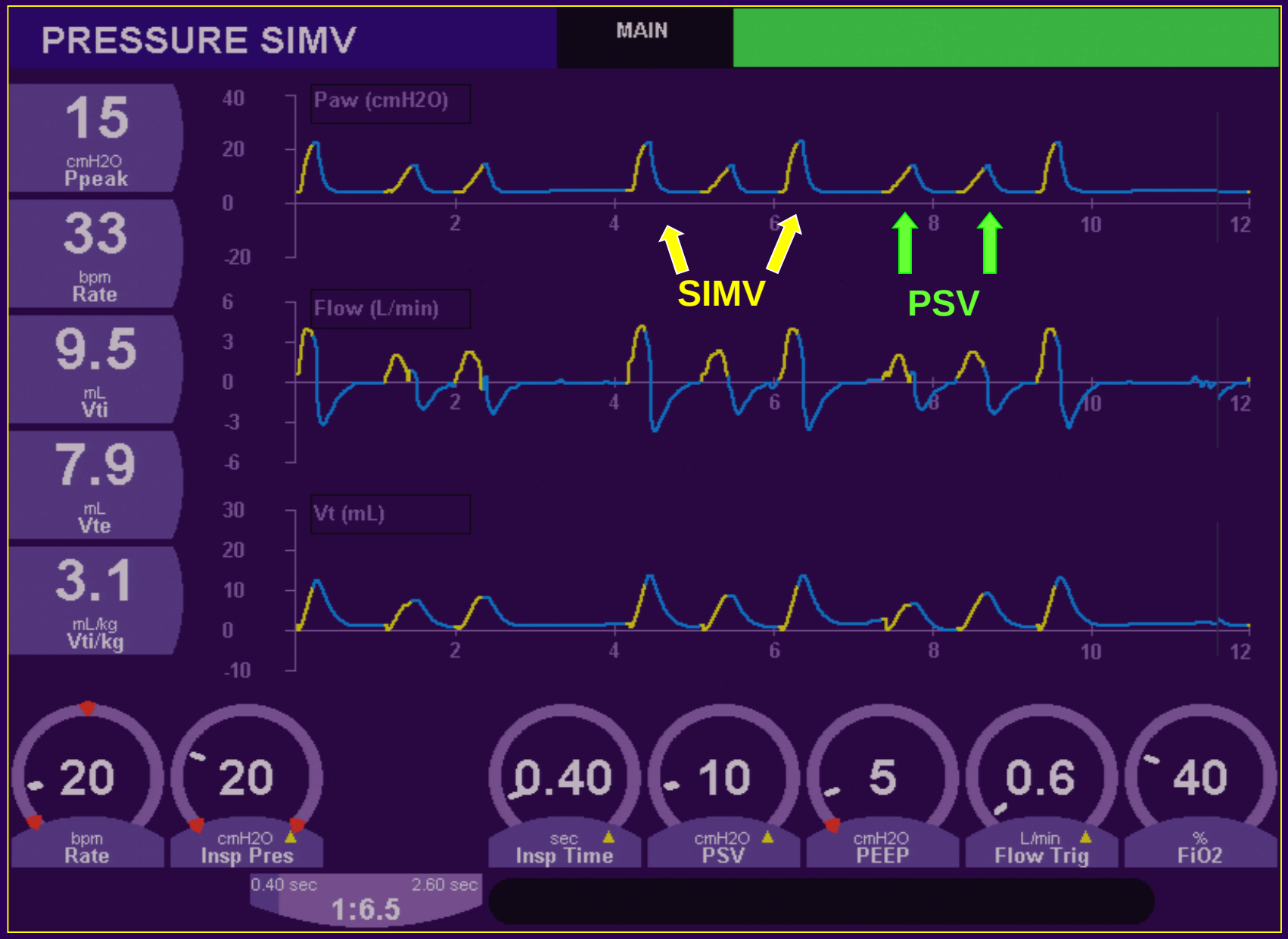
- Secretions in the path of gas flow create turbulence
- This causes a “noisy” signal on both waveforms and loops
- May enable avoidance of “routine” suctioning of the endotracheal tube


