When Two Become One: Optimizing Patient/Ventilator Synchrony

Beno Thompson MSrt, RRT-NPS – Clinical Applications Specialist

Hamilton Medical Inc.

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Conflicts of Interest

- ✓ Current Clinical Applications Specialist for Hamilton Medical Inc.

We have a problem…

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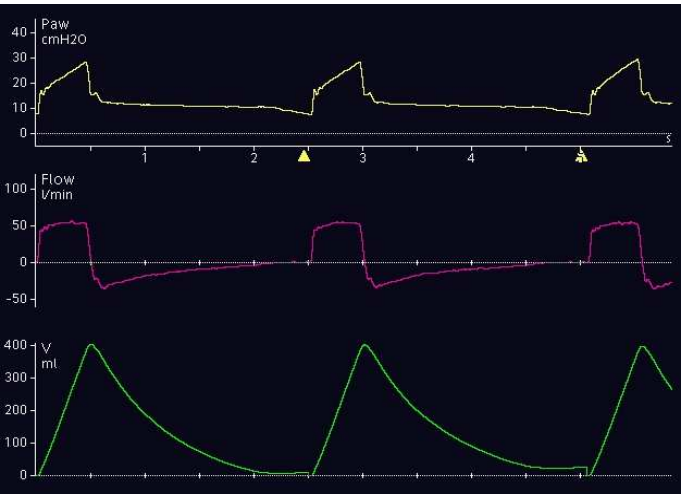
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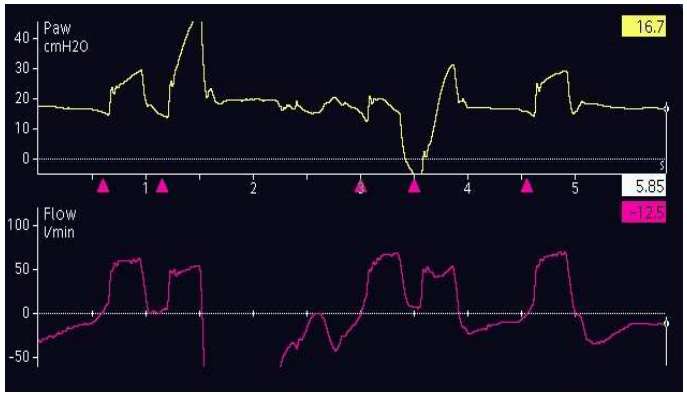
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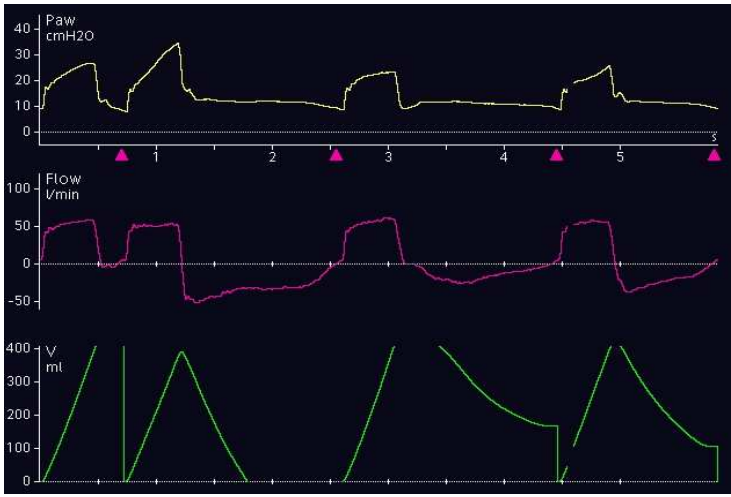
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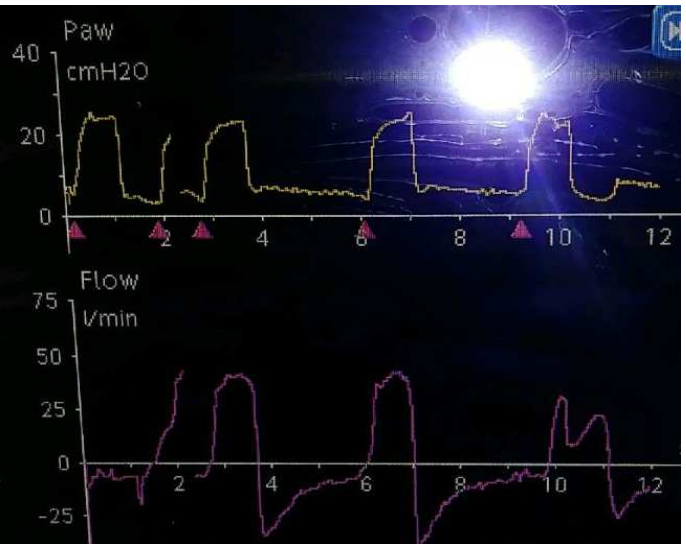
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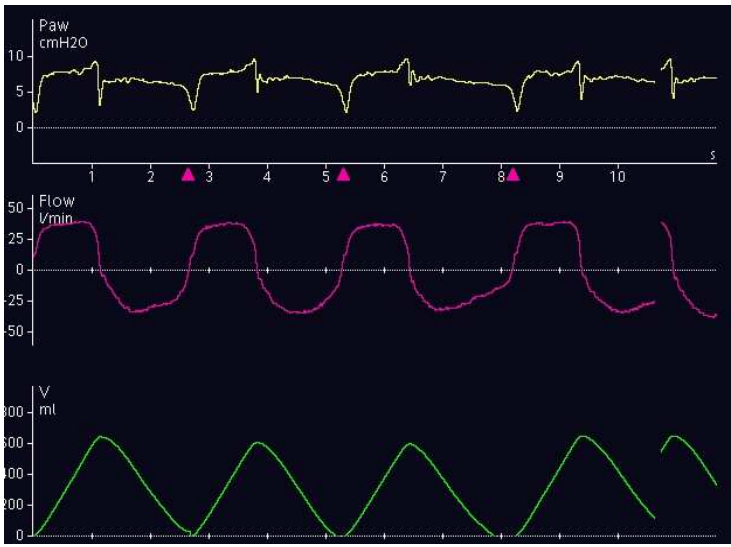
Paw
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Interactive Poll

