



بنام خدا

کارگاه آموزشی تهویه
مکانیکی

فیزیولوژی تنفس

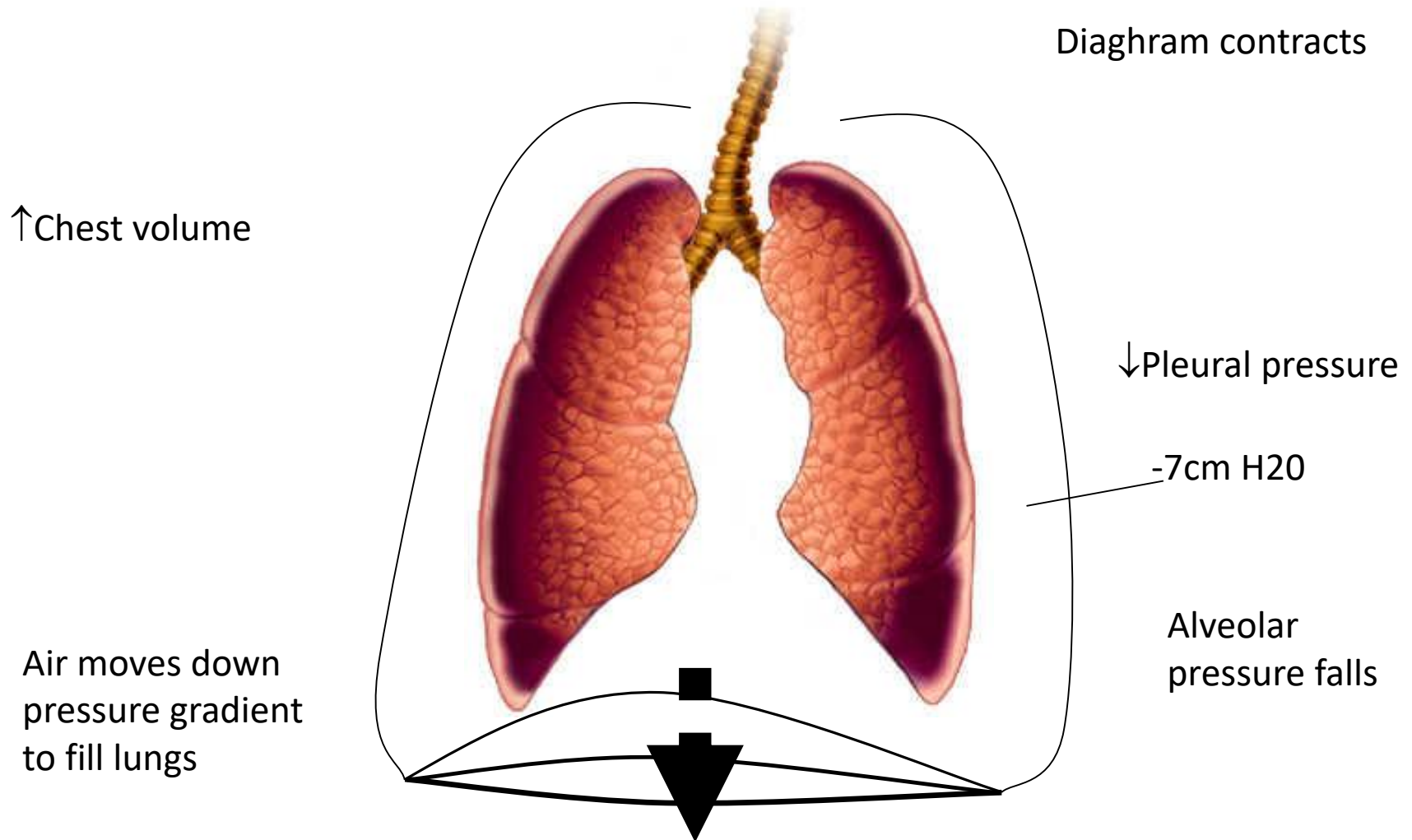
پارامترهای تنفسی

مودهای تنفسی

Normal breath



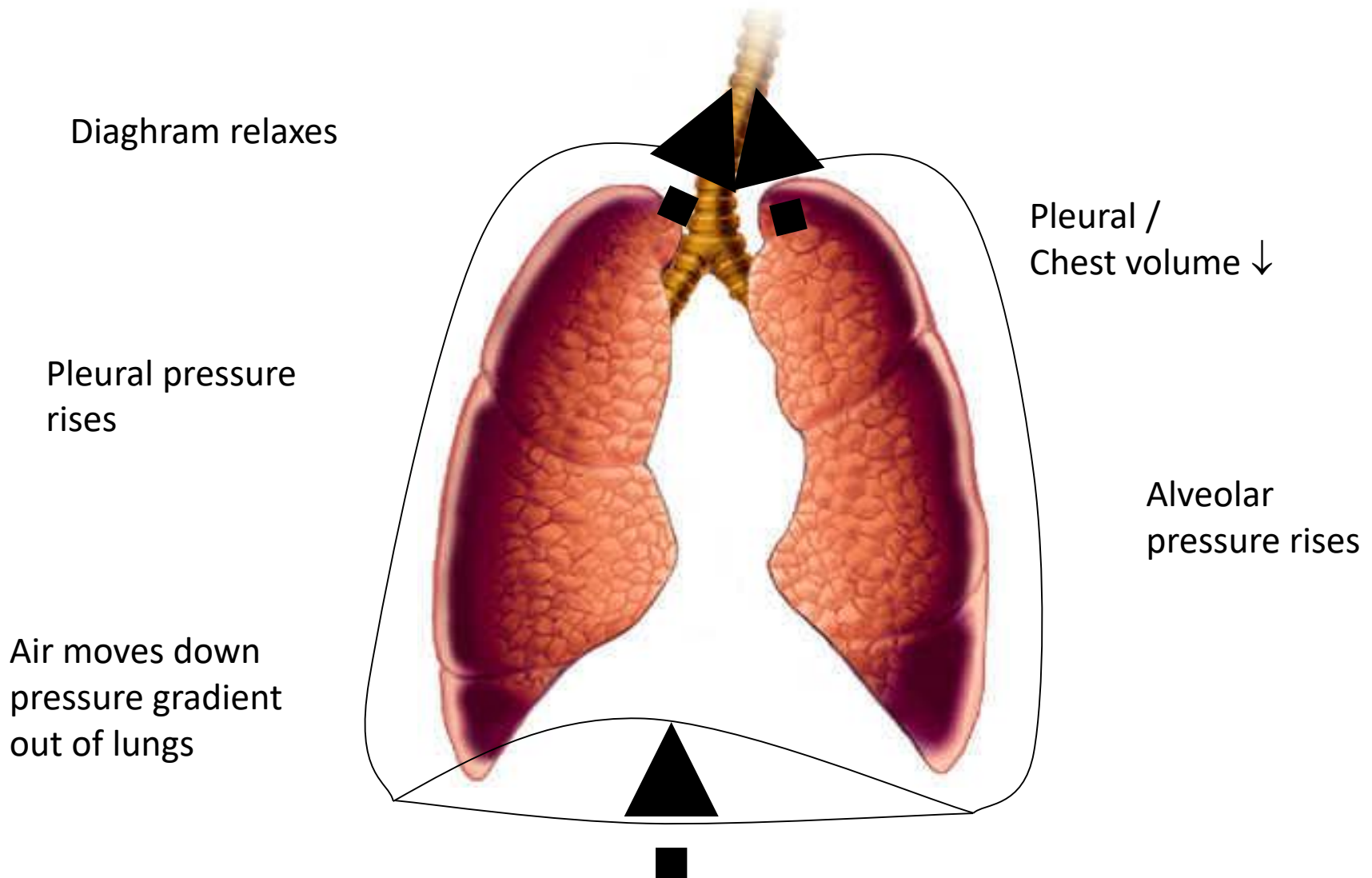
Inspiration



Normal breath



Expiration





Negative pressure ventilator





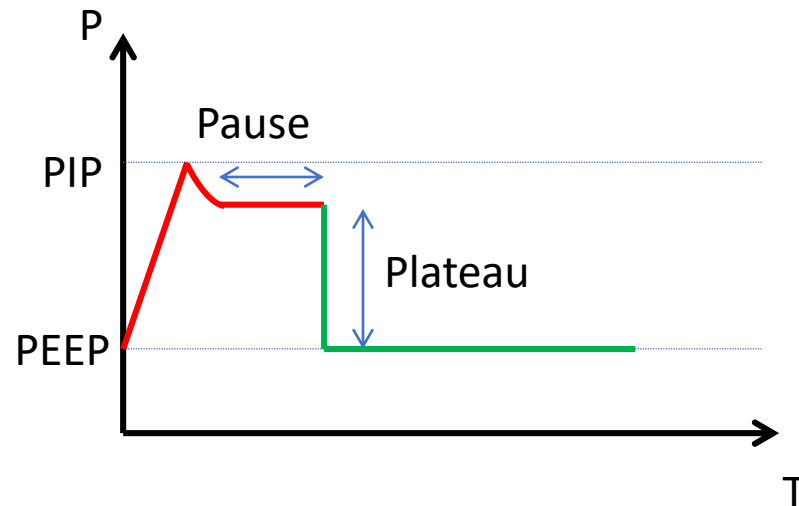
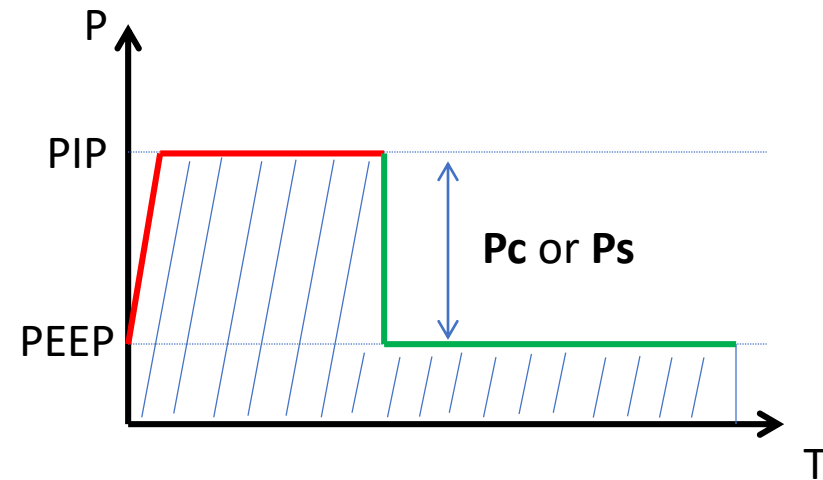
Positive pressure ventilator



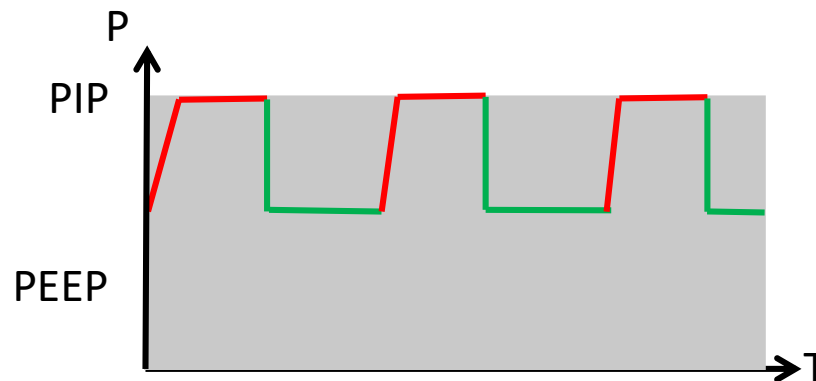
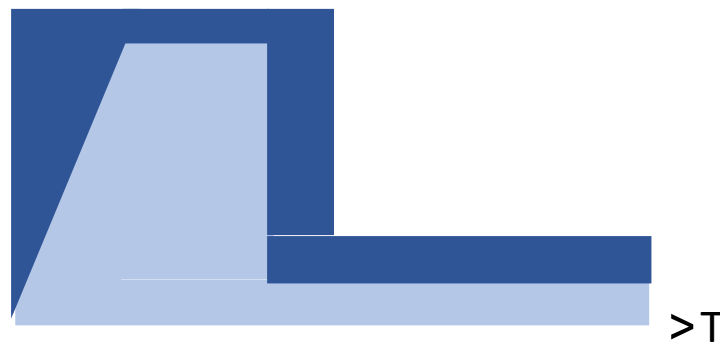
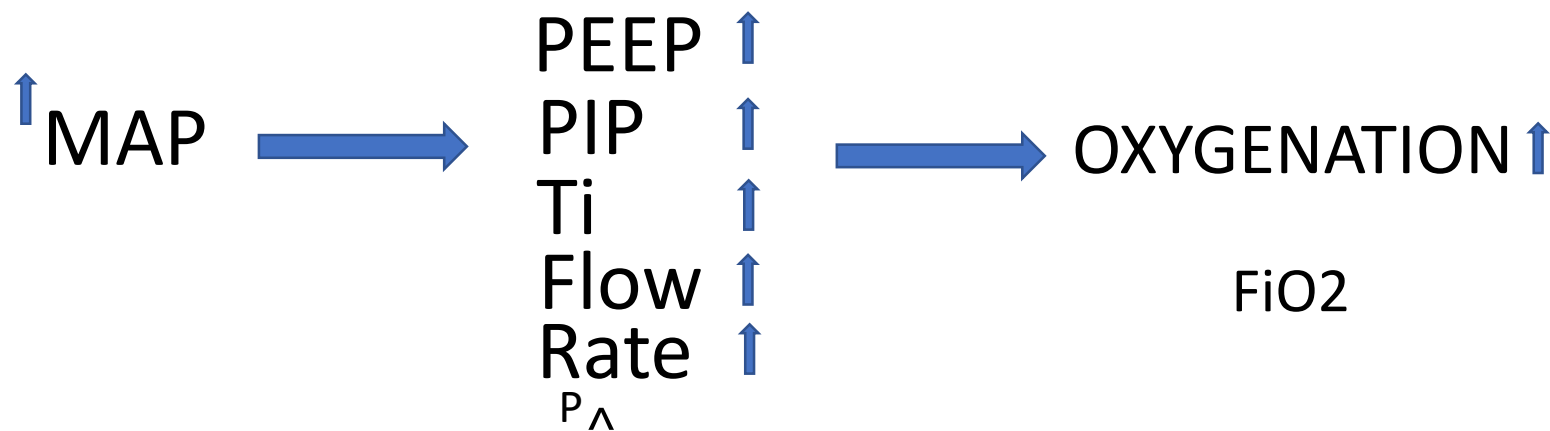


