ADULT VENTILATOR DYSSYNCHRONY… CAUSES AND CURES

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DISCLOSURES

- No financial disclosures or conflicts of interest

OBJECTIVES

- Define ventilator dyssynchrony and understand the negative patient effects associated with it
- Recognize different types of ventilator dyssynchrony
- Become familiar with ways to correct dyssynchrony

WORK OF BREATHING

WORK OF BREATHING

- Metabolic cost of breathing
- Amount of energy/O2 consumption used by the respiratory muscles to produce ventilation and respiration to meet the metabolic demands of the body
- Normal WOB ~2-5% of VO2 max
- Acute and/or chronic lung disease can increase this to >50%
  - Reduced energy reserve, increased strain on other systems

WORK OF BREATHING VARIABLES

- Systemic metabolic demands
  - Exercise, fever, catabolic states
- Affected by force required to overcome resistance to airflow to move air in/out of lungs
- Respiratory system inefficiencies

GOALS OF MECHANICAL VENTILATION

- Improve gas exchange and oxygenation
- Reduce work of breathing
- Support respiratory system during times of extremis

WHAT IS VENTILATOR DYSSYNCHRONY?

- Mechanical ventilation is SYNCHRONUS when:
  - The ventilator provides flow and pressure as soon as the patient's respiratory effort begins
  - The magnitude of pressure and flow meets the patient's demand
  - The ventilator support terminates when the patient effort ends
- Mechanical ventilation is DYSSYNCHRONUS when:
  - Mismatch between patient respiratory demands and ventilator delivery
  - Patient demands are NOT being met by the ventilator
  - Interference with respiration, causing increased work of breathing

VENTILATOR DYSSYNCHRONY EFFECTS

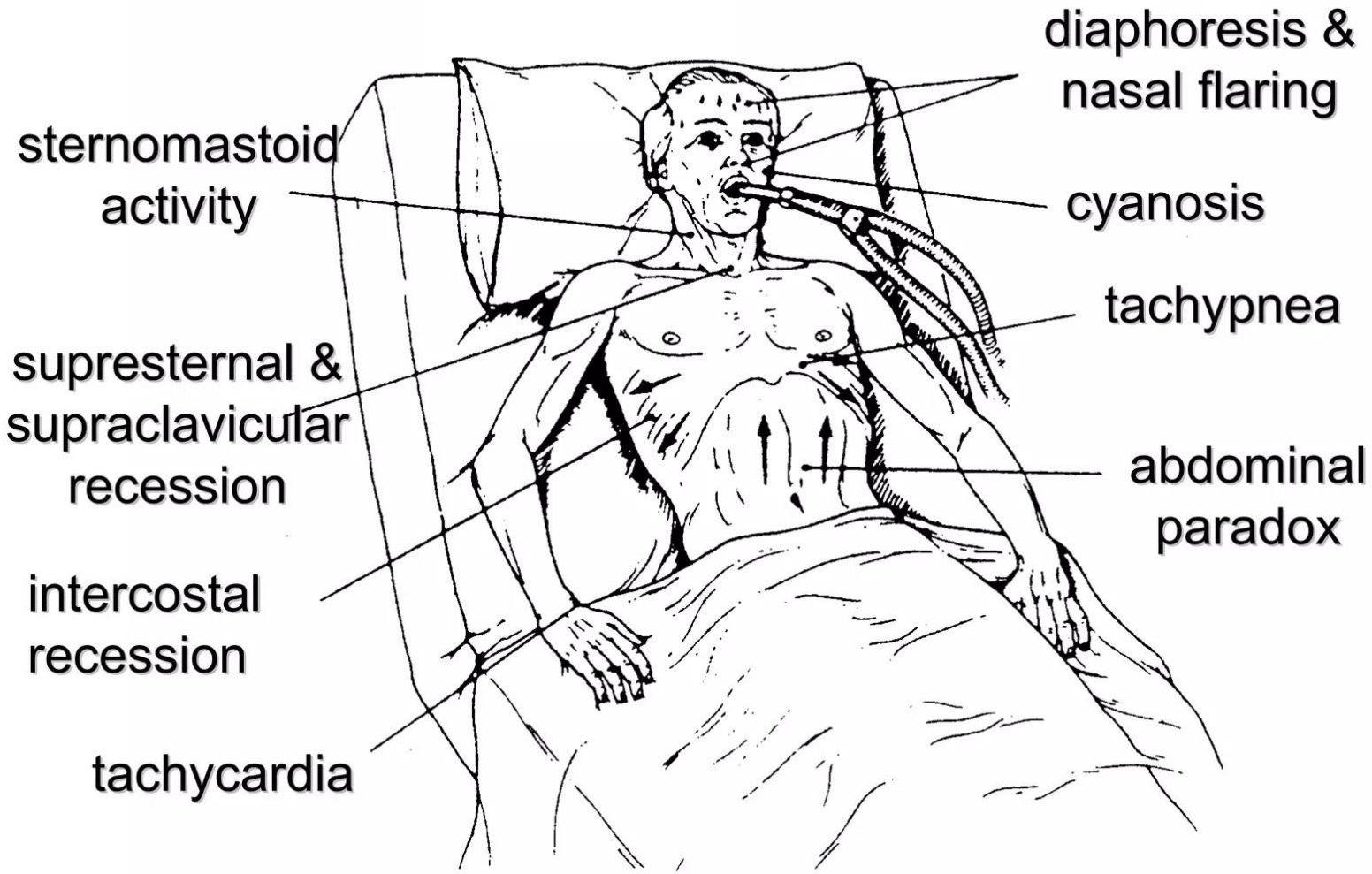
- Increased work of breathing
- Increased oxygen demand
- Tachycardia/adrenergic system activation/cardiac dysfunction
- Patient stress/distress, sleep disruption
- Barotrauma, VILI, Diaphragm dysfunction
- Excess sedation or neuromuscular blockade use
- Increased ICP, decreased CPP
- Increased ventilator and ICU LOS
- Increased mortality

Blanch, L., et al. (2015). "Asynchronies during mechanical ventilation are associated with mortality." Intensive Care Med **41**(4): 633-641.

VENTILATOR DYSSYNCHRONY

- Common in clinical practice
  - Worse in patients with underlying chronic lung diseases
- >1/4 of intubated patients have frequent asynchrony
  - Up to 80% of NIPPV patients
- Increased incidence with longer duration of mechanical ventilation

Dissynchrony between Patient & Ventilator

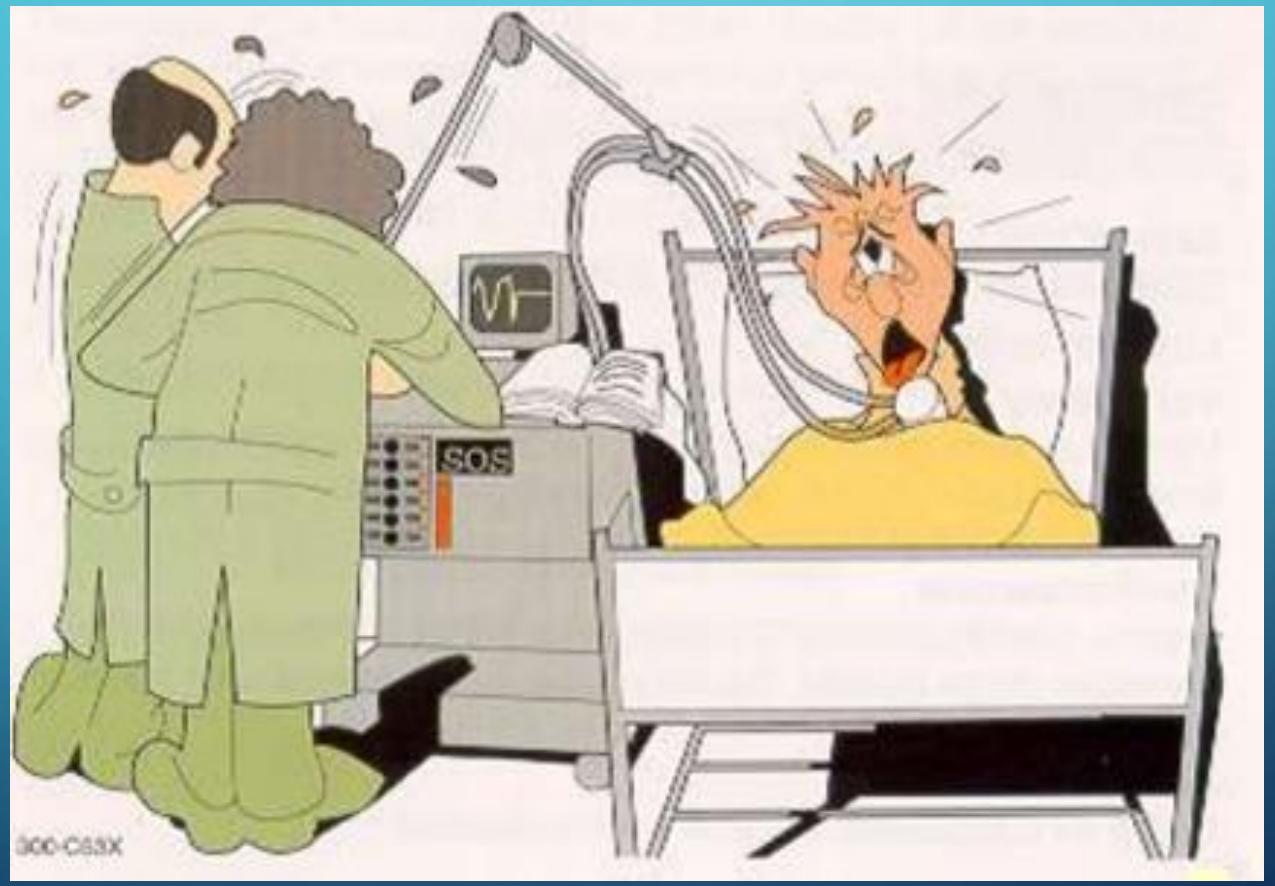


Tobin MJ. Principles and Practice of MV. 1994.