- ✓ Text
  - ✓ benothompson557 to 22333
  - ✓ Choose your answer and text A, B, C, D, or E to this thread.

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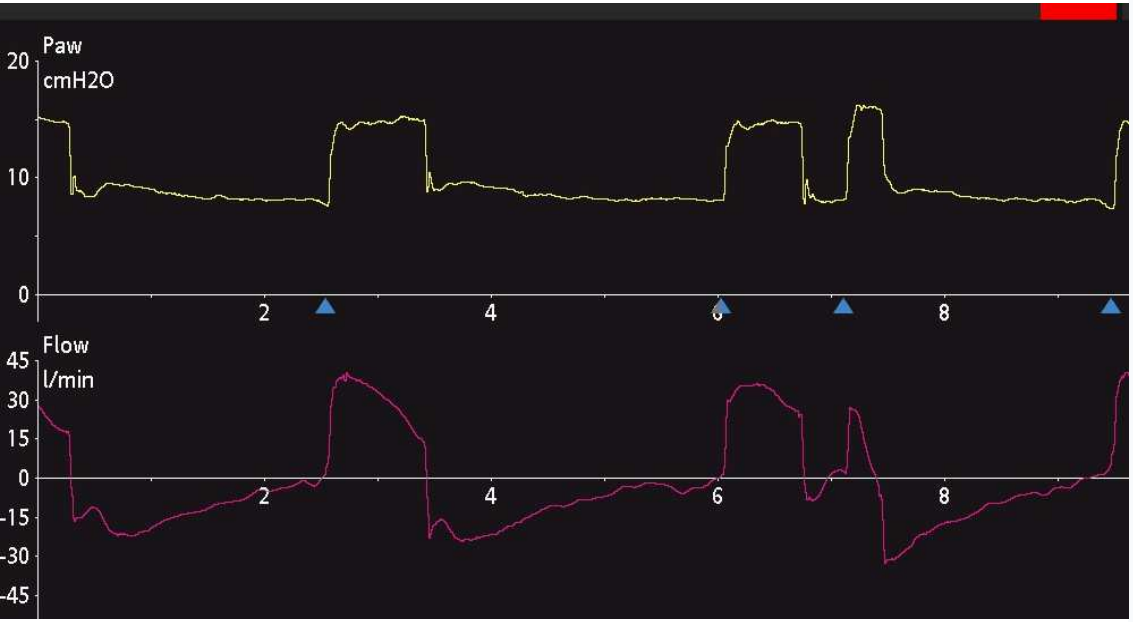
#1



What dyssynchrony is present?

A. Flow Starvation

B. Double Trigger

C. Delayed Cycle

D. Reverse Trigger

E. I have no idea!

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#2

Which dyssynchrony is present?

A. Delayed Cycling

B. Early Cycling

C. Flow Starvation

D. Trick question. There's no dyssynchrony

There's something wrong, but I have no idea!