PRESSURE A/C
MAIN
CIRCUIT DISCONNECT
20
cmH2O
Ppeak
51
bpm
Rate
14.8
mL
Vti
12.2
mL
Vte
4.8
mL/kg
Vti/kg
Paw (cmH2O)
Flow (L/min)
Vt (mL)
30
bpm
Rate
16
cmH2O
Insp Pres
0.40
sec
Insp Time
4
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.40 sec
1.60 sec
1:4.0
Fri Oct 20, 2006 11:27, Hours Run: 3923


PRESSURE A/C
LOOPS
CIRCUIT DISCONNECT
37
bpm
Rate
20
cmH2O
Ppeak
10.8
mL
Vti
3.5
mL/kg
Vti/kg
36
%
FiO2
Vt (mL) - Flow (L/min)
6
3
0
-3
-6
5
10
15
Paw (cmH2O) - Vt (mL)
15
10
5
-20
0
20
40
30
bpm
Rate
16
cmH2O
Insp Pres
0.40
sec
Insp Time
4
cmH2O
PEEP
0.5
L/min
Flow Trig
40
%
FiO2
0.40 sec
1.60 sec
1:4.0

SIMV and Pressure Support

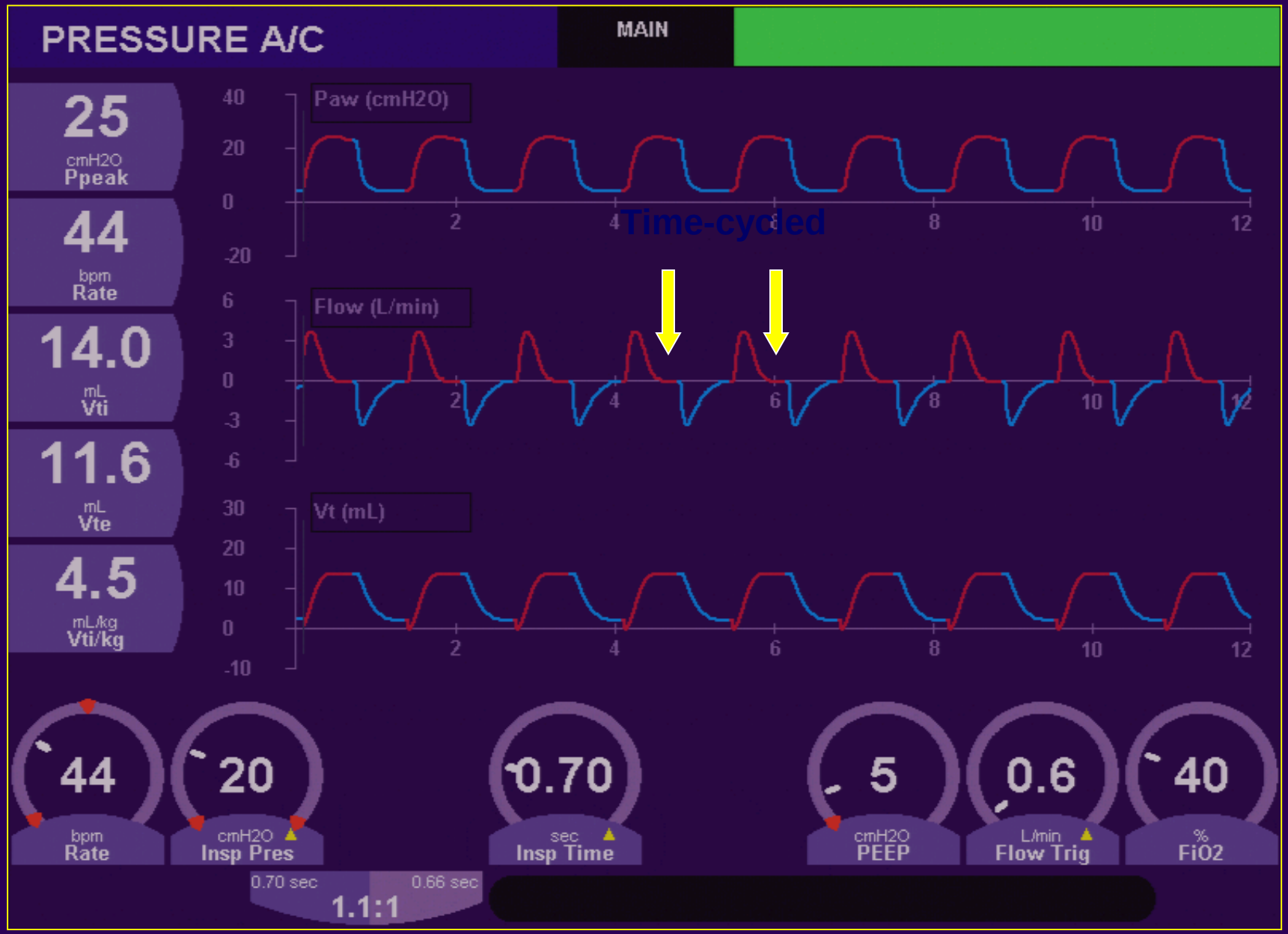
- Inspiratory pressure boost to support spontaneous breaths with something more than just PEEP
- Decreases the work of breathing
- Patient-controlled and fully synchronized
- May be full Vt (PS_{max}) or partial
- PS_{min} matches imposed work of breathing