PATIENT-VENTILATOR INTERACTION

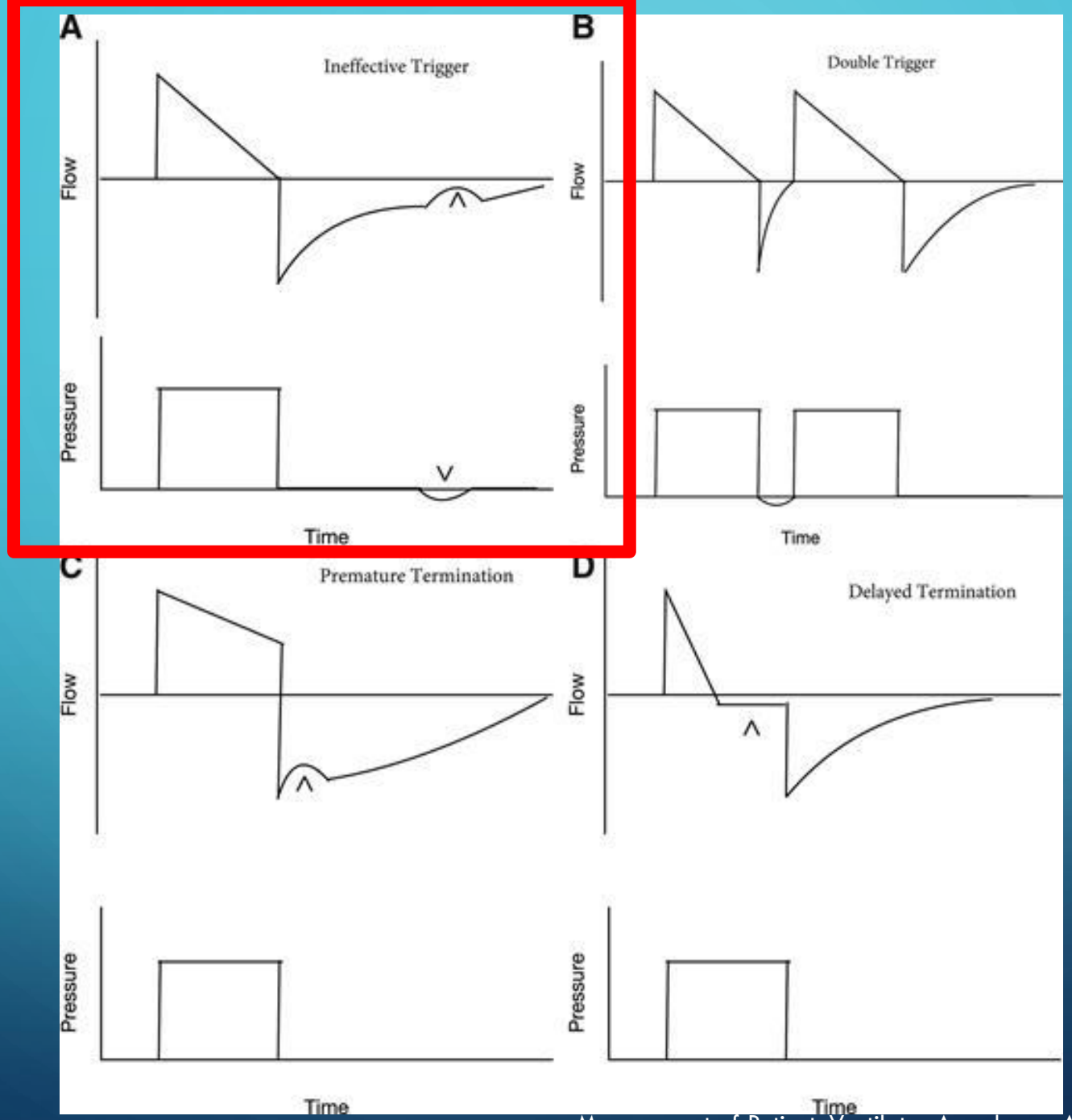
- Patient related factors
  - Respiratory drive
  - Respiratory mechanics
  - Ventilatory requirements
  - Disease states
  - Artificial airway/interface
- Ventilator related factors
  - Trigger variable
  - Cycling off variable
  - Flow/pressure variable
  - Dead space

TYPES OF DYSSYNCHRONY



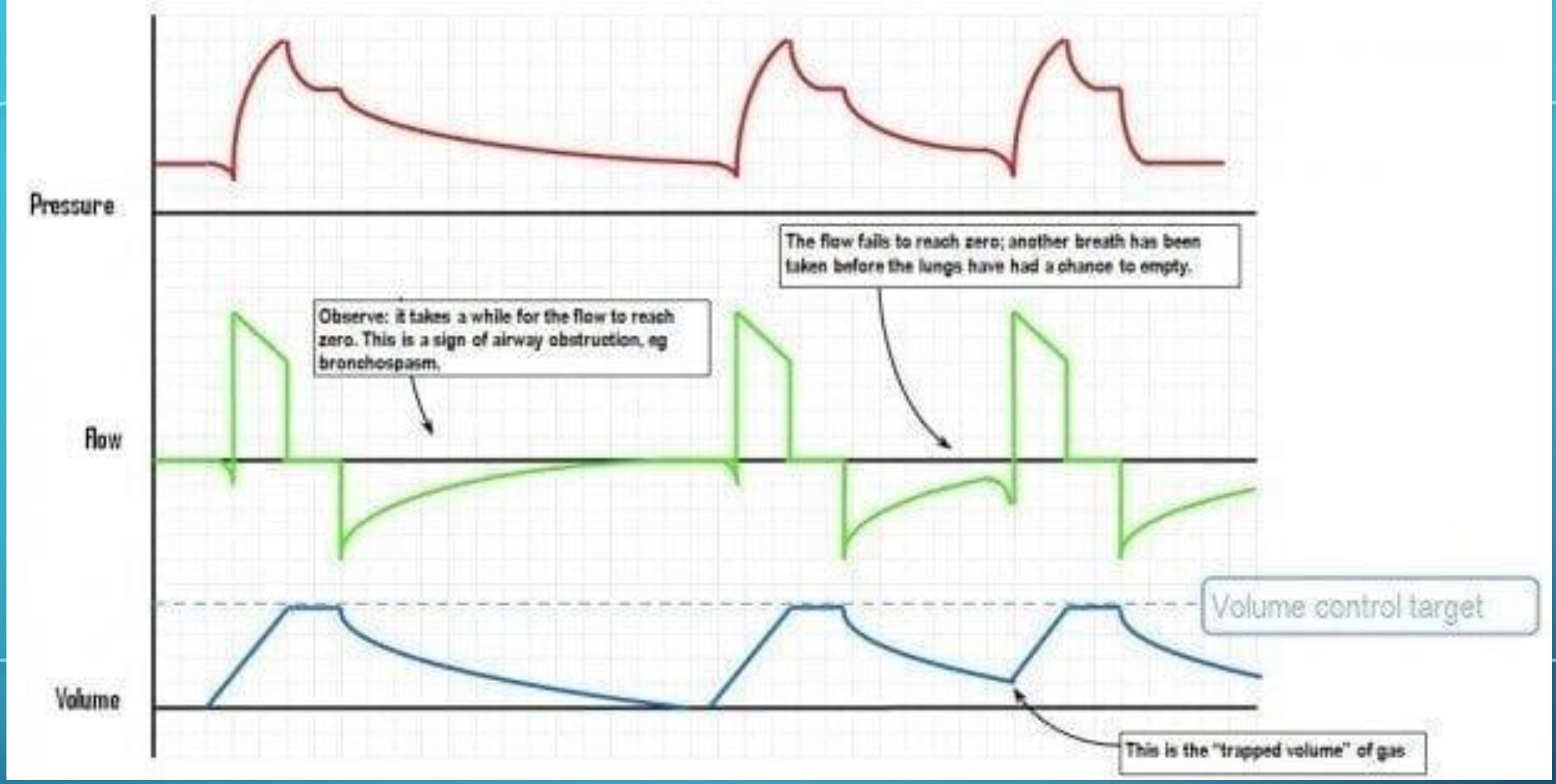
TRIGGER RELATED DYSSYNCHRONY

- Ineffective trigger
  - Patient inspiratory effort not followed by a ventilator breath
  - Causes
    - Weakness
    - Auto-PEEP
    - Inadequate threshold setting
    - Ventilator dysfunction



Management of Patient–Ventilator Asynchrony. Anesthesiology. 2021;134(4):629-636. doi:10.1097


A
P PEAK
28
P MEAN
9.3
PEEP
4.2
I:E
1:1.6
f TOT
13
V TE
324
V̇ E TOT
5.29
Circuit Type: Adult
Humidification Type: HME
09:00
20 Jul 2011
PLOT SETUP
FREEZE
P CIRC
cmH2O
40
20
0
-20
0
2
4
6
8
10
12s
INSP
V̇
L/min
EXP
40
30
20
10
0
10
20
30
40
MANUAL EVENT