پارمترهای تنفسی

- PIP : (Peak Inspiratory Pressure)
- PEEP : (Positive End Expiratory Pressure)
- MAP : (Mean Airway Pressure)



پارمترهای تنفسی



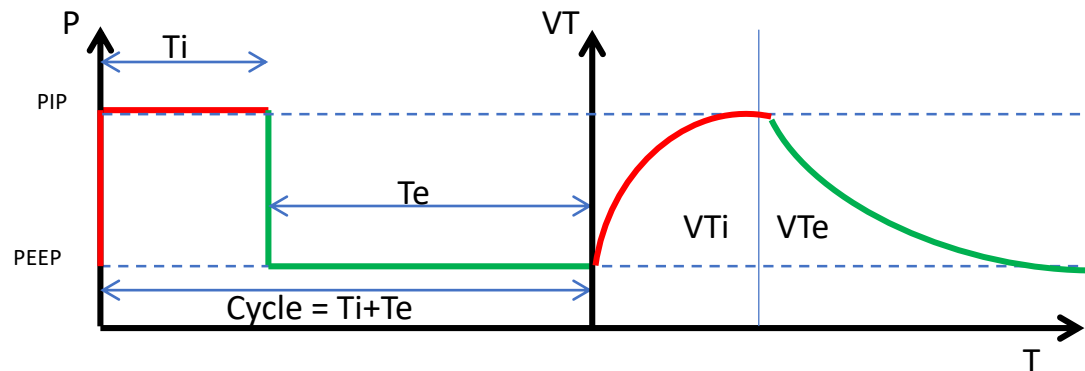


پارمترهای تنفسی

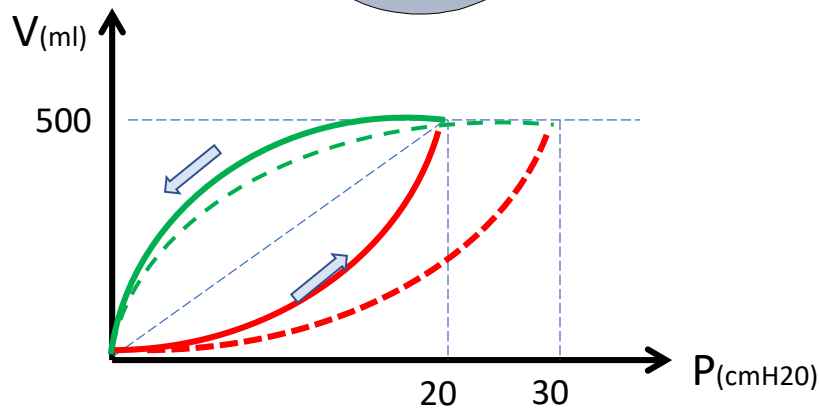
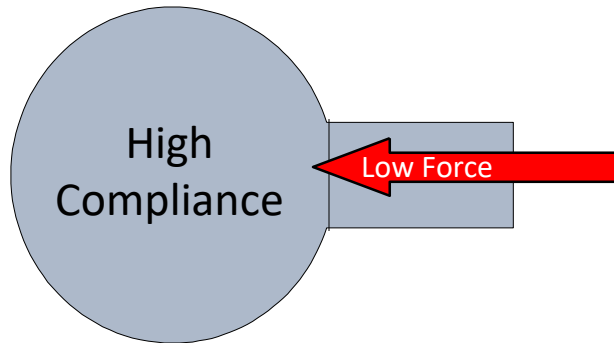
Respiratory Parameters

- V_t : Tidal Volume
- M_v : Minute Volume
- T_i : Inspiration Time
- T_e : Expiration Time
- I:E Ratio
- F : Rate
- Flow
- FiO_2
- Minute Volume ($\dot{V}_t$) $\approx$ Ventilation
- $\dot{V}_t = \text{Rate} \times V_t$

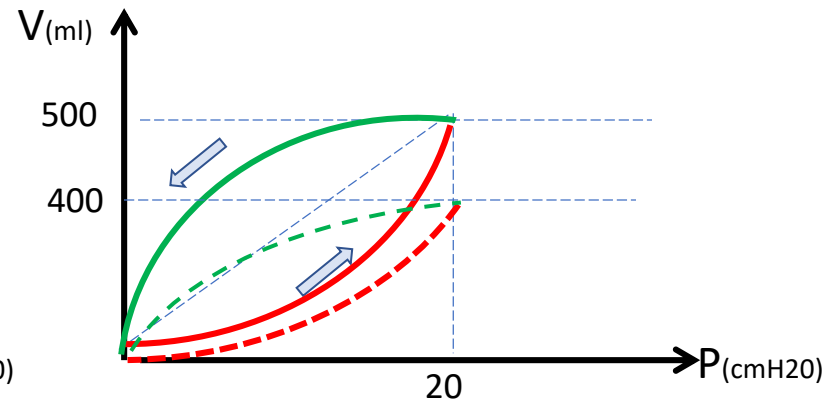
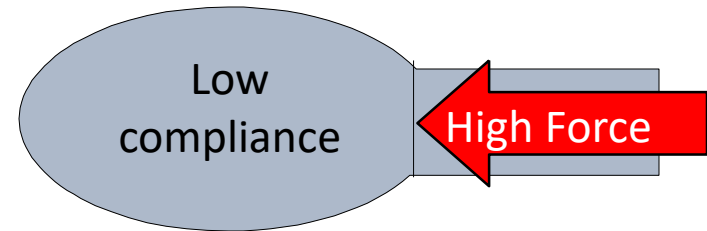
$\dot{V}_t \uparrow$ $CO_2 \downarrow$



- C: Compliance $\rightarrow C = \Delta V / \Delta P$



Volume Control Modes

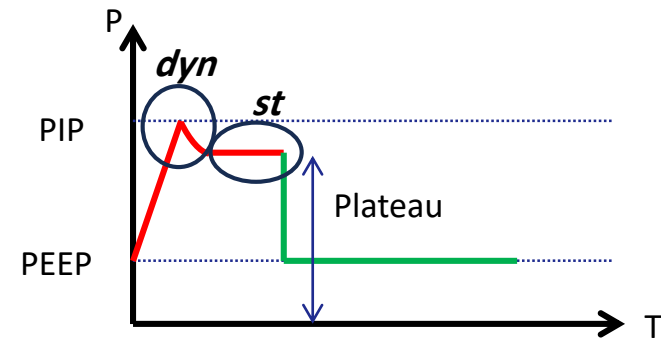


Pressure Control Modes



Compliance

- Static = $\frac{\Delta V}{Plateau - PEEP}$ (Flow = 0) $\rightarrow C_{lung \& chest}$
- Dynamic = $\frac{\Delta V}{PIP - PEEP}$ (Flow = $\neq 0$) $\rightarrow C_{lung \& chest} + C_{airways}$

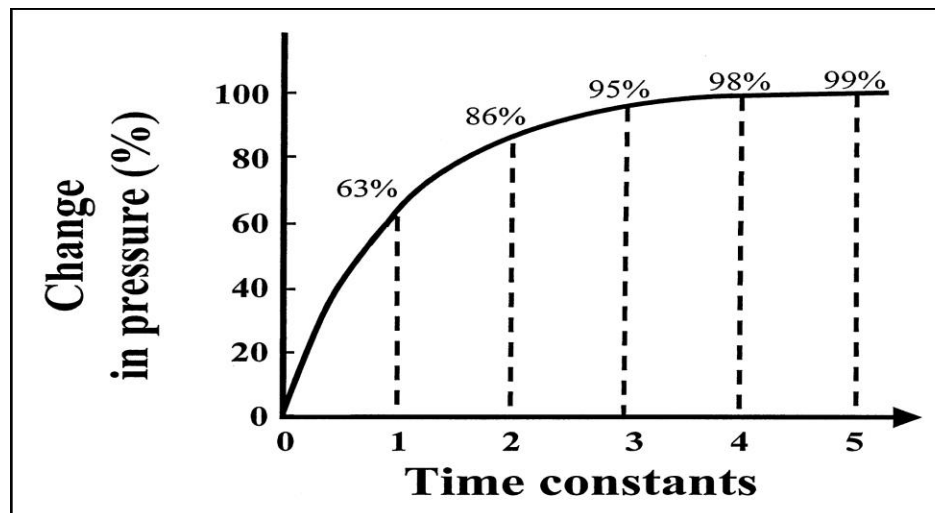




- R : (Resistance) $\longrightarrow R = \Delta P / \Delta V'$ Resistance = $\frac{8 \cdot \eta \cdot l}{\pi \cdot r^4} = [\text{cmH}_2\text{O}/\text{l/s}]$

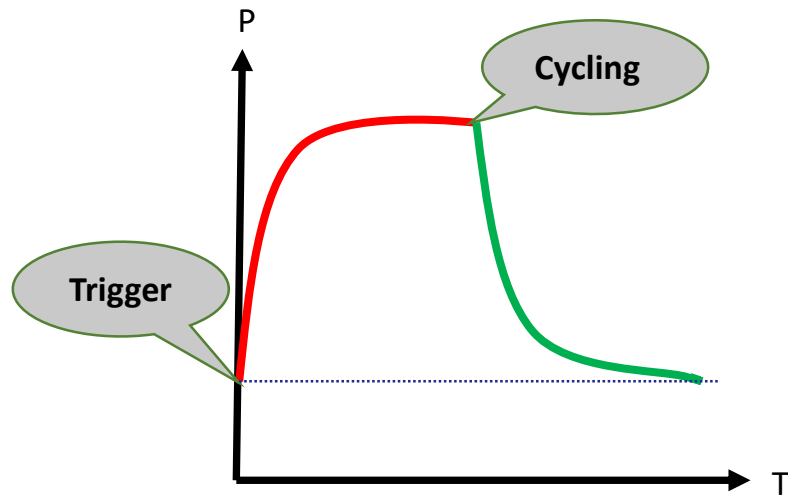
η viscosity of the gas
 l length of the tube
 r diameter of the tube

- Time Constant $\longrightarrow TC = R \cdot C$





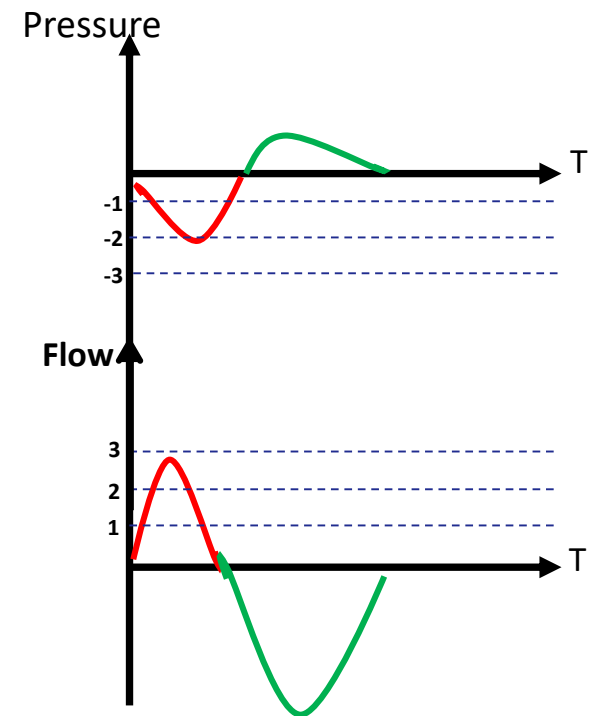
Respiratory Parameters



Trigger or Sensitivity

Device can detect patient effort

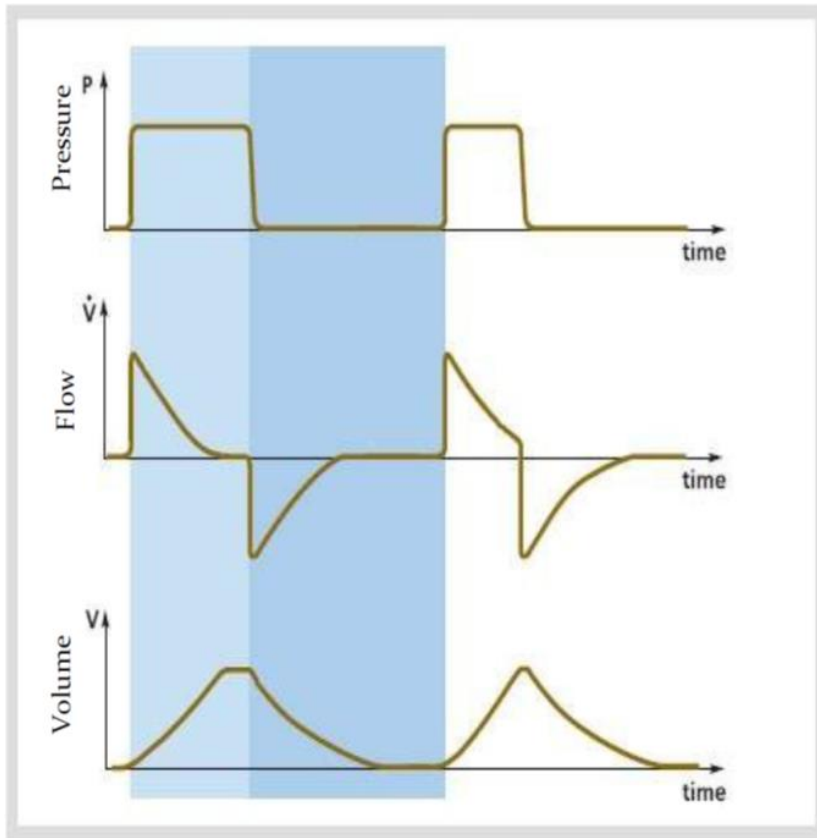
- Pressure Trigger
- Positive Flow Trigger



