MECH VENT WORKSHOP

RECOGNIZING AND CORRECTING PATIENT-VENTILATOR ASYNCHRONY IN VC-AC

Eric Kriner BSRT,RRT
Adult Critical Care Clinical Specialist
Medstar Washington Hospital Center
Washington, DC
eric.j.kriner@medstar.net

Conflict of Interest and Disclosure

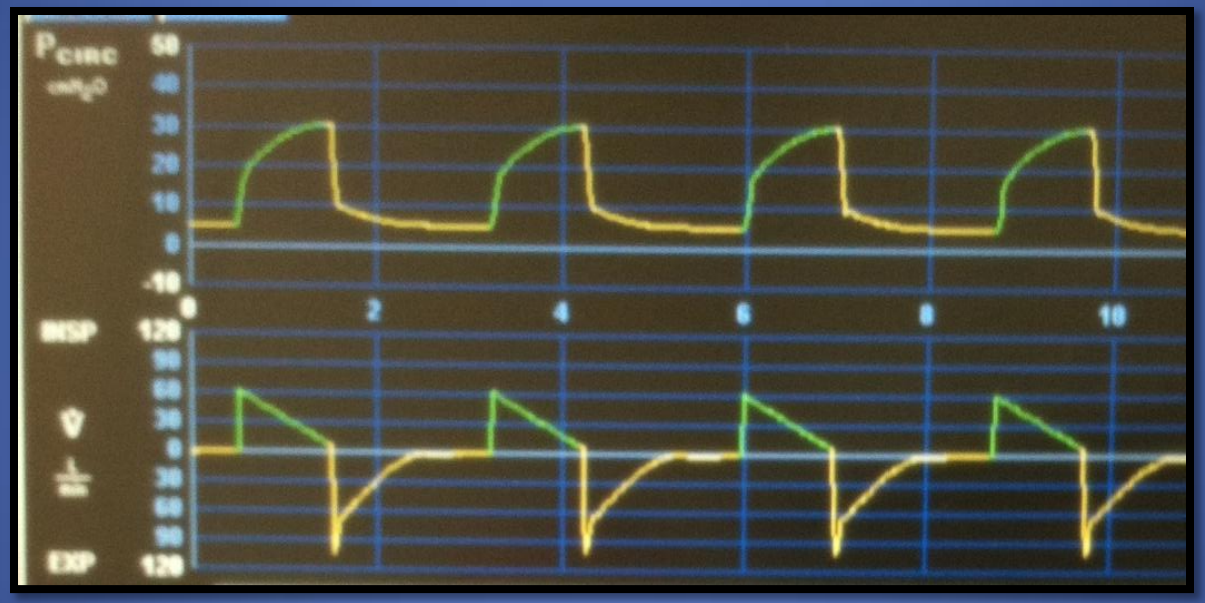
Received travel expenses and honoraria for speaking engagements from IngMar Medical and Medtronic

Unless cited, the contents and conclusion of the following presentation are solely those of the speaker

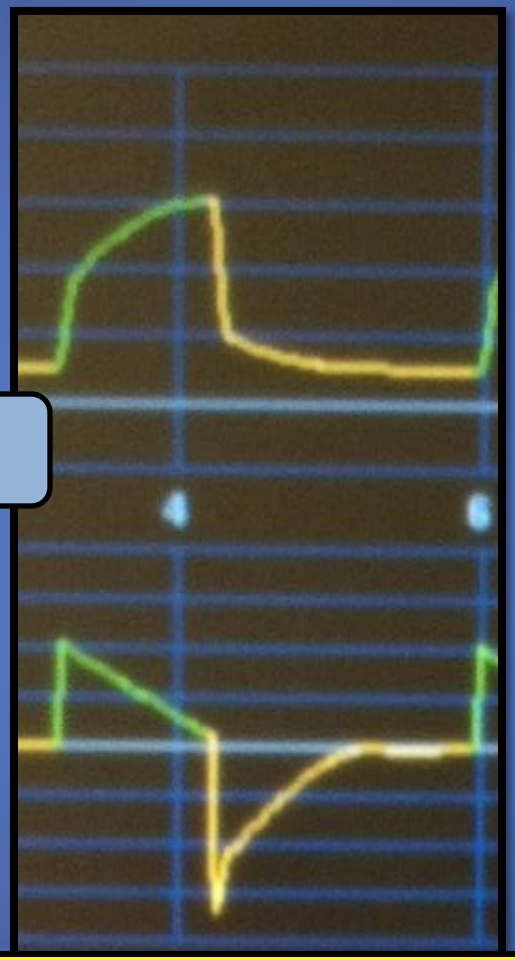
Objectives

- Recognize various forms of patient-ventilator asynchrony in the VC-AC mode of ventilation using widely available scalar waveforms
- Discuss the physiologic causes and clinical implications of various forms of uncorrected patient-ventilator asynchrony
- Recommend potential ventilator parameter changes to correct recognized asynchronies

patient-ventilator asynchrony

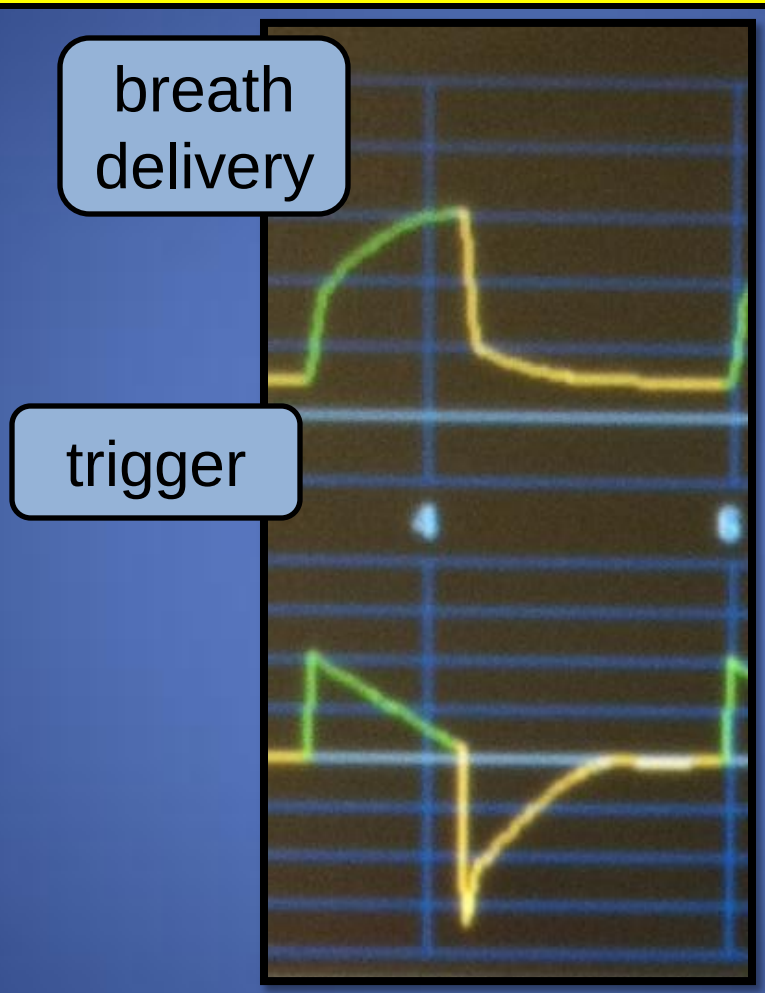


There are four distinct parts to each breath, mandatory or spontaneous



The trigger is how the breath is initiated (or what turns inspiration on)

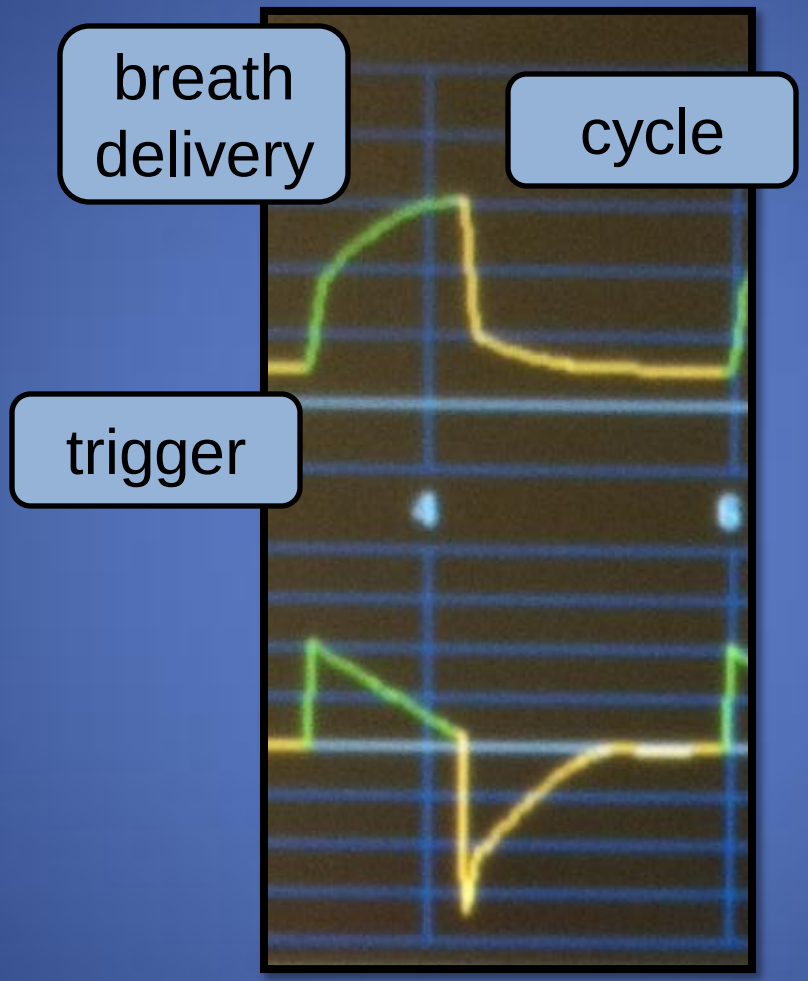
During breath delivery there are physiologic variables that are set by the clinician….

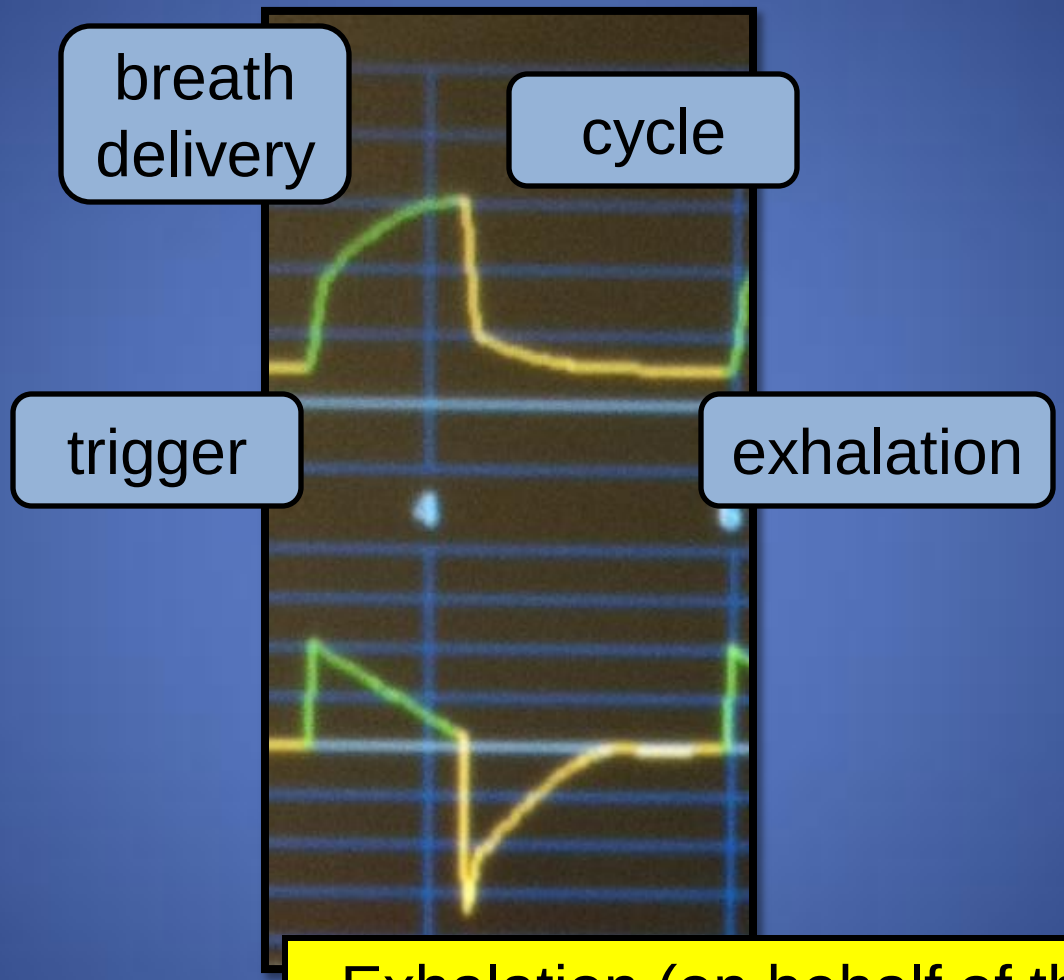


….and there are physiologic variables that are dependent or variable

Those physiologic variables that are set and dependent are determined by the control variable selected by the clinician

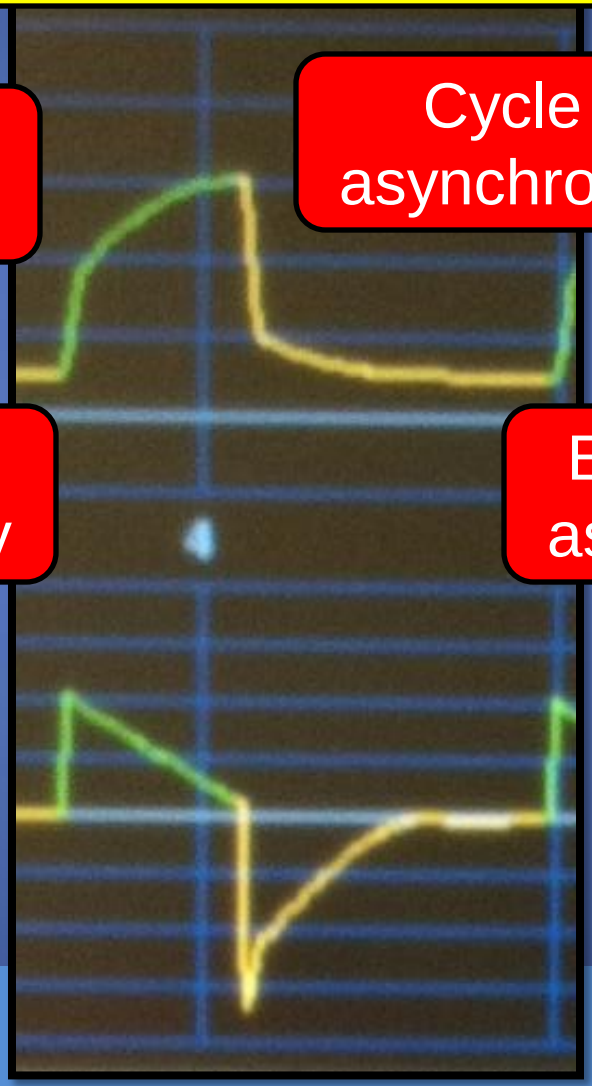
The cycle is how the breath is ended
(or what turns inspiration off)





Exhalation (on behalf of the ventilator) is passive

patient-ventilator asynchrony



Inspiratory asynchrony

Cycle asynchrony

Trigger asynchrony

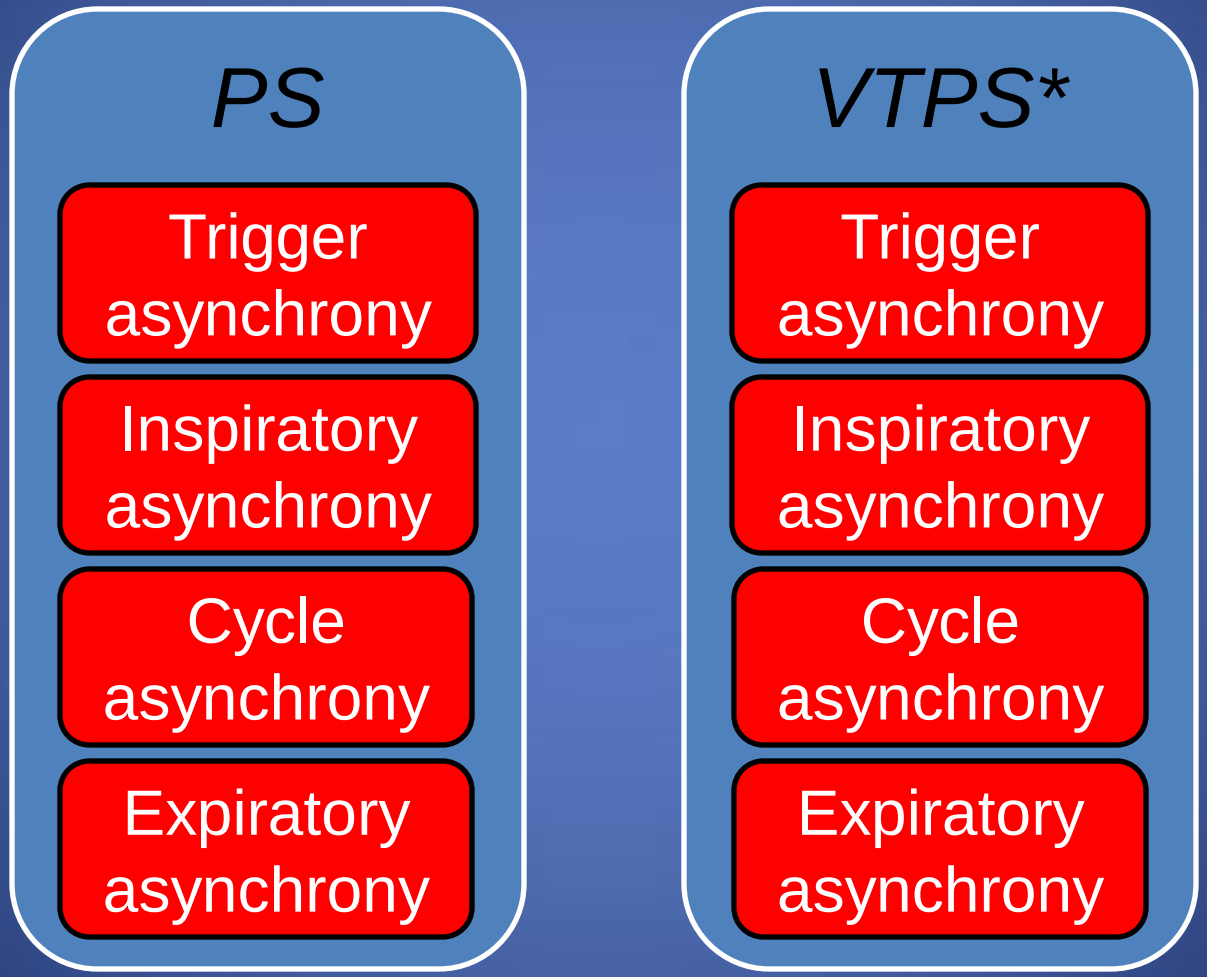
Expiratory asynchrony

Continuous Mandatory Ventilation

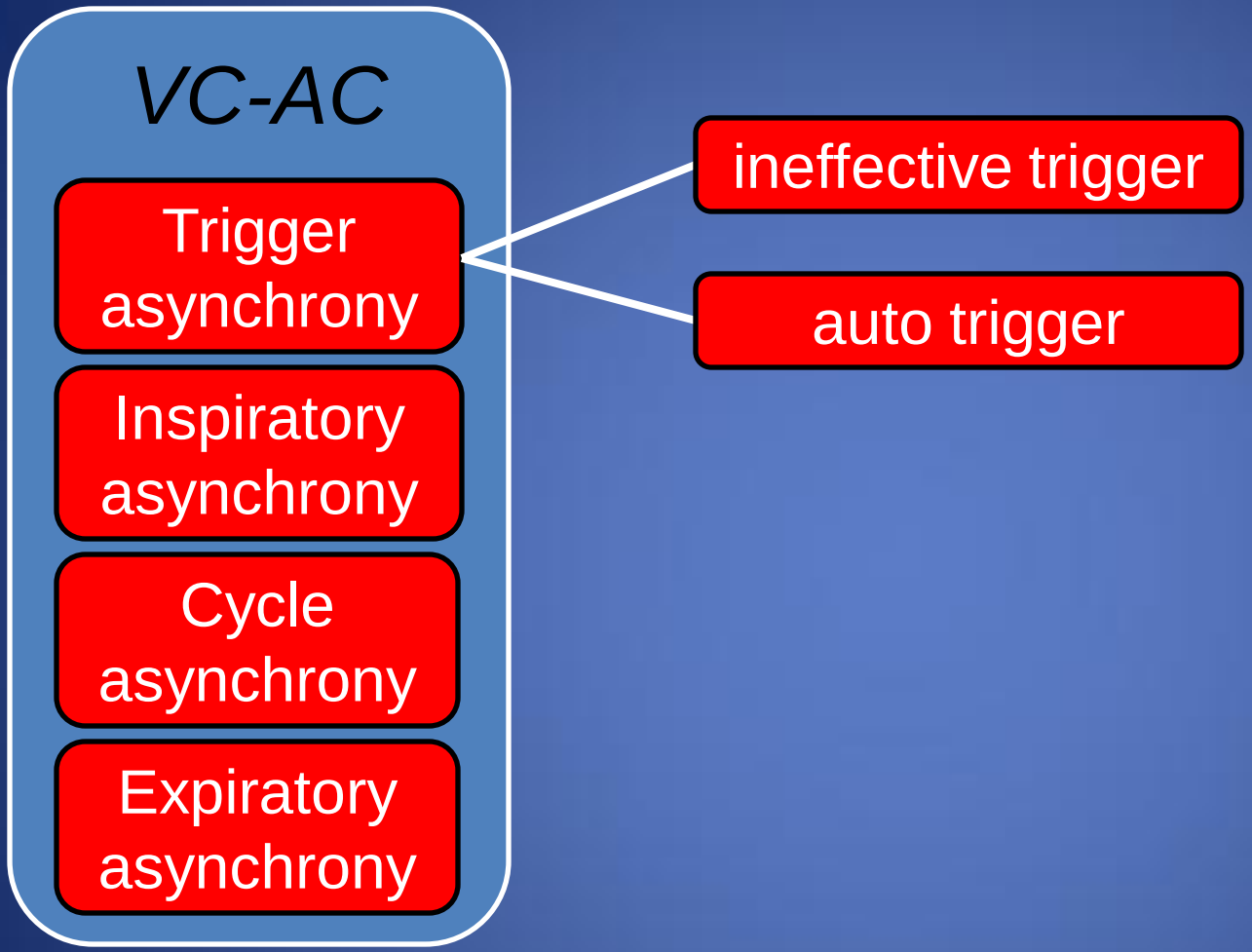
VC-AC	*PC-AC*	*VTPC*-AC*
Trigger asynchrony	Trigger asynchrony	Trigger asynchrony
Inspiratory asynchrony	Inspiratory asynchrony	Inspiratory asynchrony
Cycle asynchrony	Cycle asynchrony	Cycle asynchrony
Expiratory asynchrony	Expiratory asynchrony	Expiratory asynchrony

**volume-targeted pressure control*

Continuous Spontaneous Ventilation



**volume-targeted pressure support*

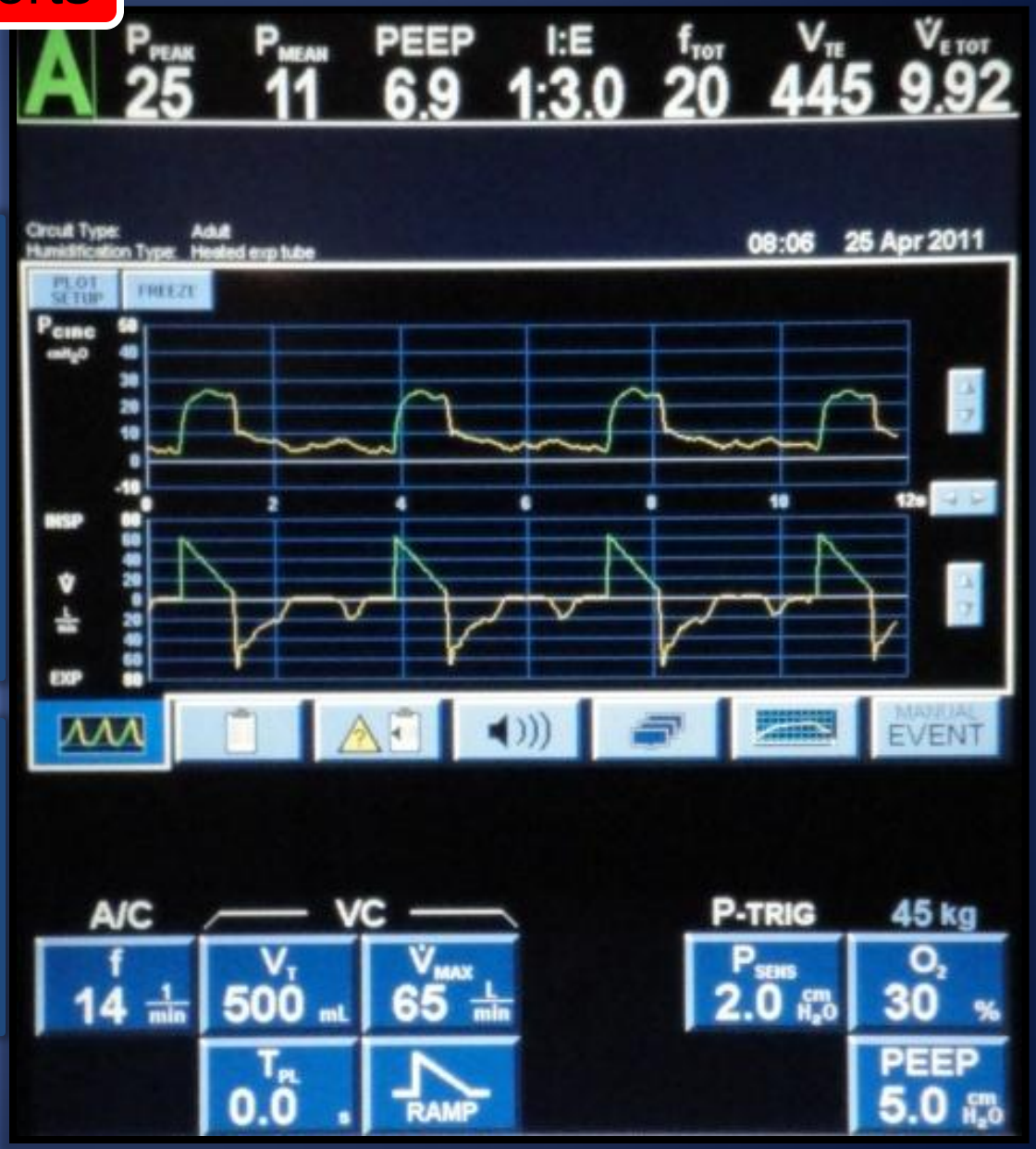

VC-AC
Trigger asynchrony
Inspiratory asynchrony
Cycle asynchrony
Expiratory asynchrony
ineffective trigger
auto trigger

Trigger Dysynchrony

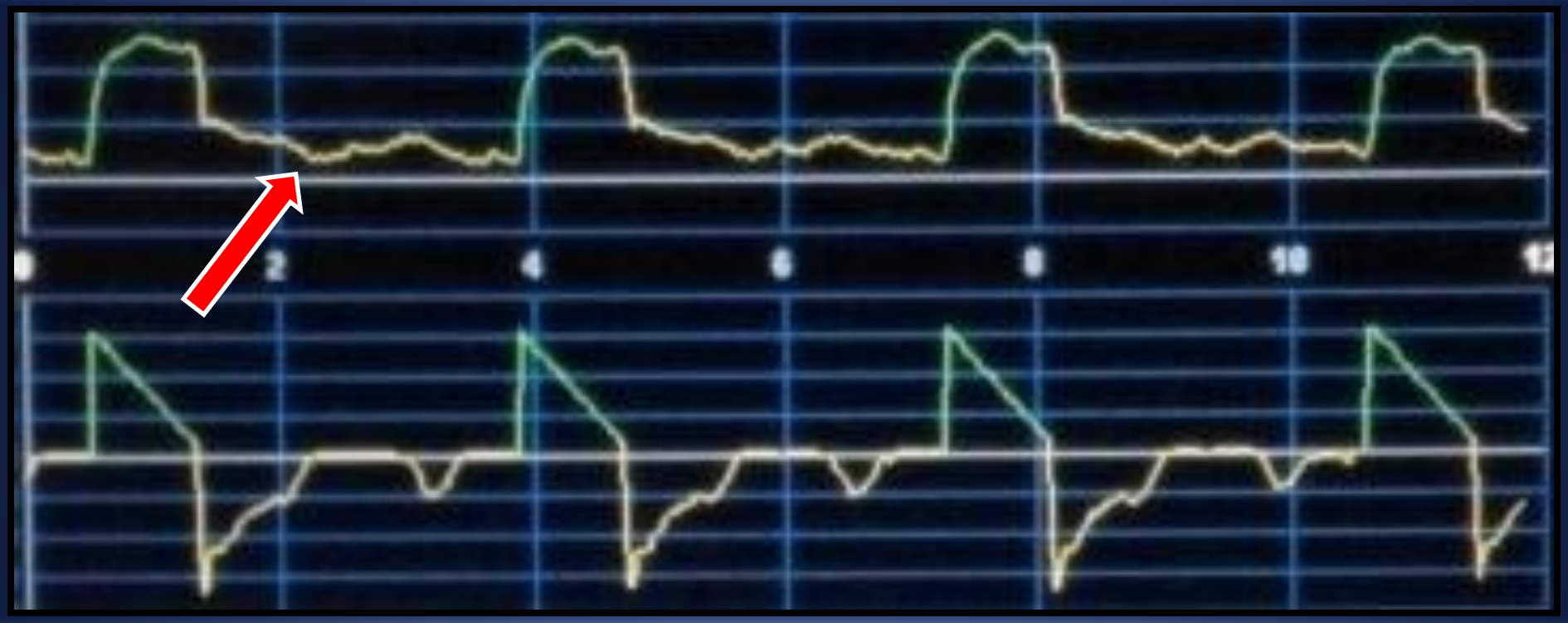
Recognizing ineffective efforts

Ineffective trigger occurs when the patient's inspiratory effort fails to trigger the ventilator and the patient is not rewarded with a breath

Ineffective trigger is also referred to as ineffective efforts or untriggered breaths



When the patient begins the inspiratory effort, the pressure decreases slightly.