AUTO PEEP

Hyperinflation resulting from inadequate expiratory time

Air trapping causes higher end exhalation positive pressure

Most common in COPD, asthma, inverted ratio ventilation

Measured with end expiratory hold

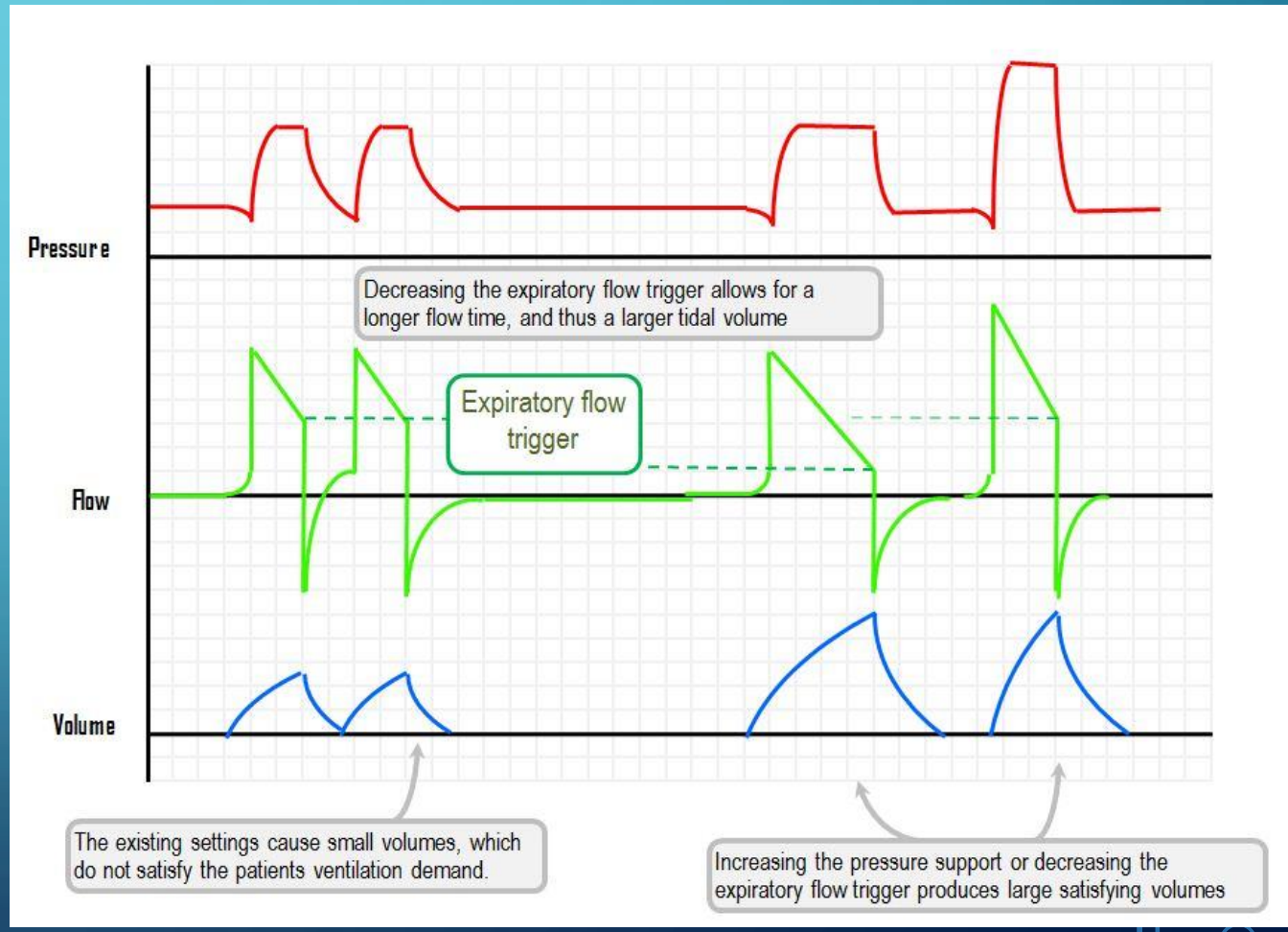

PPEAK 19 cmH2O
PMEAN 12 cmH2O
fTOT 24 1/min
VTE 481 mL
PEEP 5.4 cmH2O
I:E 1:1.0
PEF 44 L/min
V̇E TOT 11.5 L/min
Menu
PCIRC
cmH2O
INSP
V̇CIRC
L/min
EXP
6s
O2 sensor disabled
Adult
A/C
VC
50 kg
10.0 mL/kg
Manual Insp
VT 500 mL
VIKING_8.2.0.54
f 24 1/min
VT 500 mL
V̇MAX 44 L/min
TPL 0.0 s
Ramp
V̇SENS 3.0 L/min
O2 40 %
PEEP 5.0 cmH2O
Manual Event
O2 100%
09:06:54

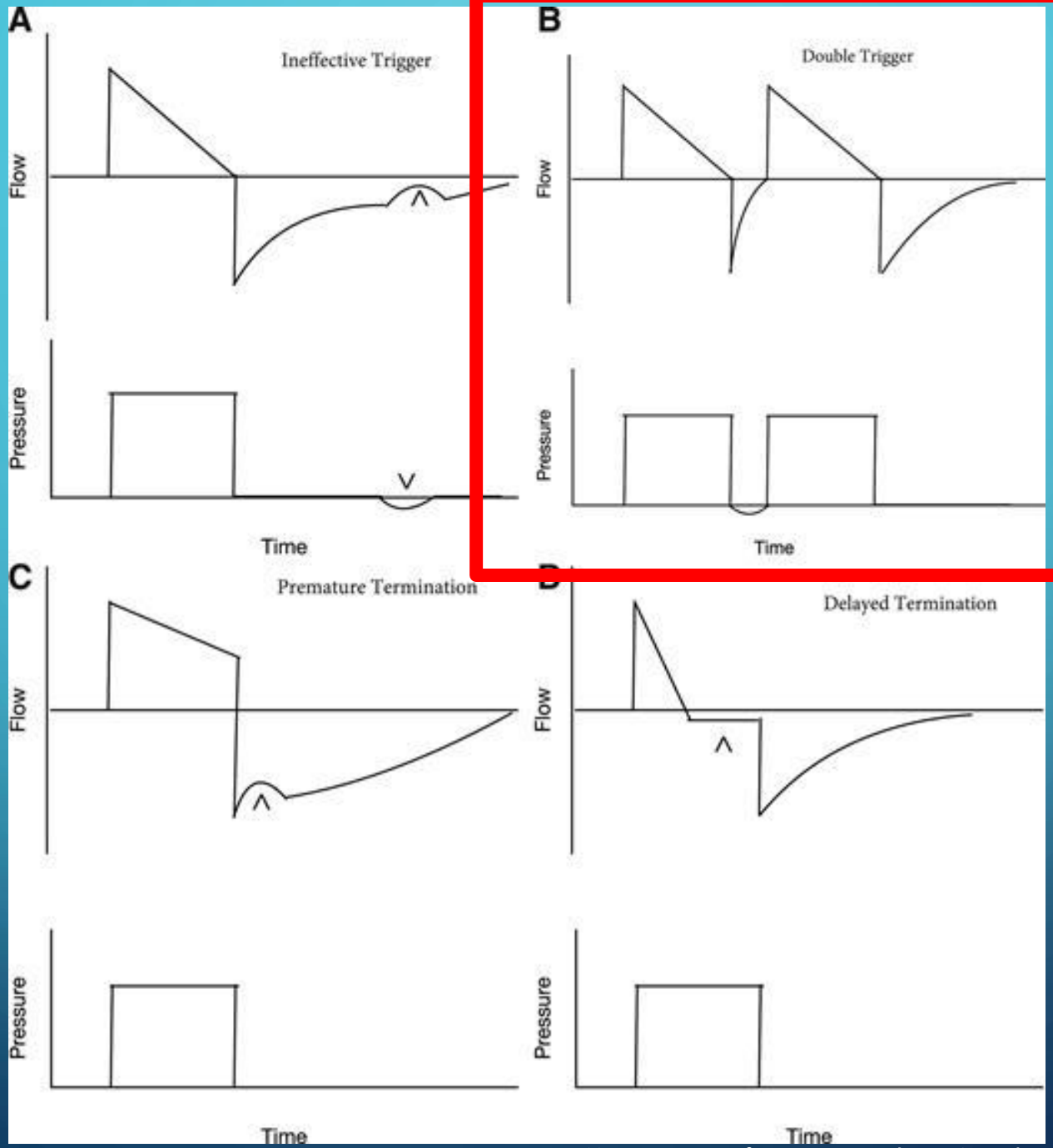
MANAGEMENT INEFFECTIVE TRIGGER

- Minimize sedation/NMB
- Adjust sensitivity or type of trigger
- Correct HYPERventilation
- Ensure adequate expiratory time
  - Bronchodilators
  - I:E ratio
  - Decrease respiratory rate
- Correct Auto-PEEP
  - Raise external PEEP to match measured PEEP

TRIGGER RELATED DYSSYNCHRONY

- Double trigger
  - Inspiratory time of delivered breath is shorter than neural breath effort
  - Results in one patient effort delivering 2 breaths
  - Common in poor compliance, low Vt, short I time