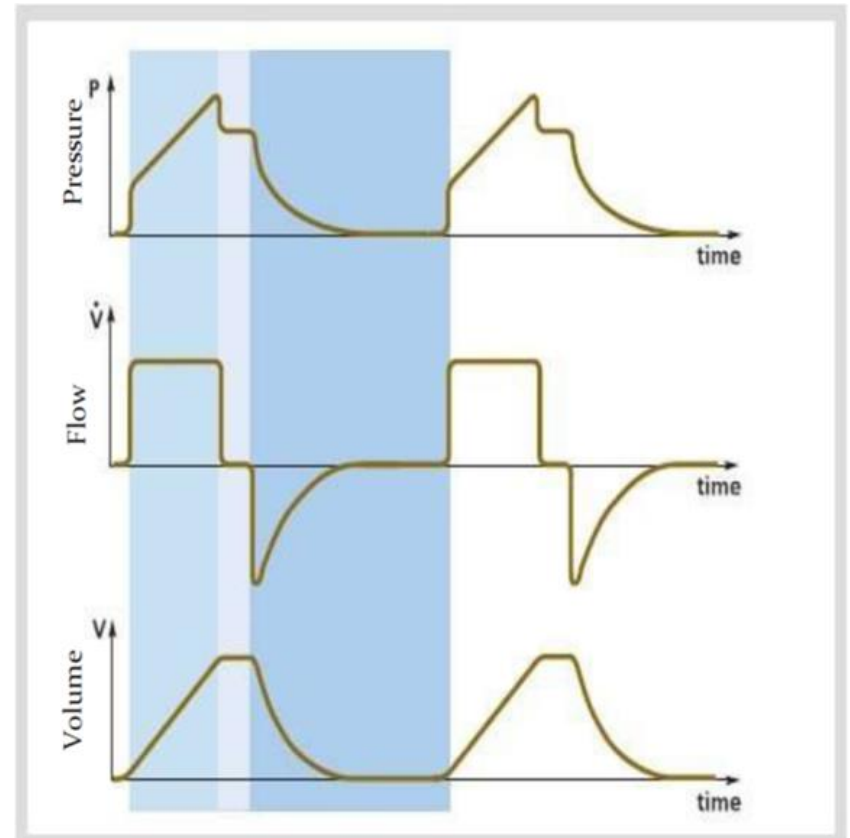


مود های تنفسی

Pressure Control Modes



Volume Control Modes



مود های تنفسی

IMV : (Intermittent Mandatory Ventilation)

SIMV : (Synchronized Intermittent Mandatory Ventilation)

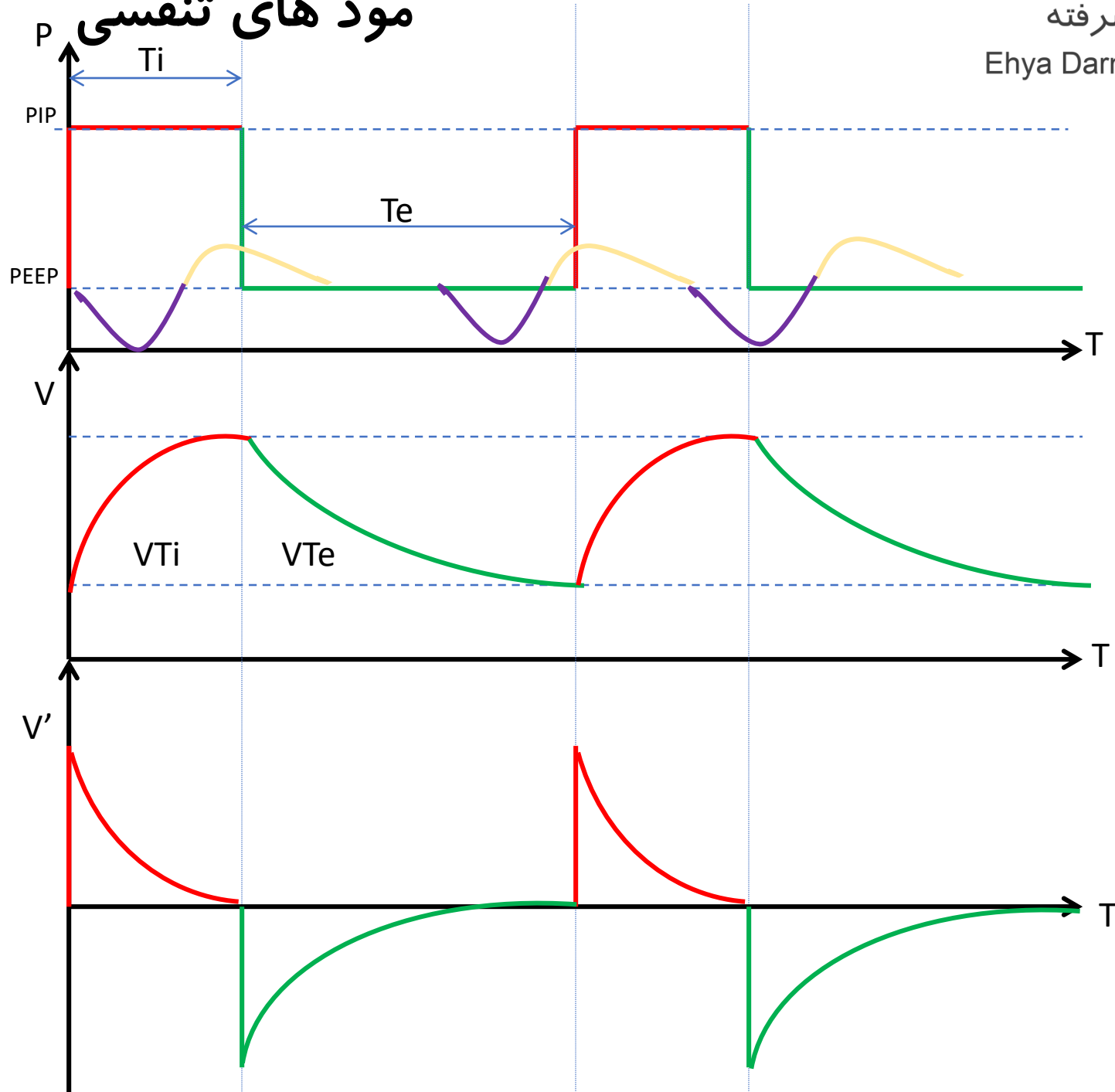
A/C : (Assisted / Controlled)

CPAP : (Continues Positive Airway Pressure)

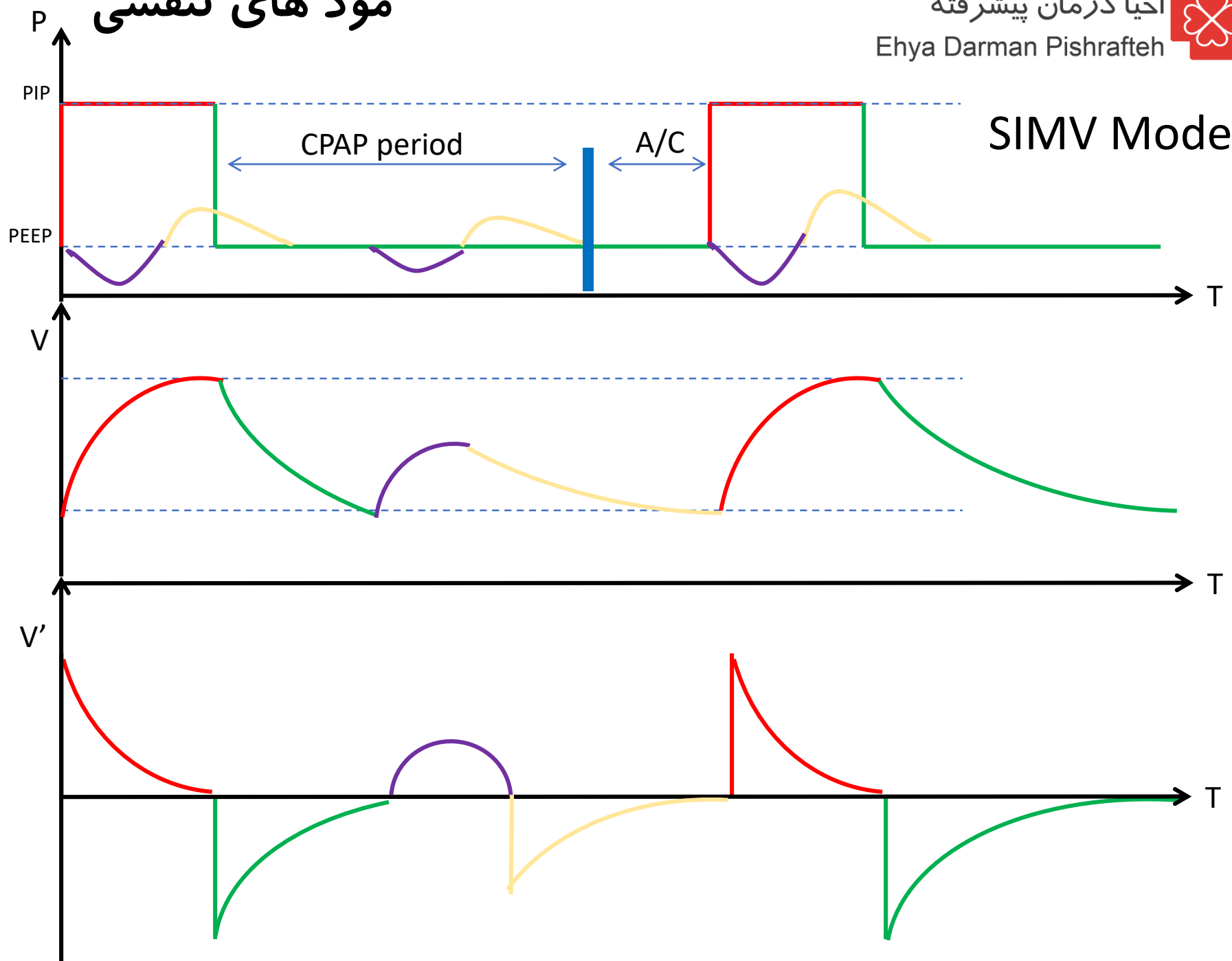
PSV : (Pressure Support Ventilation)