The expiratory flow also goes towards the inspiratory scale

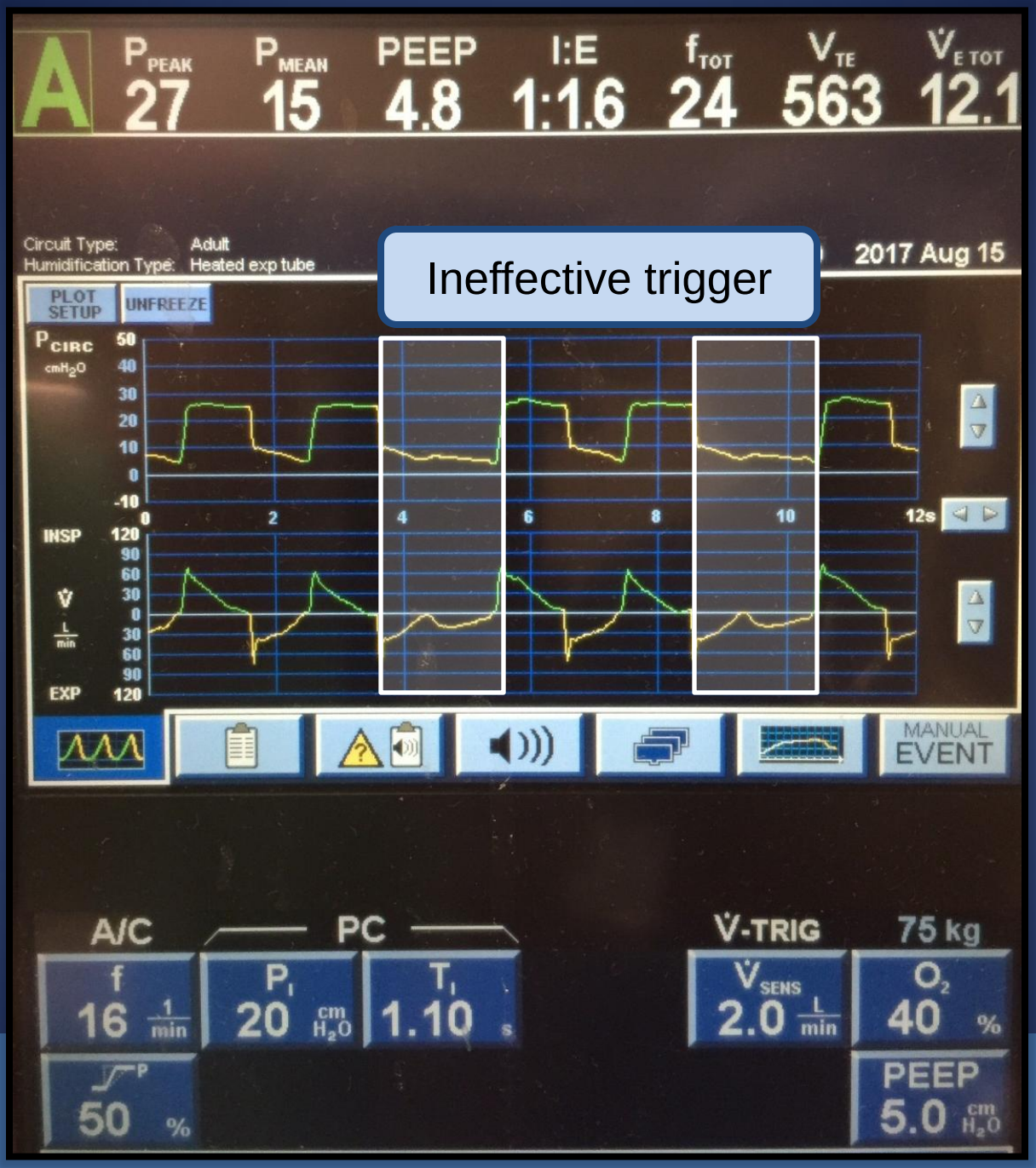
When the patient begins the inspiratory effort, the pressure decreases slightly.

The expiratory flow also goes towards the inspiratory scale

The ventilator doesn’t detect the drop in pressure to initiate an assisted breath, observed by a lack of inspiratory flow

When the patient finishes the inspiratory effort and effectively exhales out, the pressure begins to increase

Flow exits the patient's lung and travels towards the expiratory valve, observed as a re-acceleration on the expiratory arm of the flow-time scalar


A
P PEAK 27
P MEAN 15
PEEP 4.8
I:E 1:1.6
f TOT 24
V TE 563
V̇ E TOT 12.1
Circuit Type: Adult
Humidification Type: Heated exp tube
2017 Aug 15
Ineffective trigger
PLOT SETUP
UNFREEZE
P CIRC
cmH2O
50
40
30
20
10
0
-10
0
2
4
6
8
10
12s
INSP
120
90
60
30
0
30
60
90
120
EXP
V̇
L/min
MANUAL EVENT
A/C
PC
V̇-TRIG
75 kg
f 16 1/min
P I 20 cm H2O
T I 1.10 s
V̇ SENS 2.0 L/min
O2 40 %
P 50 %
PEEP 5.0 cm H2O

Clinical implications of ineffective trigger

- Ineffective efforts result in an increased work of breathing on the patient's behalf
  - This is due to the patient's employment of muscles of inspiration to expand the thoracic cage in an effort to initiate a breath
- Ineffective efforts can also result in a phenomenon of breathlessness and agitation because of the undelivered breath

Branson, R, Blakeman, T, Robinson, B. Asynchrony and dyspnea. *Respiratory Care* June 2013, 58 (6) 973-989

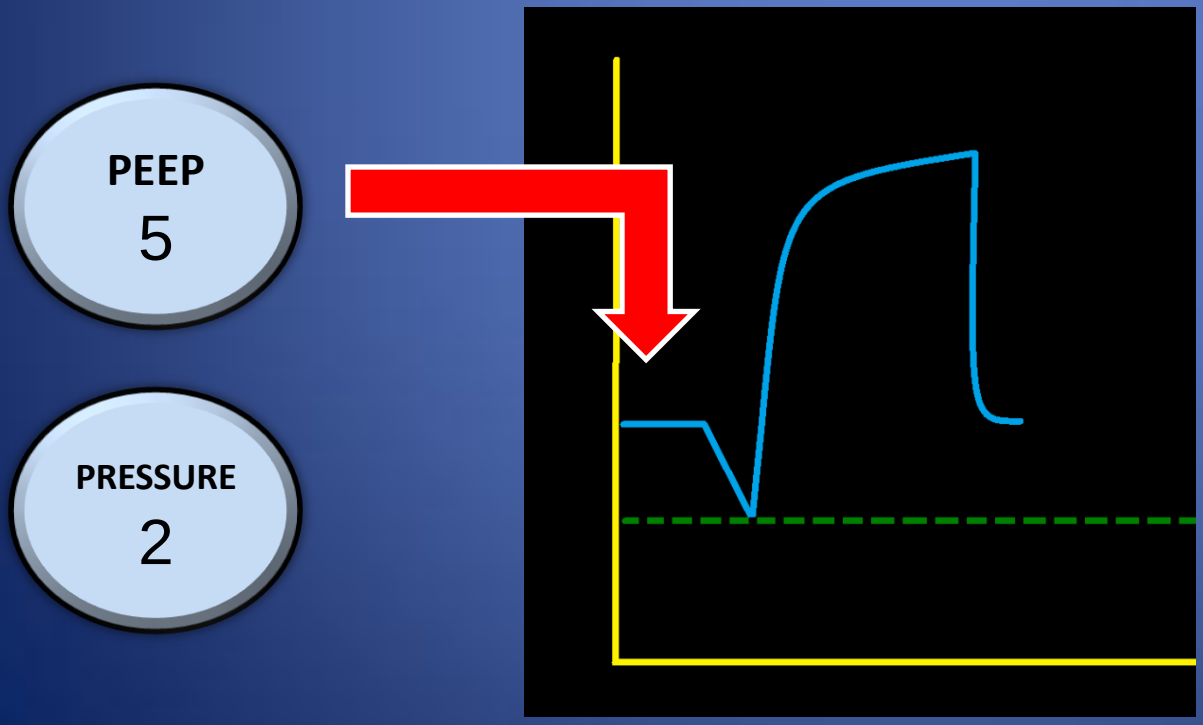
Thille AW, Rodriguez P, Cabello B, Lellouche F, Brochard L. Patient-ventilator asynchrony during assisted mechanical ventilation. *Intensive care medicine*. 2006;32(10):1515-1522.

de Wit M, Miller KB, Green DA, Ostman HE, Gennings C, Epstein SK. Ineffective triggering predicts increased duration of mechanical ventilation. *Critical care medicine.* 2009;37(10):2740-2745

Trigger Dysynchrony

Correcting ineffective efforts

The ventilator's trigger mechanism is mathematically / numerically based on the actual PEEP setting and that sensitivity which is set



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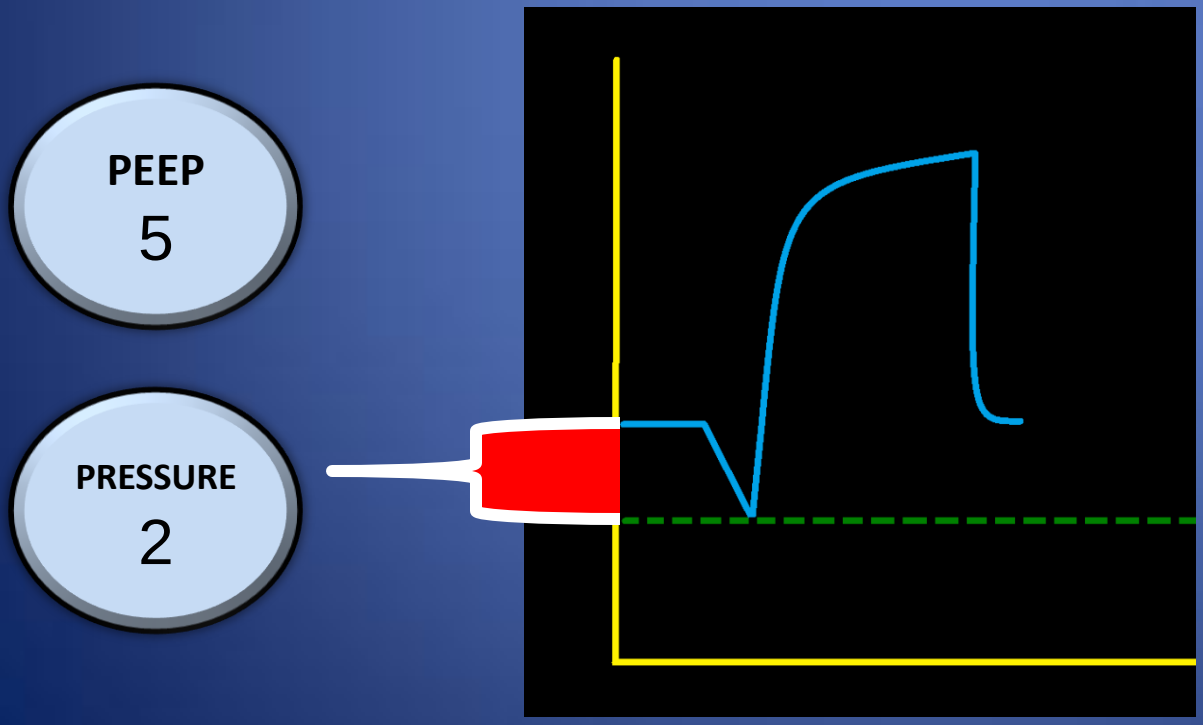
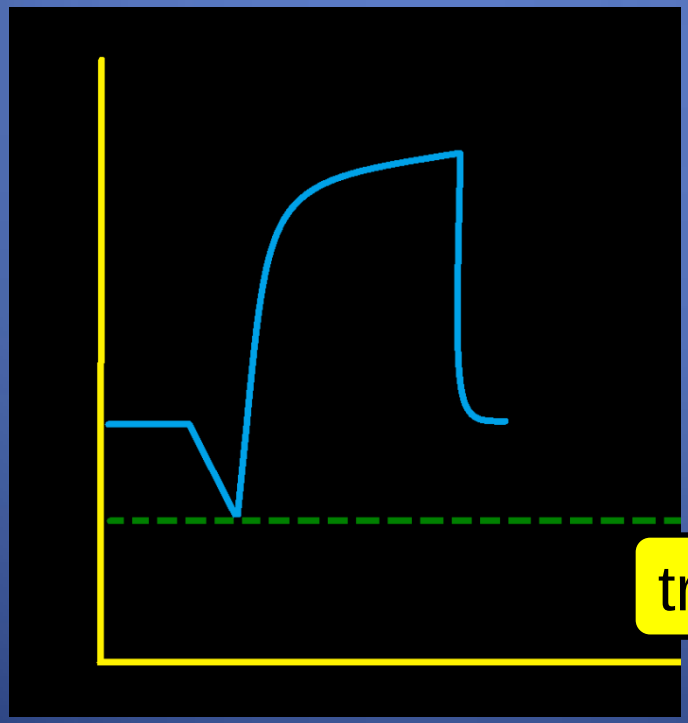


The ventilator's trigger mechanism is mathematically / numerically based on the actual PEEP setting and that sensitivity which is set

PEEP
5

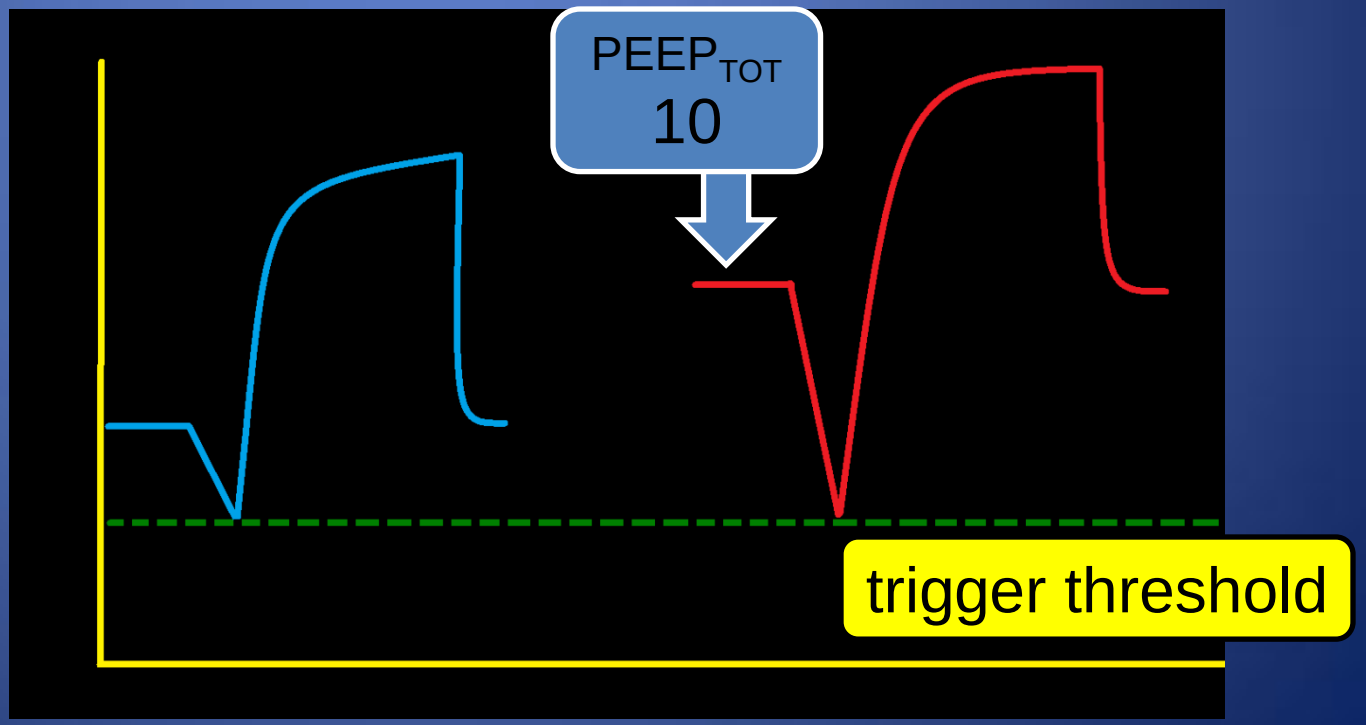
PRESSURE
2



Ineffective efforts often come in the presence of unintentional PEEP or auto-PEEP because the ventilator “does not know about the auto-PEEP” and still requires the patient to alter the pressure to the “pre-auto-PEEP levels” to trigger a breath

PEEP
5

PRESSURE
2



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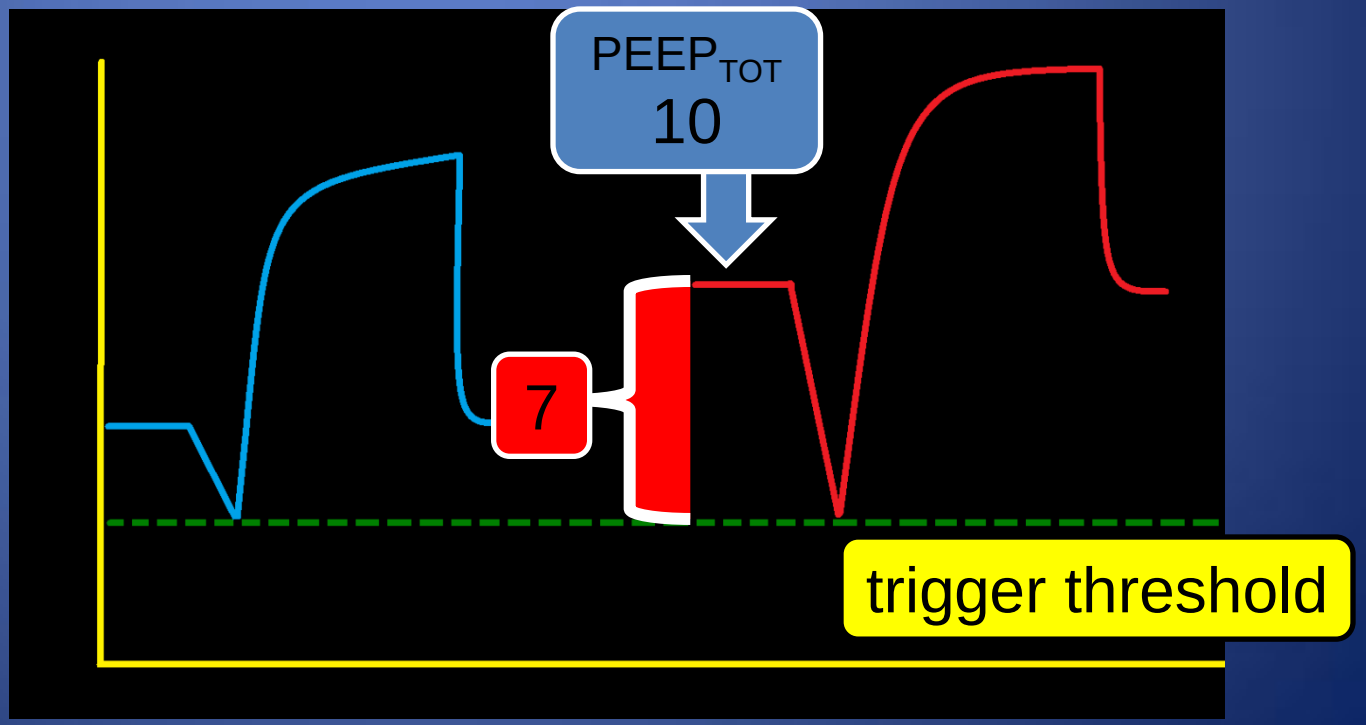
PEEP
5

PRESSURE
2



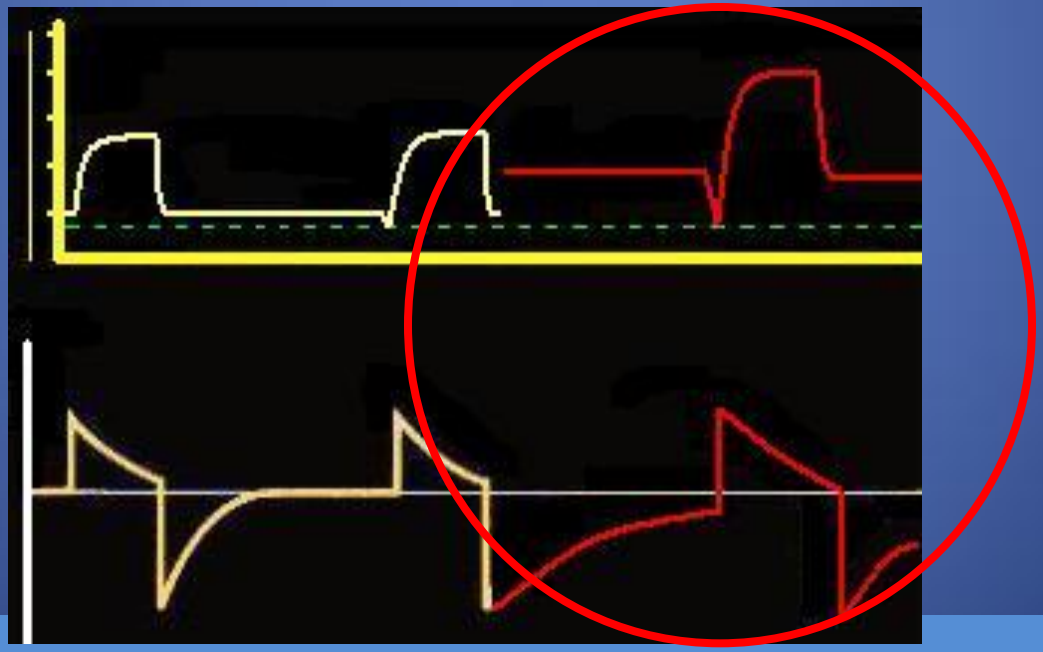
PEEP
5

FLOW
2

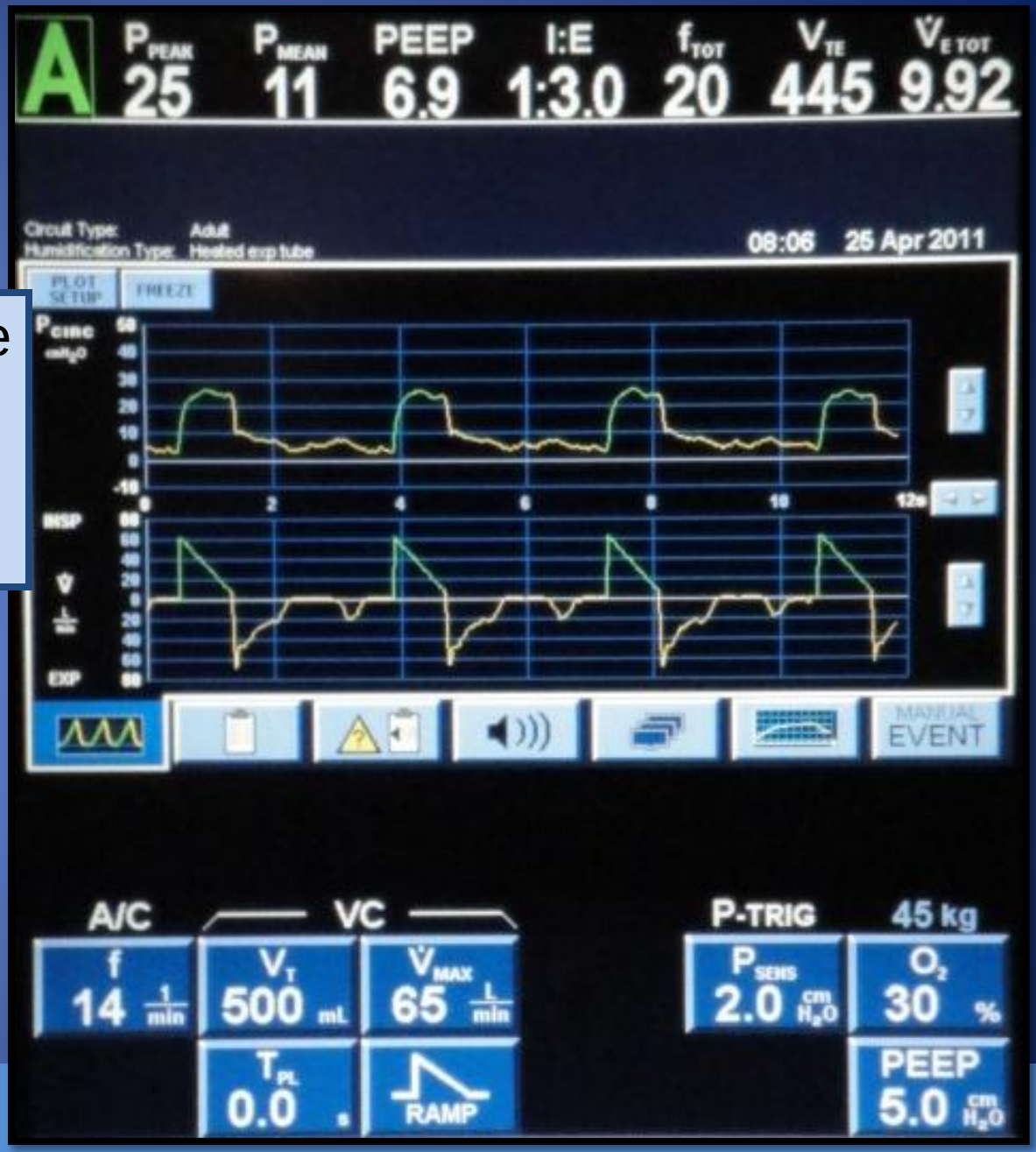
Ineffective efforts occur when utilizing a flow trigger much the same way except…..