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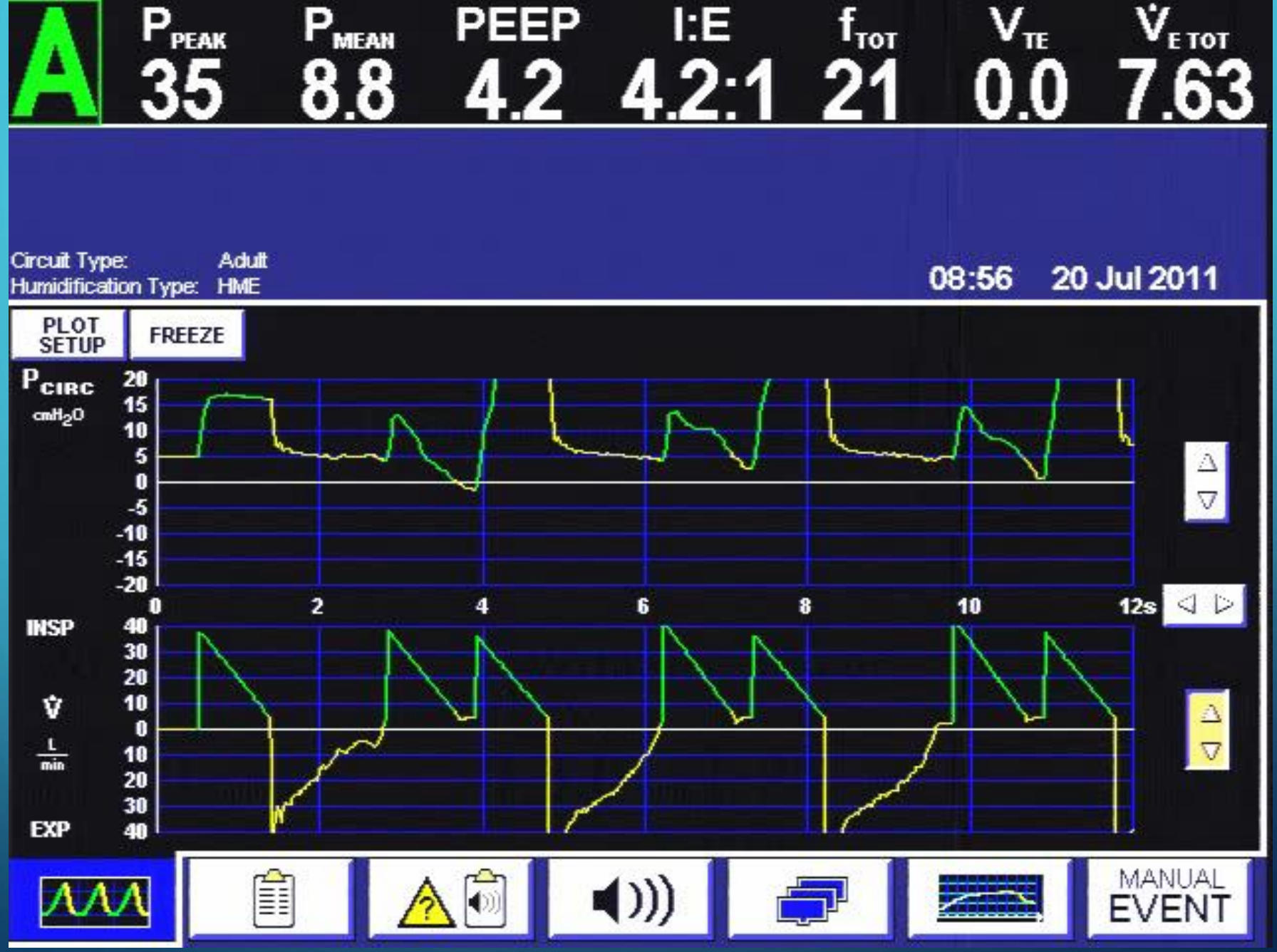
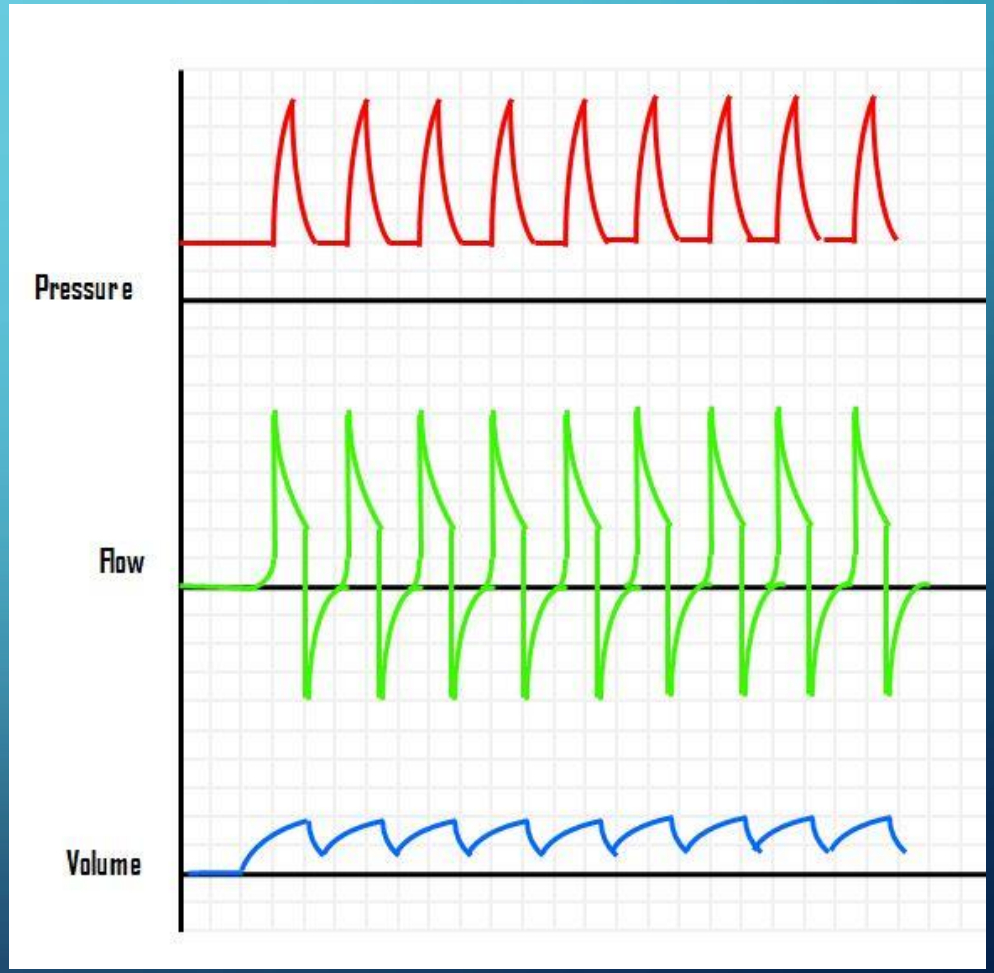

A
P PEAK
35
P MEAN
8.8
PEEP
4.2
I:E
4.2:1
f TOT
21
V TE
0.0
V̇ E TOT
7.63
Circuit Type: Adult
Humidification Type: HME
08:56 20 Jul 2011
PLOT SETUP
FREEZE
P CIRC
cmH2O
20
15
10
5
0
-5
-10
-15
-20
0
2
4
6
8
10
12s
INSP
V̇
L/min
EXP
40
30
20
10
0
10
20
30
40
MANUAL EVENT

MANAGEMENT OF DOUBLE TRIGGER

- Increase inspiratory time
- Adjust sedation or drive
- Increase tidal volume (appropriate patient populations)
- Change to PCV (mode that allows variable Vt)

TRIGGER RELATED DYSSYNCHRONY

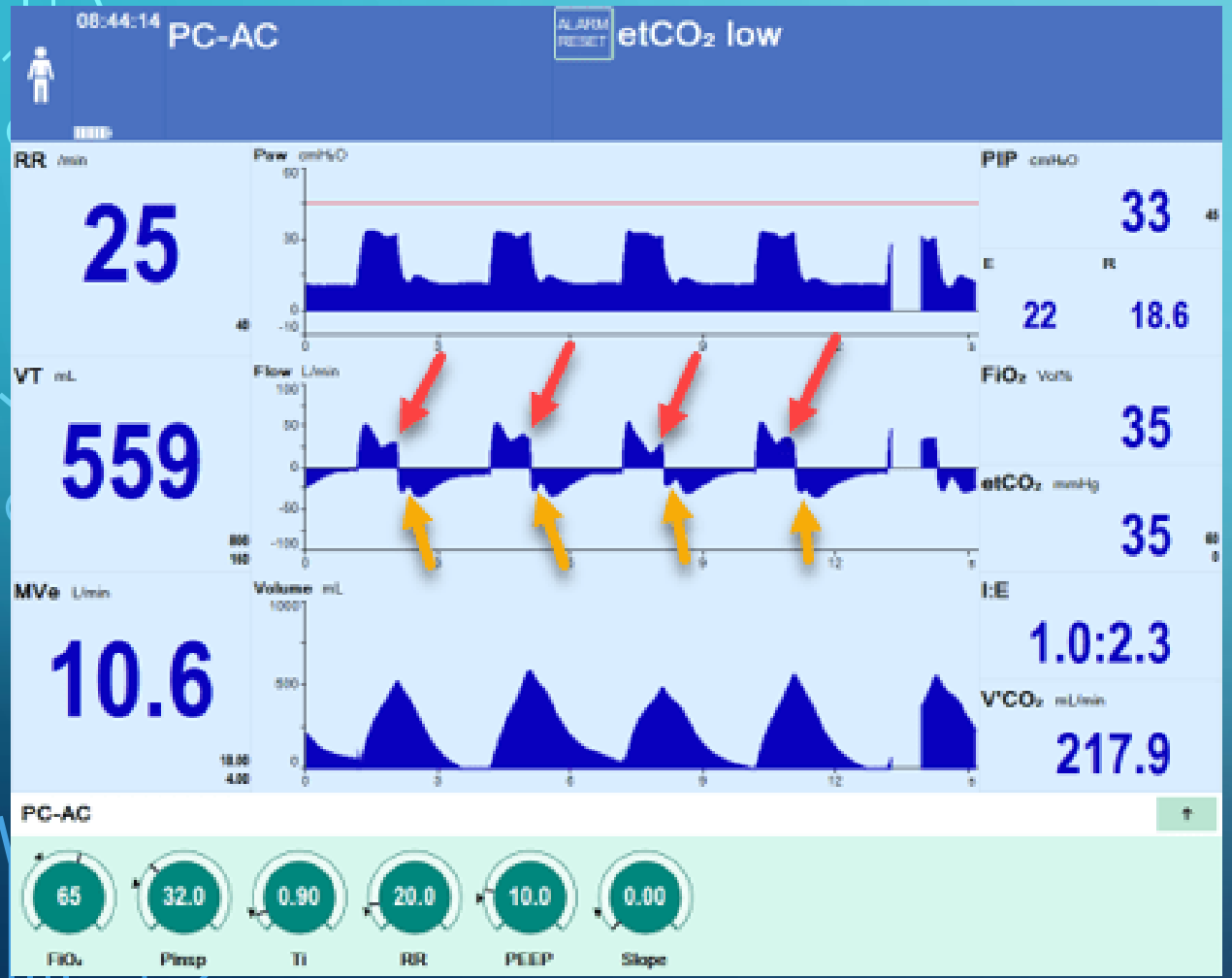
- Auto triggering
  - Ventilator senses air movement that is not respiratory effort
  - “Excessive Sensitivity”
  - Cardiac oscillation, circuit leak, condensation, cough, hiccup, shivering, swallowing, bowel peristalsis, cardiac pacing, IABP