مود های تنفسی

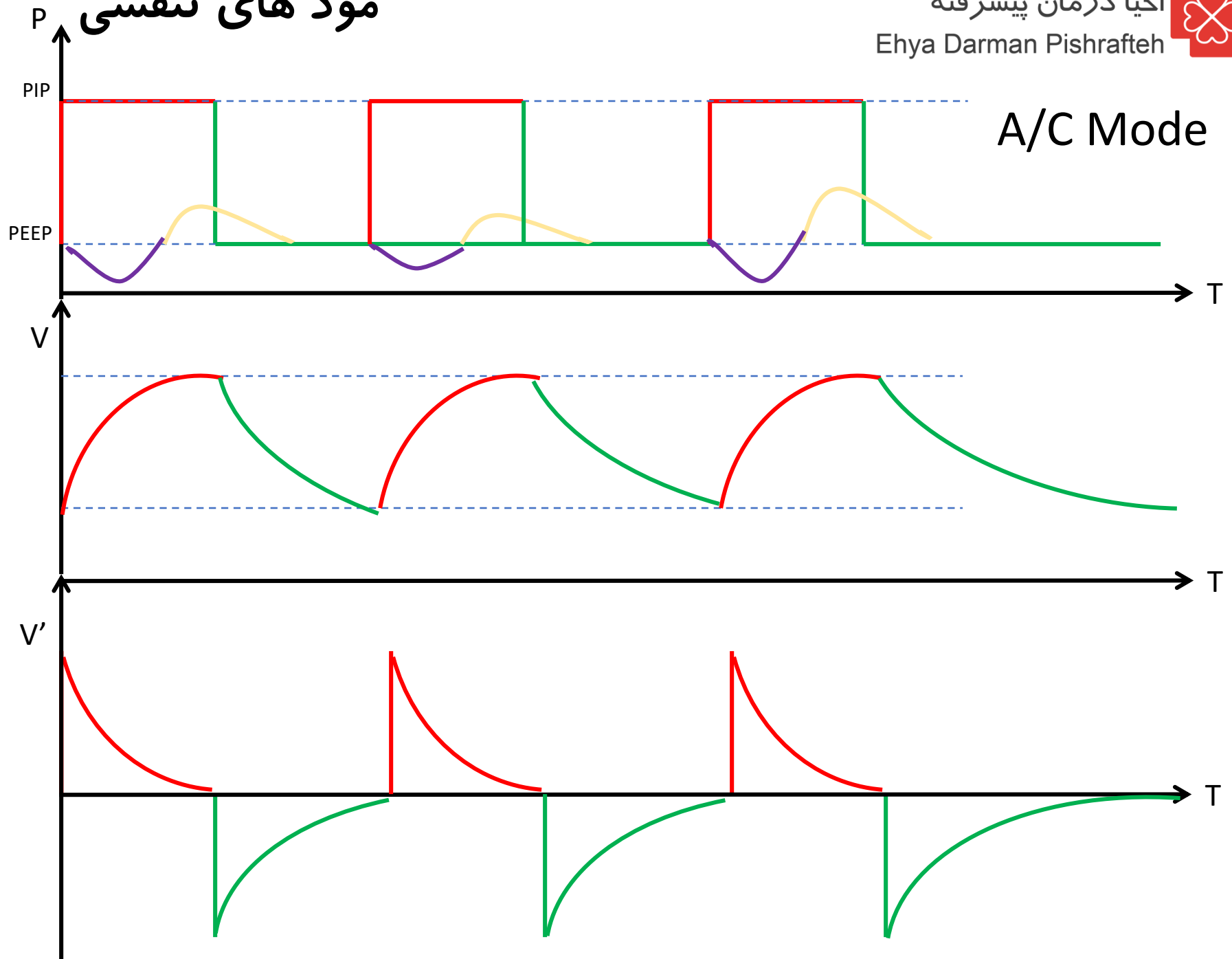


IMV Mode





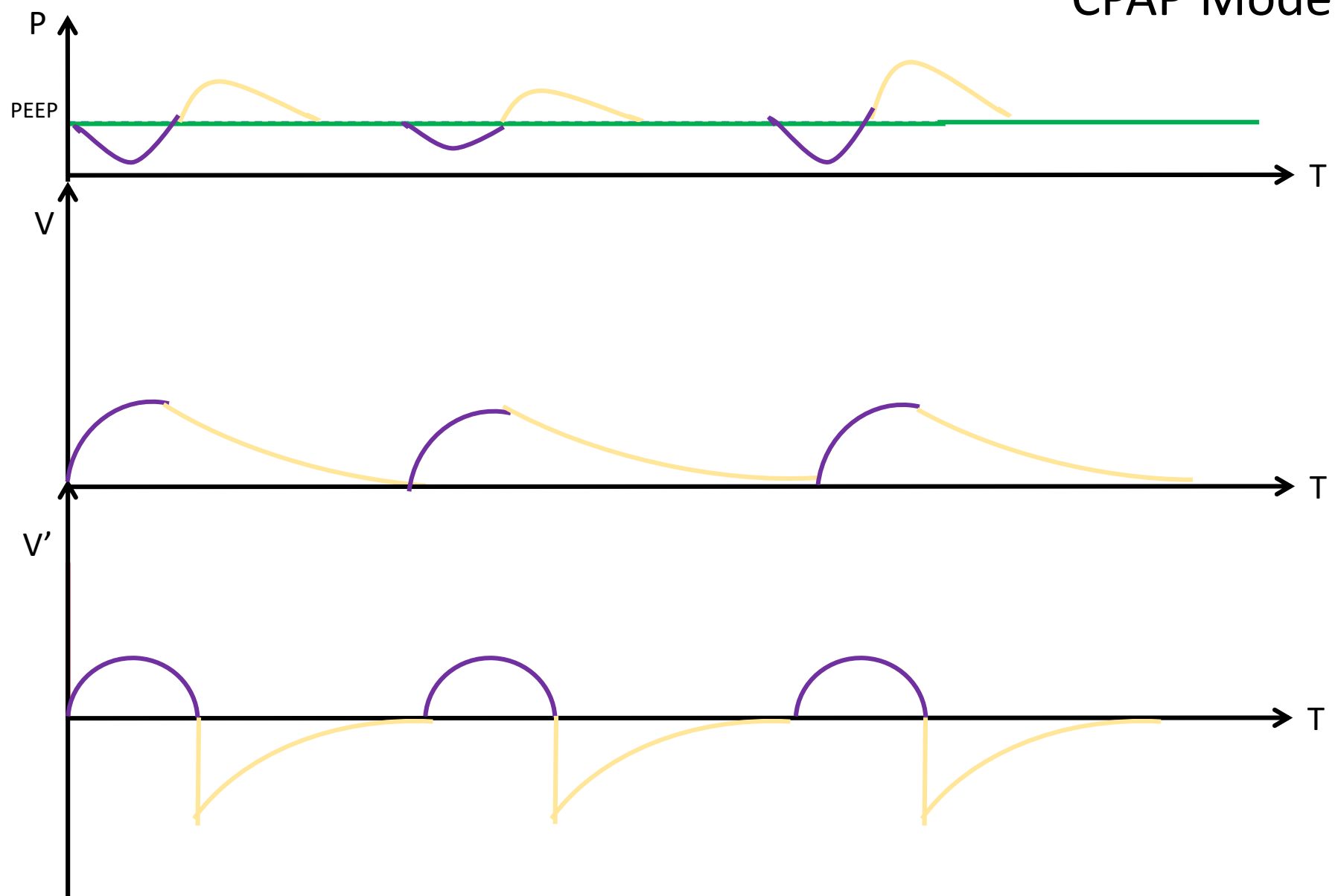
مود های تنفسی





مود های تنفسی

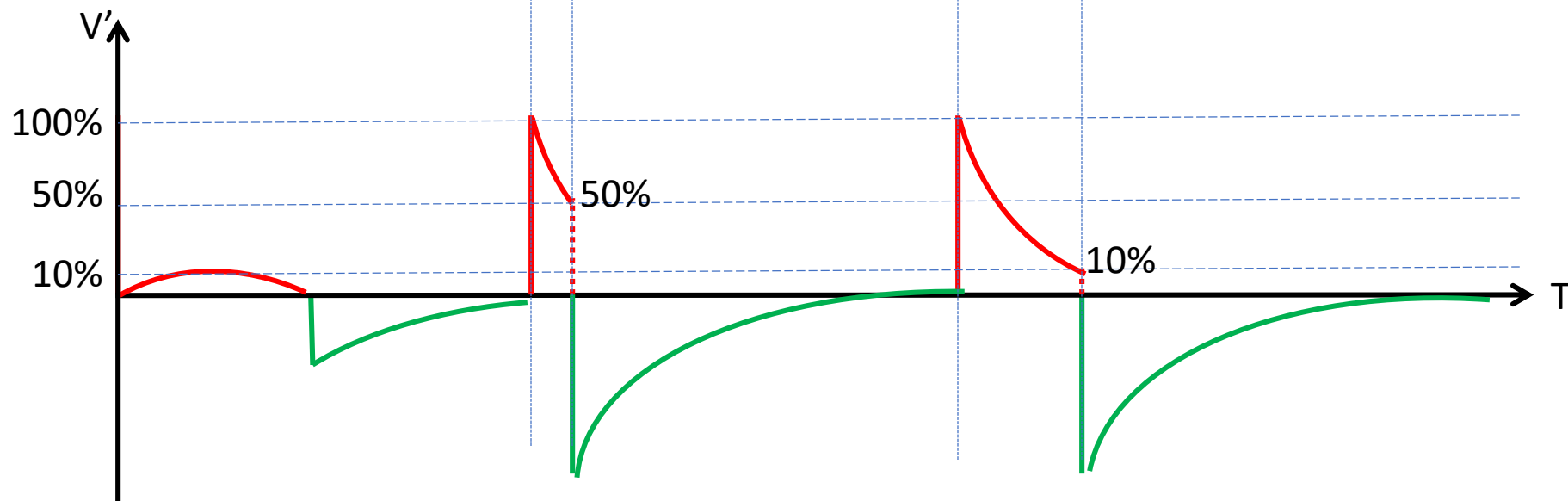
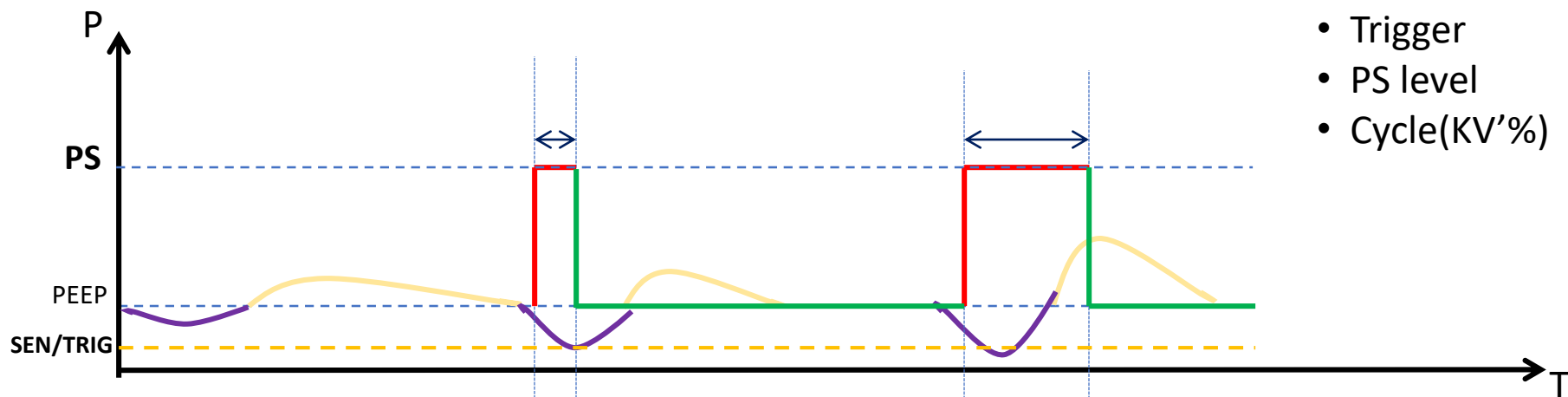
CPAP Mode





PSV

- Trigger
- PS level
- Cycle(KV'%)

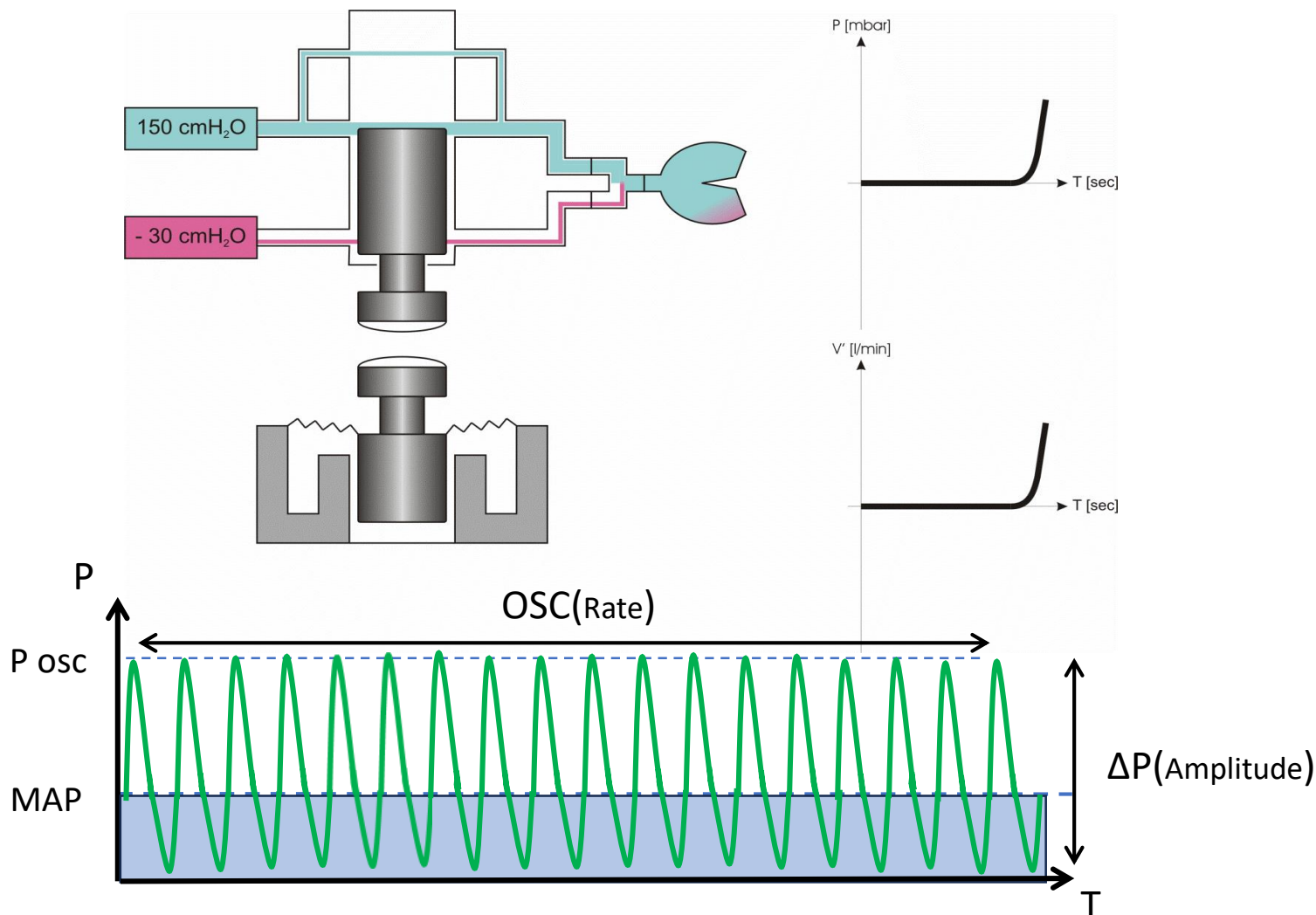


HFO (High Frequency Oscillation)

- High-Frequency Positive Pressure Ventilation
(HFPPV): 100-170/min, expiration passive
- High-Frequency Jet Ventilation
(HFJV): 150-600/min, expiration passive
- High-Frequency Oscillatory Ventilation
(HFOV): 300-2400/min, expiration active



HFO principle function





HFO: Parameters to be Set

- **Mean airway pressure**, improves Oxygenation through better independent setting of **MAP** and **Pmax**. (MAP: 2-3 mbar higher compared to the conventional ventilation, approx. 10-12mbar, increase stepwise as long as oxygenation is improving. Adjustment depends on the diaphragm position)
- **Oscillatory pressure amplitude** (delta Paw, CO₂ removal)
- **Rate (f)**, around 10 Hz
- **Ratio of inspiration to expiration** (default to 40% to avoid inadvertent PEEP)
- Intermittent sustained inflations (recruitment maneuver)

Ventilator Settings

▲ Initial pediatric frequency settings

1000 g	15 Hz
1000-2000 g	12 Hz
2.0-10.0 kg	10 Hz
13-20 kg	8 Hz
21-30 kg	7 Hz
>30 kg	6 Hz
Meconium aspiration	3-6 Hz

Ventilator Settings

▲ TI% - proportion of cycle occupied by inspiration

- ◆ initial setting = 33%
- ◆ increased TI% ==> increased TV
==> affects PCO₂
- ◆ increased TI% decreases PCO₂

مودهای تنفسی ونتیلاتور EDP-TS

- VCV
- PCV
- PSV/CPAP
- SIMV(VCV)+PSV
- SIMV(PCV)+PSV
- NIV

ADL
VCV

17/02/11
09:21

48
L/min
Peak Flow

1.00
s
Ti

4.0
s
Te

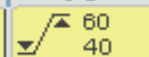
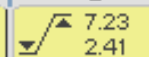
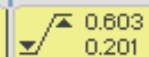
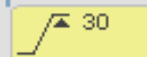
1:4.0
Current
I:E

12
bpm
 f_{Total}

0.403
L
VT

4.82
L/min
 $\dot{V}_E$

50
%
Oxygen



Peak
23

Trach.