If there is no drop in airway/lung pressure when the patient initiates the inspiratory effort then there will not be flow reversal and flow into the patient

1) If ineffective efforts are due to air trapping and the development of auto-PEEP, then the cause of air trapping (obstruction to expiratory flow or inappropriate ventilator settings) must be identified and corrected



2) Correcting ineffective efforts due to inappropriate trigger setting



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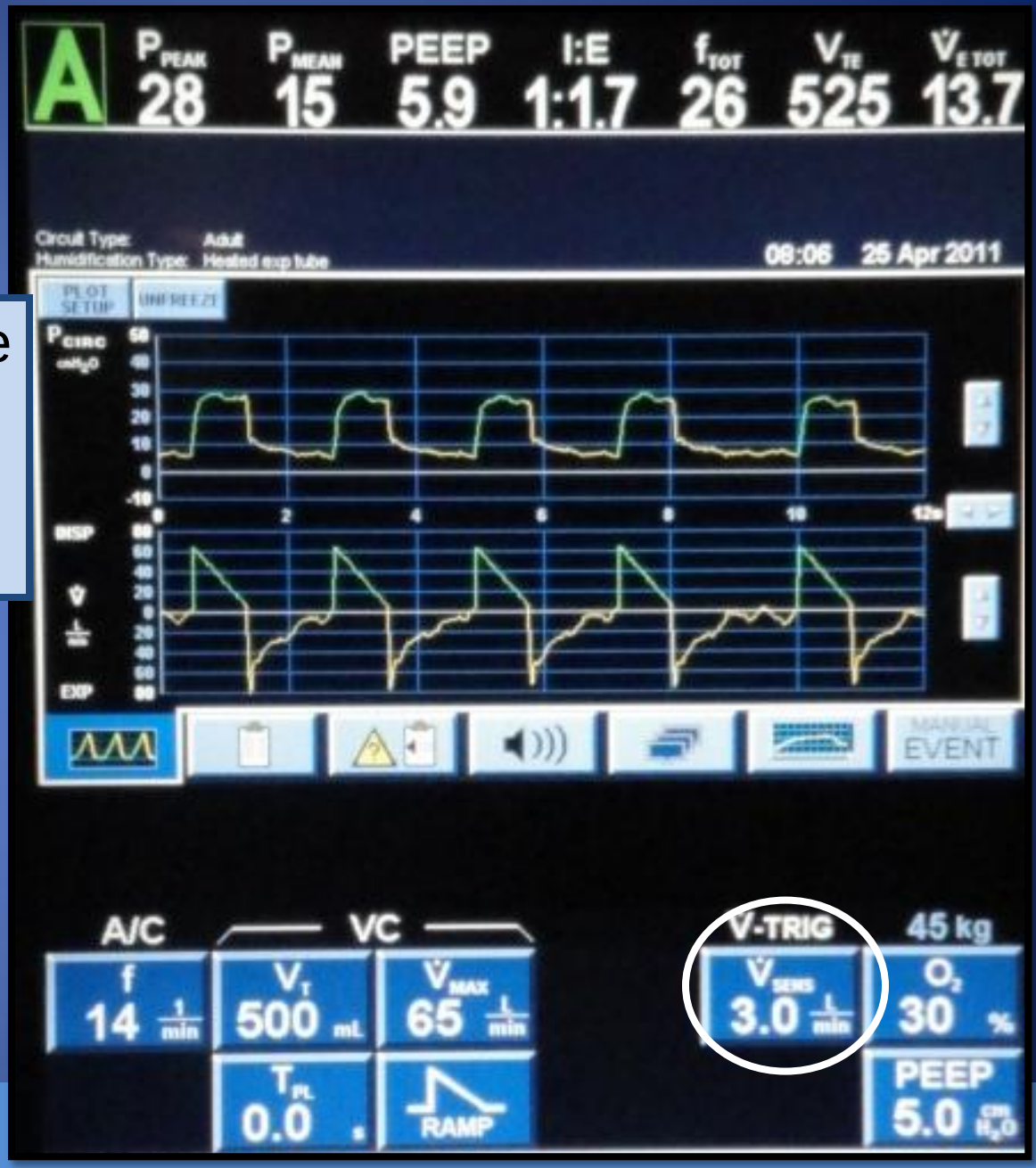
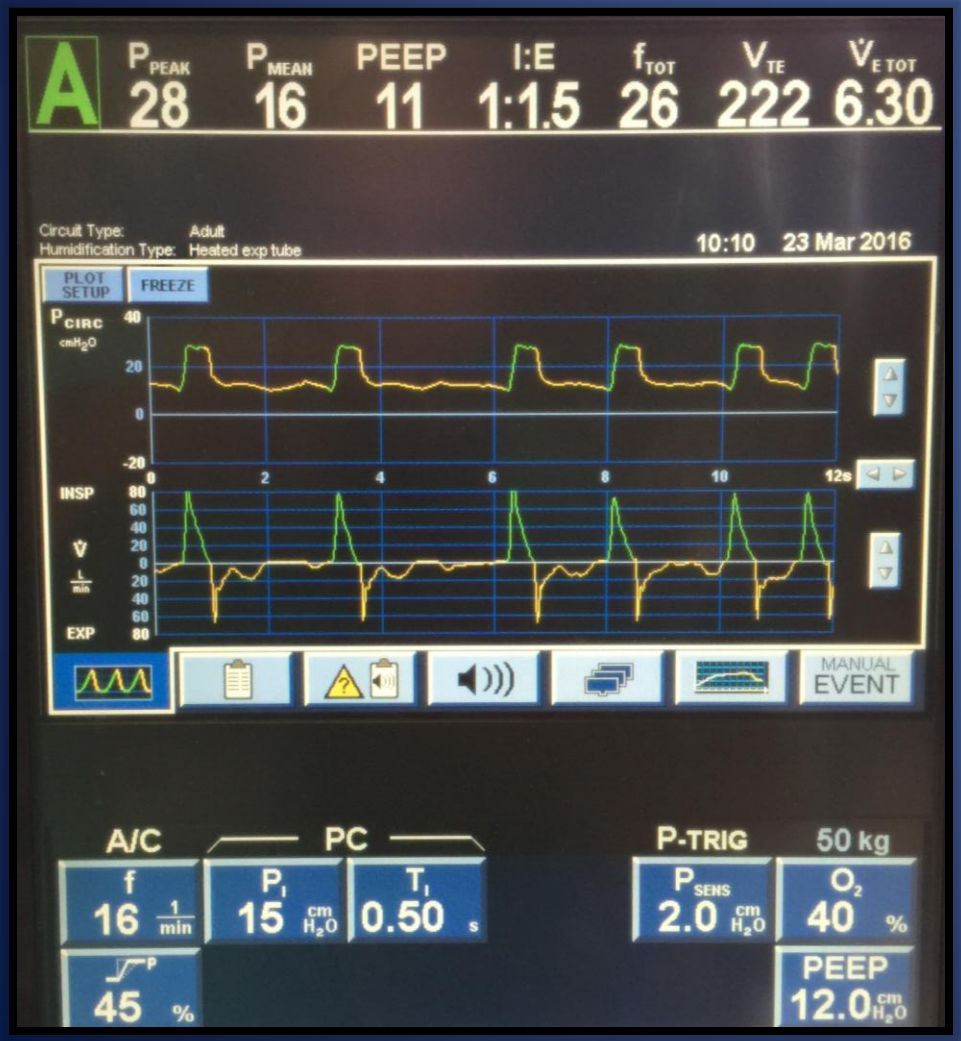
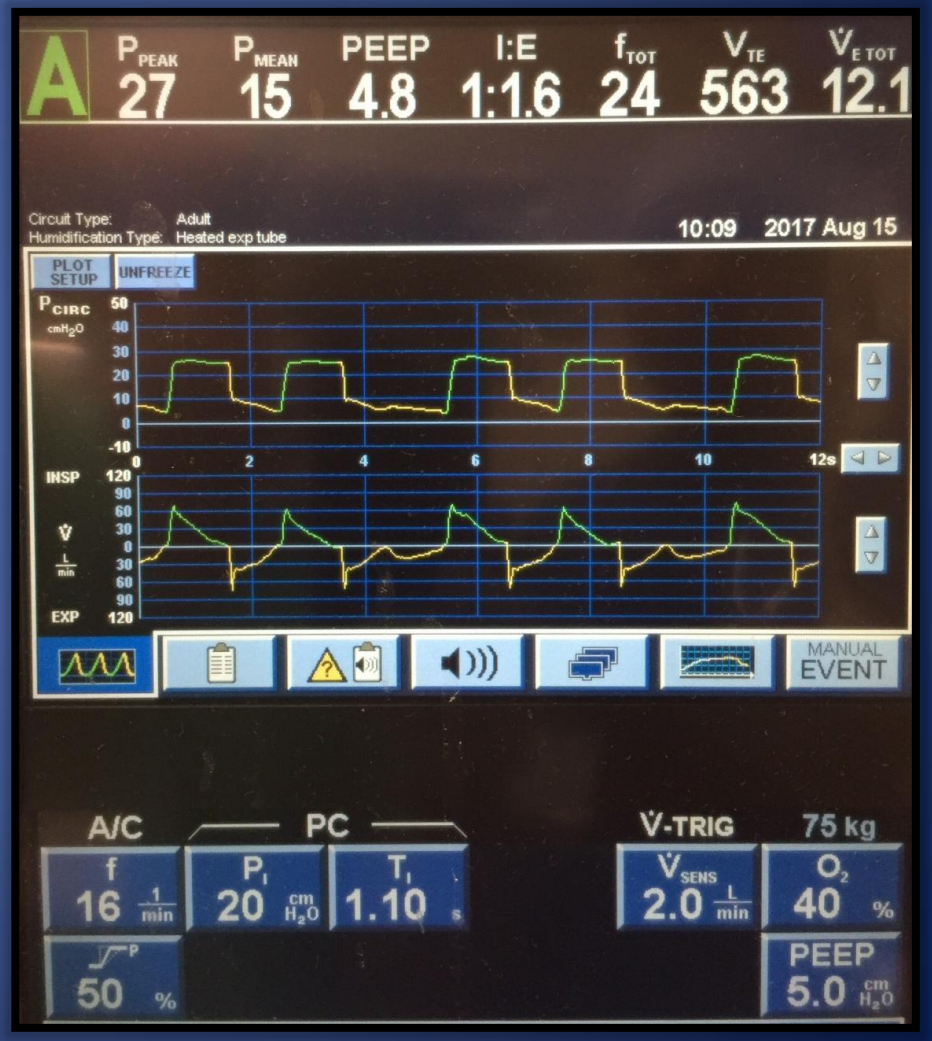


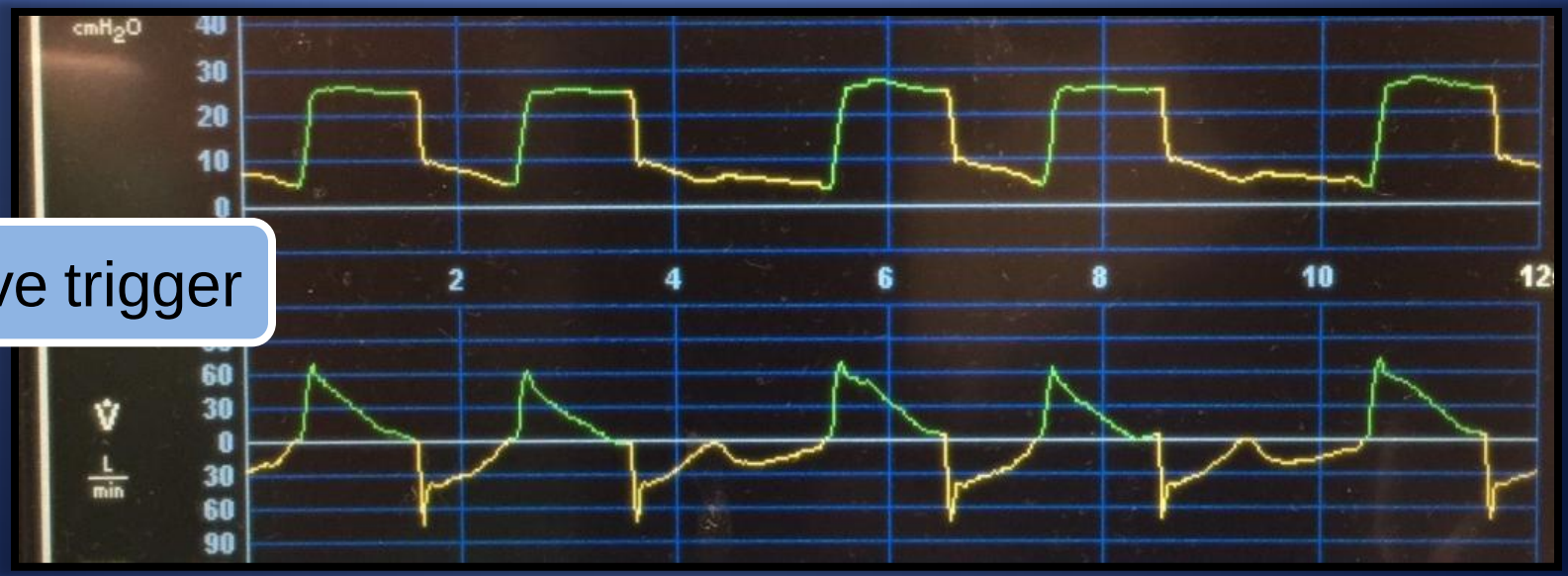
Ineffective trigger versus active exhalation





Ineffective trigger versus active exhalation

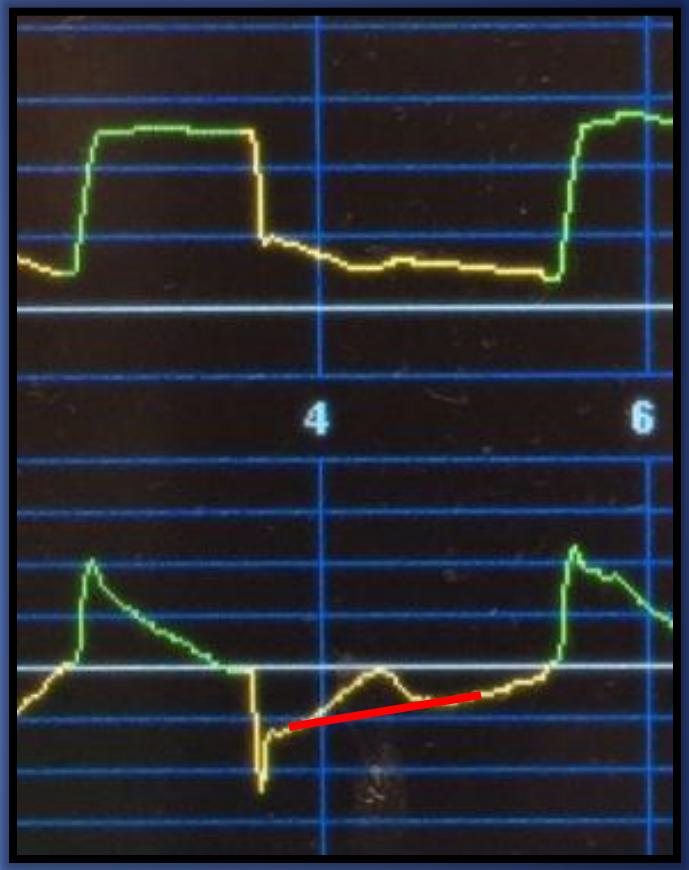
active exhalation



ineffective trigger

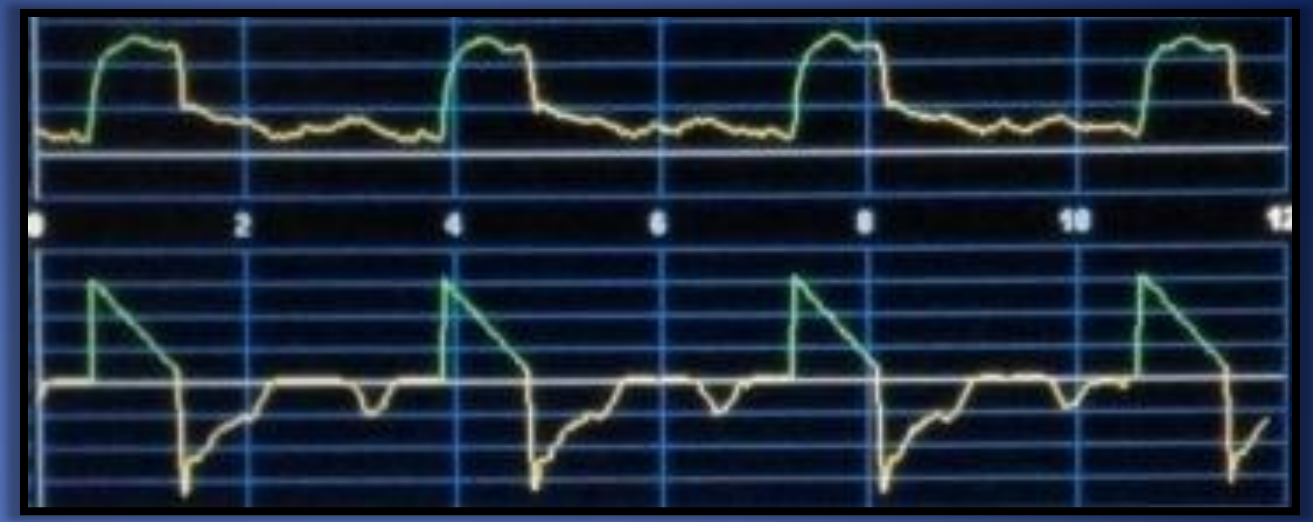
Ineffective trigger versus active exhalation