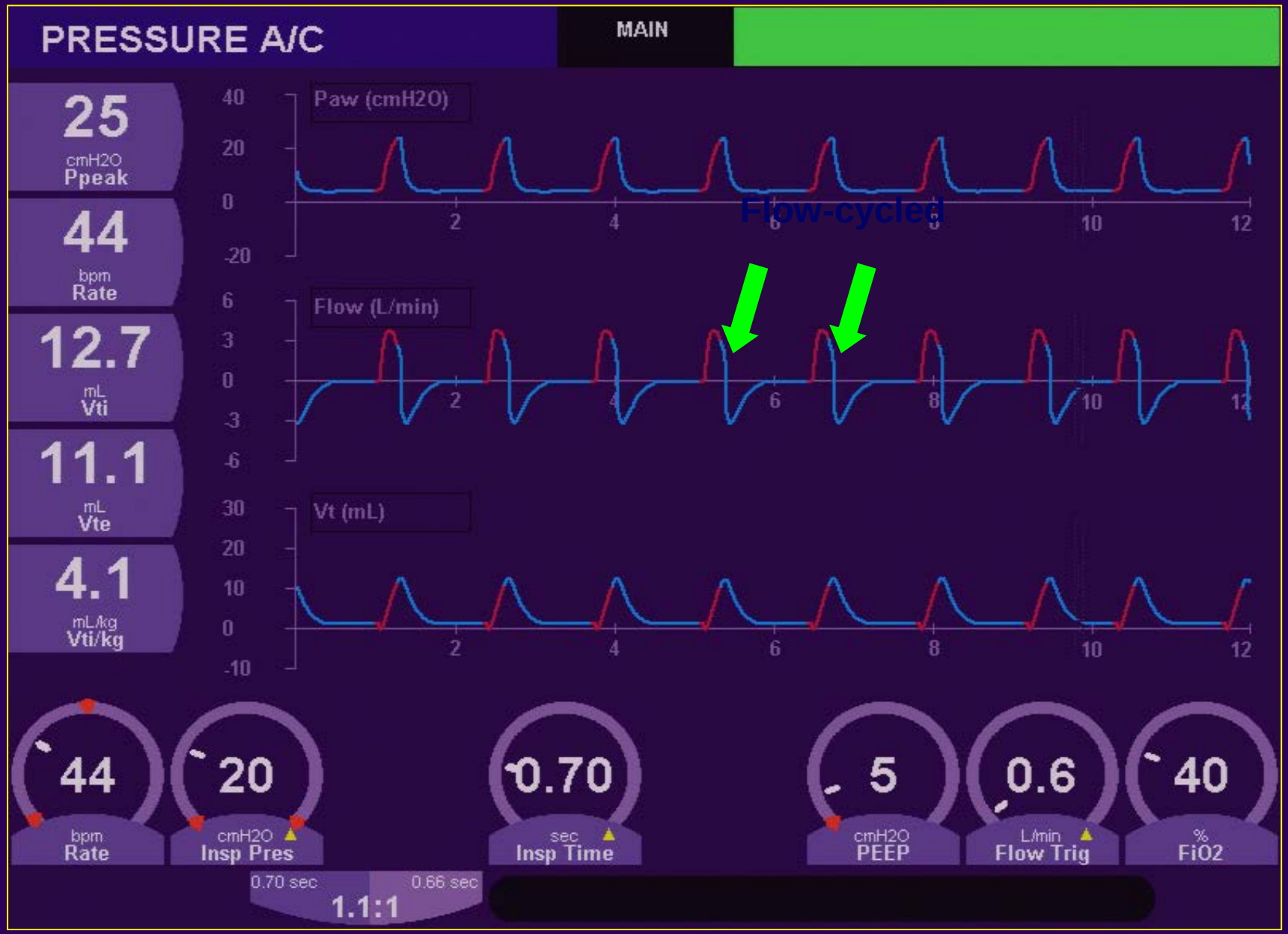

PRESSURE SIMV
MAIN
15
cmH2O
Ppeak
33
bpm
Rate
9.5
mL
Vti
7.9
mL
Vte
3.1
mL/kg
Vti/kg
Paw (cmH2O)
40
20
0
-20
2
4
6
8
10
12
SIMV
PSV
Flow (L/min)
6
3
0
-3
-6
Vt (mL)
30
20
10
0
-10
20
bpm
Rate
20
cmH2O
Insp Pres
0.40
sec
Insp Time
10
cmH2O
PSV
5
cmH2O
PEEP
0.6
L/min
Flow Trig
40
%
FiO2
0.40 sec