Plateau

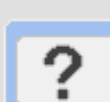
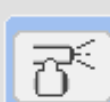
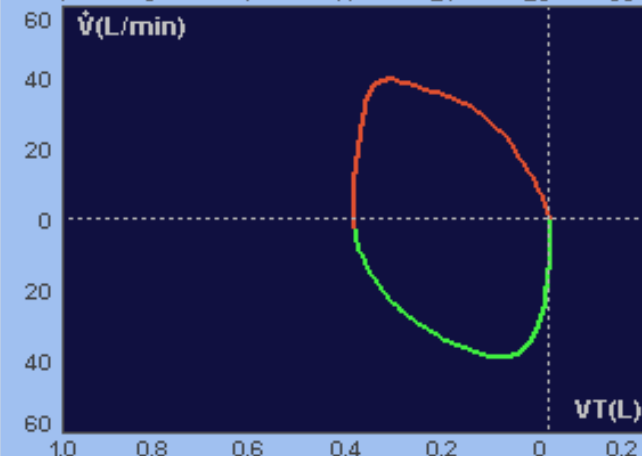
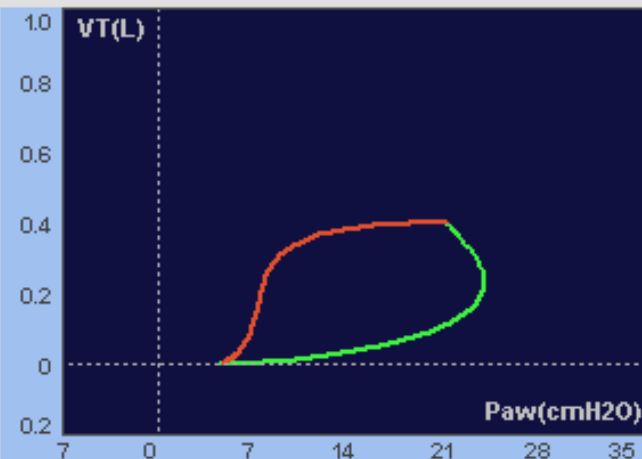
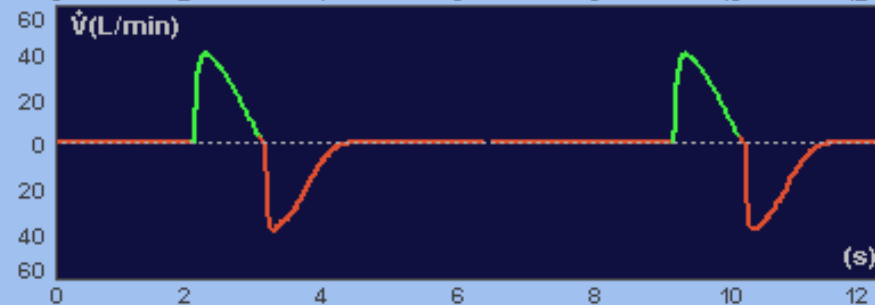
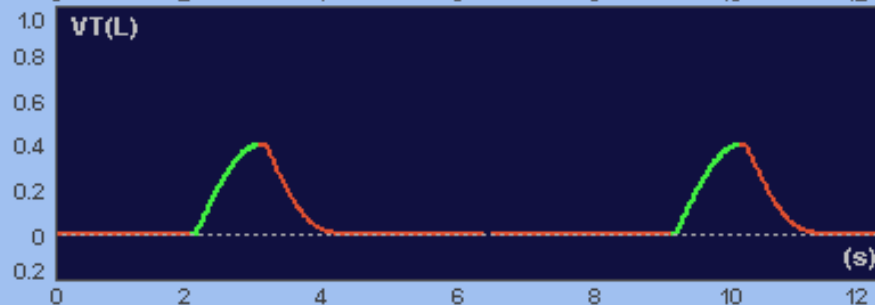
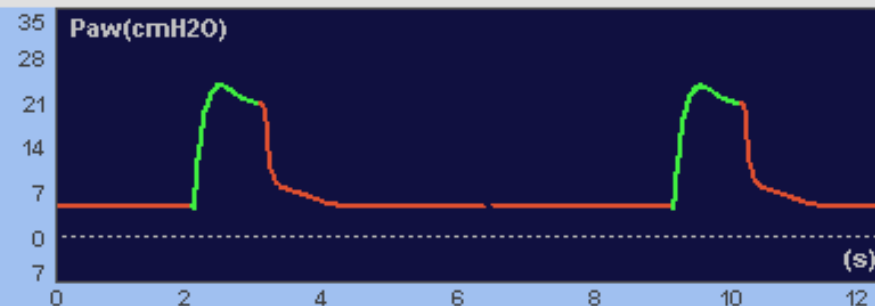
Mean
8.9

PEEP
5.0

Pressure
Limits

40

5



0.402
L
VT

1.00
s
Ti

1:4.0
I:E

12
bpm
 f

5
cmH2O
PEEP

3.0
L/min
Sens

50
%
Oxygen

Flow
Waveform

ADL
PCV

17/02/11
10:41

39
L/min
Peak Flow

1.00
s
Ti

4.0
s
Te

1:4.0
Current
I:E

12
bpm
 f_{Total}

0.363
L
VT

4.38
L/min
 $\dot{V}_E$

50
%
Oxygen

30

0.600
0.150

7.23
2.41

60
40



Peak
20
Trach.

Plateau

Mean
8.4
PEEP
5.0

Pressure
Limits

40

5

15

cmH2O
PCV

1.00

s
Ti

1:4.0

I:E

12

bpm
 f

5

cmH2O
PEEP

3.0

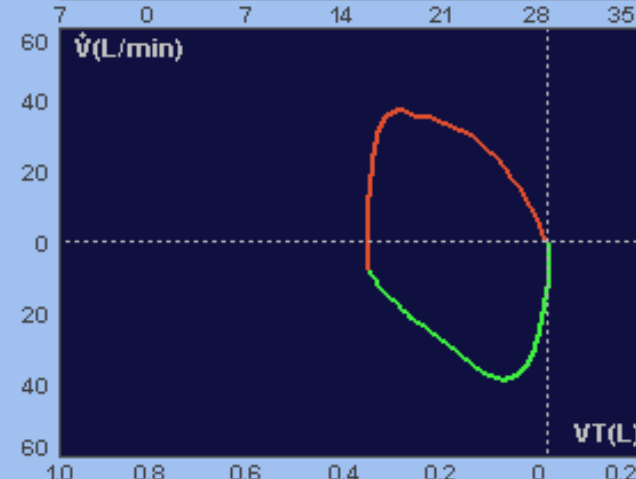
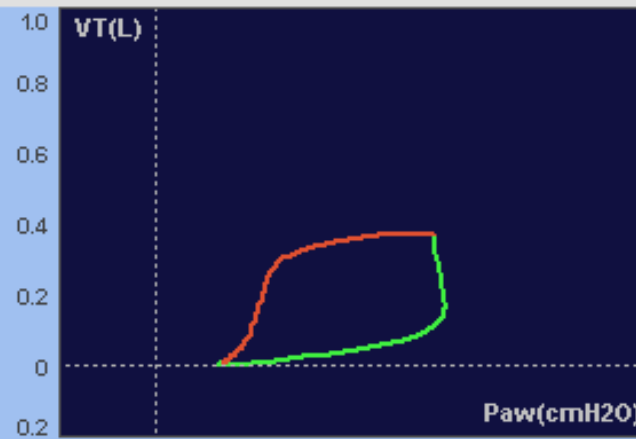
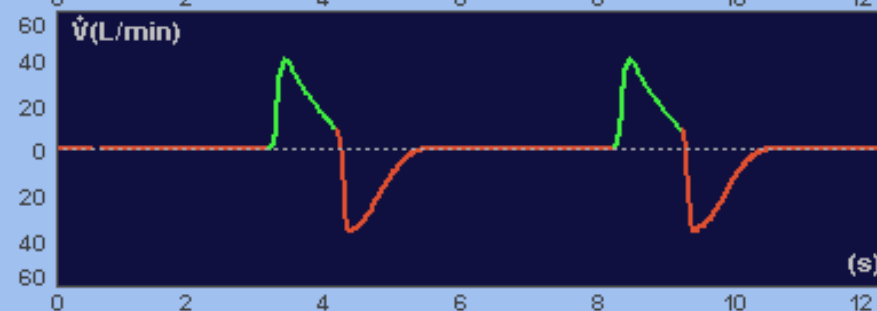
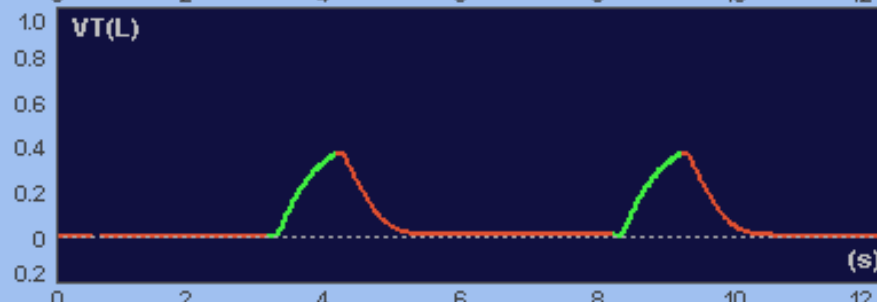
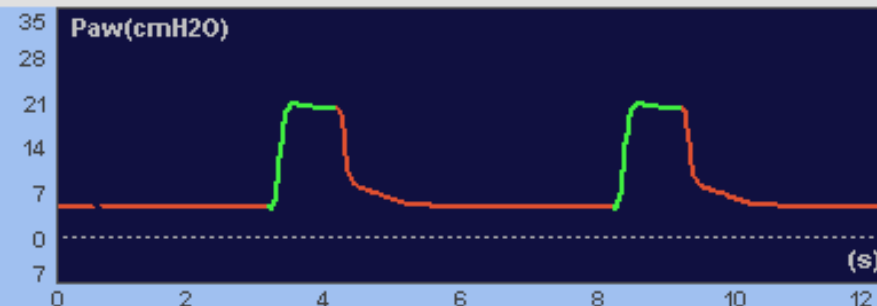
L/min
Sens

50

%
Oxygen



Rise
Time



ADL PSV/CPAP

Backup: VCV

17/02/11
10:46

24
L/min
Peak Flow

0.30
s
Ti

3.13
s
Te

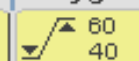
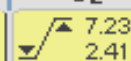
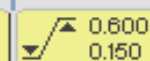
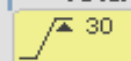
1:10
Current
I:E

25
bpm
 f_{Total}

0.072
L
VT

1.84
L/min
 $\dot{V}_E$

50
%
Oxygen

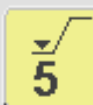


Peak
10
Trach.