active exhalation



ineffective trigger

ineffective trigger



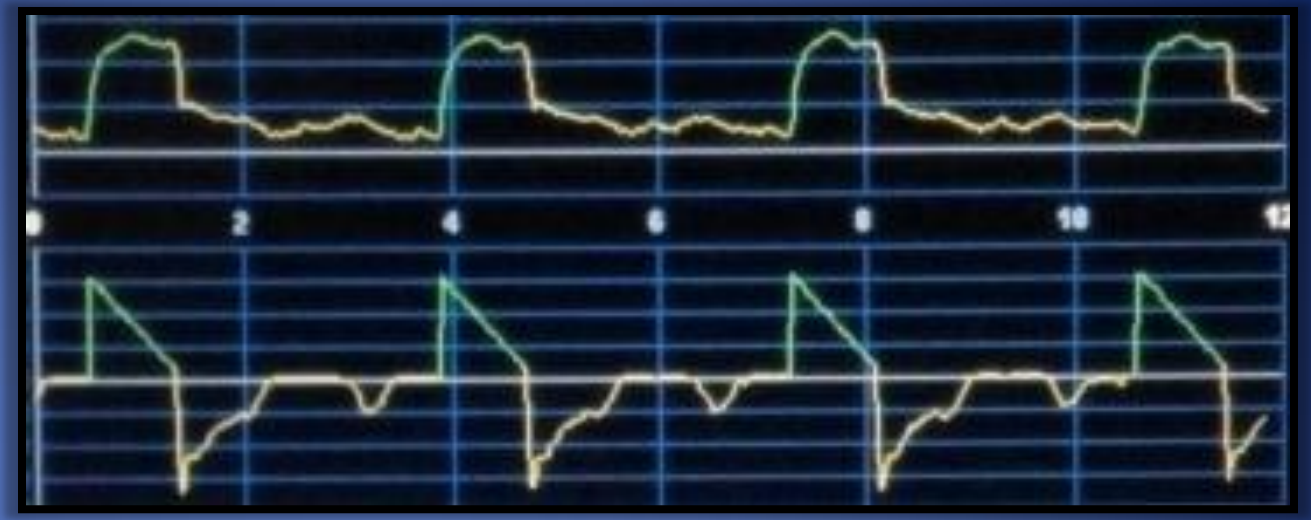
VC-AC

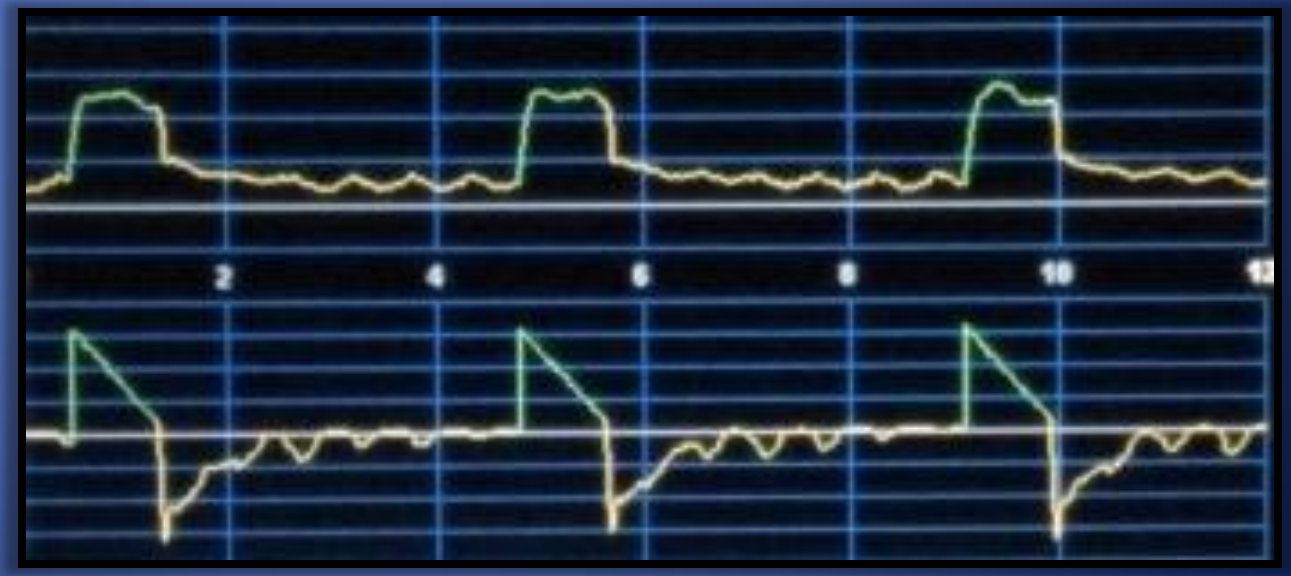
Trigger asynchrony

VC-AC

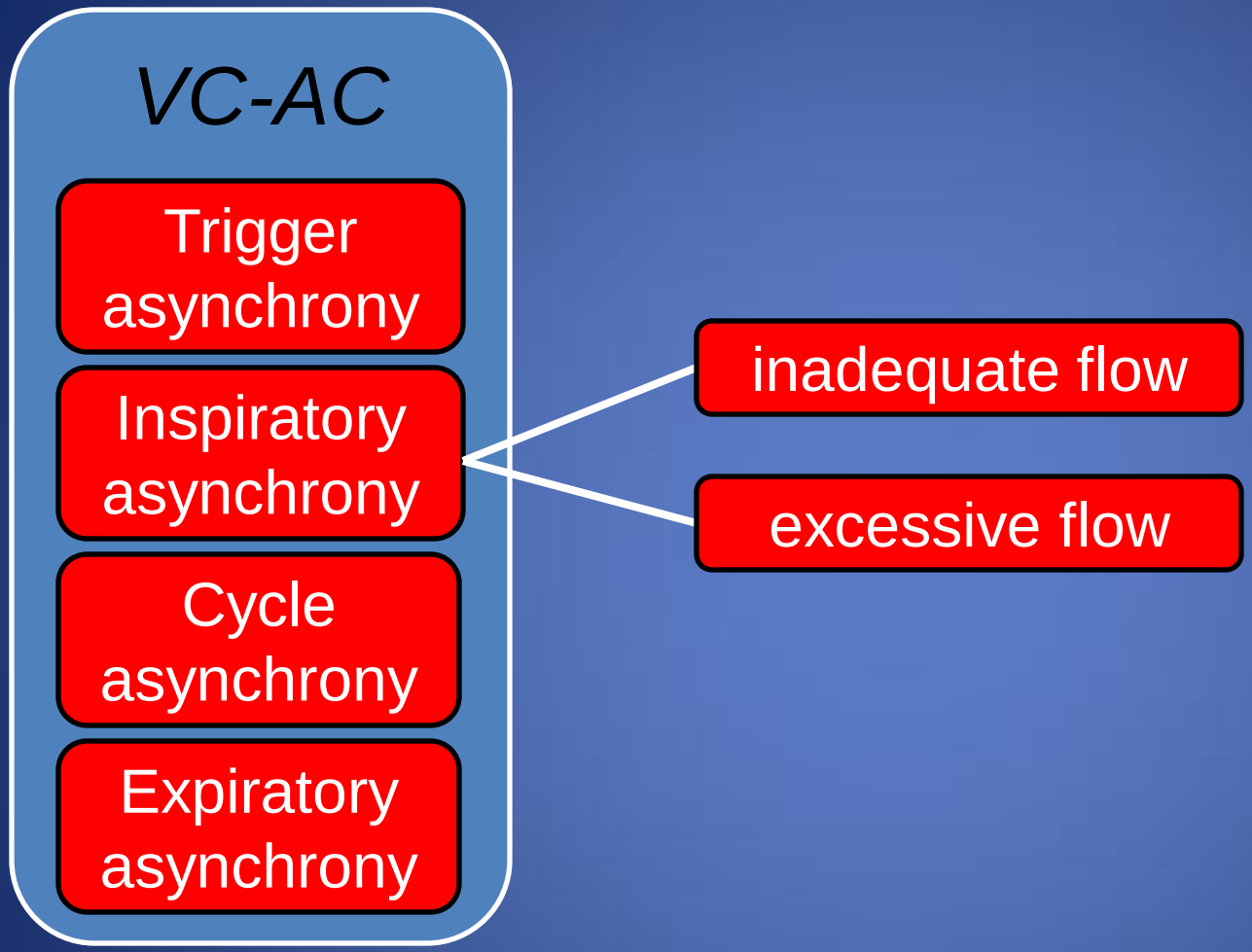
Trigger asynchrony

ineffective trigger



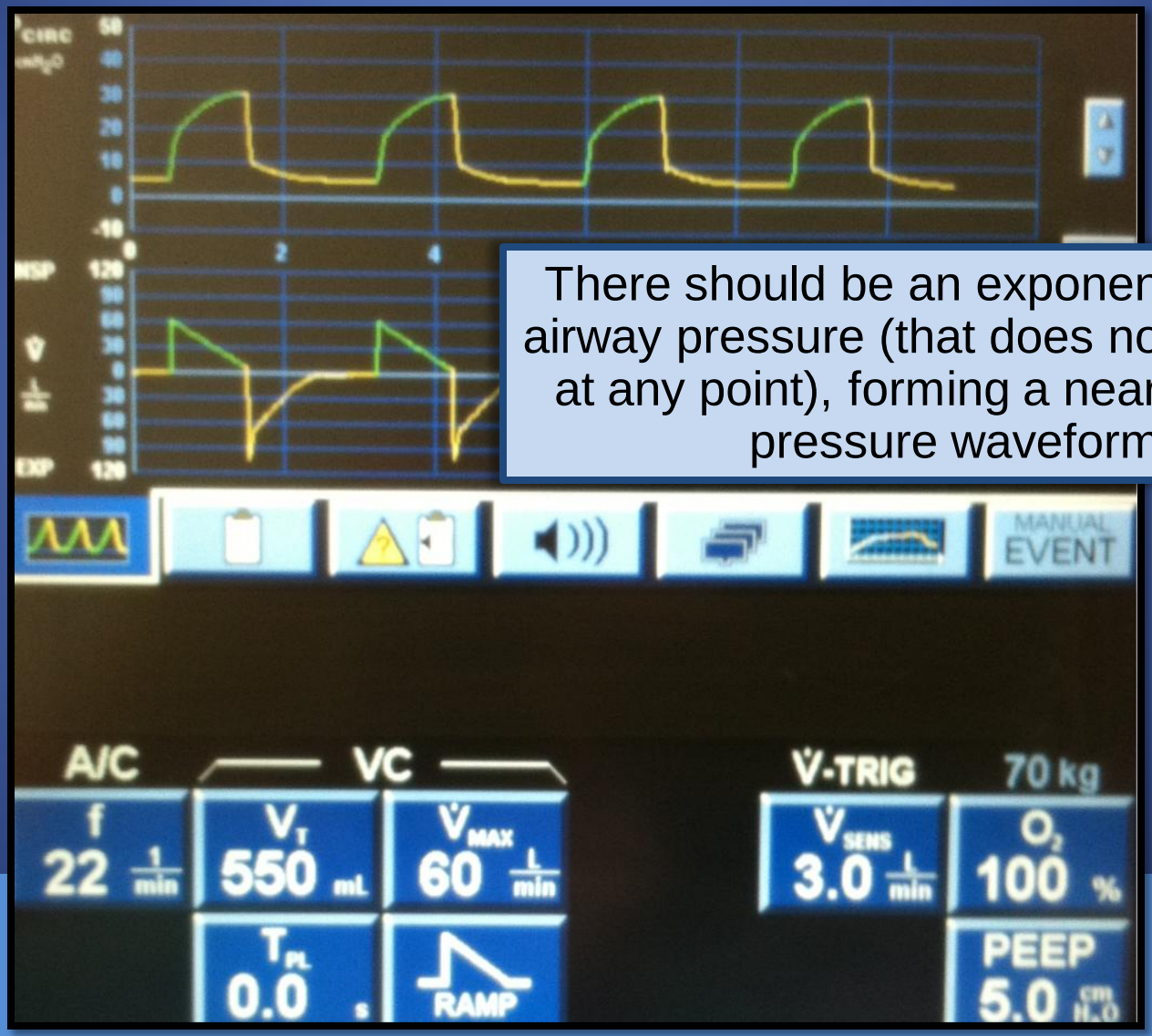


auto trigger

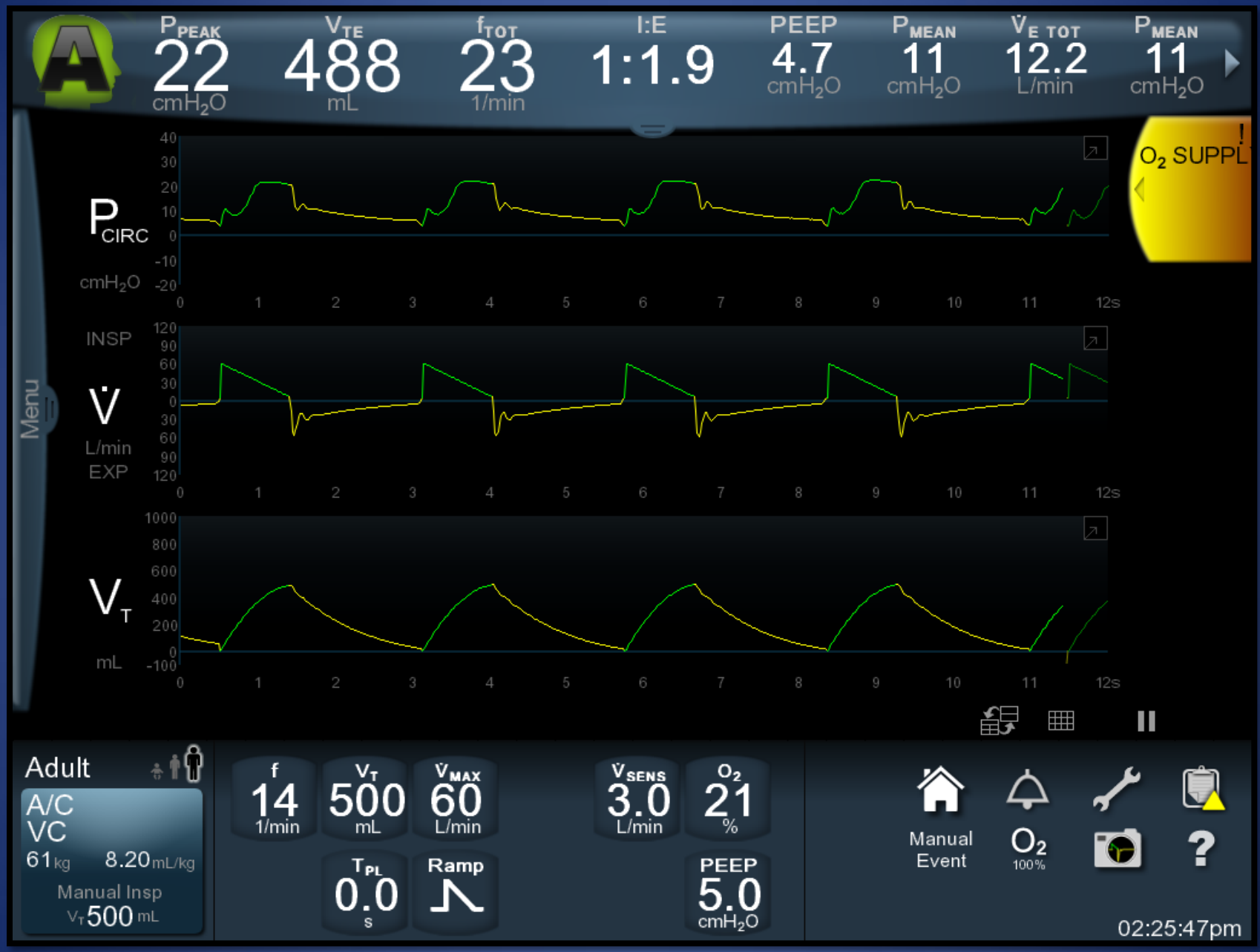

VC-AC
Trigger asynchrony
Inspiratory asynchrony
Cycle asynchrony
Expiratory asynchrony
inadequate flow
excessive flow

Inspiratory Dysynchrony in VC-AC

Recognizing inadequate flow



There should be an exponential rise in airway pressure (that does not decrease at any point), forming a nearly square pressure waveform


P PEAK
22
cmH2O
V TE
488
mL
f TOT
23
1/min
I:E
1:1.9
PEEP
4.7
cmH2O
P MEAN
11
cmH2O
V̇ E TOT
12.2
L/min
P MEAN
11
cmH2O
O2 SUPPL
P CIRC
cmH2O
INSP
V̇
L/min
EXP
V T
mL
12s
Menu
Adult
A/C
VC
61 kg
8.20 mL/kg
Manual Insp
VT 500 mL
f
14
1/min
VT
500
mL
V̇MAX
60
L/min
V̇SENS
3.0
L/min
O2
21
%
TPL
0.0
s
Ramp
PEEP
5.0
cmH2O
Manual
Event
O2
100%
02:25:47pm


CIRC
50
40
30
20
10
0
-10
0
2
4
6
8
10
MSP
120
90
60
30
0
30
60
90
120
EXP


PPEAK
22
cmH2O
VTE
488
mL
ITOT
23
1/min
I:E
1:1.9
PEEP
4.
cmH
40
30
20
10
0
-10
-20
PCIRC
cmH2O
0
1
2
3
4
5
6
7
8


Wendy's
Wendy's


PPEAK
22
cmH2O
VTE
488
mL
ITOT
23
1/min
1:1.9
4.
PCIRC
cmH2O
40
30
20
10
0
-10
-20
0
1
2
3
4
5
6
7
8

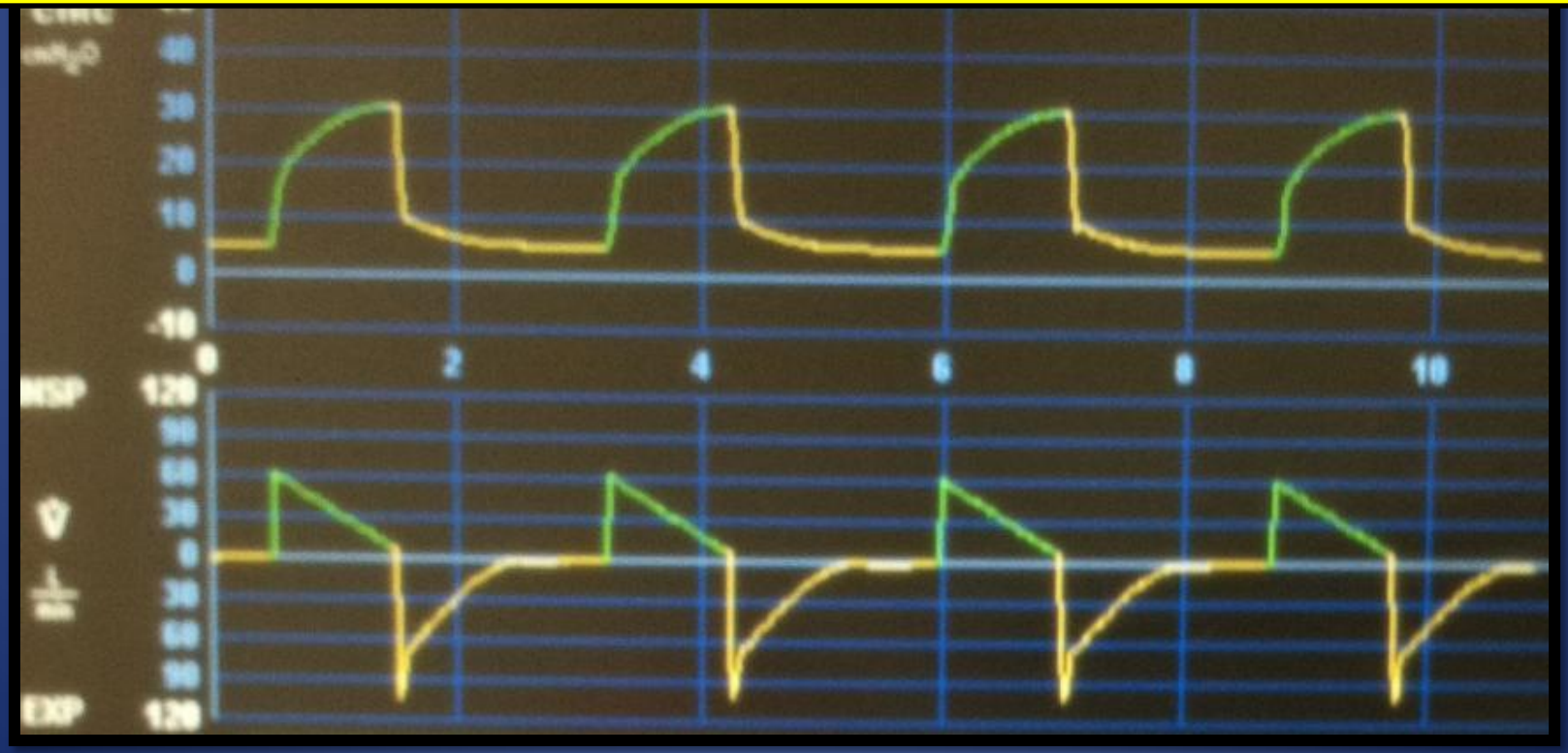
Applied equation of motion in VC-AC

this is variable

these are set

these are fixed once inspiration starts

$$P_{AW} = \text{flow} \times \text{resistance} + \frac{\text{volume}}{\text{compliance}} + \text{PEEP}$$



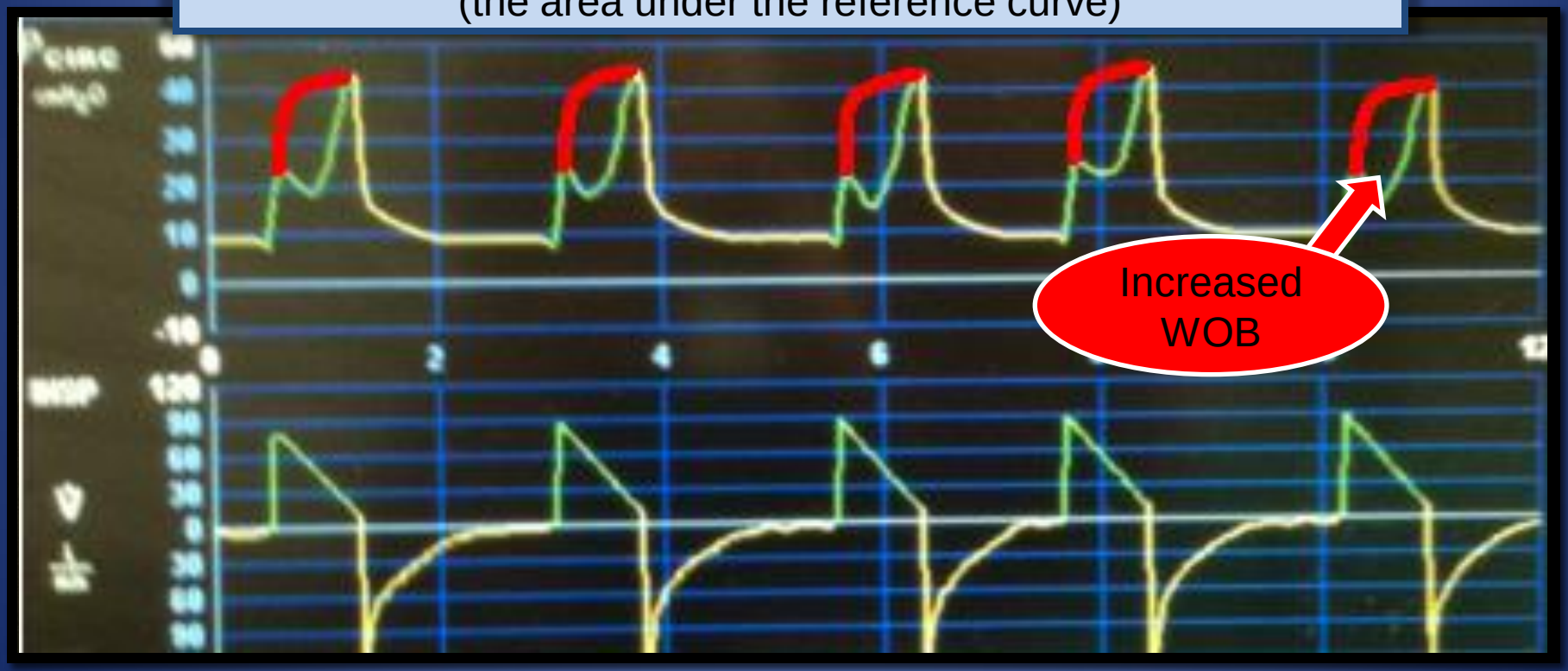
When a patient is interacting with the ventilator an additional variable is added

$$P_{aw} + P_{mus} = \text{flow} \times \text{resistance} + \frac{\text{volume}}{\text{compliance}} + \text{PEEP}$$

Clinical implications of inadequate flow

The clinical implication of continued inadequate flow is an increased WOB on the patient's behalf

(the area under the reference curve)



Clinical implications of inadequate flow

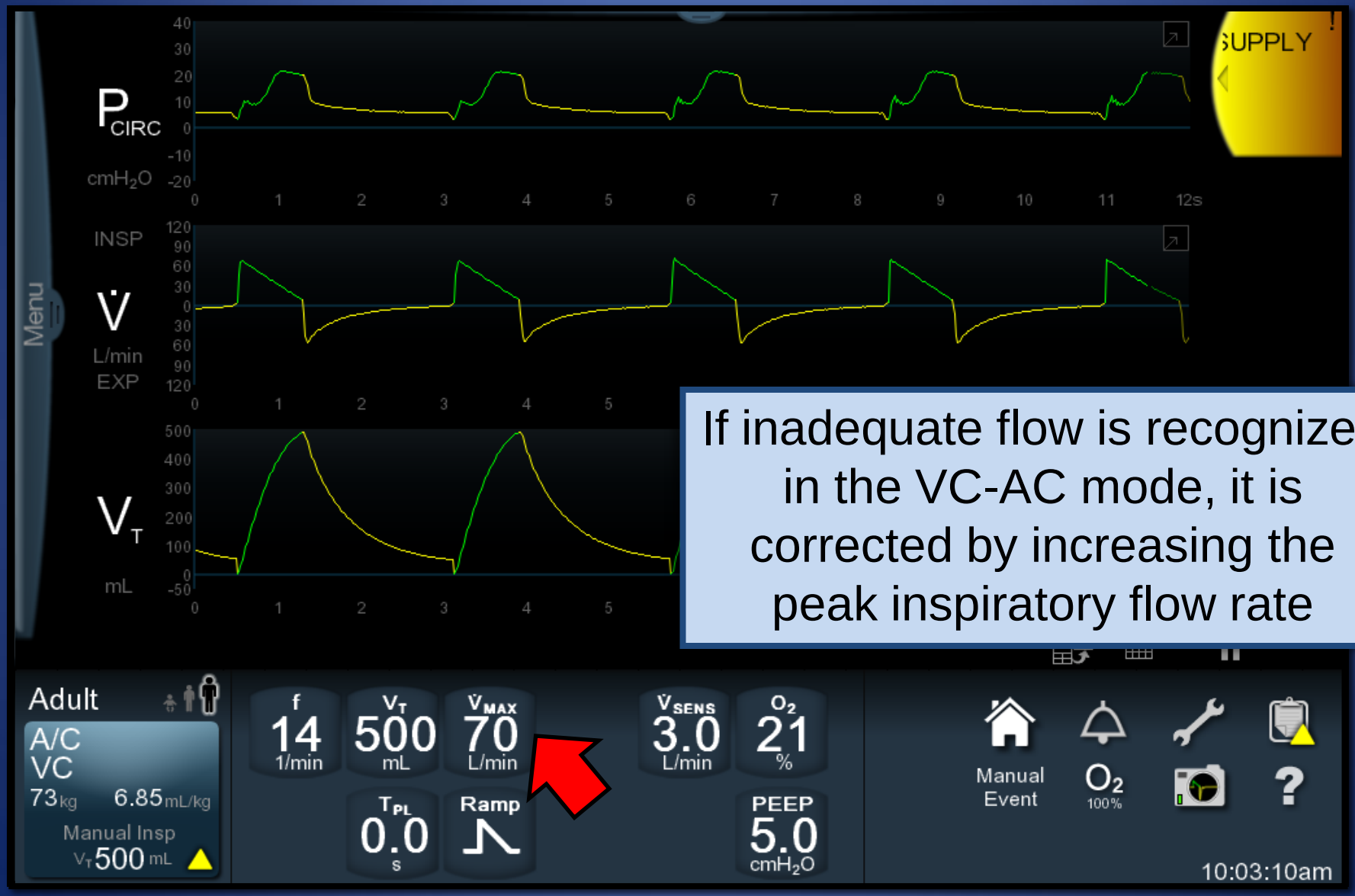
The clinical implication of continued inadequate flow is an increased WOB on the patient's behalf

(the area under the reference curve)

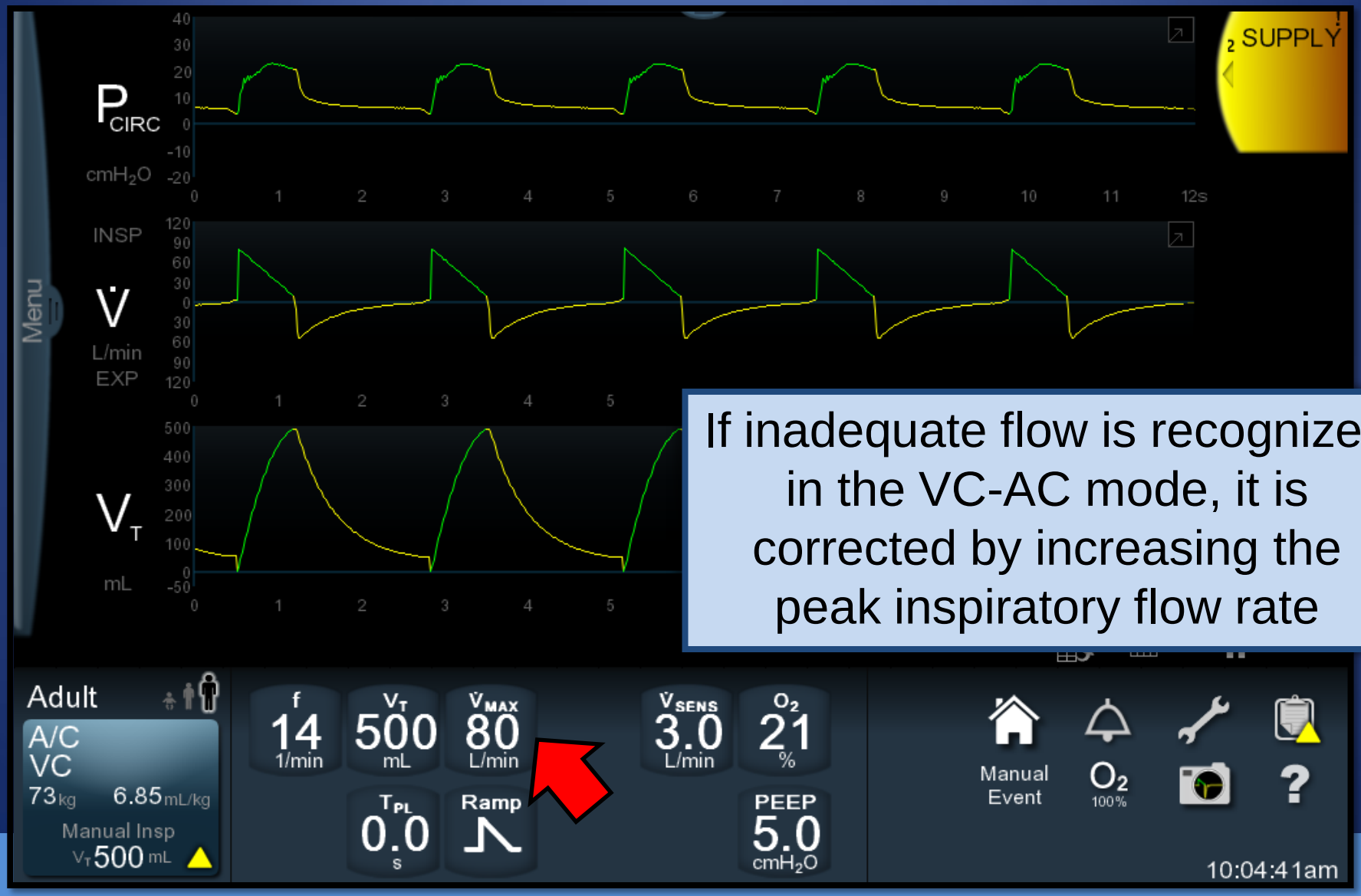
There may be a feeling of breathlessness and agitation or anxiety

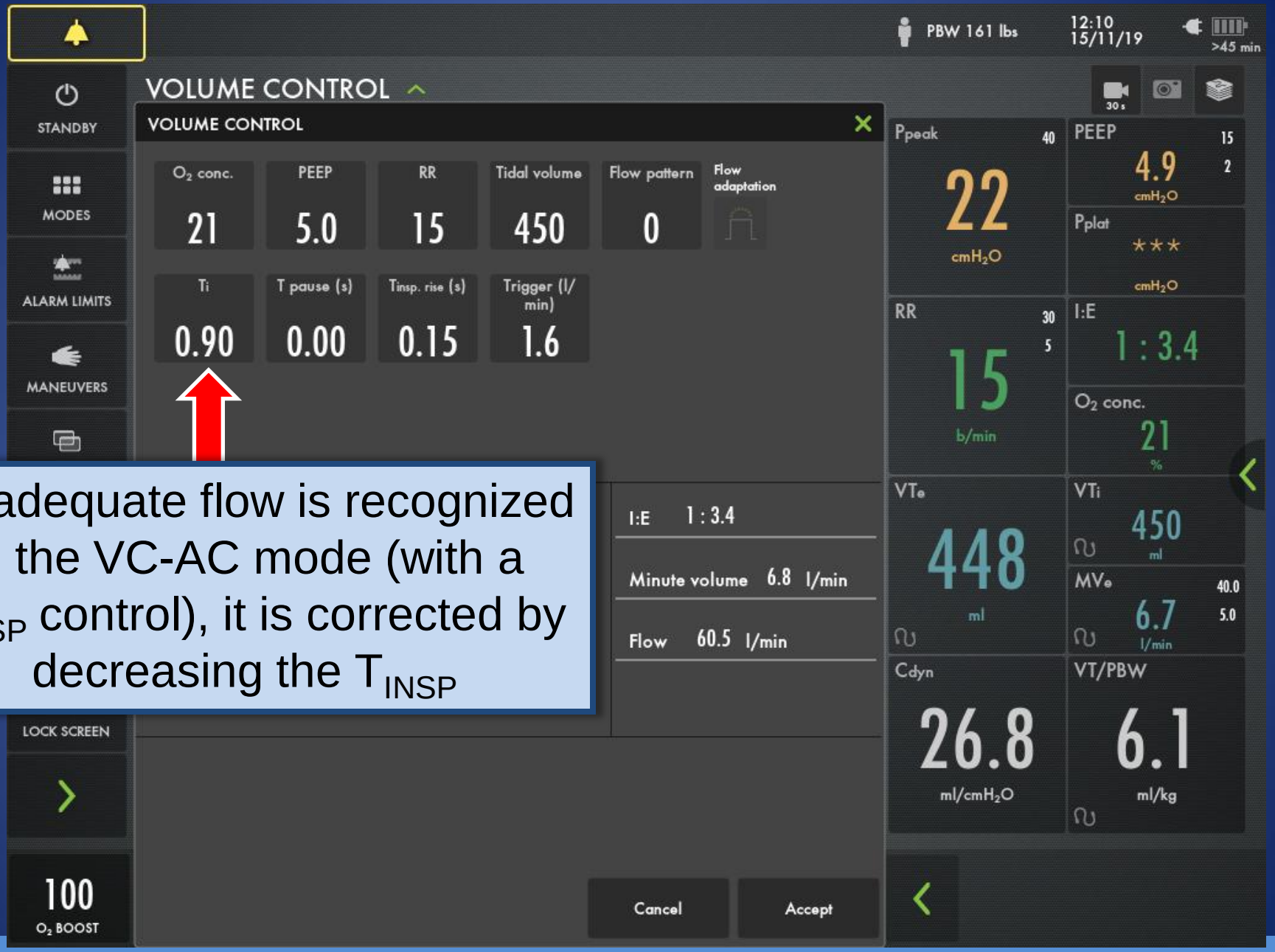
Inspiratory Dysynchrony in VC-AC

Correcting inadequate flow



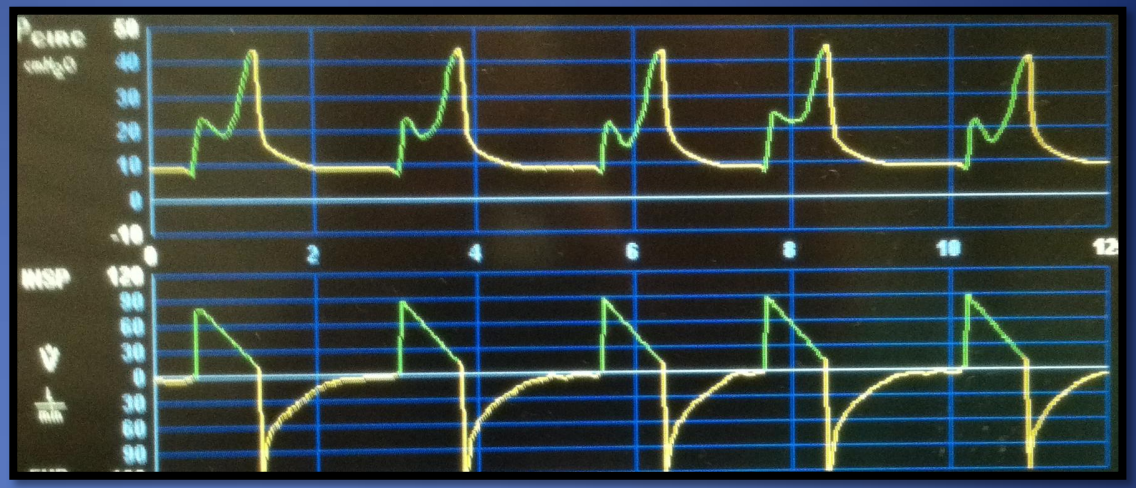
If inadequate flow is recognized in the VC-AC mode, it is corrected by increasing the peak inspiratory flow rate