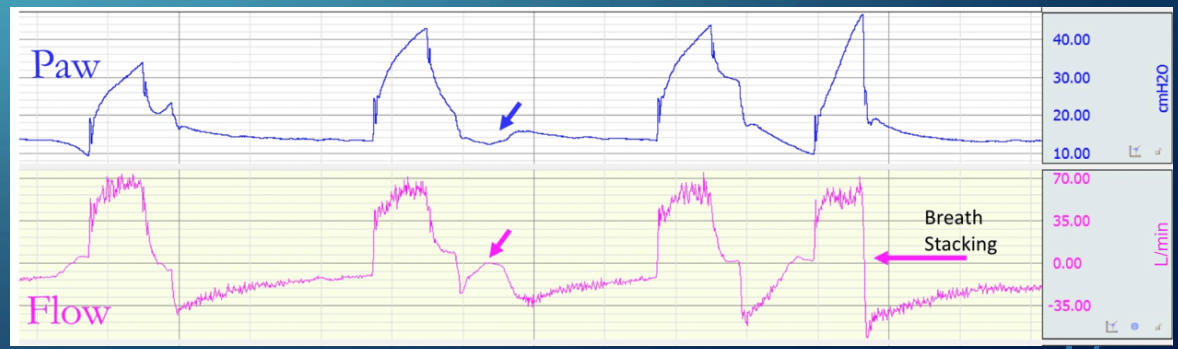
MANAGEMENT OF AUTO TRIGGER

- Check the ventilator
  - Fix leaks
  - Correct condensation or tube motion
  - Adjust ETT position or external device position
- Adjust sensitivity settings

TRIGGER RELATED DYSSYNCHRONY



- Reverse/Inappropriate Triggering
  - Inspiratory effort comes after a ventilator delivered breath
    - Triggered by insufflation, continues during expiration



REVERSE TRIGGERING

- Seen frequently in patients despite level of sedation or mode of ventilation
- Results in entrainment to the vent
  - Patient follows ventilator pattern rather than driving respiratory pattern
  - Has been seen with high sedation, awake patients, and brain death
- Can lead to overdistention


P PEAK 14 cmH2O
P MEAN 7.4 cmH2O
f TOT 11 1/min
V TE 356 mL
PEEP 5.0 cmH2O
I:E 1:5.5
PEF 33 L/min
V̇ E TOT 3.98 L/min
Menu
P CIRC
cmH2O
INSP
V̇ CIRC
L/min
EXP
12s
O2 sensor disabled
Adult
A/C
VC
50 kg
7.50 mL/kg
Manual Insp
VT 375 mL
VIKING 8.2.0.54
f 10 1/min
VT 375 mL
V̇MAX 44 L/min
V̇SENS 3.0 L/min
O2 40 %
TPL 0.0 s
Ramp
PEEP 5.0 cmH2O
Manual Event
O2 100%
09:09:39

MANAGEMENT OF REVERSE TRIGGERING

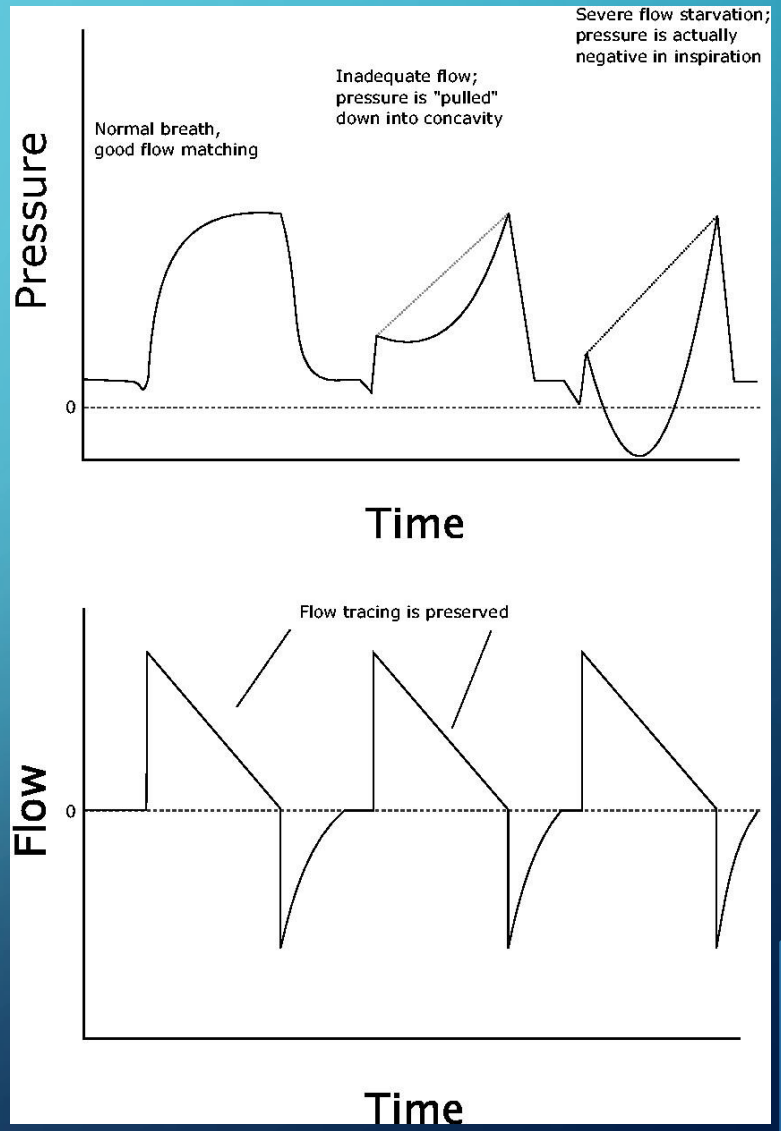
- Depends on timing of the cycle and mode
  - PCV and VCV both at risk
  - Determine intrinsic respiratory rate
    - Set RR below IRR
  - Increase I time
  - Increase Vt
  - Transition to spontaneous mode
  - Adjust inspiratory stimuli
    - Allow increase in PaCO2

FLOW RELATED DYSSYNCHRONY

- Flow asynchrony
  - Less common in modern ventilators due to “autoflow” settings
  - VCV = fixed flow, PCV/PRVC = variable flow, PSV = patient determined flow
  - Most common in VCV
- Results in work shifting (increases work of breathing)
- Increased risks barotrauma, excess sedation,

FLOW RELATED DYSSYNCHRONY

- Flow starvation (“Air Hunger”)
  - Flow is inadequate for patient demand
    - Strong patients, vigorous drive
  - Concave pressure-time curve
- Excess flow (“Overshoot”)
  - Excess flow to patient demands
  - Rare




A
P PEAK 14 cmH2O
P MEAN 6.3 cmH2O
f TOT 13 1/min
V TE 501 mL
PEEP 4.8 cmH2O
V TE/PBW 7.7 mL/kg
PEF 34 L/min
V̇ E TOT 7.74 L/min
Menu
P CIRC
cmH2O
INSP
V̇ CIRC
L/min
EXP
12s
O2 sensor disabled
Adult
A/C
VC
65 kg
7.69 mL/kg
Manual Insp
VT 500 mL
VIKING_8.2.0.54
f 10 1/min
VT 500 mL
V̇MAX 50 L/min
TPL 0.0 s
Ramp
V̇SENS 3.0 L/min
O2 35 %
PEEP 5.0 cmH2O
Manual Event
O2 100%
11:24:09