2.60 sec
1:6.5

Cycling Mechanisms

What causes inspiration to start and end?

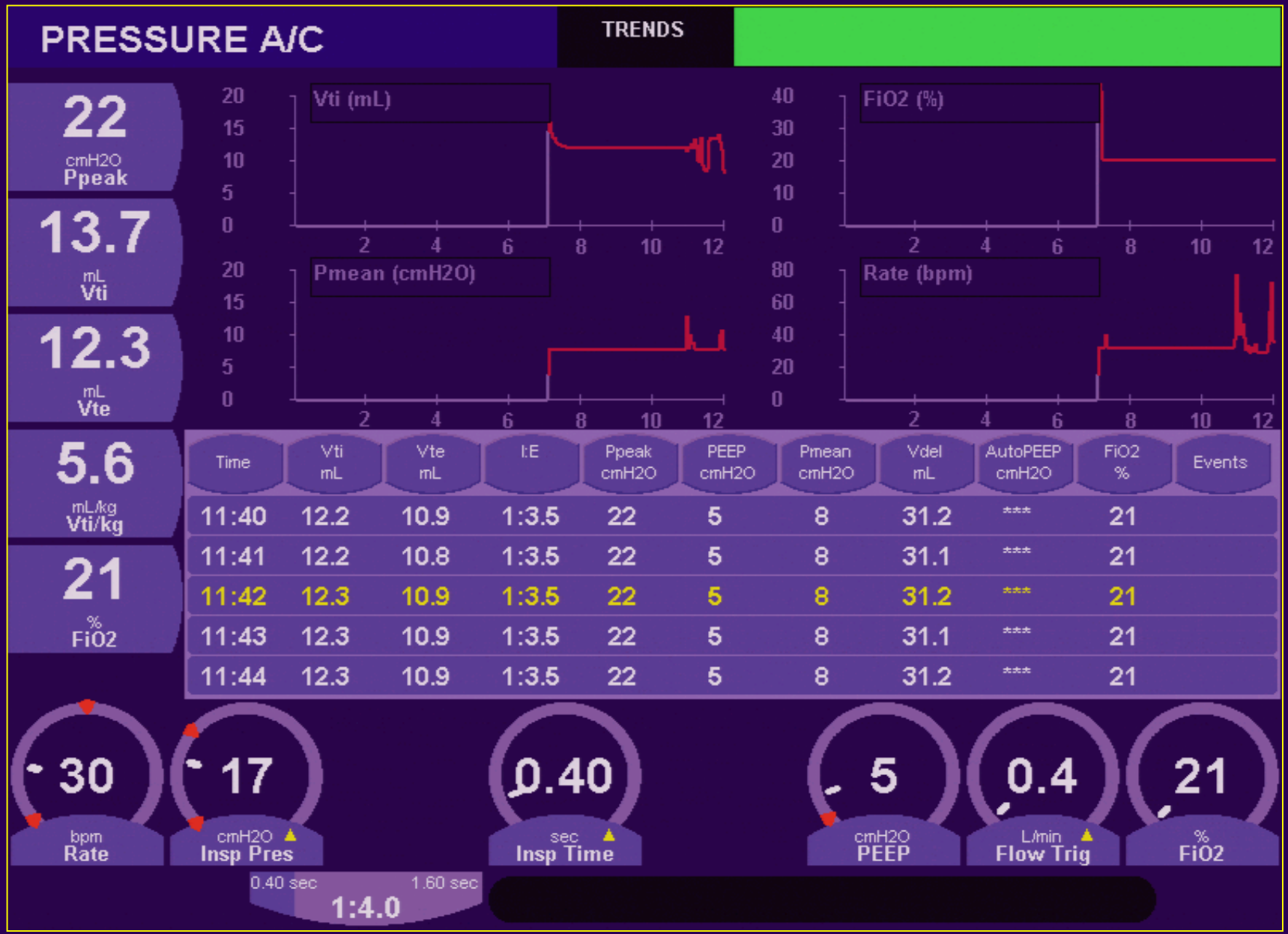
- Time
  - Inspiration ends after a set time, chosen by the clinician
  - Back-up mechanism on all modes
- Flow
  - Inspiration ends at a percentage of PIF
- Volume
  - Not in the neonate because of uncuffed ETT