Menu
P_{CIRC}
cmH_2O
INSP
$\dot{V}$
L/min
EXP
V_T
mL
SUPPLY
If inadequate flow is recognized in the VC-AC mode, it is corrected by increasing the peak inspiratory flow rate
Adult
A/C
VC
73 kg
6.85 mL/kg
Manual Insp
V_T 500 mL
f
14
1/min
V_T
500
mL
$\dot{V}_{MAX}$
80
L/min
$\dot{V}_{SENS}$
3.0
L/min
O_2
21
%
T_{PL}
0.0
s
Ramp
PEEP
5.0
cmH_2O
Manual
Event
O_2
100%
10:04:41am



If inadequate flow is recognized in the VC-AC mode (with a T_{INSP} control), it is corrected by decreasing the T_{INSP}

inadequate flow



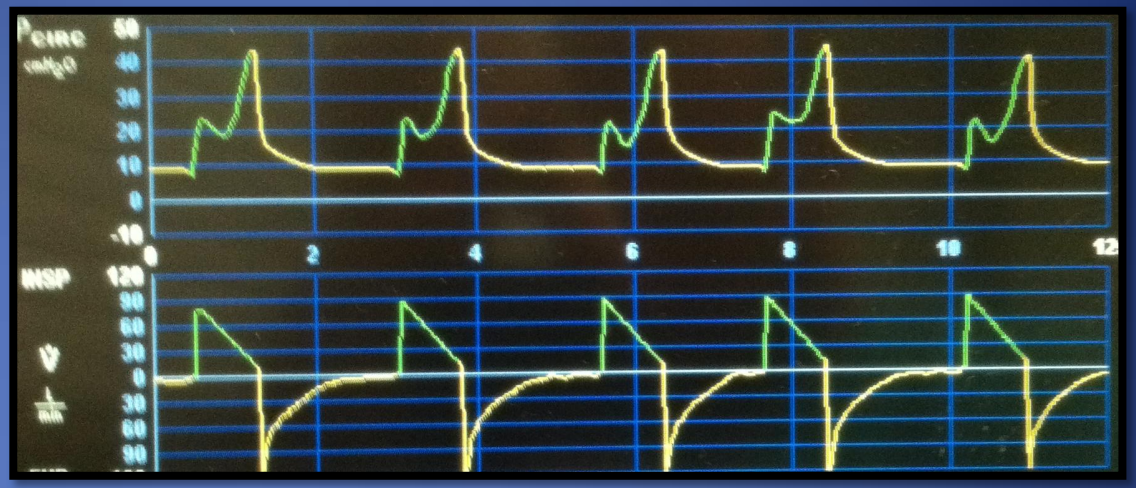
VC-AC

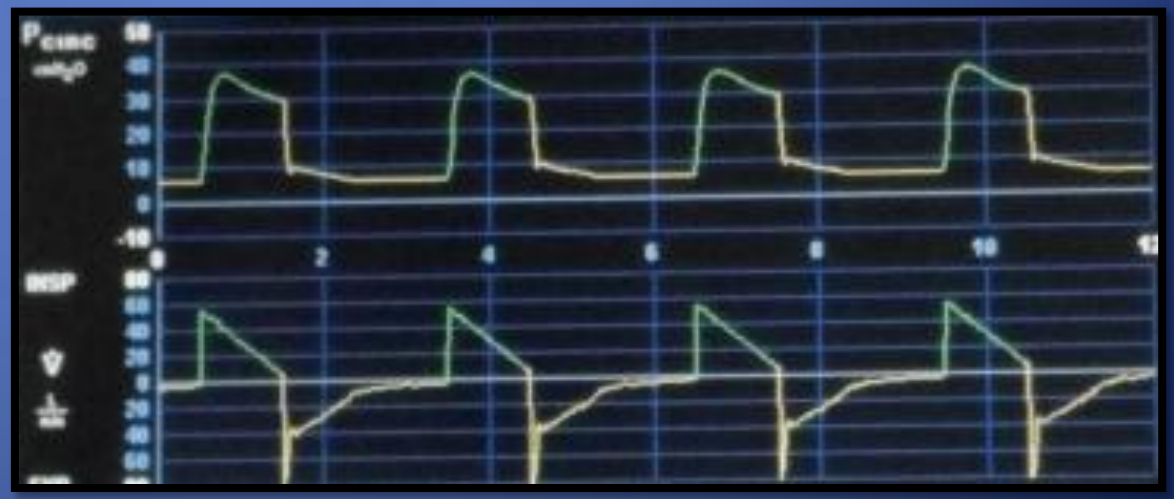
Inspiratory asynchrony

VC-AC

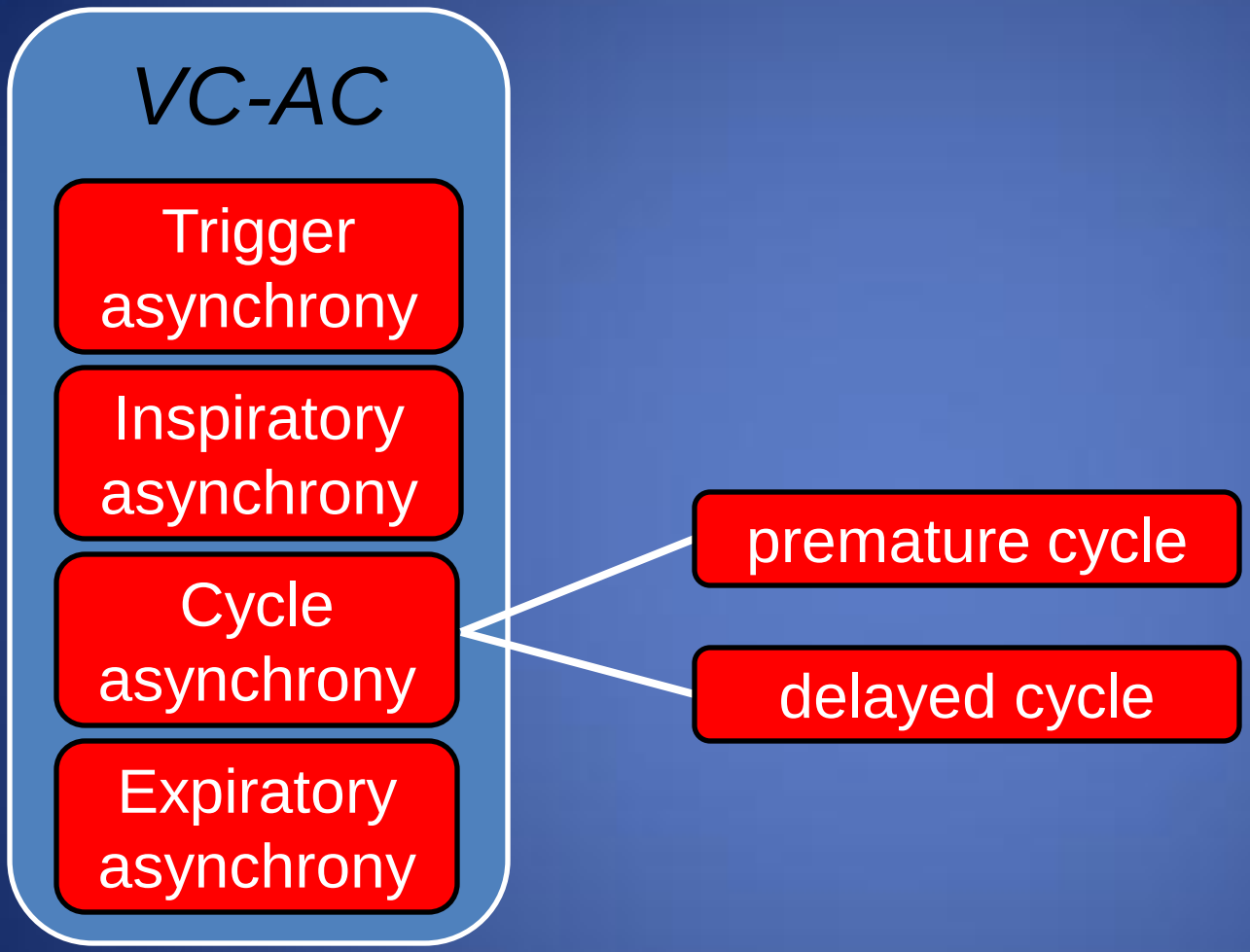
Inspiratory asynchrony

inadequate flow





excessive flow


VC-AC
Trigger asynchrony
Inspiratory asynchrony
Cycle asynchrony
Expiratory asynchrony
premature cycle
delayed cycle

Cycle Dysynchrony in VC-AC

Recognizing premature cycling

Premature cycling or “double-triggering”

Caused by a dysynchrony between the patient’s neural inspiratory time and the ventilator’s inspiratory time

ventilator cycles / ends inspiration

pressure / flow decrease in circuit

the ventilator delivers the set volume

the patient continues to inspire and expand their thoracic cage

Premature cycling or “double-triggering”

Caused by a dysynchrony between the patient’s neural inspiratory time and the ventilator’s inspiratory time

ventilator cycles / ends inspiration

the ventilator delivers the set volume

the ventilator delivers the set volume

the expiratory valve opens and allows for exhalation

the patient continues to inspire and expand their thoracic cage

the patient exhales (two inspiratory breathes from the ventilator within one inspiratory effort from the patient)

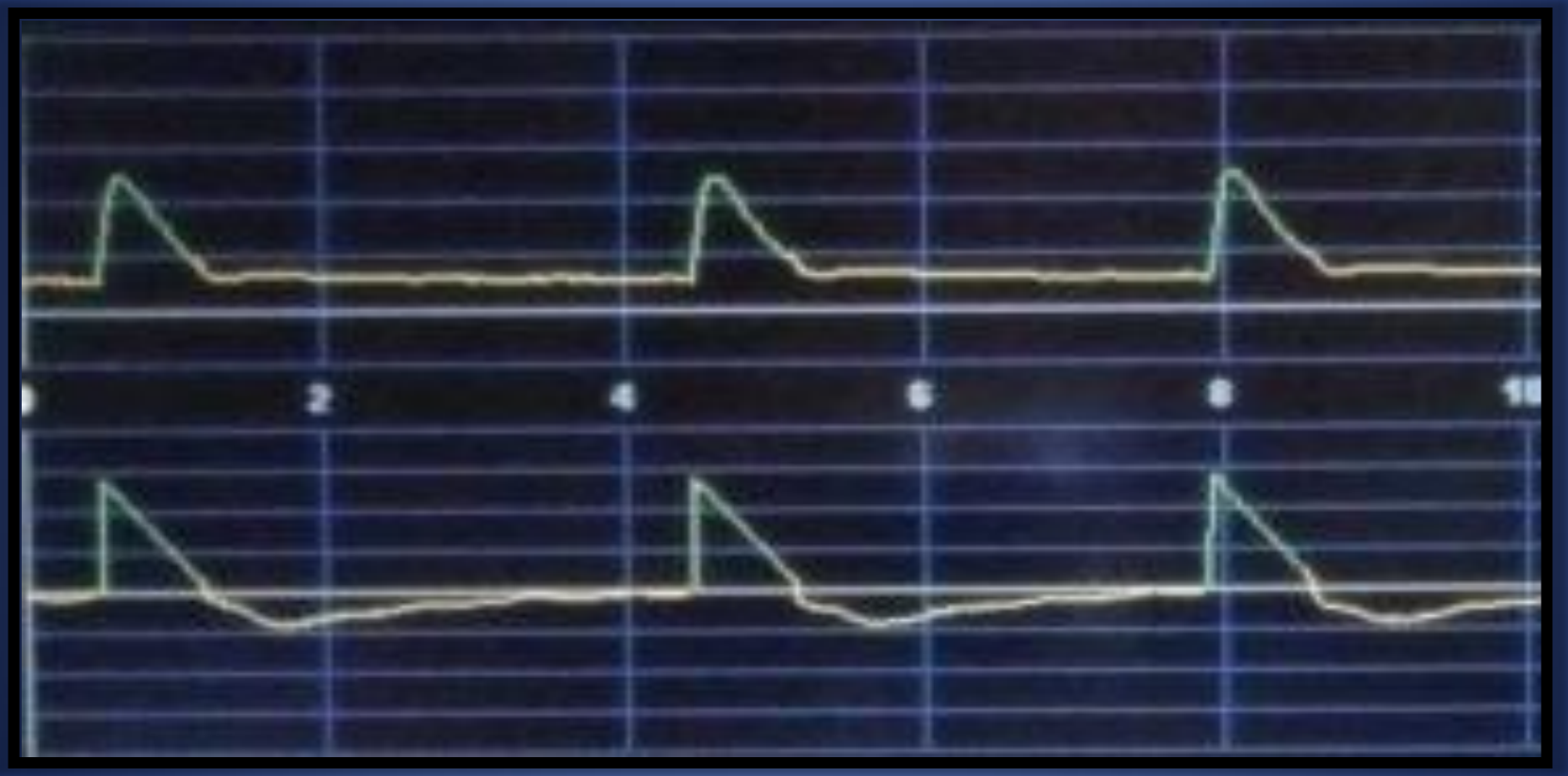
the exhaled V_T will read *0 ml* for the breaths that were not exhaled

This is immediately followed by a “doubled volume” as the patient exhales two set inspiratory volumes that were delivered on top of each other

severe cycle dysynchrony

moderate cycle dysynchrony

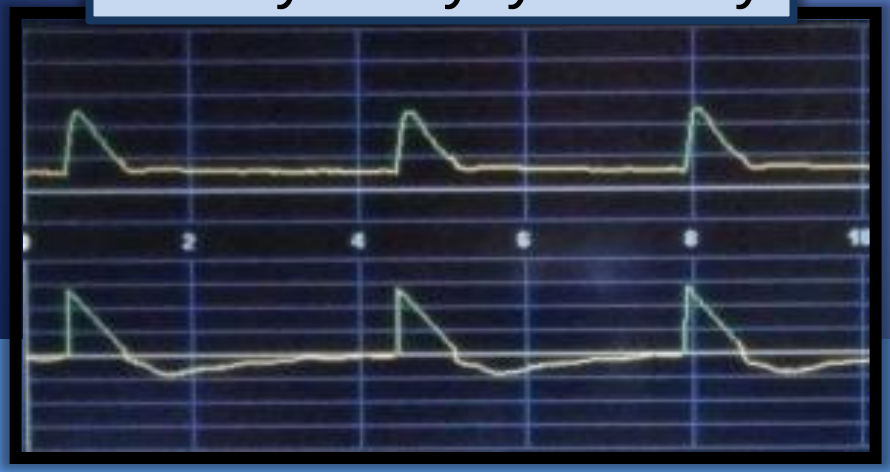
mild cycle dysynchrony



severe cycle dysynchrony

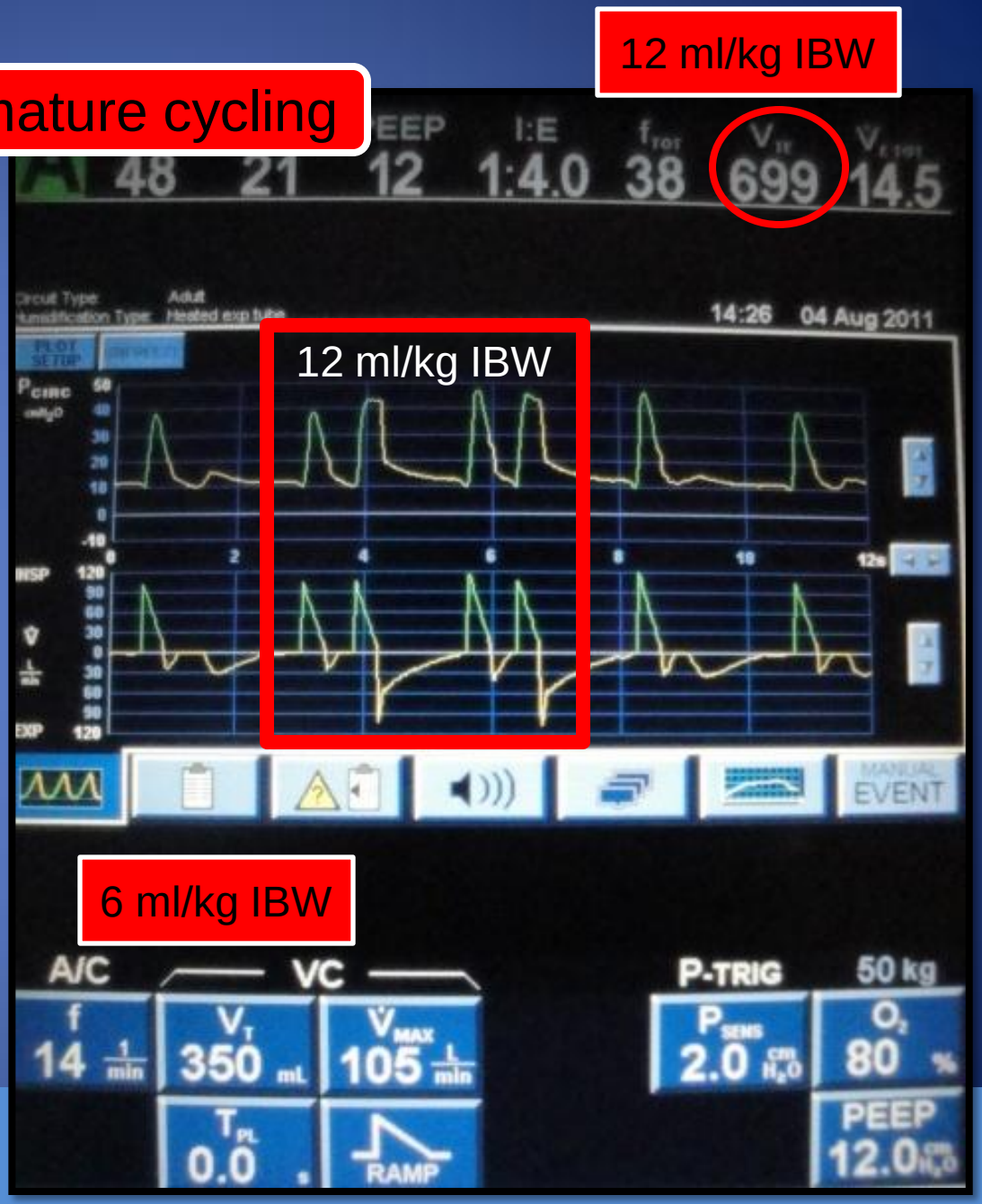
moderate cycle dysynchrony

mild cycle dysynchrony



Clinical implications of premature cycling

The clinical implication of severe cycle dysynchrony can be profound if the intention is to volume limit a patient who has ARDS

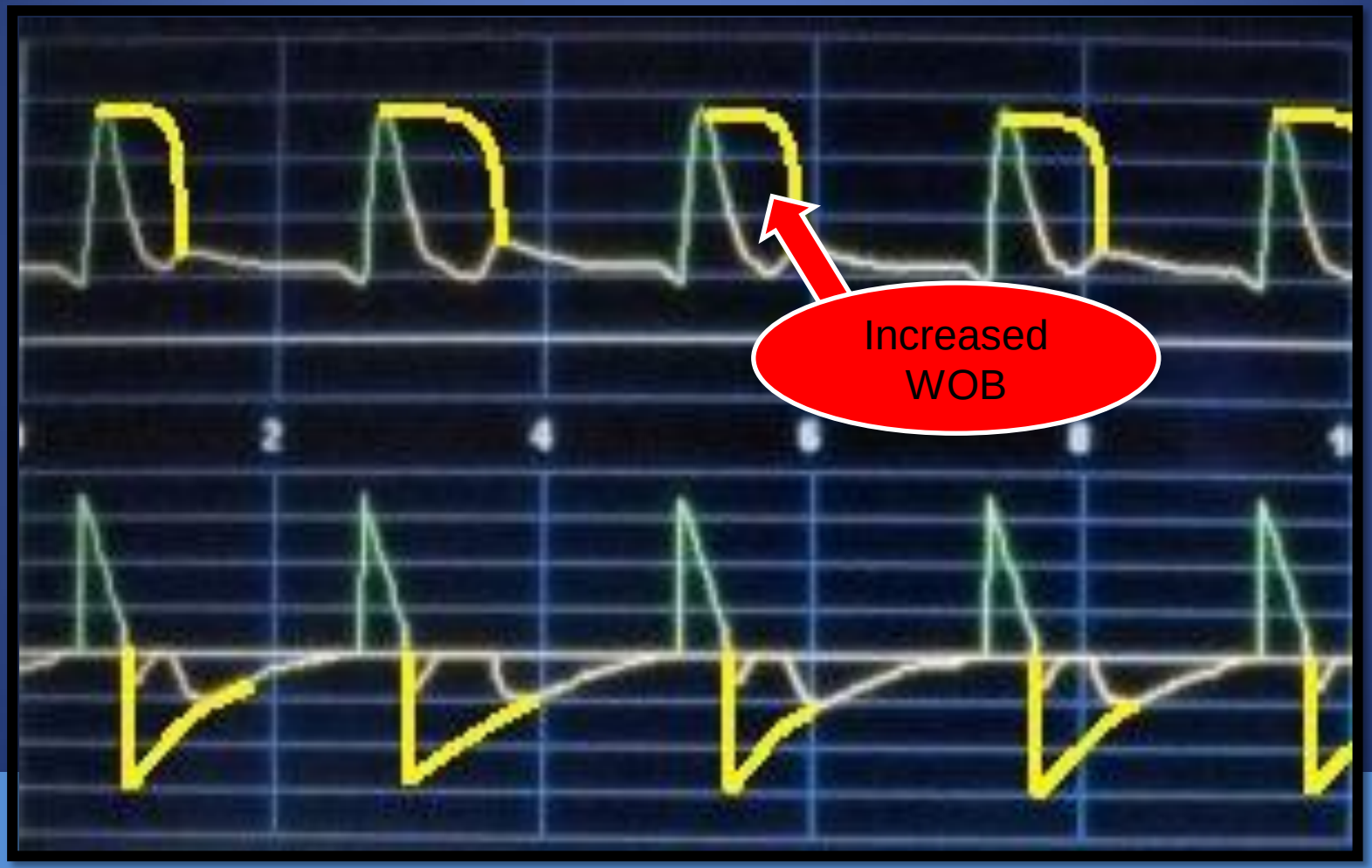


The clinical implication of moderate or minimal cycle dysynchrony is an increased WOB on the patient's behalf

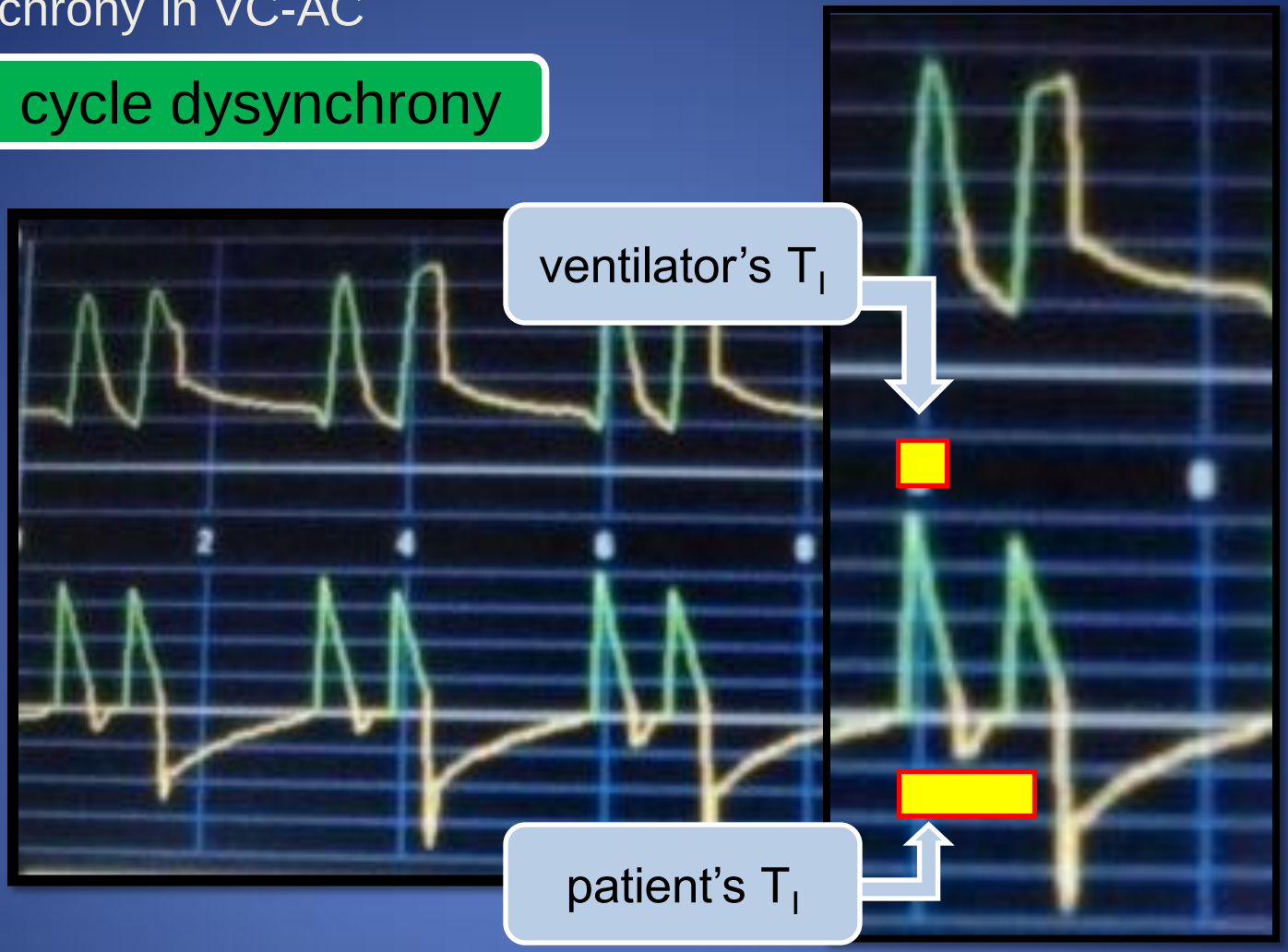
(the area under the reference curve)