Plateau

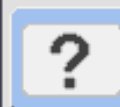
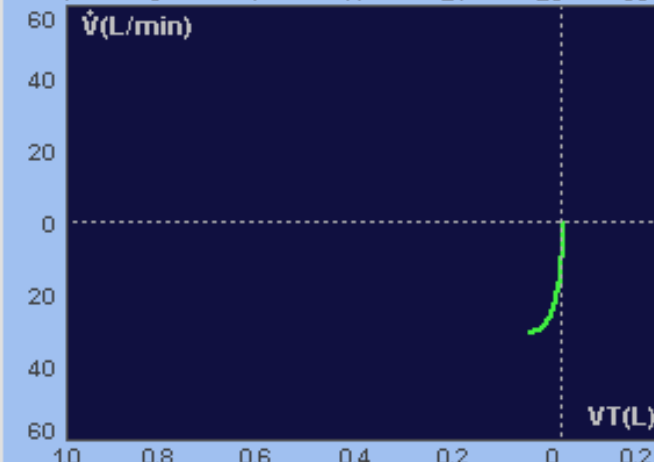
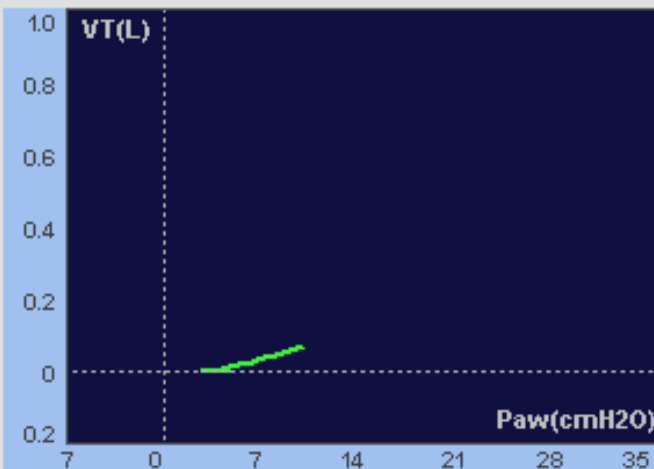
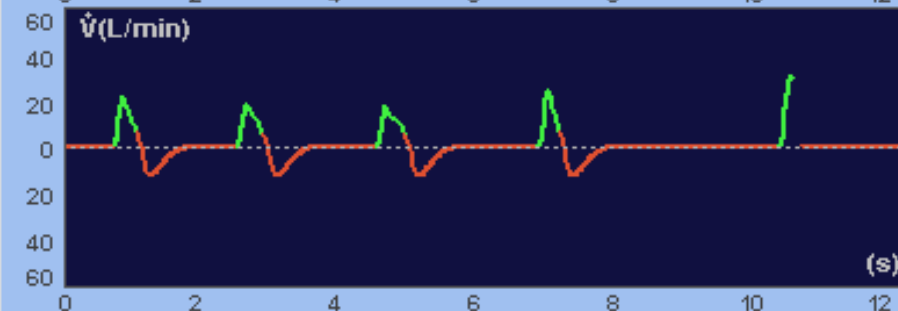
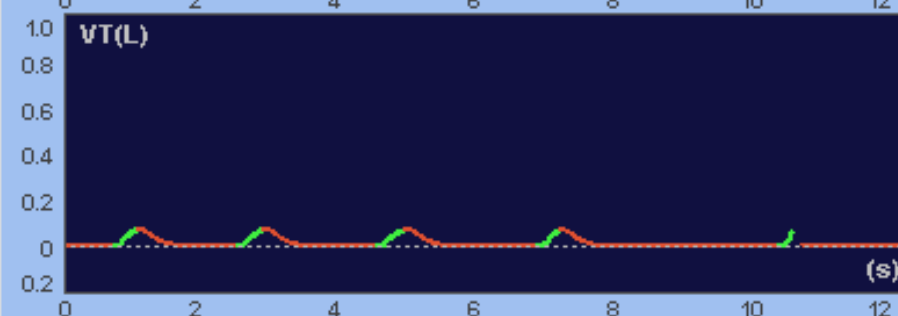
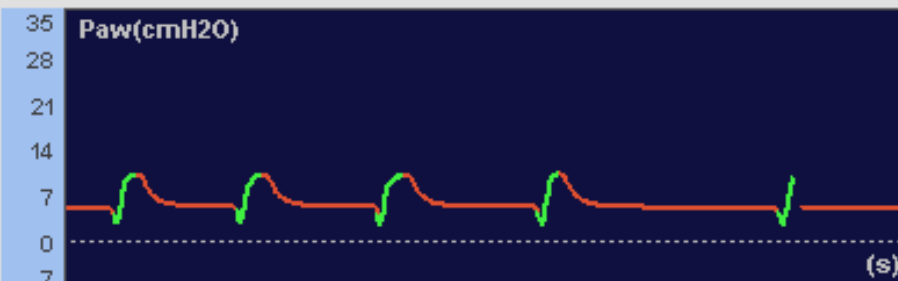
Mean
6.0
PEEP
5.1

Pressure
Limits



5
cmH2O
PSV

25
%
Exp. Sensitiv.



5
cmH2O
PEEP

3.0
L/min
Sens

50
%
Oxygen

Rise
Time

ADL SIMV(VCV)+PSV

Backup: OFF

17/02/11
10:49

48
L/min
Peak Flow

1.00
s
Ti

3.10
s
Te

1:3.1
Current
I:E

27
bpm
f_{Total}

0.395
L
VT

4.39
L/min
V̇_E

50
%
Oxygen

30

0.603
0.201

7.23
2.41

60
40



Peak
23

Trach.

Plateau

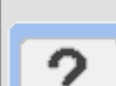
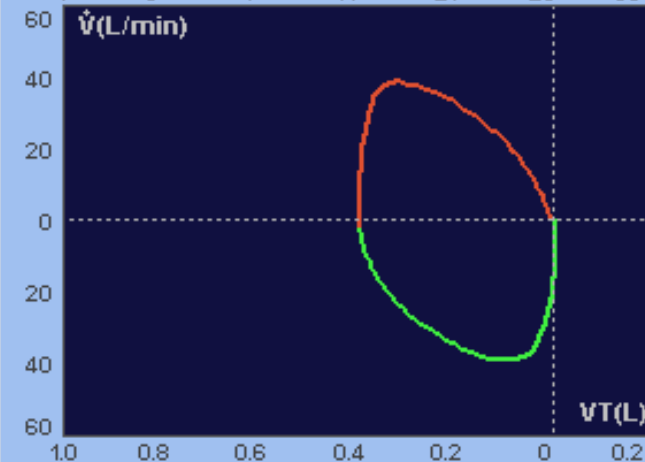
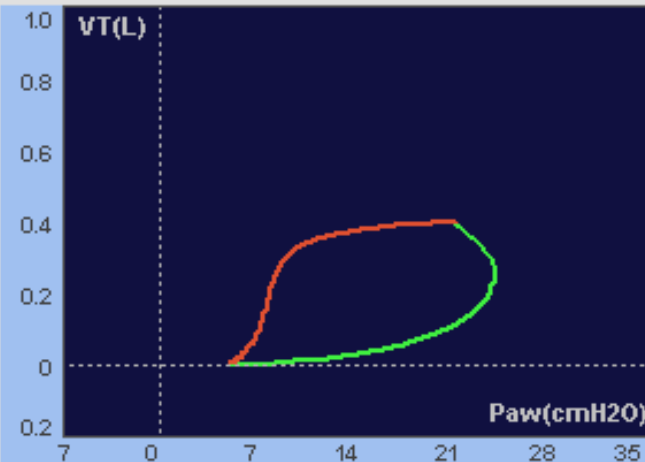
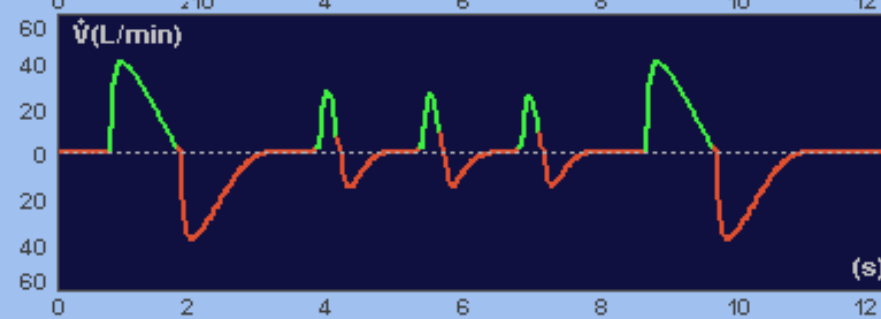
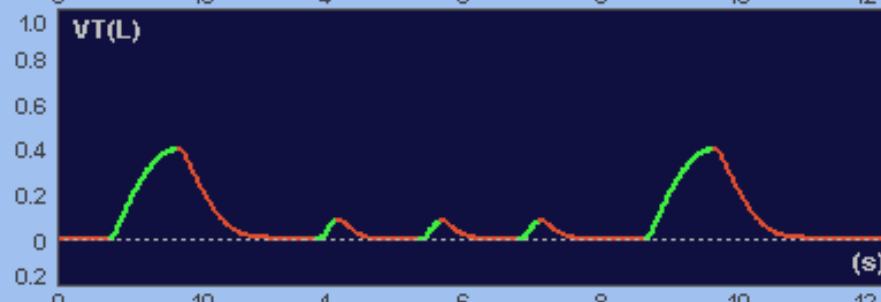
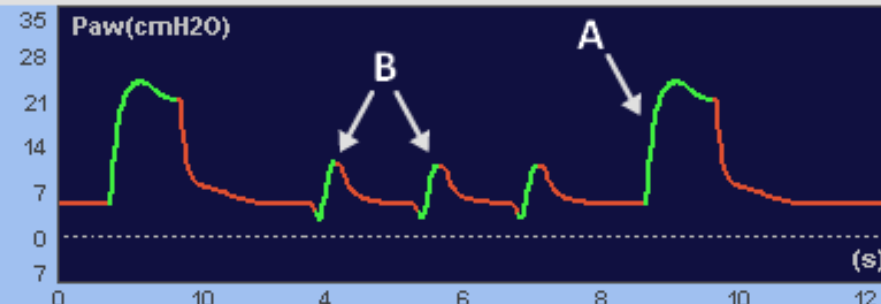
Mean
6.6

PEEP
5.0

Pressure
Limits

40

5



0.402
L
VT

1.00
s
Ti

1:9.0
I:E

6
bpm
f

5
cmH2O
PSV

25
%
Exp. Sensitiv.

5
cmH2O
PEEP

3.0
L/min
Sens

50
%
Oxygen

**Rise
Time**

**Flow
Waveform**

ADL SIMV(PCV)+PSV

Backup: OFF

17/02/11
10:55

37
L/min
Peak Flow

1.00
s
Ti

1.39
s
Te

1:4.6
Current
I:E

32
bpm
 f_{Total}

0.087
L
VT

4.44
L/min
 $\dot{V}_E$

50
%
Oxygen

30

0.600
0.150

7.23
2.41

60
40



Peak
20

Trach.

Plateau

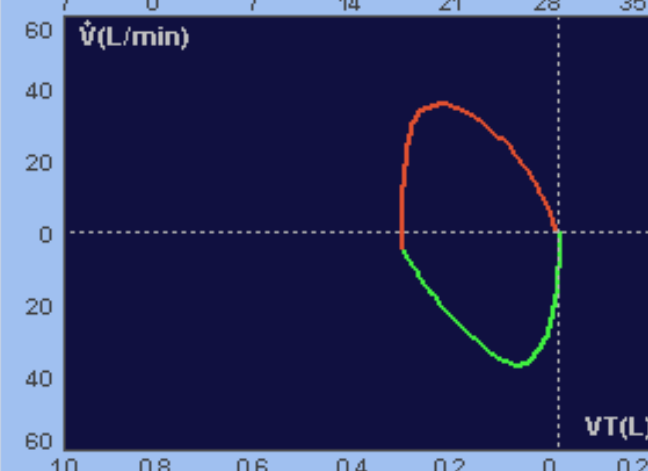
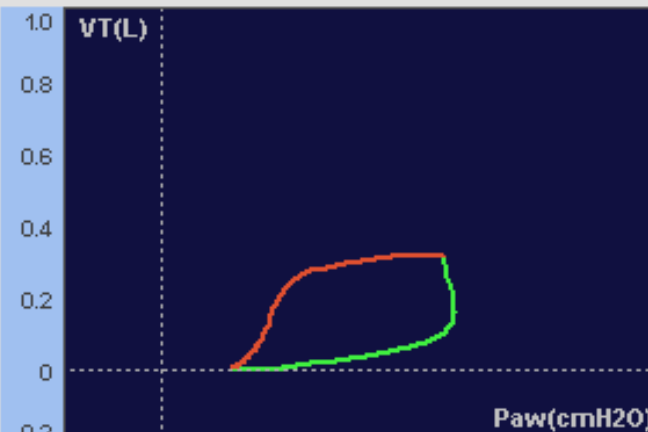
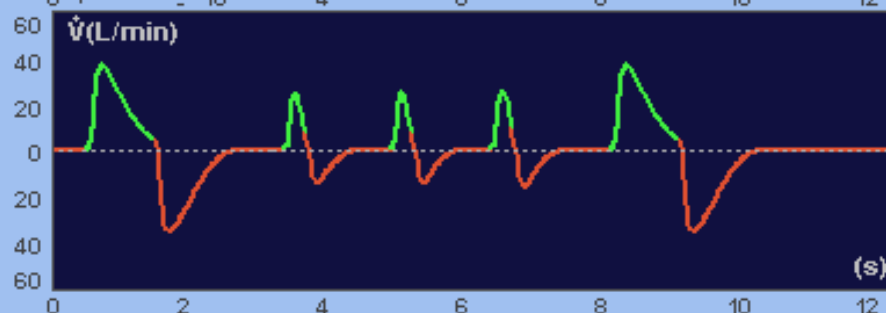
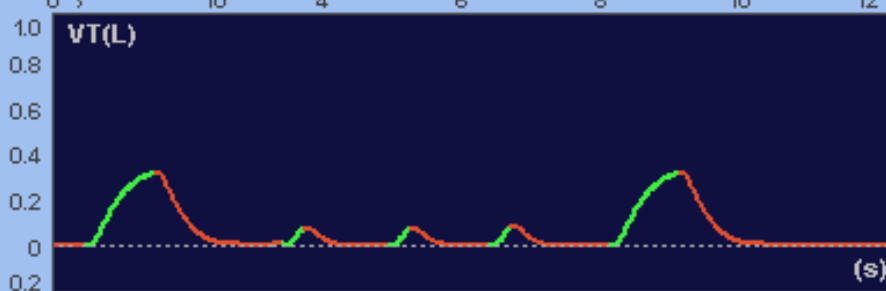
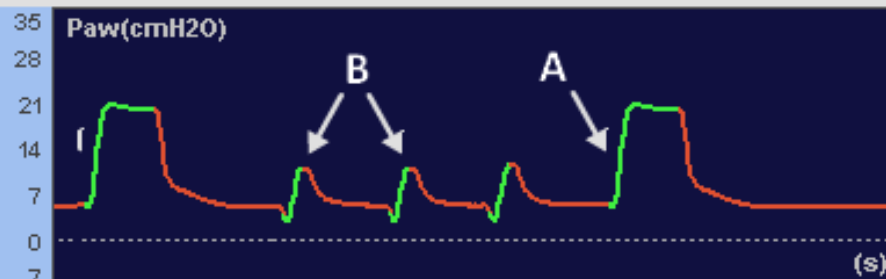
Mean
6.8

PEEP
5.0

Pressure
Limits

40

5



15
cmH2O
PCV

1.00
s
Ti

1:9.0
I:E

6
bpm
 f

5
cmH2O
PSV

25
%
Exp. Sensitiv.