PRESSURE A/C
MAIN
25
cmH2O
Ppeak
44
bpm
Rate
14.0
mL
Vti
11.6
mL
Vte
4.5
mL/kg
Vti/kg
Paw (cmH2O)
Time-cycled
Flow (L/min)
Vt (mL)
44
bpm
Rate
20
cmH2O
Insp Pres
0.70
sec
Insp Time
5
cmH2O
PEEP
0.6
L/min
Flow Trig
40
%
FiO2
0.70 sec
0.66 sec
1.1:1


PRESSURE A/C
MAIN
25
cmH2O
Ppeak
44
bpm
Rate
12.7
mL
Vti
11.1
mL
Vte
4.1
mL/kg
Vti/kg
Paw (cmH2O)
Flow (L/min)
Vt (mL)
Flow-cycled
44
bpm
Rate
20
cmH2O
Insp Pres
0.70
sec
Insp Time
5
cmH2O
PEEP
0.6
L/min
Flow Trig
40
%
FiO2
0.70 sec
0.66 sec
1.1:1

Trend Data

- Multiple parameters can be tracked over time
- May aid in interpreting cause of desaturation episodes or in evaluation of pharmacologic therapy


PRESSURE A/C
TRENDS
22
cmH2O
Ppeak
13.7
mL
Vti
12.3
mL
Vte
5.6
mL/kg
Vti/kg
21
%
FiO2
Vti (mL)
FiO2 (%)
Pmean (cmH2O)
Rate (bpm)
Time
Vti mL
Vte mL
I:E
Ppeak cmH2O
PEEP cmH2O
Pmean cmH2O
Vdel mL
AutoPEEP cmH2O
FiO2 %
Events
11:40 12.2 10.9 1:3.5 22 5 8 31.2 *** 21
11:41 12.2 10.8 1:3.5 22 5 8 31.1 *** 21
11:42 12.3 10.9 1:3.5 22 5 8 31.2 *** 21
11:43 12.3 10.9 1:3.5 22 5 8 31.1 *** 21
11:44 12.3 10.9 1:3.5 22 5 8 31.2 *** 21
30
bpm
Rate
17
cmH2O
Insp Pres
0.40
sec
Insp Time
5
cmH2O
PEEP
0.4
L/min
Flow Trig
21
%
FiO2
0.40 sec
1.60 sec
1:4.0

Practical Hints

- Make sure graphs are properly scaled
  - P and V axes should be equal
  - Wave forms should not be off scale
- Check for leaks, condensation, and secretions
- When all else fails, LOOK AT THE BABY!

Pulmonary Graphics

"You can observe
a lot by watching."

-Yogi Berra