The clinical implication of moderate or minimal cycle dysynchrony is an increased WOB on the patient's behalf

(the area under the reference curve)

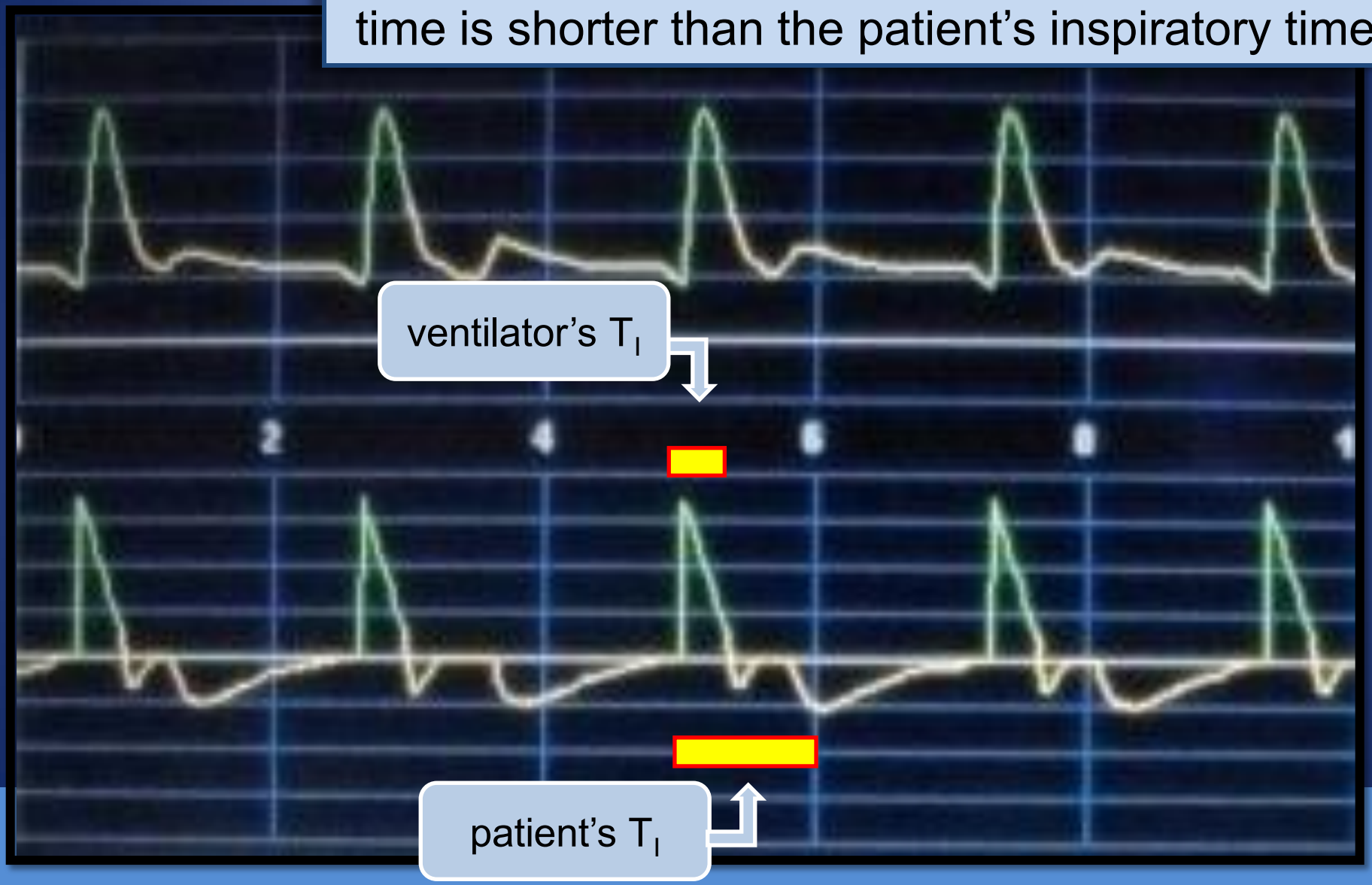


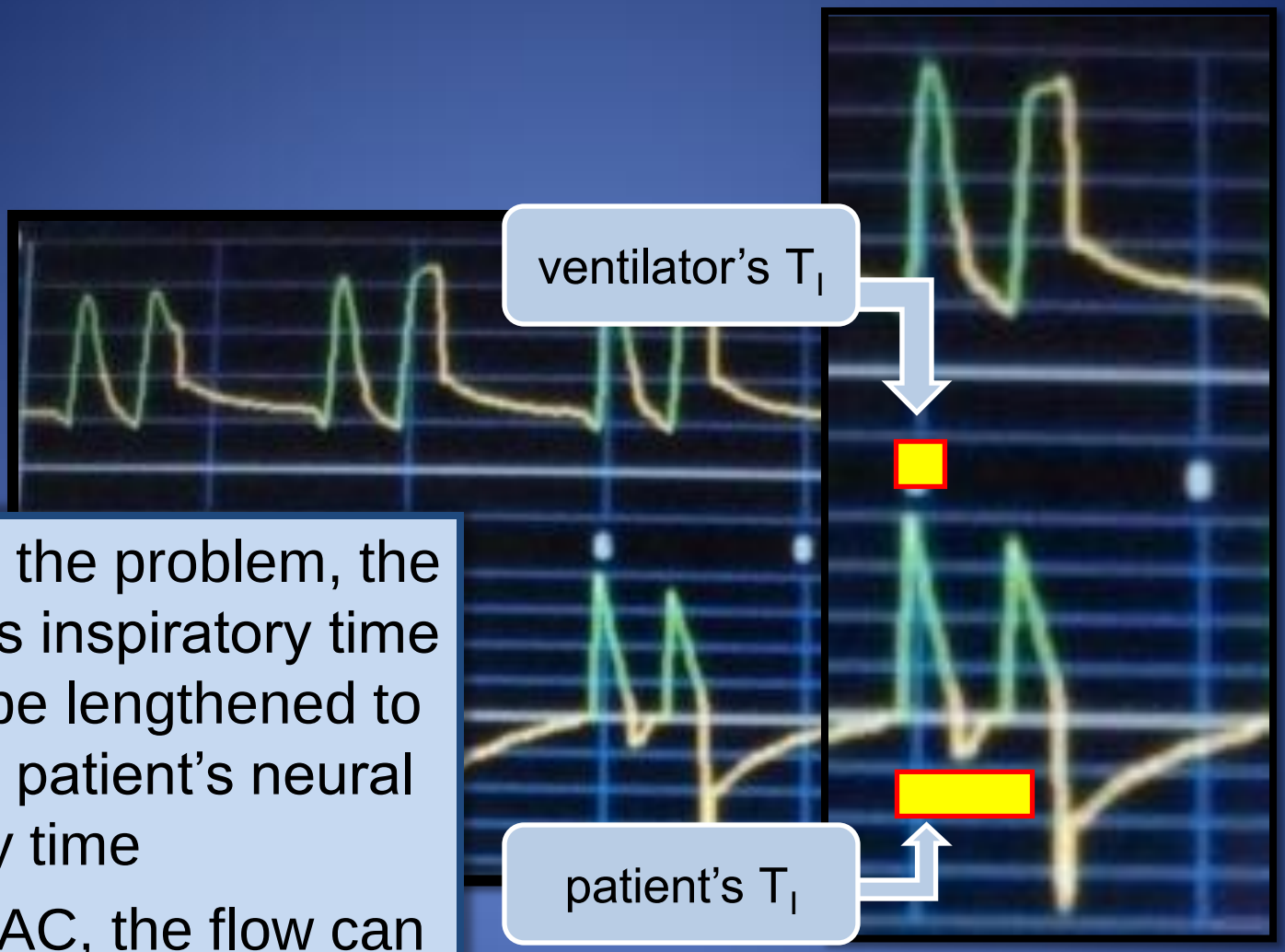
Correcting cycle dysynchrony



The inherent problem in a cycle dysynchrony-premature cycle is that the ventilator's inspiratory time is shorter than the patient's inspiratory time

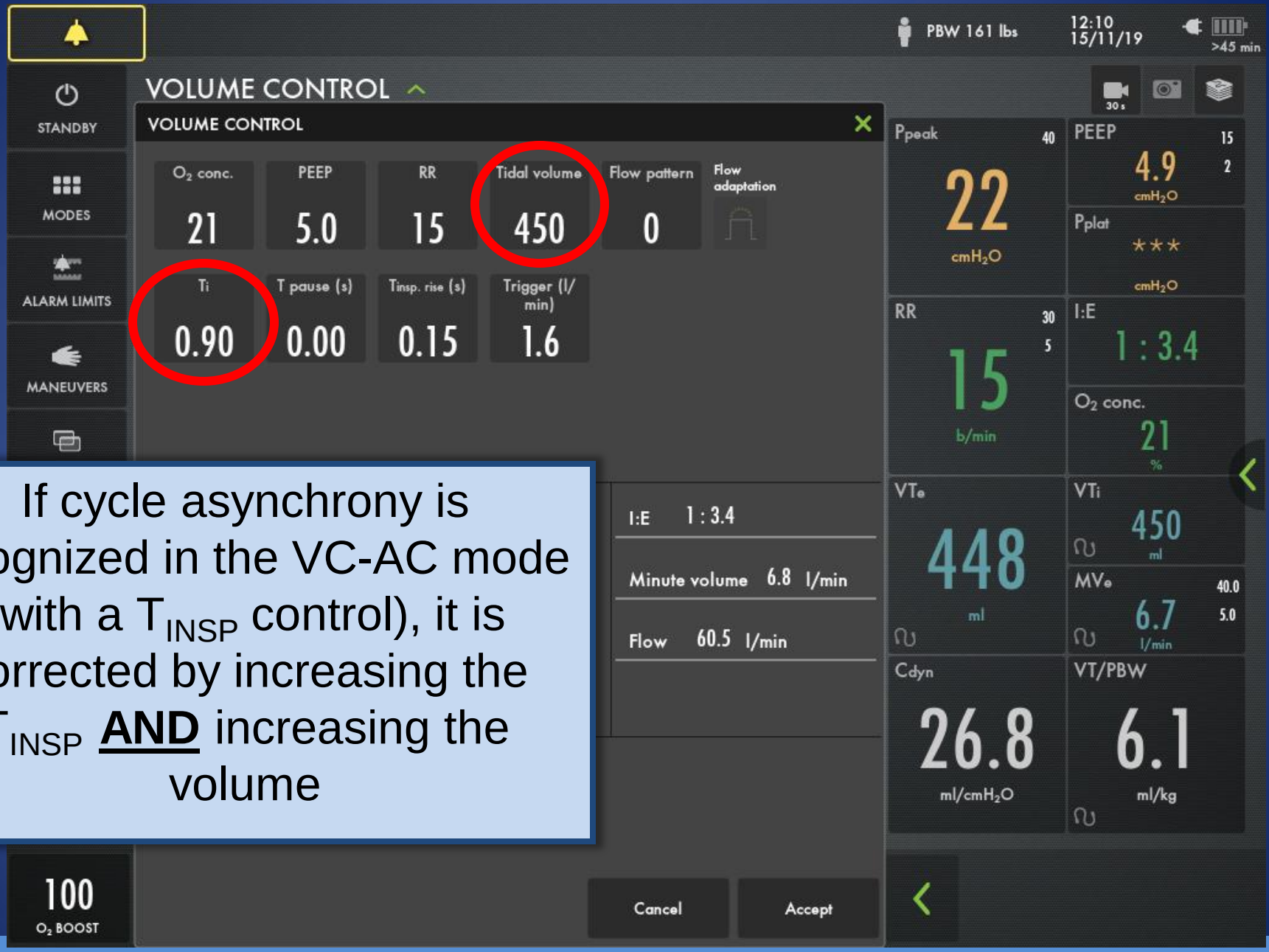
The inherent problem in a cycle dysynchrony-premature cycle is that the ventilator's inspiratory time is shorter than the patient's inspiratory time



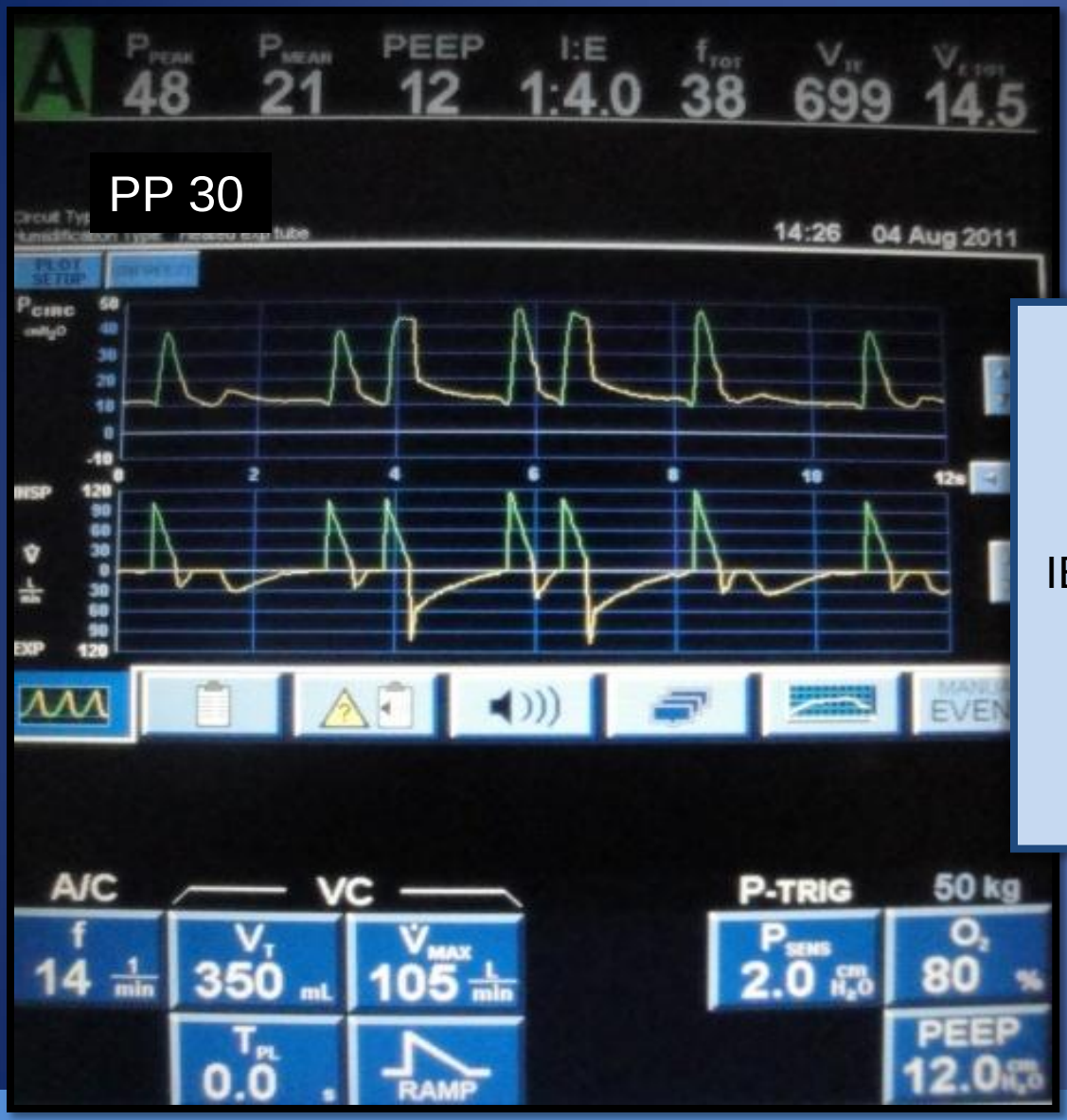


To correct the problem, the ventilator's inspiratory time needs to be lengthened to match the patient's neural inspiratory time

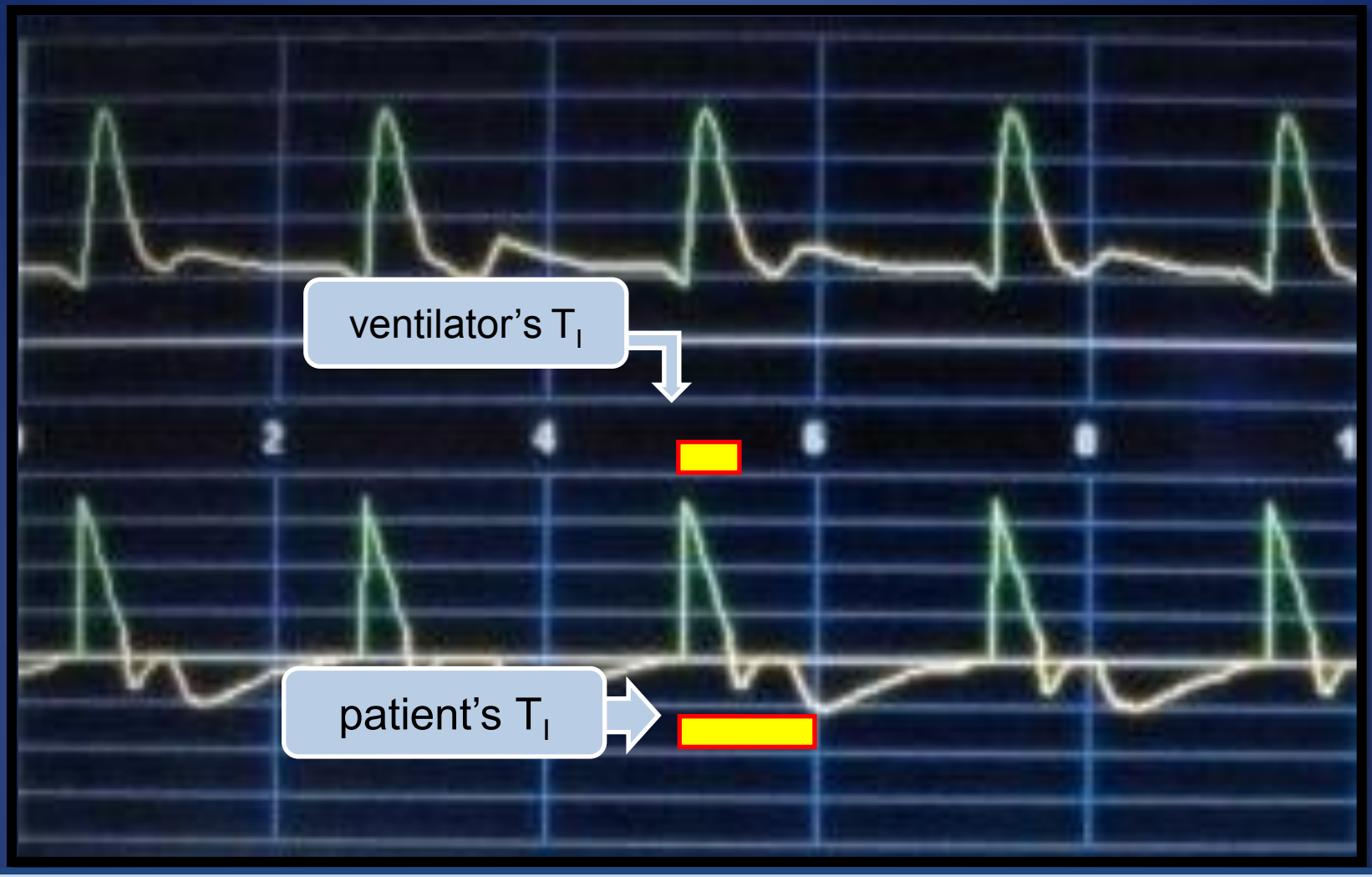
1. In VC-AC, the flow can be decreased OR
2. In VC-AC, the volume can be increased



If cycle asynchrony is recognized in the VC-AC mode (with a T_{INSP} control), it is corrected by increasing the T_{INSP} **AND** increasing the volume



However, if the your intention for management is to limit volume (i.e 6 ml/kg IBW in ARDS) then increasing volume is NOT a viable option to correct cycle dysynchrony



If increasing tidal volume is not a viable option, then the patient's neural inspiratory time needs to be shortened to match the ventilator's inspiratory time