5
cmH2O
PEEP

3.0
L/min
Sens

50
%
Oxygen

Rise
Time

ADL Noninvasive (NIV)

06/07/11
13:13

47
L/min
Peak Flow

1.13
s
Ti

4.86
s
Te

1:4.3
Current
I:E

10
bpm
 f_{Total}

0.460
L
VT

4.65
L/min
 $\dot{V}_E$

52
%
Oxygen

30

0.780
0.150

22.00
2.43

60
40



Volume compensation
Leak compensation

Peak
20
Trach.

Plateau

Mean
9.1
PEEP
5.0

Pressure
Limits

40

5

15

cmH2O
PSV

1.20

s
Ti

1:4.0

I:E

10

bpm
 f

25

%
Exp. Sensitiv.

5

cmH2O
PEEP

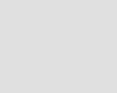
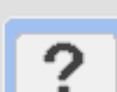
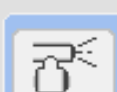
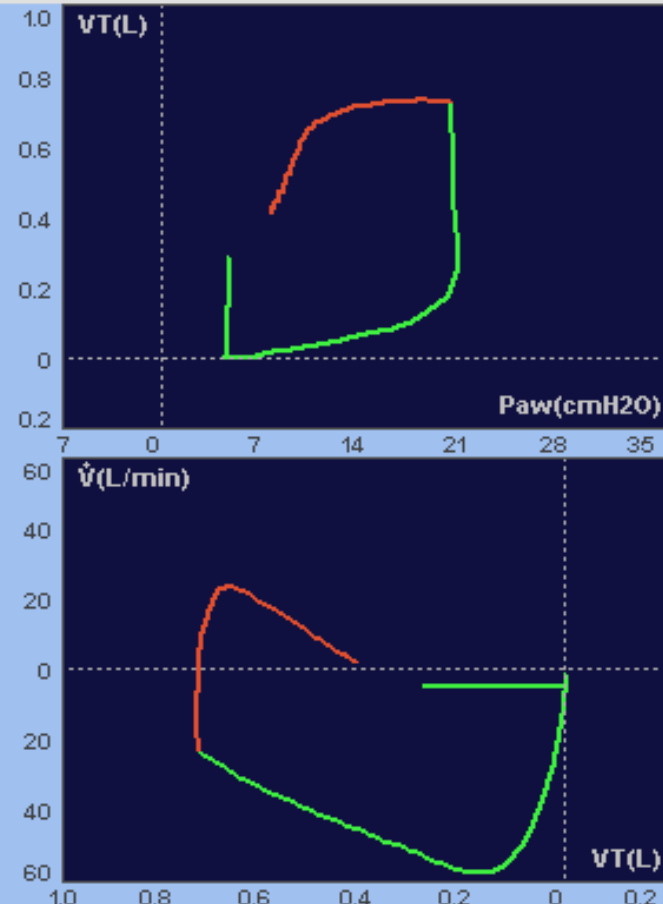
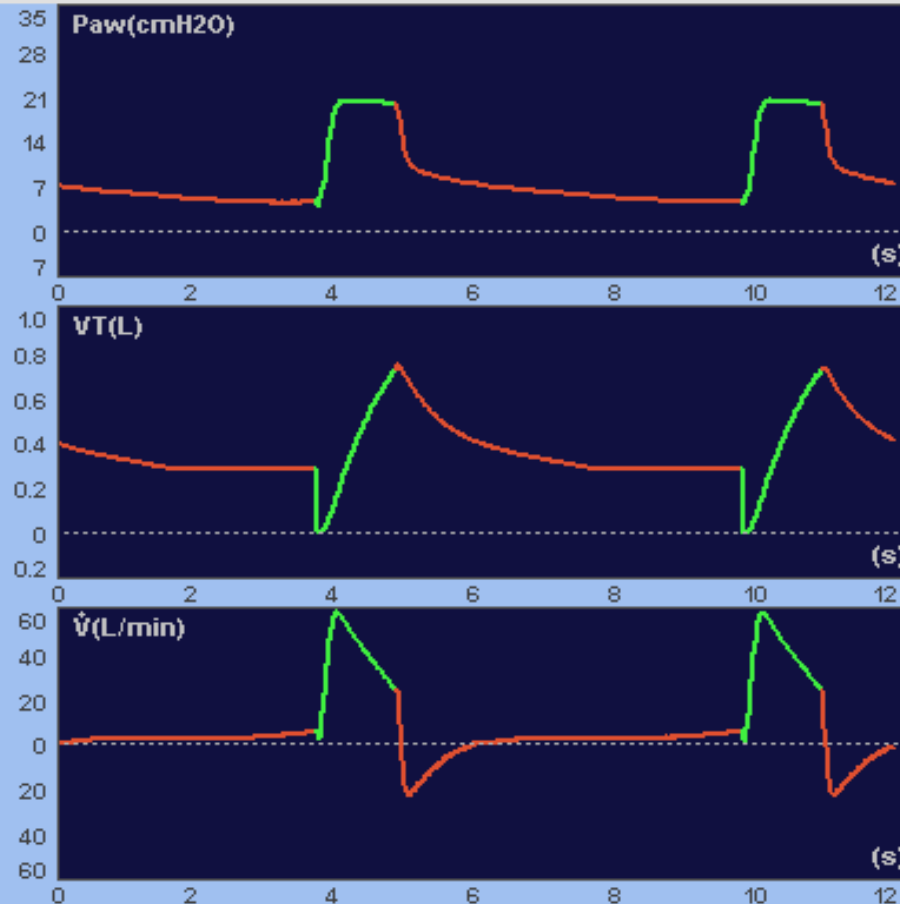
1.0

L/min
Sens

50

%
Oxygen

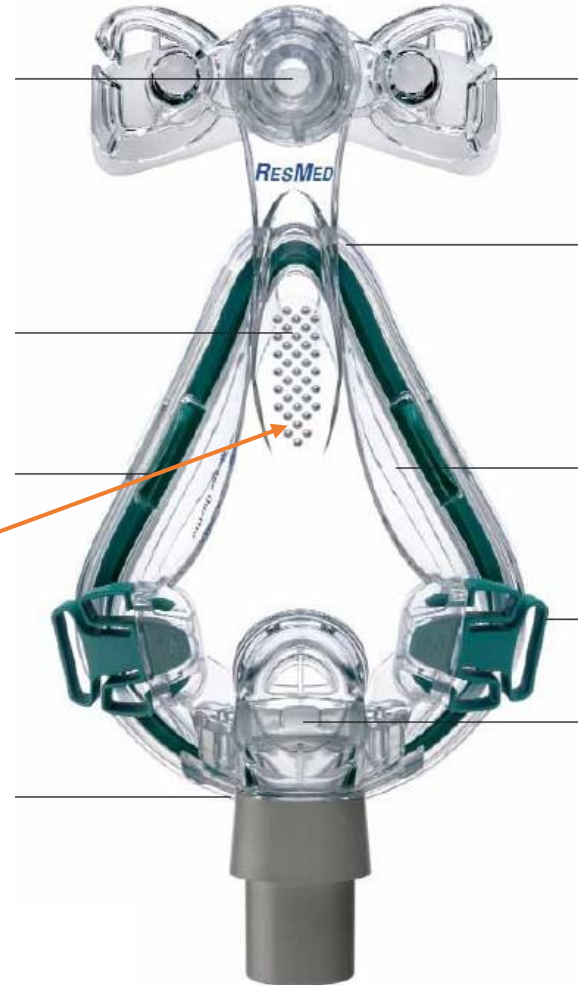
Rise
Time



VENTED MASK



Leak



NON-VENTED MASK



مود های تنفسی پیشرفته Dual Control modes (ترکیبی ، هیبرید)

- **MMV+PSV** (Mandatory Minute Ventilation+PSV)
- **PSV+VT** Assured
- **PRVC** (Pressure Regulated Volume Control)
- **APRV** (Airway Pressure Release Ventilation)

ADL MMV+PSV

Backup: VCV

17/02/11
11:01

38
L/min
Peak Flow

0.63
s
Ti

1.55
s
Te

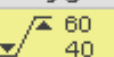
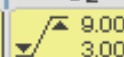
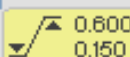
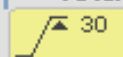
1:2.4
Current
I:E

28
bpm
 f_{Total}

0.237
L
VT

5.48
L/min
 $\dot{V}_E$

50
%
Oxygen



Peak
18
Trach.

Plateau

Mean
9.8
PEEP
5.0

Pressure
Limits

40

5

6.0
L/min
 $\dot{V}_E$

5
cmH2O
PSV

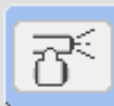
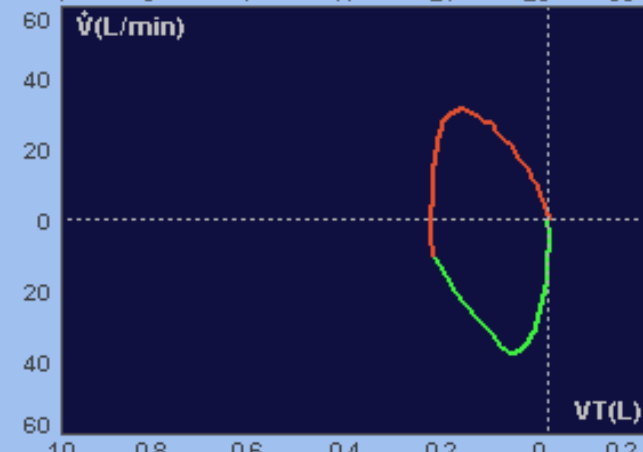
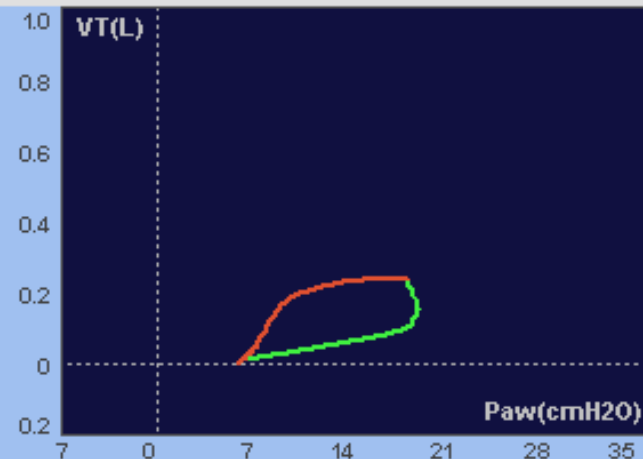
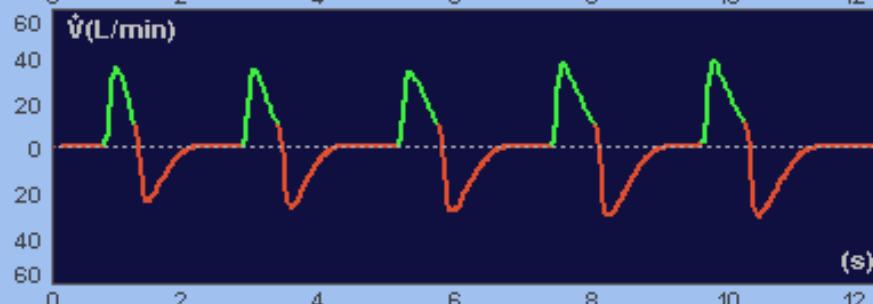
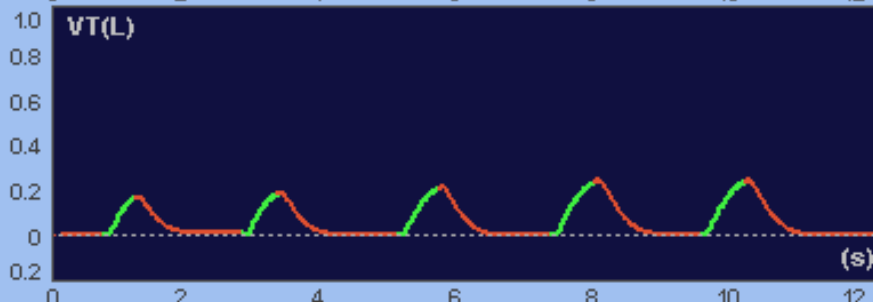
25
%
Exp. Sensitiv.

5
cmH2O
PEEP

3.0
L/min
Sens

50
%
Oxygen

**Rise
Time**



Peak
20

Trach.