MANAGEMENT OF FLOW DYSSYNCHRONY

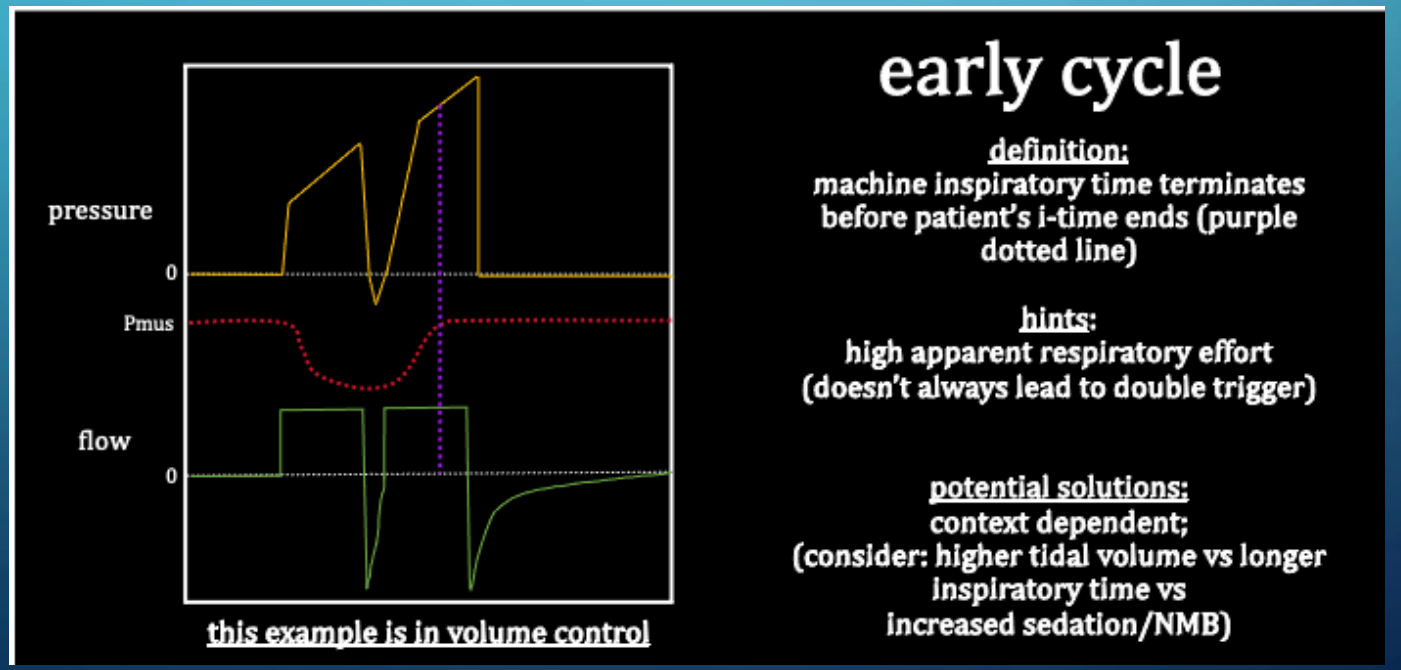
- Change modes from VCV to pressure or spontaneous mode
- Increase inspiratory flow
- Increase pressure or shorten rise time
- Reduce ventilatory demand
  - Sedation, control pain, reduce temperature, correct acidosis
  - (Do the opposite for overshoot)

CYCLE RELATED DYSSYNCHRONY

- Machine breath ends before or after patient neural breath
- Early cycling
  - Machine breath stops before patient's effort stops
- Late cycling
  - Machine breath terminates after patient effort stops

EARLY CYCLE OFF DYSSYNCHRONY

- Results in air hunger, respiratory muscle injury, breath stacking/inappropriate trigger
  - Breath stacking/Double trigger



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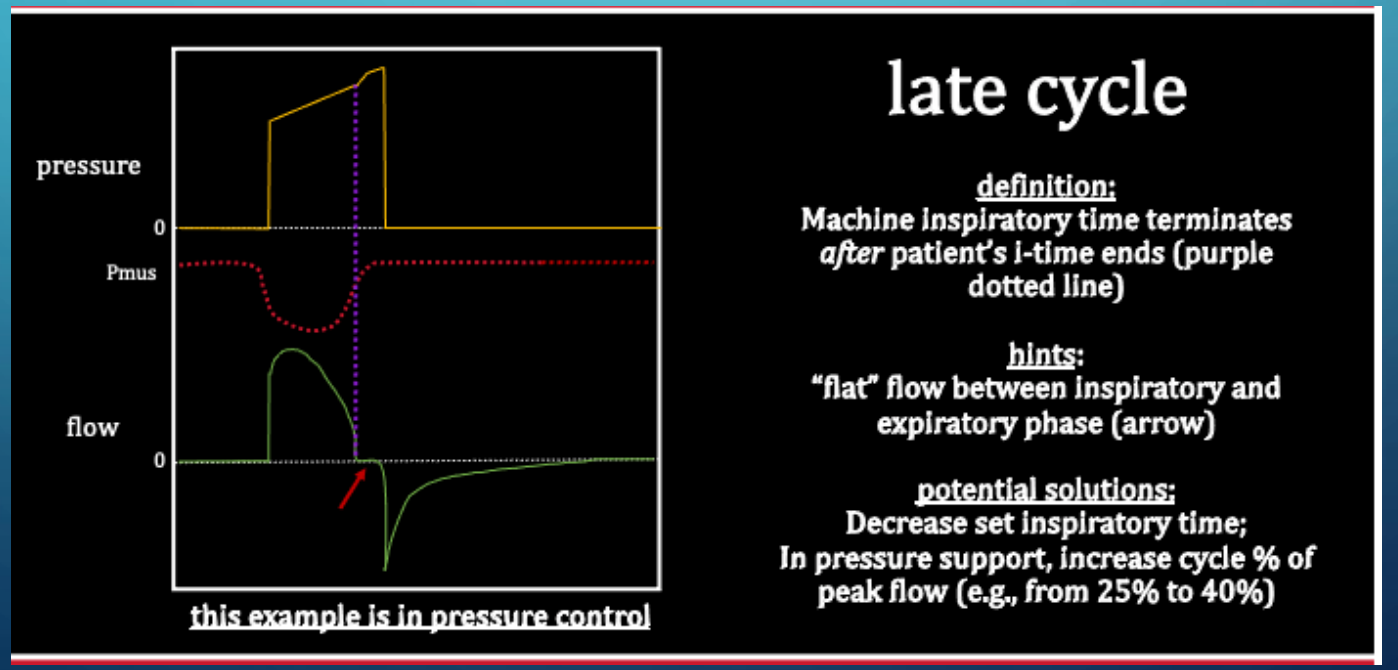
A
P PEAK 11 cmH2O
P MEAN 7.4 cmH2O
f TOT 20 1/min
V TE 0.0 mL
PEEP 5.3 cmH2O
V TE/PBW 0.0 mL/kg
PEF 4.8 L/min
V̇ E TOT 9.24 L/min
Menu
P CIRC
cmH2O
INSP
V̇ CIRC
L/min
EXP
O2 sensor disabled
Adult
A/C
PC
65 kg
Manual Insp
PI 5 cmH2O
VIKING_8.2.0.54
f 10 1/min
PI 5 cmH2O
TI 0.70 s
V̇SENS 3.0 L/min
O2 35 %
ΔP 70 %
PEEP 5.0 cmH2O
Manual Event
O2 100%
11:20:24

LATE CYCLE OFF DYSSYNCHRONY

- Results in active use of muscles for expiration to counter ongoing breath
  - Barotrauma, overdistention, altered I:E, dynamic hyperinflation, auto-PEEP



M Siuba. Critical Care Now. 2021

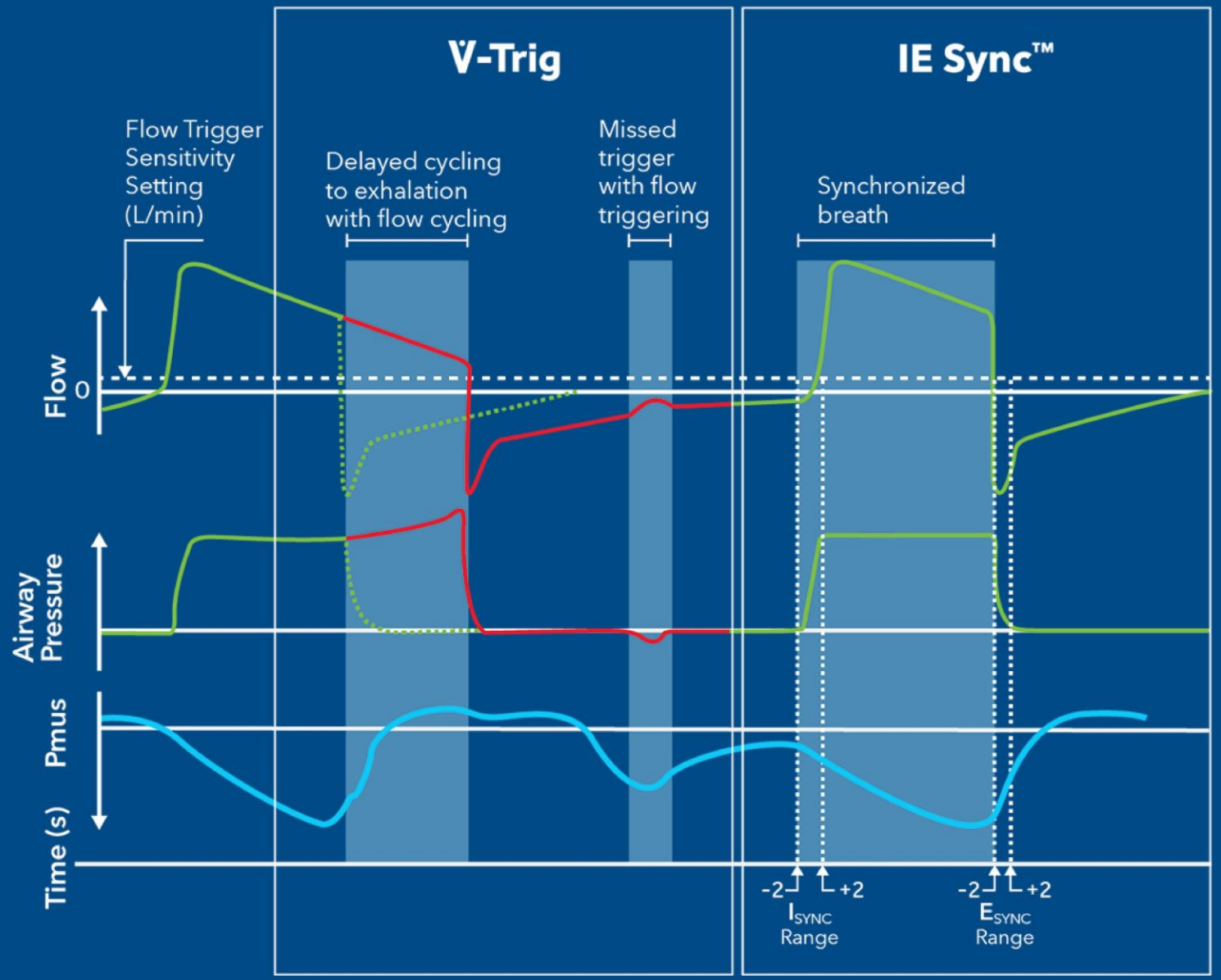

S
P PEAK
18
cmH2O
P MEAN
10
cmH2O
f TOT
15
1/min
V TE
855
mL
PEEP
4.4
cmH2O
I:E
1:3.6
PEF
29
L/min
V̇E TOT
9.29
L/min
Menu
P CIRC
cmH2O
INSP
V̇CIRC
L/min
EXP
O2 sensor disabled
Adult
SPONT
PS
50 kg
6.00 mL/kg
Manual Insp
VT 300 mL
VIKING 8.2.0.54
ΔP
70
%
P SUPP
13
cmH2O
V̇SENS
3.0
L/min
O2
40
%
ESENS
25
%
PEEP
5.0
cmH2O
Manual
Event
O2
100%
09:22:54