3. The patient requires increased sedation or paralysis

premature cycle

VC-AC

Cycle asynchrony

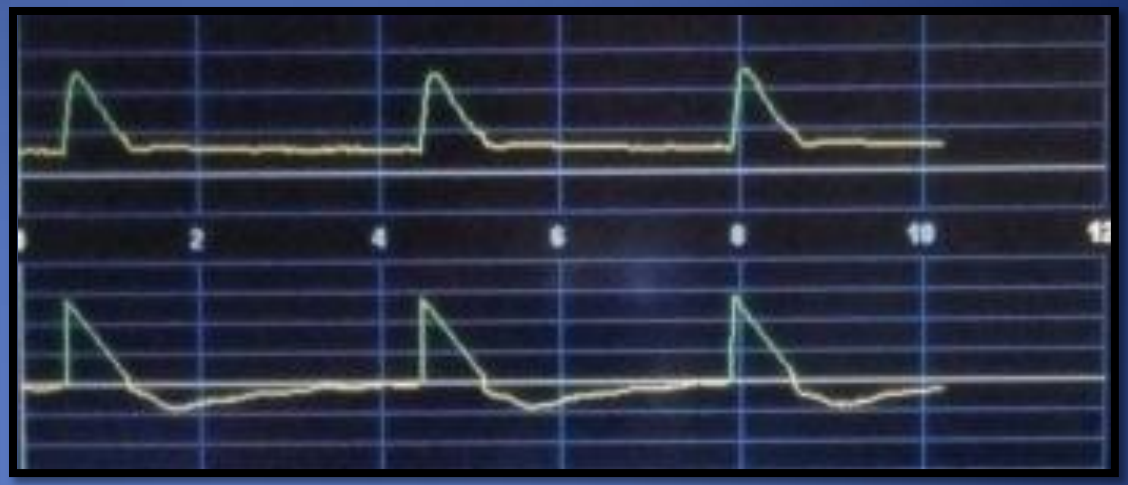
premature cycle

VC-AC

Cycle asynchrony

premature cycle

VC-AC

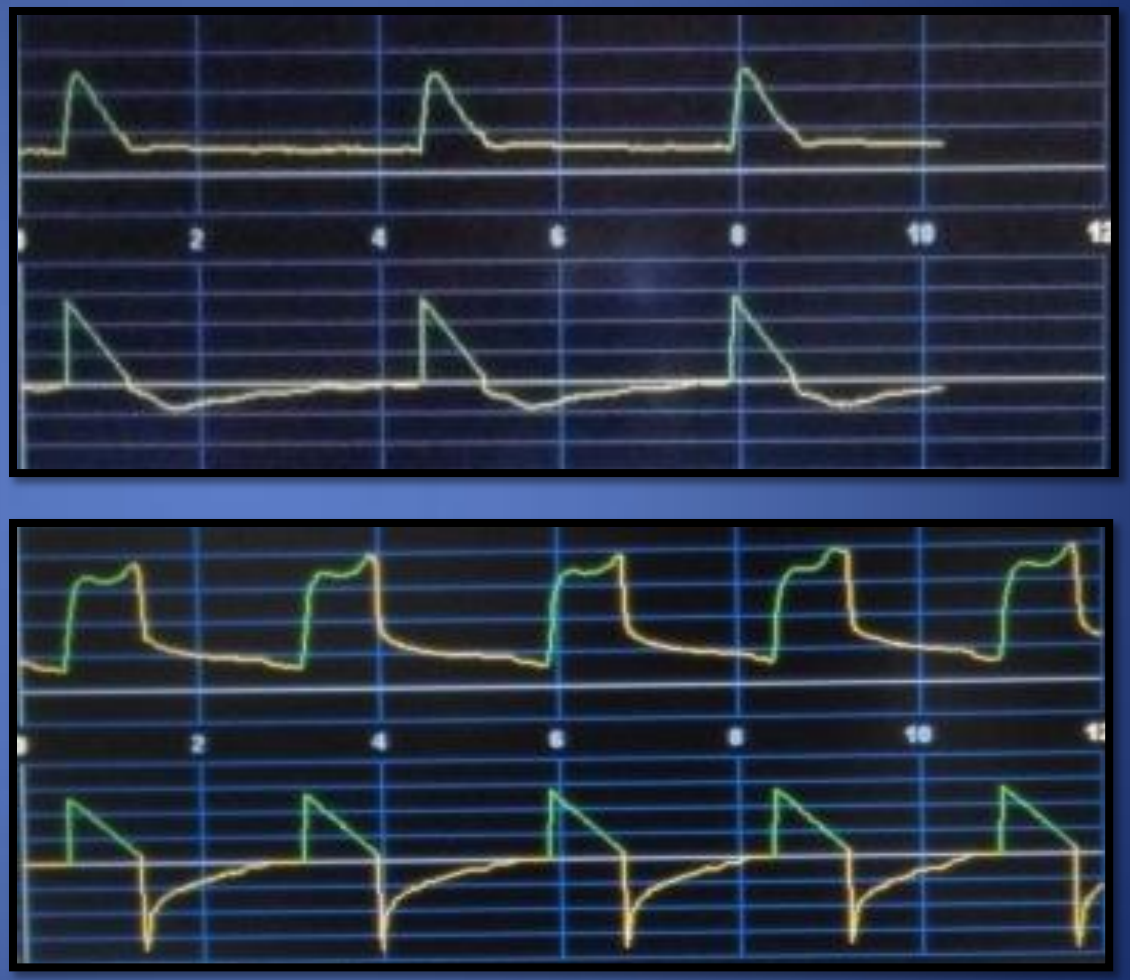


Cycle asynchrony

premature cycle

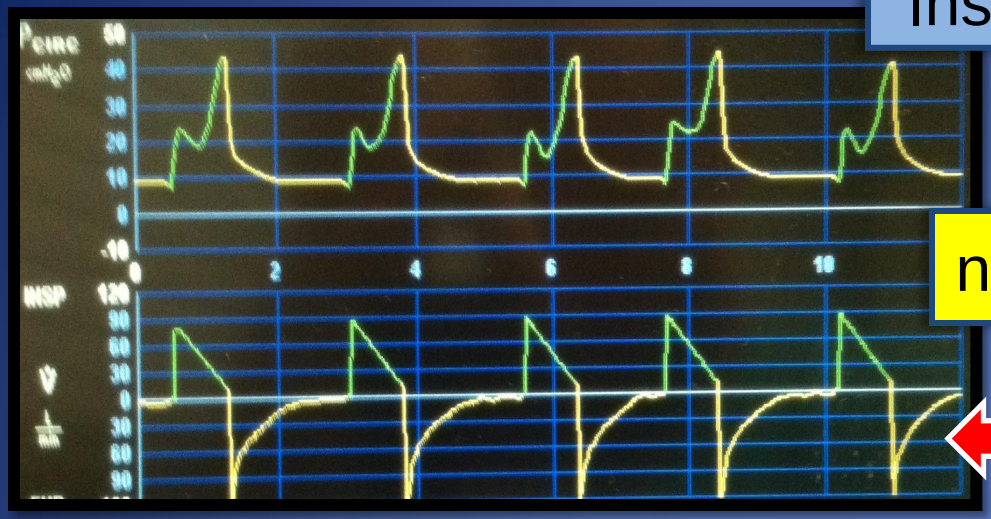
VC-AC

Cycle asynchrony



delayed cycle

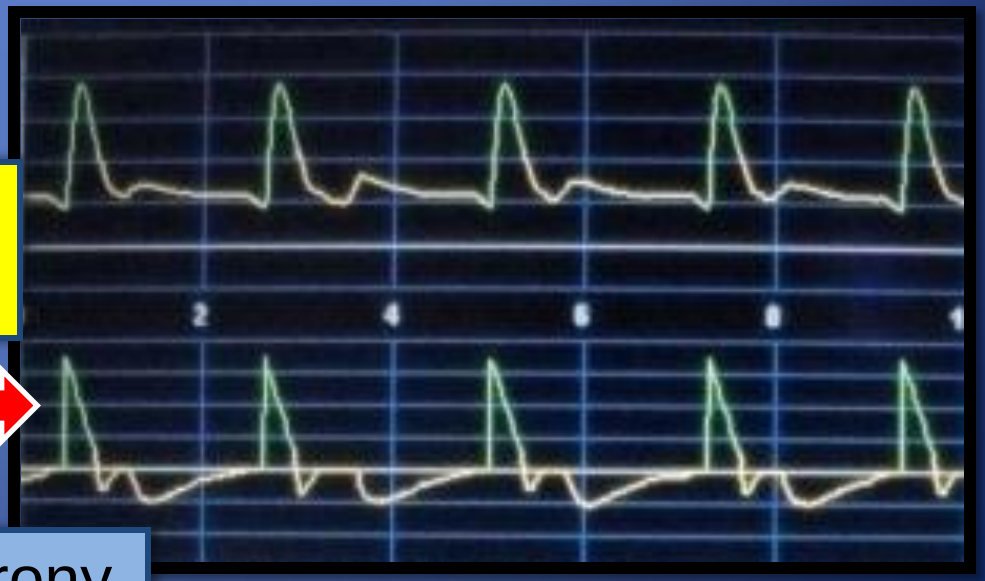
Inspiratory dysynchrony



normal expiratory flow

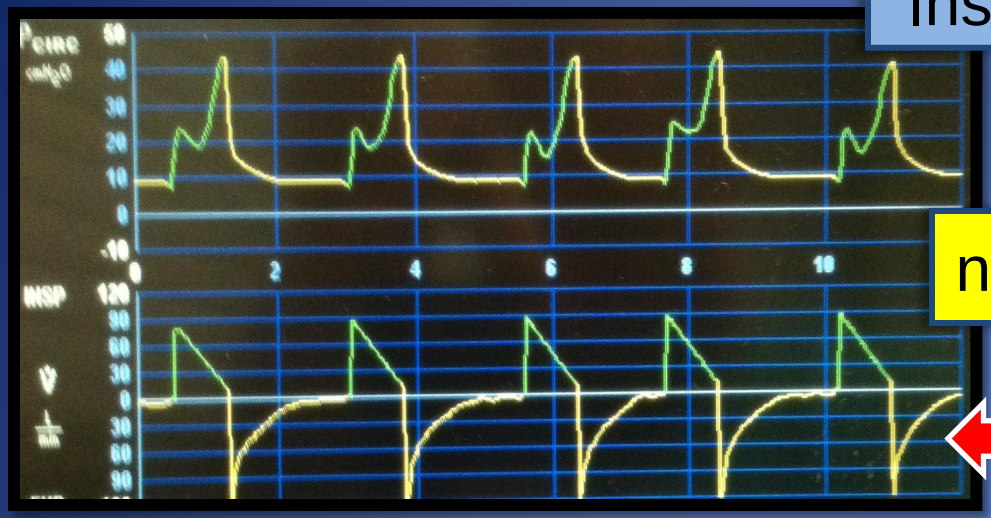
VS.

absent or abnormal expiratory flow



Cycle dysynchrony

Inspiratory dysynchrony

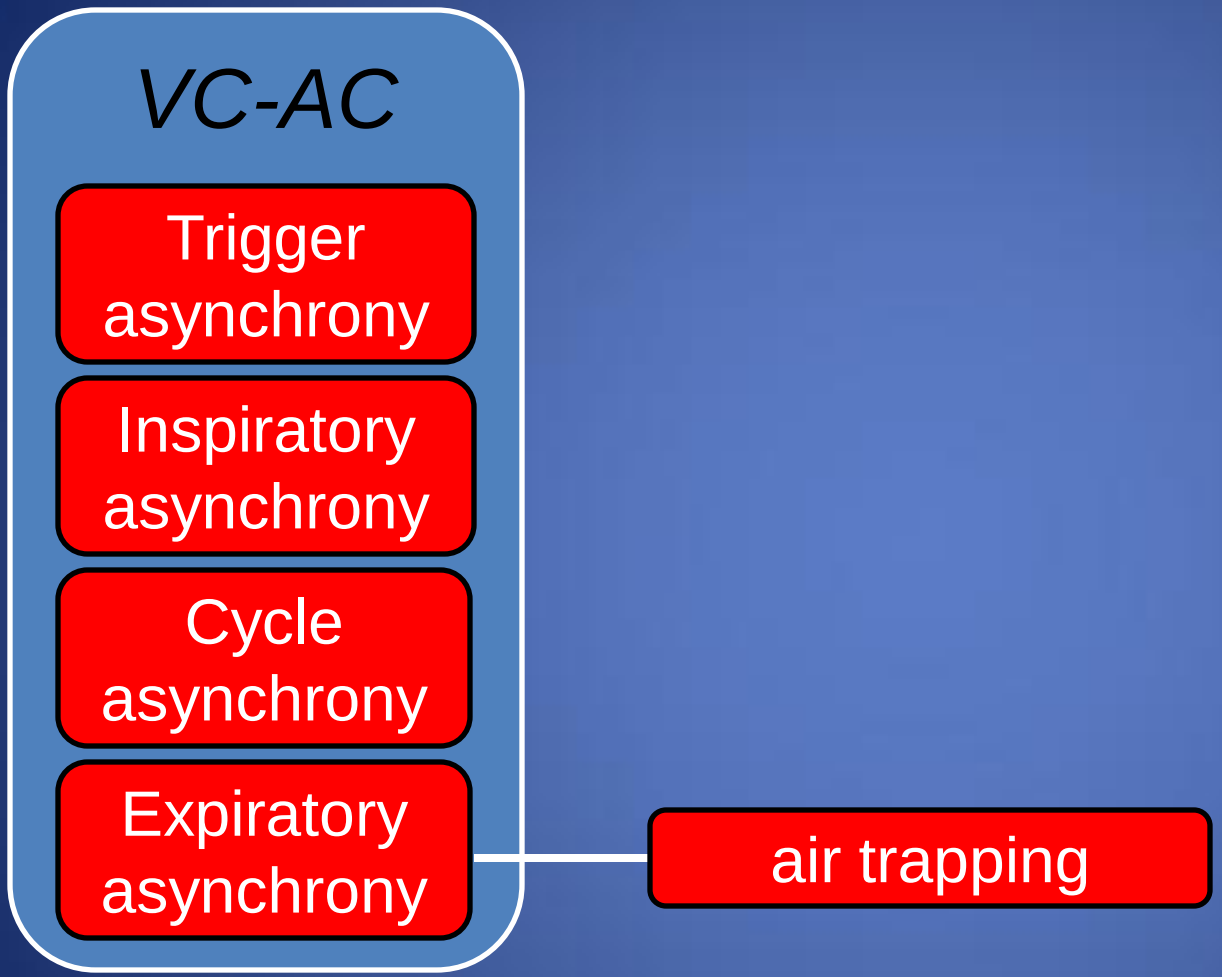


normal expiratory flow

VS.

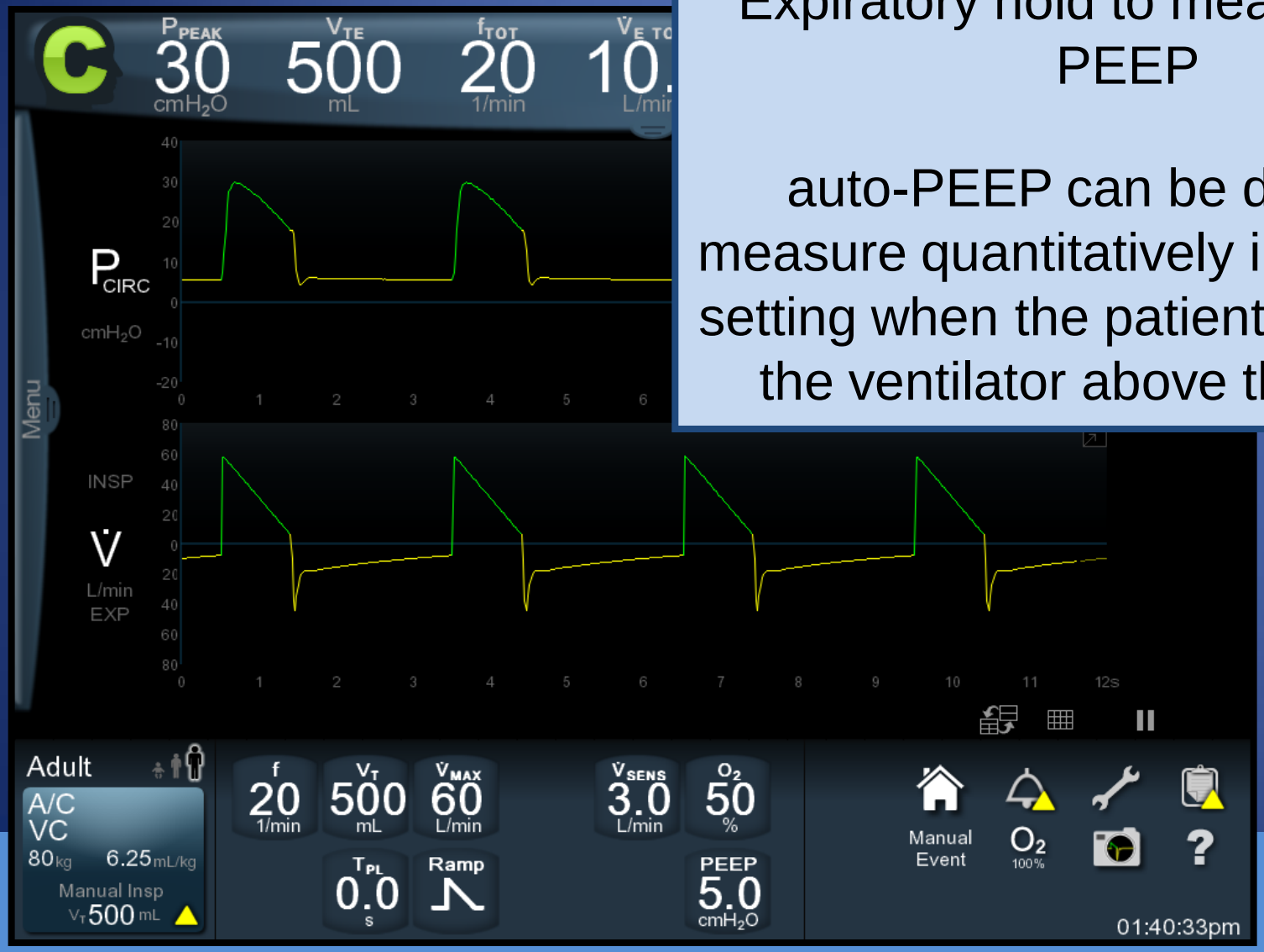
absent or abnormal expiratory flow

Cycle dysynchrony


VC-AC
Trigger asynchrony
Inspiratory asynchrony
Cycle asynchrony
Expiratory asynchrony
air trapping

Expiratory Dysynchrony in VC-AC

Recognizing air-trapping



Expiratory hold to measure auto-PEEP

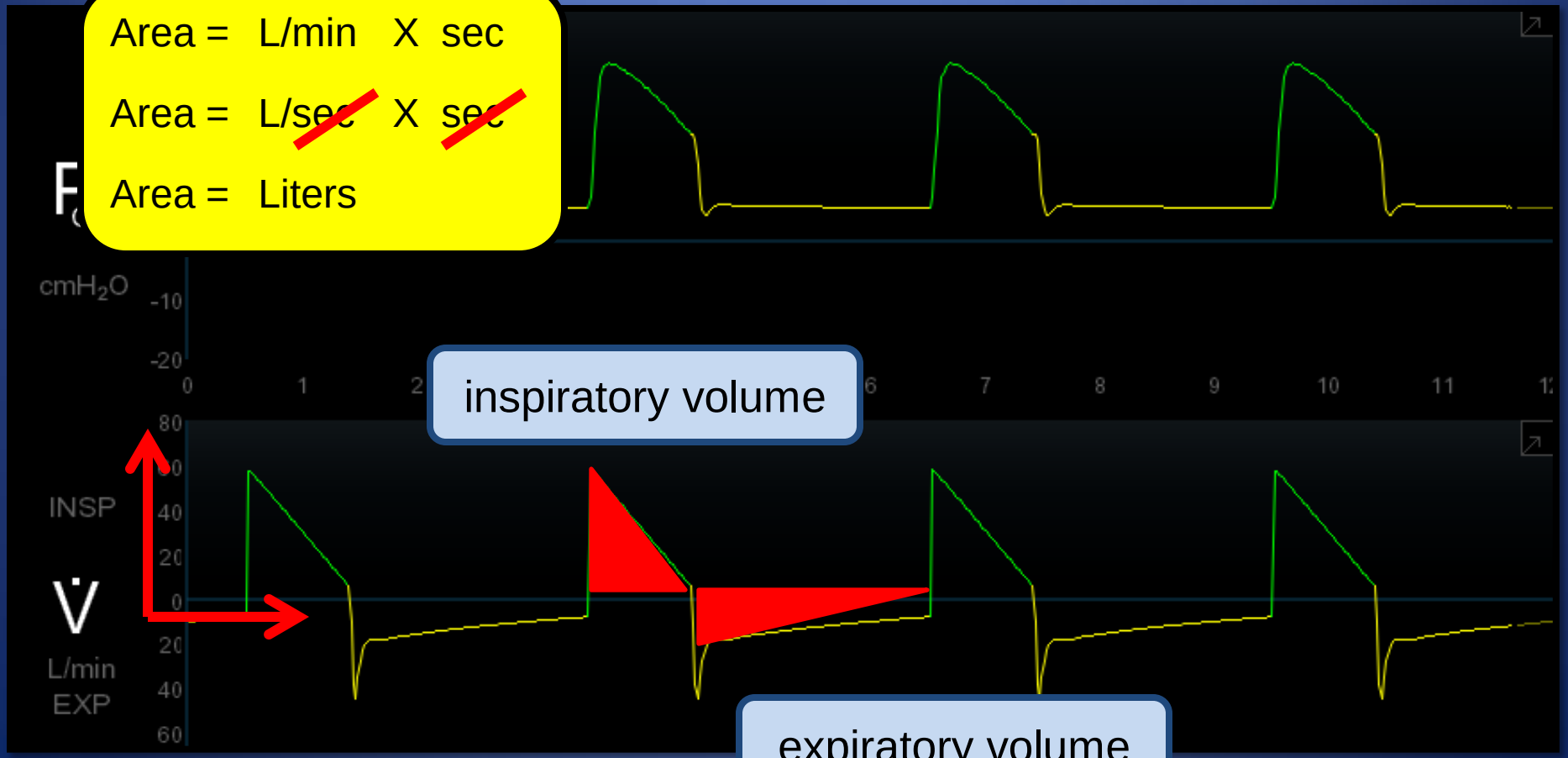
auto-PEEP can be difficult to measure quantitatively in the clinical setting when the patient is triggering the ventilator above the set RR

air trapping is present if the area under the expiratory flow curve is less than the area under the inspiratory flow curve

Area = L/min X sec

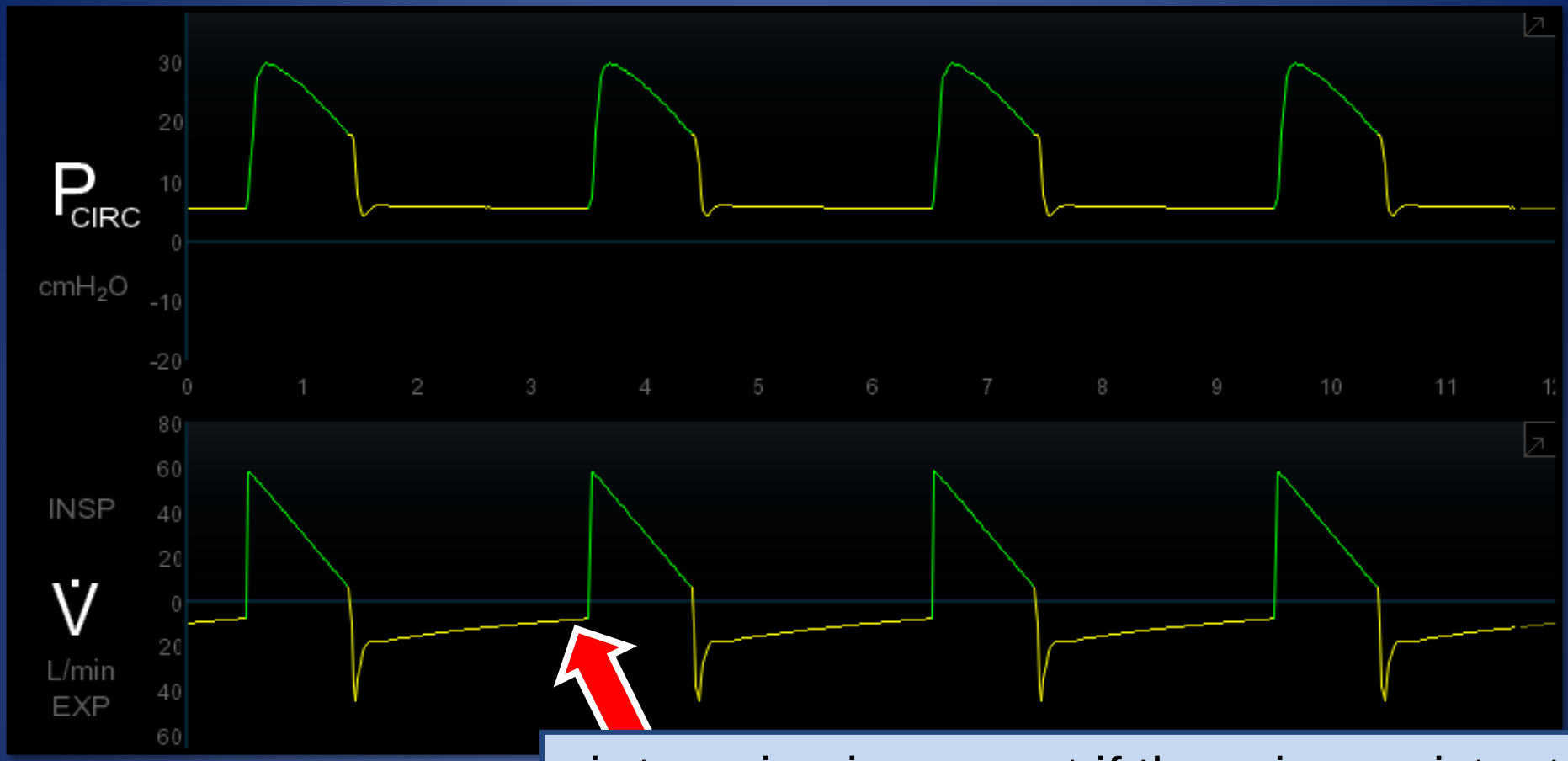
Area = ~~L/sec~~ X ~~sec~~

Area = Liters



inspiratory volume

expiratory volume



air-trapping is present if there is persistent end expiratory flow or expiratory flow does not return to baseline

air trapping is (most likely) present if there is evidence of ineffective triggers

Clinical implications of air trapping

Air-trapping → auto-PEEP can cause:

1) Increased work of breathing due to difficulty in triggering (ineffective triggering)
2) Increased end-inspiratory alveolar pressure/volume (volutrauma)
3) Increase in deadspace ventilation due to excessive PEEP / hyperinflation
4) Decreased cardiac output and blood pressure

Expiratory Dysynchrony in VC-AC

Correcting air trapping

To correct auto-PEEP the expiratory time must be lengthened

Decrease the T_I

(in appropriate manner dependent on the mode of ventilation)

VC-AC

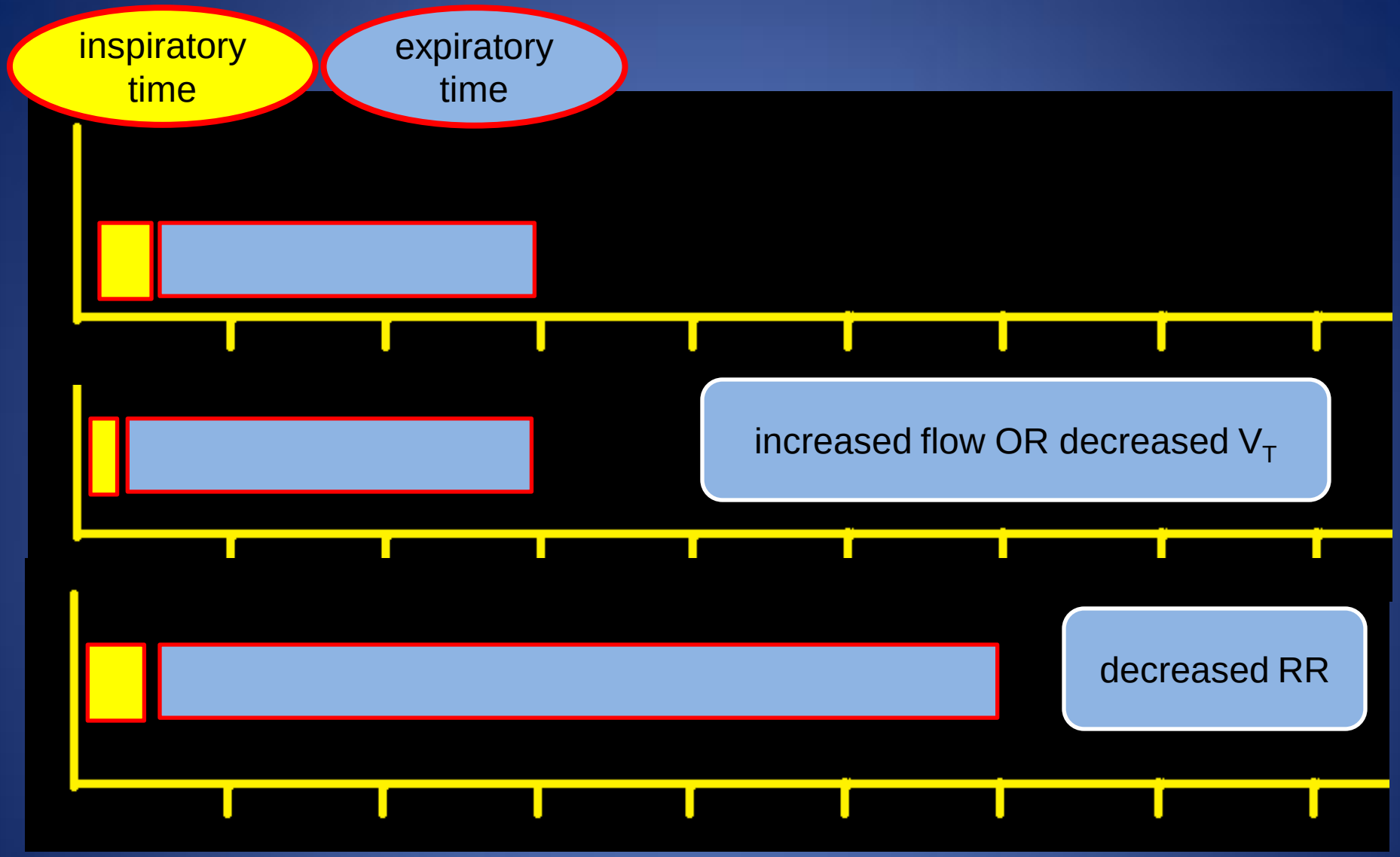
1. Increase inspiratory flow
2. Decrease tidal volume

Increase T_E

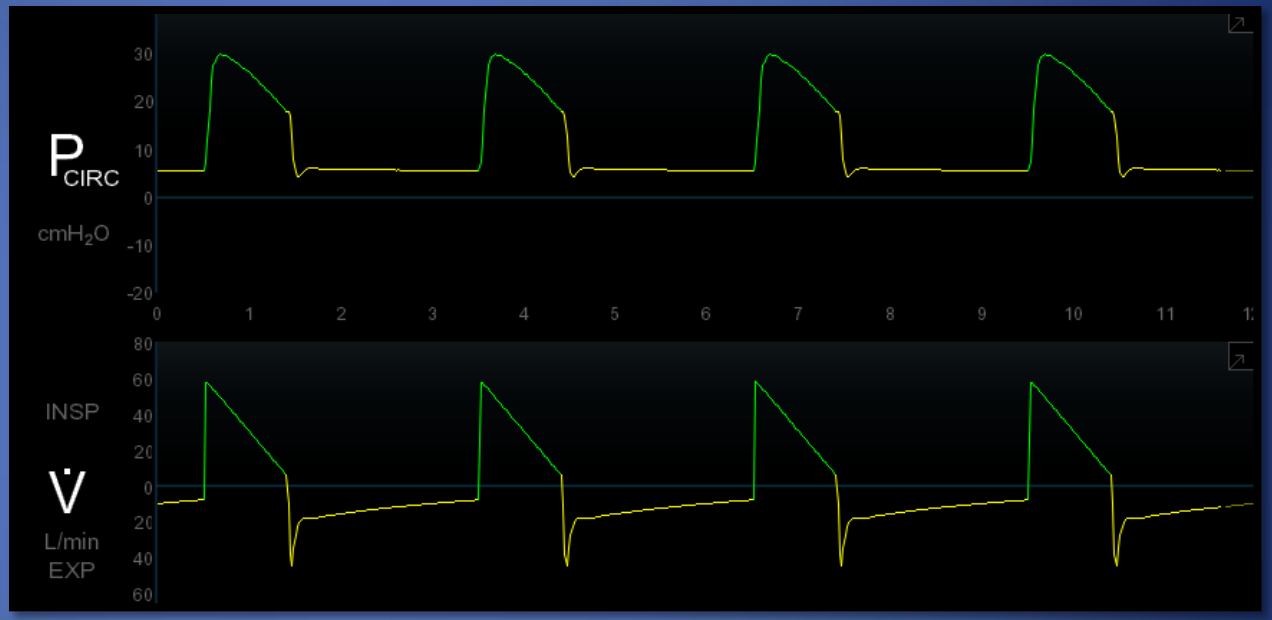
VC-AC

3. If the patient is assisting above the set respiratory rate then pharmacological means may be indicated
4. Decrease respiratory rate