Plateau

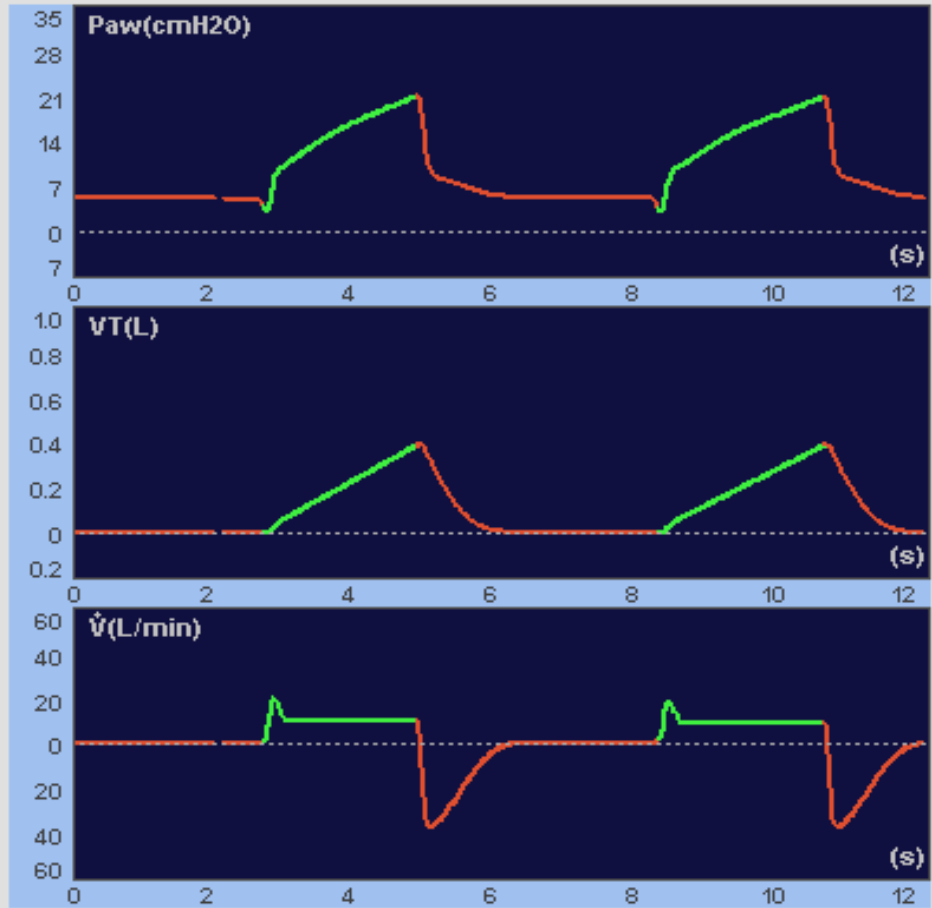
Mean
10.3

PEEP
5.0

Pressure Limits

40

5



PRVC Mode

Pressure Regulated Volume Control

- Dual Control mode
- Pressure Control with a target VT
- Assist /Control
- Maximum Limit: $P_{max} - 5 \text{ cmH}_2\text{O}$
- Minimum PCV $5 \text{ cmH}_2\text{O}$

04/07/11
16:2931
L/min
Peak Flow1.00
s
Ti4.0
s
Te1:4.0
Current
I:E12
bpm
 f_{Total} 0.341
L
VT4.08
L/min
 $\dot{V}_E$ 52
%
Oxygen

30

 0.600
0.200 7.30
2.43 60
40

Volume compensation

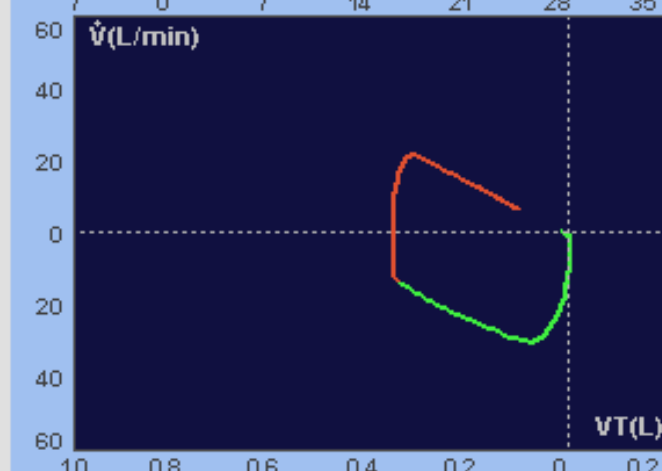
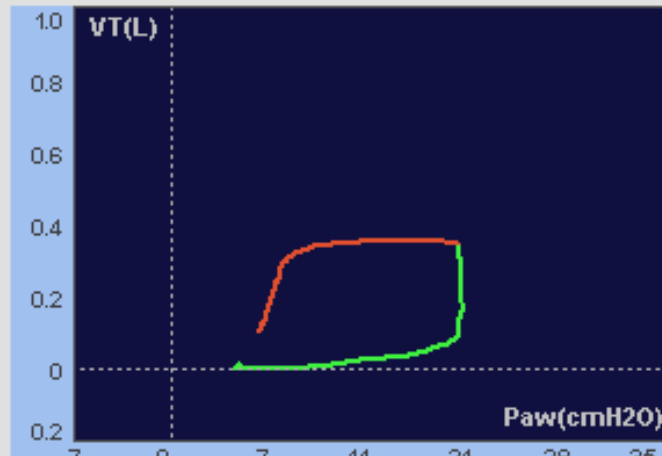
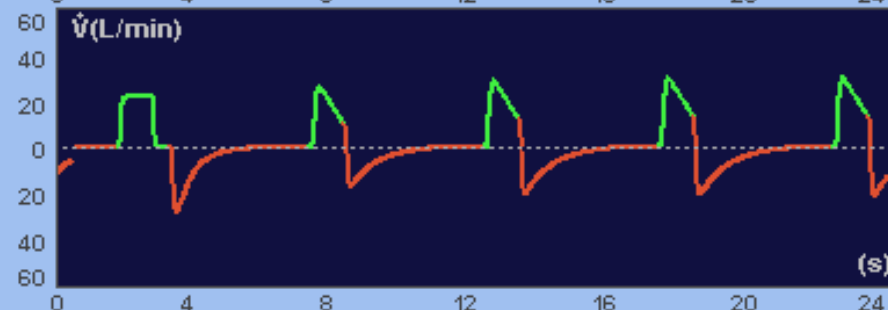
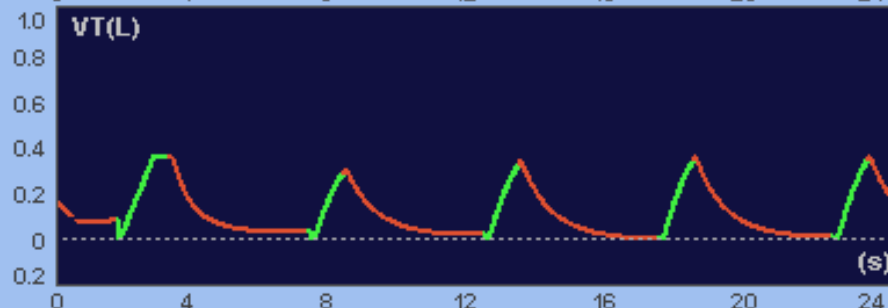
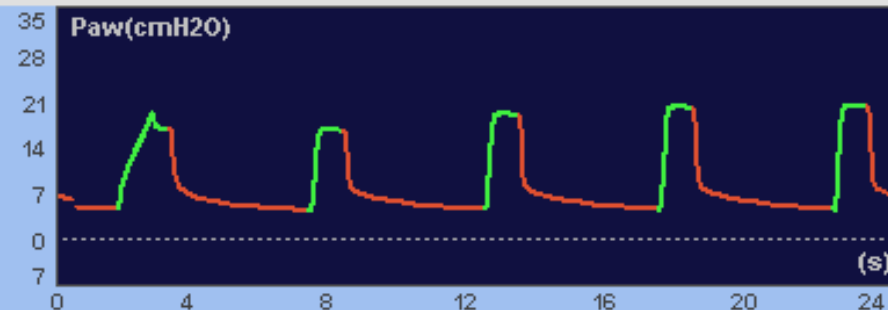
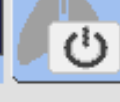
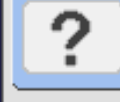
Peak
20
Trach.

Plateau

Mean
8.9
PEEP
5.1Pressure
Limits

40

5

0.400
L
VT1.00
s
Ti1:4.0
I:E12
bpm
 f 5
cmH2O
PEEP3.0
L/min
Sens50
%
Oxygen
Rise
Time

APRV Mode

- 2 levels of CPAP with intermittent pressure release
- Spontaneous breaths
- Higher Mean pressure
- Two different CPAP times (TiHi and TiLo)
- Spontaneous breaths possible in any moment of the respiratory cycle (Active Expiratory Valve)
- PSV can be added to spontaneous breaths

APRV Advantages

- Better gaseous exchange/CO₂ removal
- Dead space reduction
- Less sedation requirements
- Better hemodynamics
- Less risk of barotrauma

ADL
APRV

Backup: OFF

17/02/11
11:12

14
L/min
Peak Flow

0.30
s
Ti

4.95
s
Te

1:16
Current
I:E

18
bpm
 f_{Total}

0.016
L
VT

0.48
L/min
 $\dot{V}_E$

50
%
Oxygen

30

0.600
0.150

7.23
2.41

60
40



Peak
12
Trach.

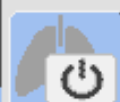
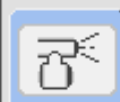
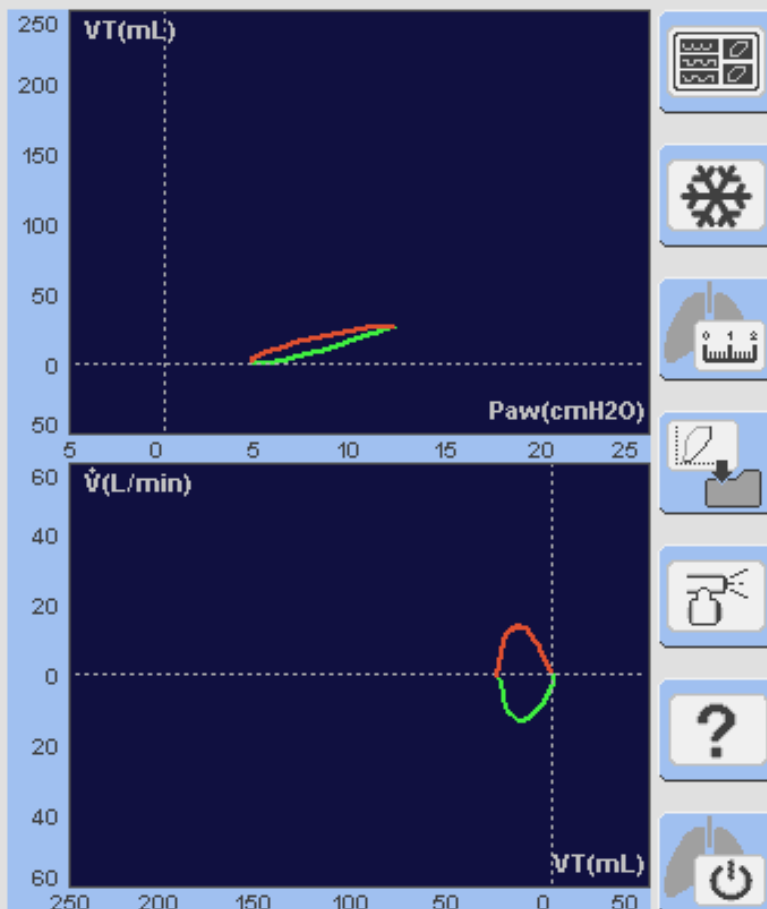
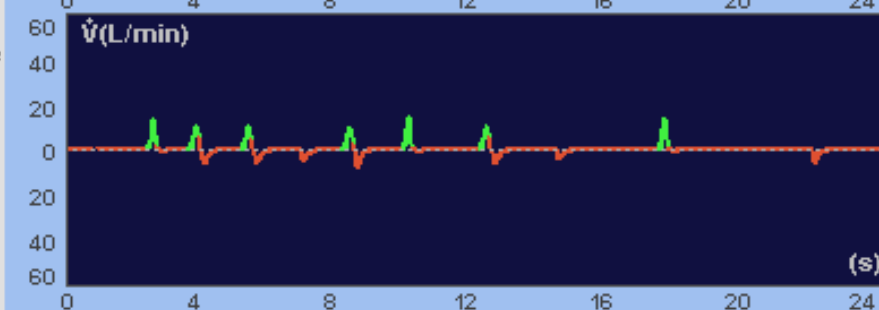
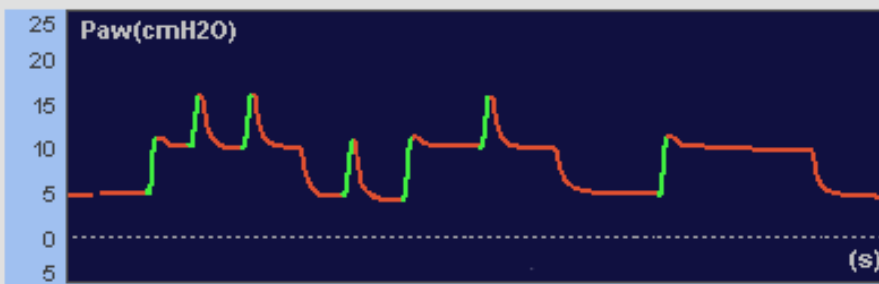
Plateau

Mean
8.8
PEEP
5.0

Pressure:
Limits

40

5



5
cmH2O
PSV

25
%
Exp. Sensitiv.

4.5
High
Ti

3.0
Low
Ti

8
bpm
 f

10
High
PEEP

5
Low
PEEP

3.0
L/min
Sens

50
%
Oxygen

Rise
Time

1.5:1
I:E