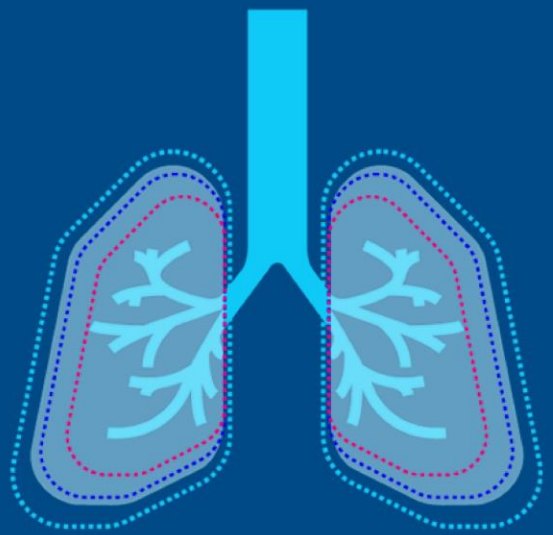
MANAGEMENT OF CYCLE OFF DYSSYNCHRONY

- Adjust I time to match patient cycle
- Correct interference (cough, gag, biting)
- Increase sedation or NMB

- Use advanced “sync” modes
  - Proprietary to vents

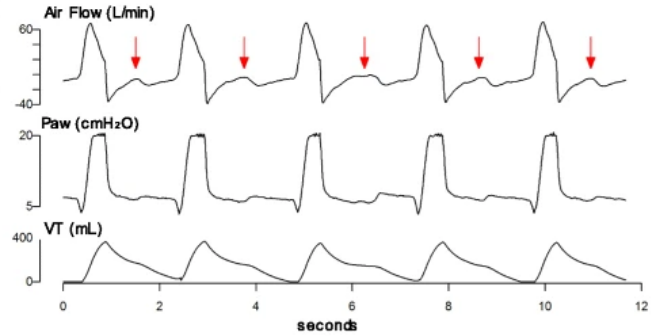
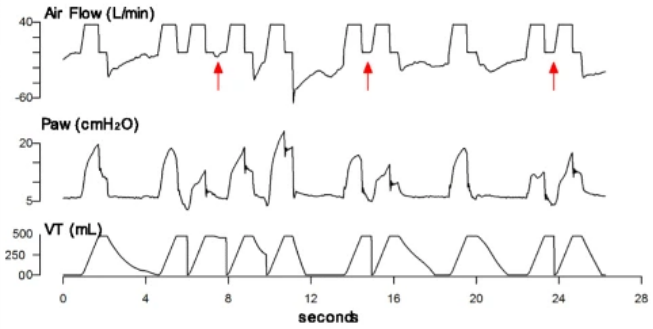
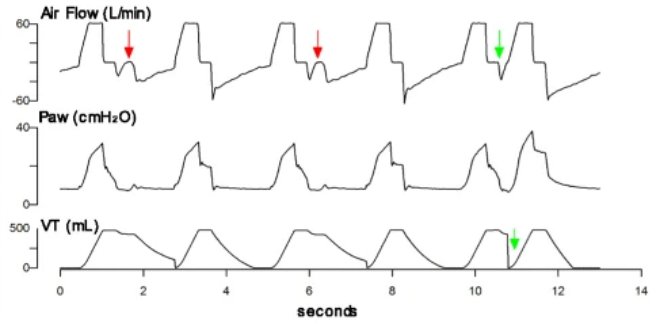
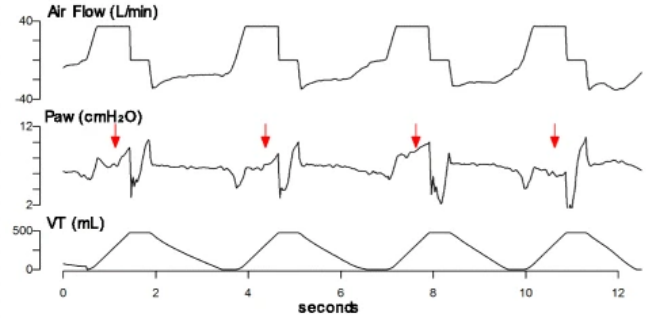

A
P PEAK 17
P MEAN 7.3
PEEP 5.2
I:E 1:2.7
f TOT 13
V TE 396
V̇ E TOT 4.45
Circuit Type: Adult
Humidification Type: HME
09:08 20 Jul 2011
PLOT SETUP
FREEZE
P CIRC
cmH2O
40
20
0
-20
0 2 4 6 8 10 12s
INSP
V̇
L/min
EXP
40 30 20 10 0 10 20 30 40
MANUAL EVENT


V̈-Trig
IE Sync™
Flow Trigger Sensitivity Setting (L/min)
Delayed cycling to exhalation with flow cycling
Missed trigger with flow triggering
Synchronized breath
Flow
0
Airway Pressure
Pmus
Time (s)
-2
+2
ISYNC Range
-2
+2
ESYNC Range



	Alternative Name	Definition	Cause
Asynchrony			
False trigger	Auto-triggering, double-triggering, multiple-triggering	Triggering by a signal other than P_{mus}	Trigger threshold set too low (ie, high sensitivity), or circuit leak, secretions, cardiac oscillations, water in circuit, etc.
Failed trigger	Ineffective effort, missed trigger	Patient trigger signal fails to start P_{vent}	Trigger threshold set too high (ie, low sensitivity) or autoPEEP higher than P_{mus}
Dyssynchrony			
Early trigger	Reverse-triggering	P_{vent} starts before P_{mus} (or surrogate)	Sedation, brain injury, pleural irritation
Late trigger	Delayed triggering	Clinically important delay in start of P_{vent} after P_{mus} (or surrogate)	Trigger threshold set too high (ie, low sensitivity) or slow ventilator response time
Early cycling	Premature cycling	Clinically important advance in P_{vent} return to baseline before P_{mus} return to baseline	Neural inspiratory time longer than waveform inspiratory time; flow cycle threshold set too high or inspiratory time set too short; may be clinically appropriate
Late cycling	Delayed cycle, runaway phenomena	Clinically important delay in P_{vent} return to baseline after P_{mus} return to baseline	Neural inspiratory time shorter than waveform inspiratory time; flow cycle threshold set too low or inspiratory time set too long; may be clinically appropriate
False cycle	None	P_{vent} return to baseline due to a signal other than P_{mus}	Pressure over-shoot activating alarm (eg, pressure rise time set too short)
Work balance			
Work shifting	Flow starvation	Decrease in P_{vent} with constant tidal volume or increase in tidal volume with constant P_{vent} resulting in increased patient work relative to total inspiratory work	High inspiratory effort due to anxiety, pain, acidosis; may be clinically appropriate
Expiratory work	None	Increase in tidal volume above passive expiration	Nonpassive expiration due to anxiety, acidosis, pain, bronchospasm, or cough

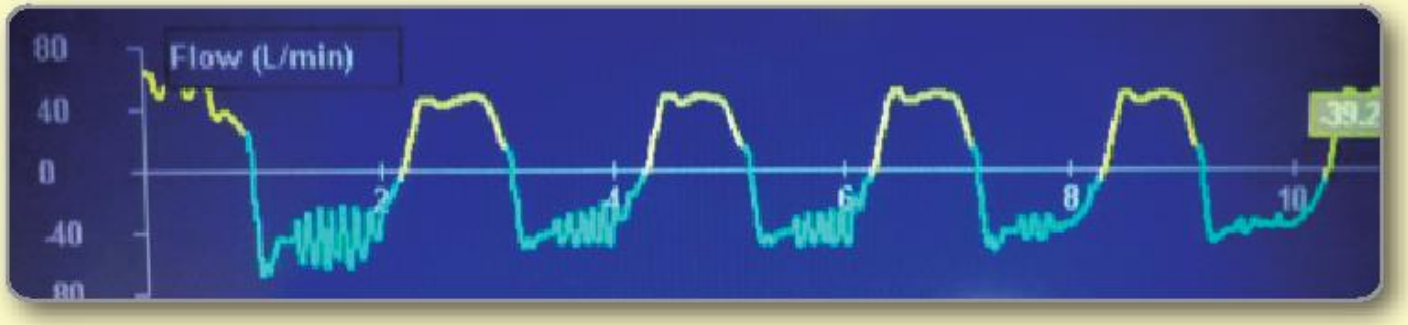
Chatburn et al. Respiratory Care April 2020, 65 (4) 558-572; DOI: https://doi.org/10.4187/respcare.07635