Bronchodilator therapy if excessive expiratory time is required due to obstructed expiratory flow


inspiratory time
expiratory time
increased flow OR decreased V_T
decreased RR

VC-AC



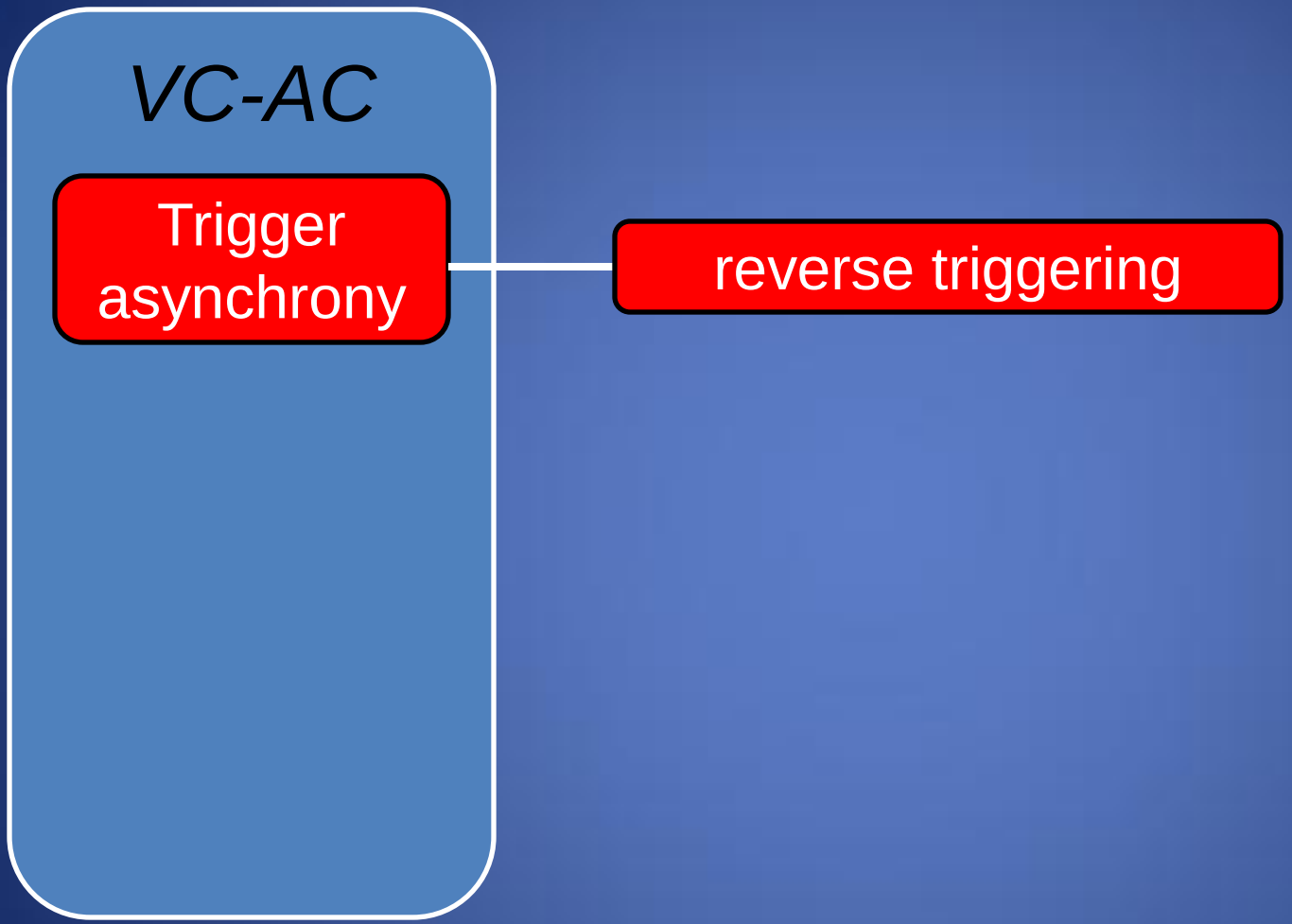
Expiratory asynchrony

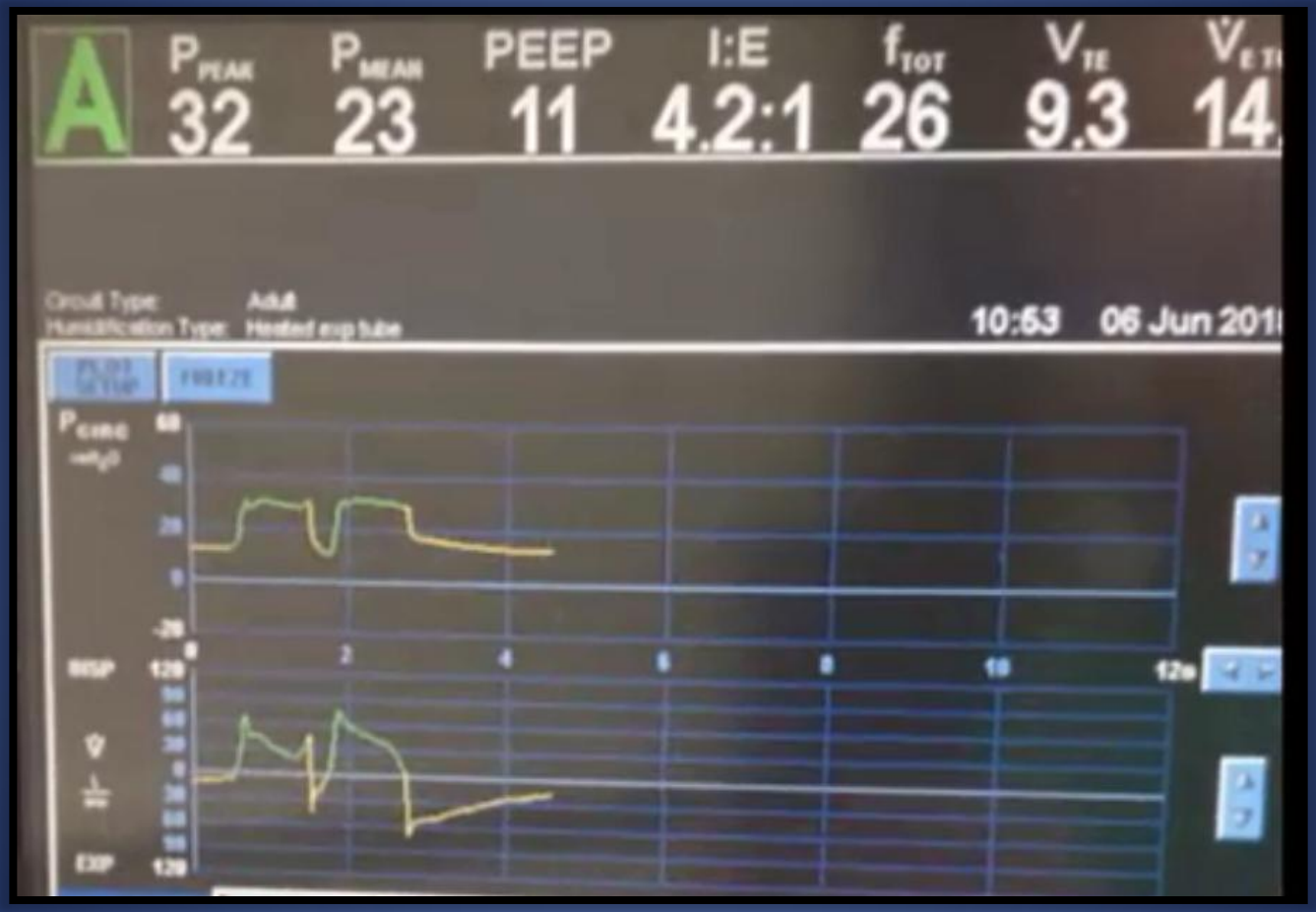
air trapping

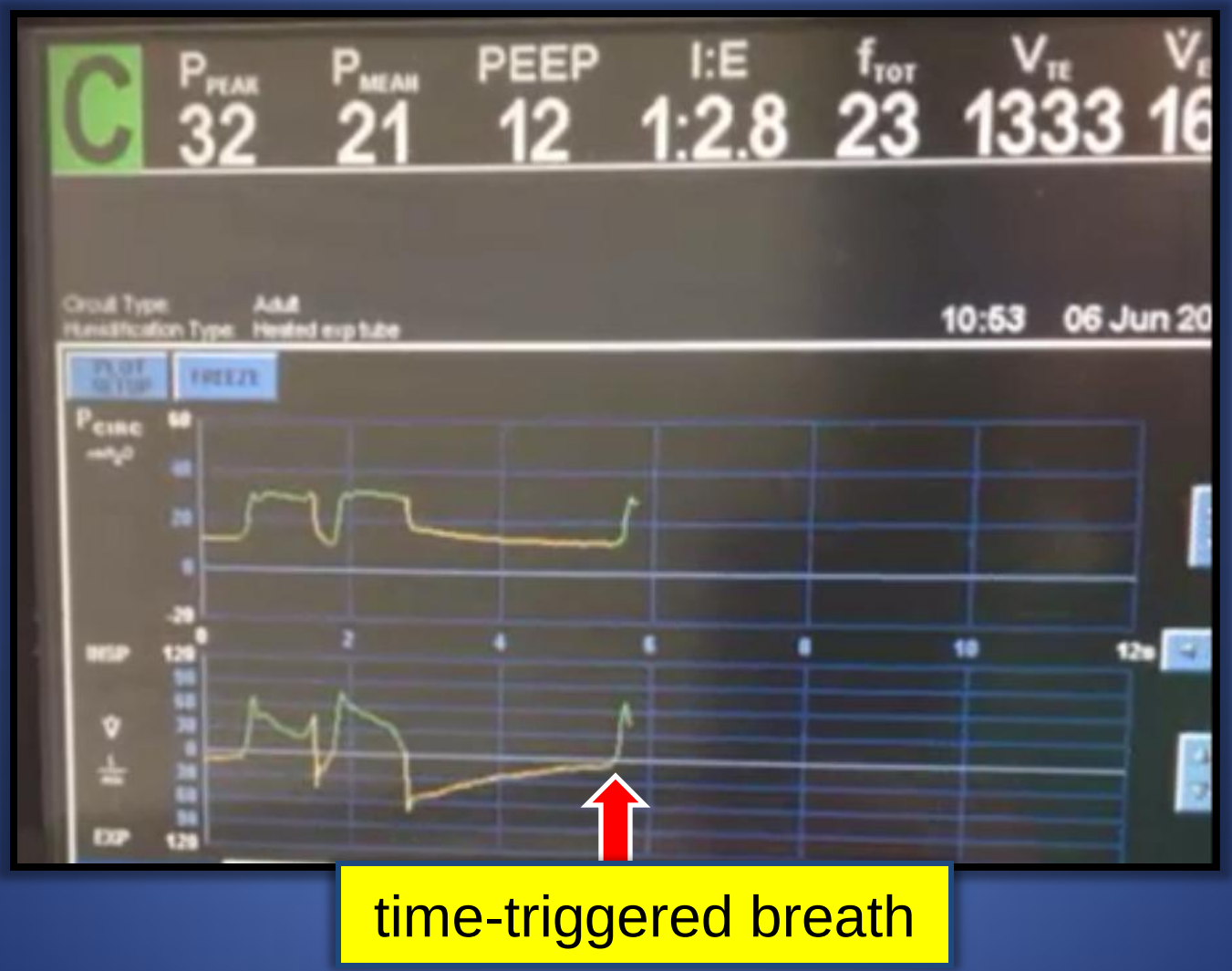
MECH VENT WORKSHOP

RECOGNIZING AND CORRECTING PATIENT-VENTILATOR ASYNCHRONY IN VC-AC

Eric Kriner BSRT,RRT
Adult Critical Care Clinical Specialist
Medstar Washington Hospital Center
Washington, DC
eric.j.kriner@medstar.net


VC-AC
Trigger asynchrony
reverse triggering


A
P PEAK
32
P MEAN
23
PEEP
11
I:E
4.2:1
f TOT
26
V TE
9.3
Circuit Type:
Humidification Type:
Heated exp tube
10:53
06 Jun 201
FREEZE
P CIRC
MSP
ESP


C
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P MEAN
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f TOT
23
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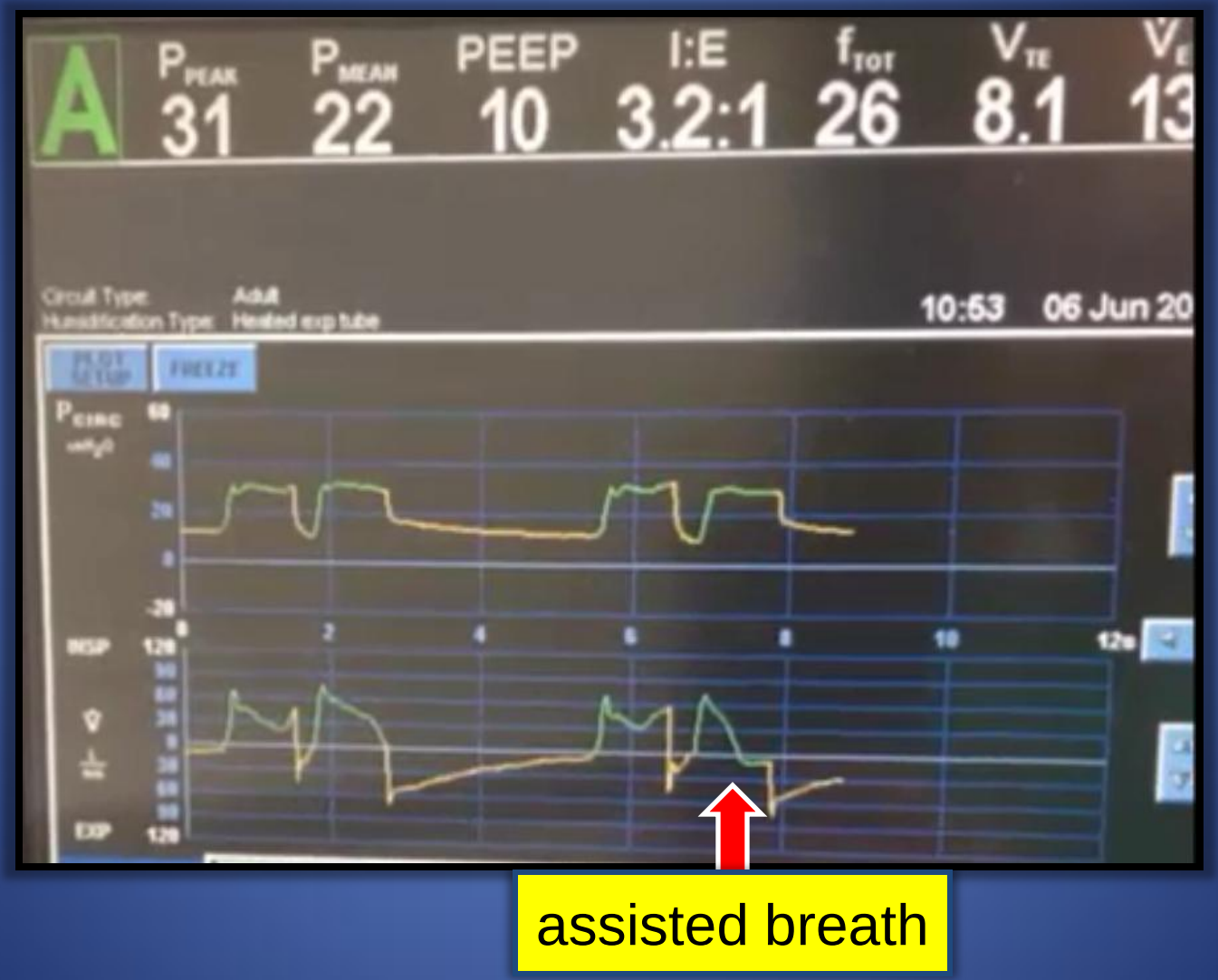
16
10:53
06 Jun 20
time-triggered breath


A
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26
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13
Circuit Type:
Adult
Humidification Type:
Heated exp tube
10:53
06 Jun 20
FREEZE
P CIRC
INSP
EXP
assisted breath

Mechanical Ventilation-Induced Reverse-Triggered Breaths

A Frequently Unrecognized Form of Neuromechanical Coupling

Evangelia Akoumianaki, MD; Aissam Lyazidi, PhD; Nathalie Rey, MD; Dimitrios Matamis, MD; Nelly Perez-Martinez, MD; Raphael Giraud, MD; Jordi Mancebo, MD; Laurent Brochard, MD; and Jean-Christophe Marie Richard, MD, PhD

AMERICAN COLLEGE OF CHEST PHYSICIANS

CHEST / 143 / 4 / APRIL 2013

An esophageal balloon or Edi catheter was placed in 8 patients and software recorded pressure, volume and flow. The tracings were subsequently analyzed for entrainment or reverse triggering

Duration, patterns or distribution, and phase angles of entrainment were defined

Mechanical Ventilation-Induced Reverse-Triggered Breaths

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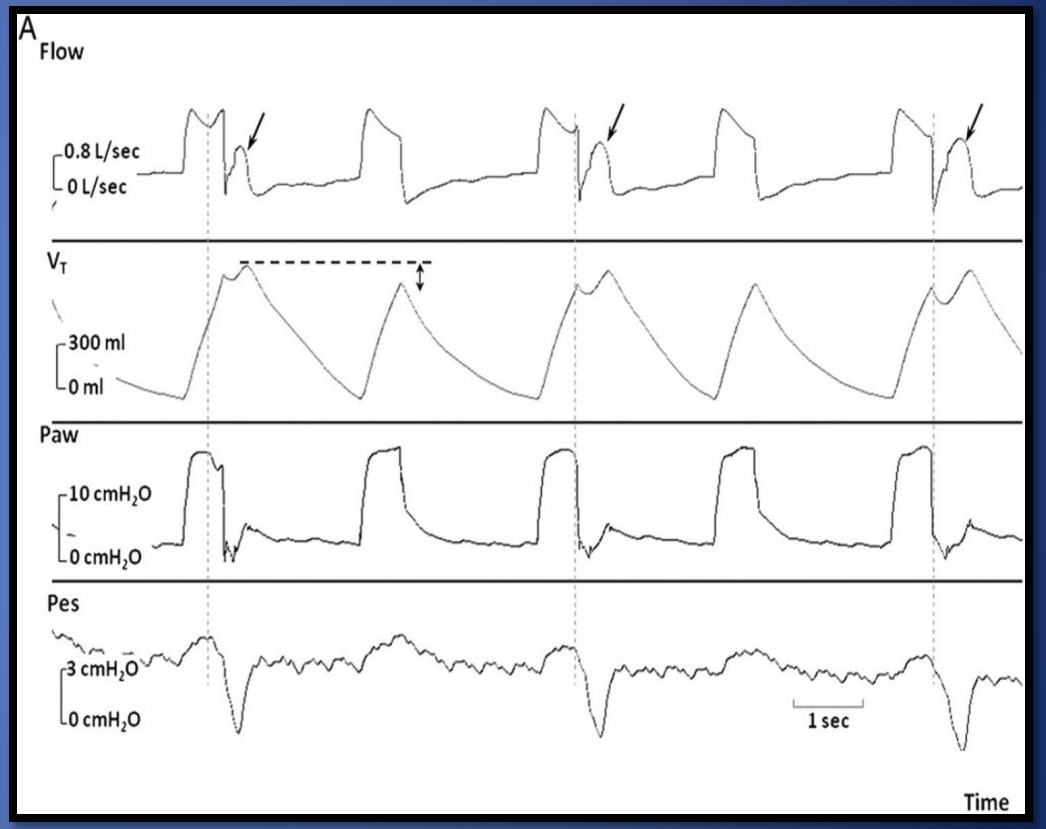
CHEST / 143 / 4 / APRIL 2013

Reverse triggering is diaphragmatic muscle contraction induced by passive insufflation of the lungs (a mandatory breath), especially in deeply sedated patients

The diaphragmatic muscle contraction occurs towards the end of the inspiratory cycle and may trigger a second breath to be delivered



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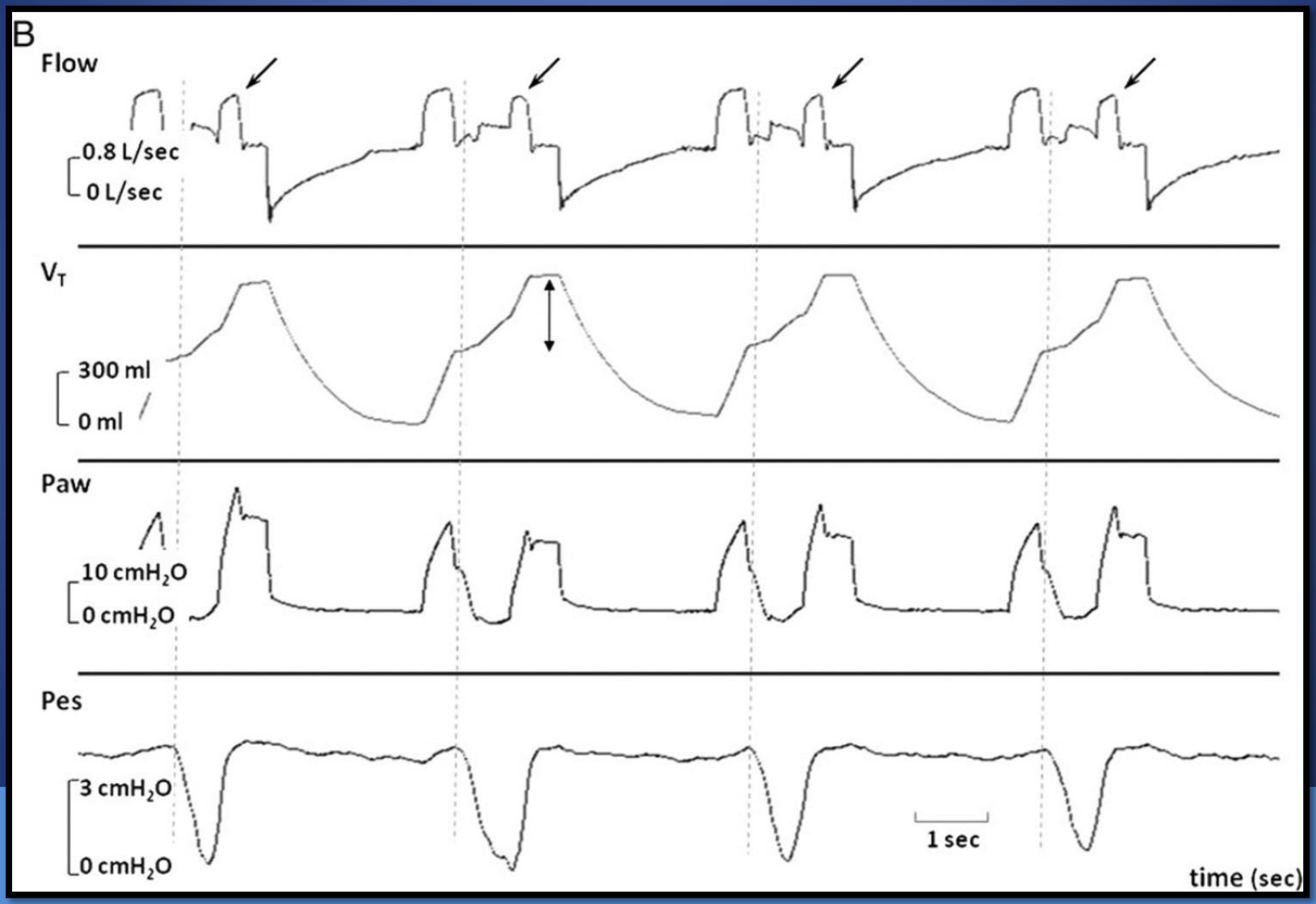

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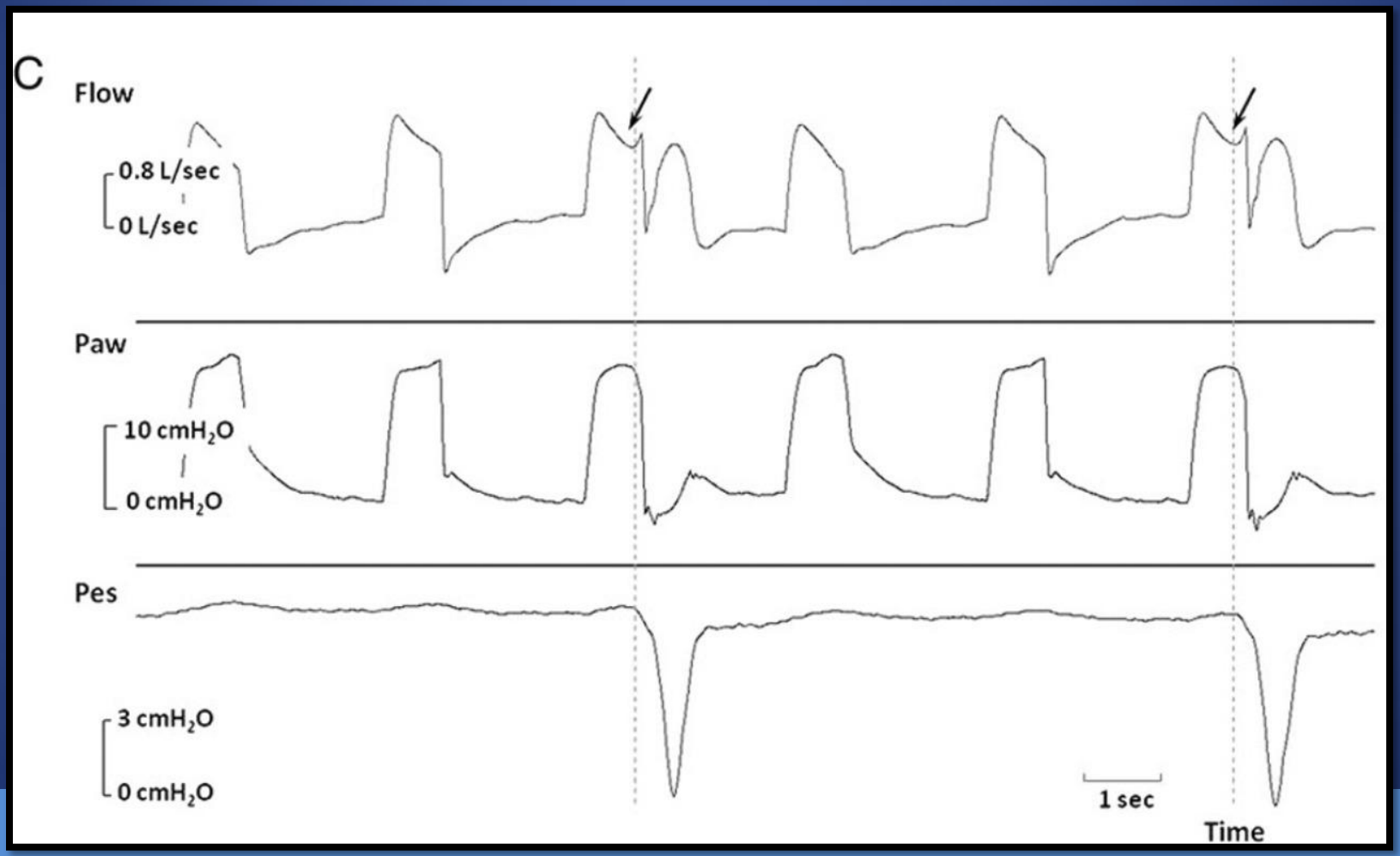

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Ventilator setting adjustments were described in four of the study patients. Increasing the respiratory rate generally resulted in a cessation of neural efforts.