Asynchrony	Graphic representation	Description	Causes
Ineffective Efforts		Inspiratory muscle efforts not followed by a ventilator breath (red arrows)	Inadequate trigger sensitivity Excessive assistance Overdistension/Air trapping Low respiratory drive Low level of pCO2 Oversedation
Double Cycling		Inspiratory effort that continues beyond the ventilator inspiratory time producing a second or a third ventilator breath (red arrows) without expiration. Consequently, the volume of the first breath is added to the second or third breath.	Inadequate setting of ventilator inspiratory time Inadequate trigger sensitivity (too sensible) Inadequate circuit pressurization Patient effort too strong Reverse triggering
Reverse Triggering		Ventilator insufflations that trigger diaphragmatic muscle contractions (red arrows) in response to passive insufflation of the lungs. When the diaphragmatic muscle contraction occurs at the end of inspiration a double cycled breath can occur (green arrow) .	Oversedation Overdistension/Air trapping
Inspiratory Airflow Dyssynchrony		Strong patient inspiratory effort (concavity in pressure tracing) due to insufficient inspiratory airflow in a patient ventilated in assist-volume controlled mode.	Inadequate gas flow Dyspnea Delirium/Pain

TREATING DYSSYNCHRONY

- CHECK THE PATIENT FIRST
  - Consider disconnect and bag/manually ventilate
- Check the machine for equipment failures
- Adjust settings
  - Mode
  - Trigger
  - Flow
  - Cycle times
- Sedation and neuromuscular blockade
  - Delays weaning, increase ICU and vent LOS, increases delirium and all cause mortality

A



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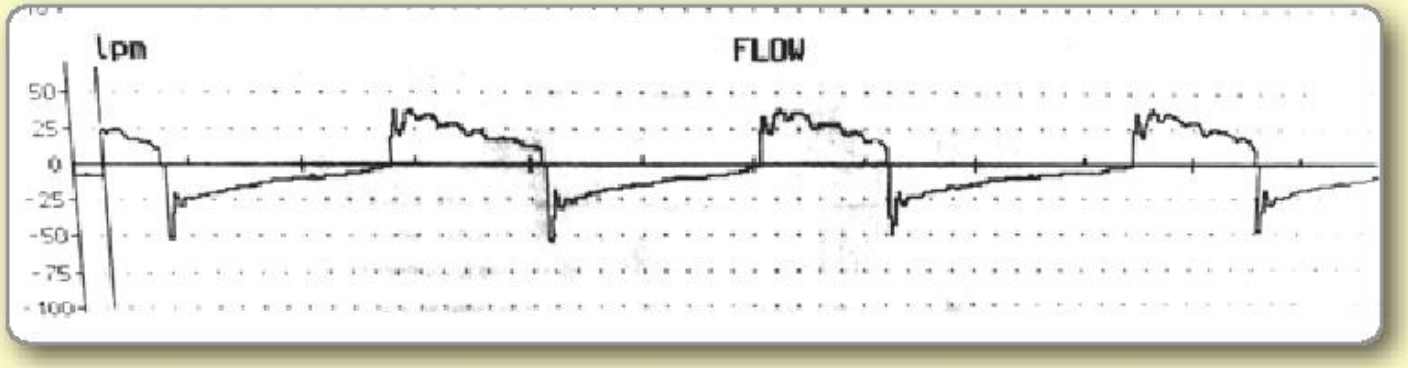

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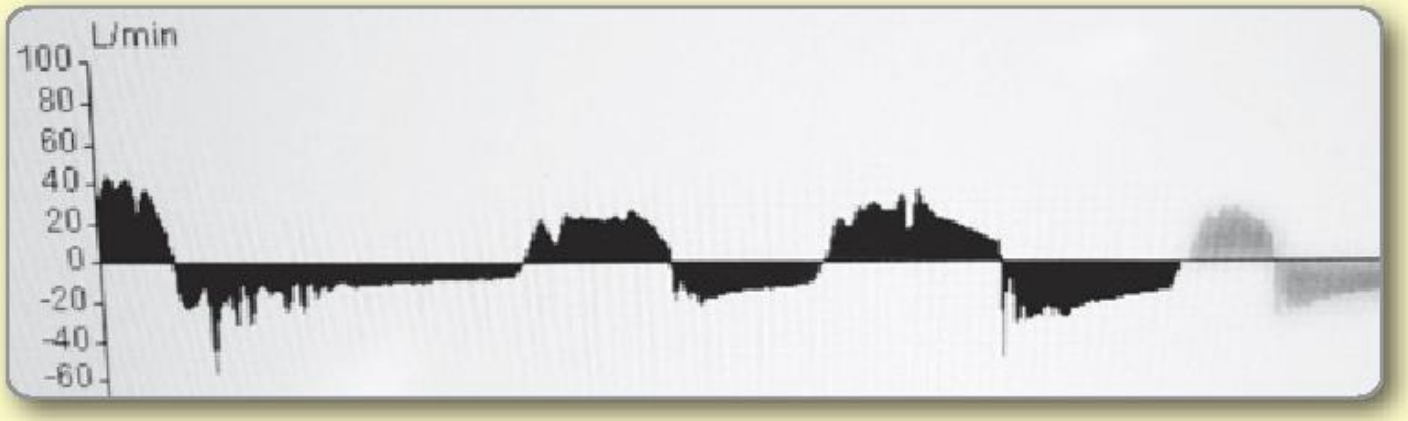
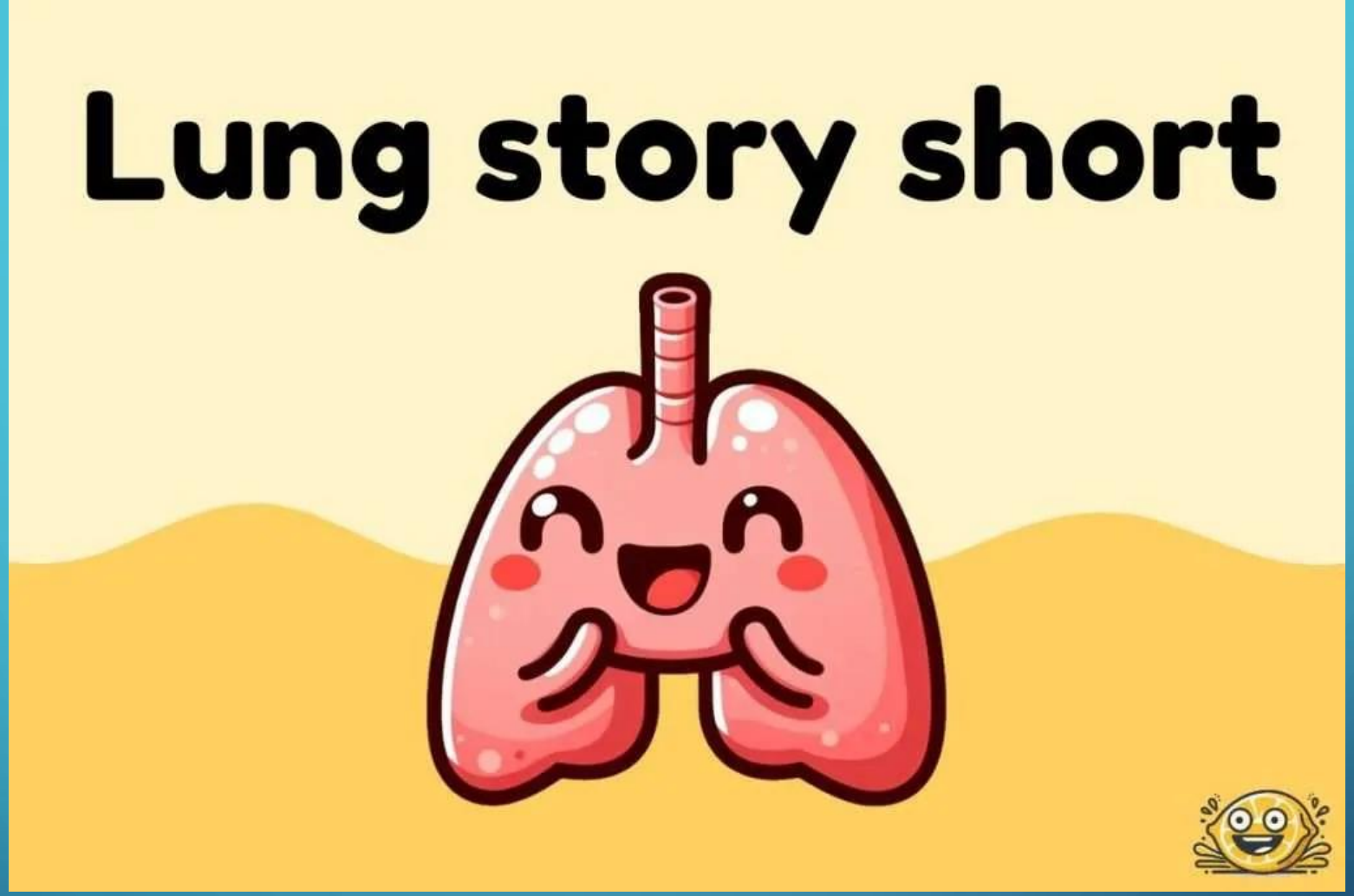


Sole, Mary Lou et al. "Clinical Indicators for Endotracheal Suctioning in Adult Patients Receiving Mechanical Ventilation." American journal of critical care : an official publication, American Association of Critical-Care Nurses 24 4 (2015): 318-24

TAKE HOME POINTS

- Ventilator dyssynchrony is VERY common and frequently missed
- Patient-ventilator dyssynchrony causes both short and long term morbidity and mortality
- Issues can be with Trigger, Flow, or Cycle
- Adjusting settings to match patient breathing patterns is preferred over sedation or neuromuscular blockade for management



Questions?