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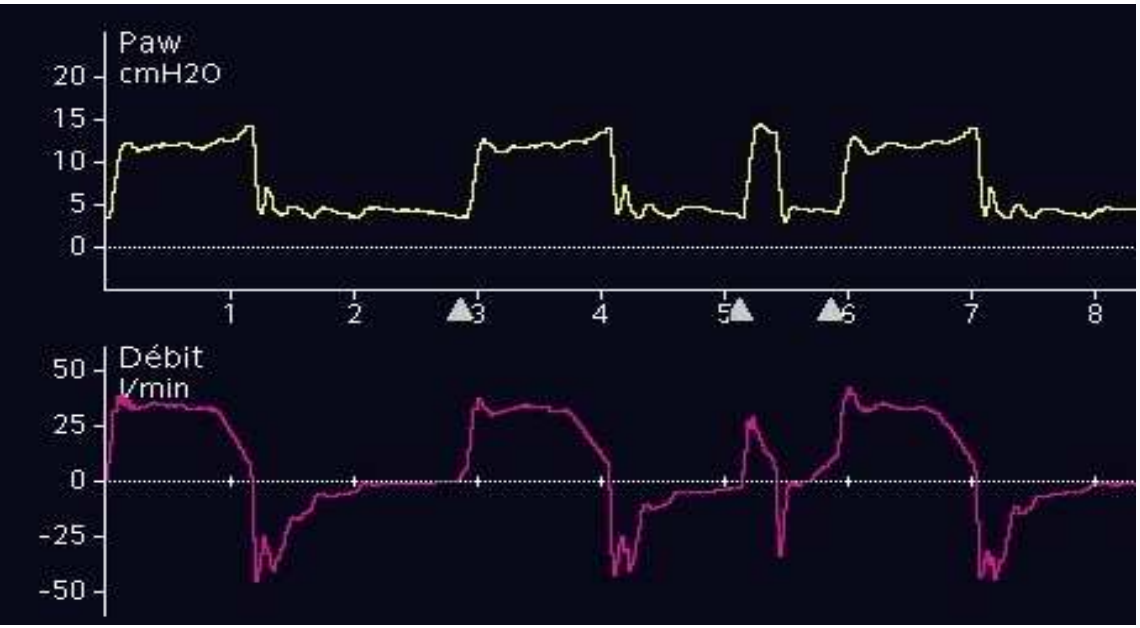
#3



What is going on here?

A. Patient initiated breath

B. Reverse Trigger

C. Autotrigger

D. Ventilator initiated breath

E. I have no idea...again!

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Synchrony & Work Of Breathing

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Synchrony Vs. Asynchrony

- ✓ Synchrony
  - ✓ “Simultaneous Occurrence”
  - ✓ “Harmonious interaction between ventilator and patients respiratory system”

- ✓ Asynchrony
  - ✓ “Absence or lack of concurrence in time”
  - ✓ “A lack of synchronization”

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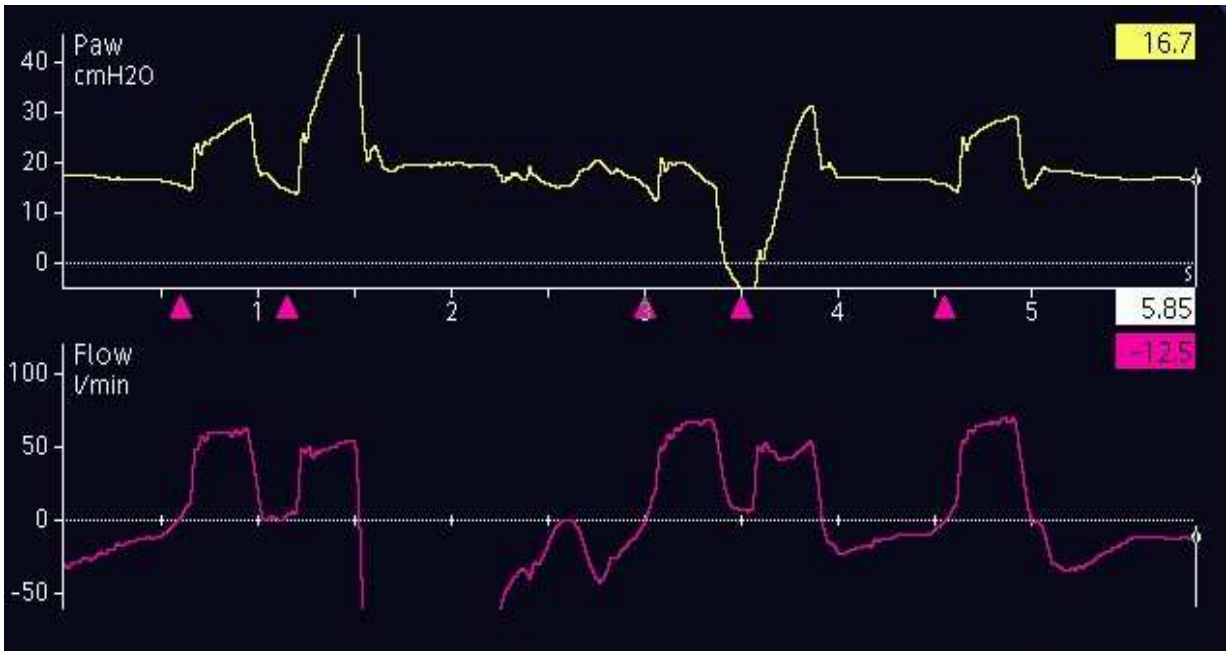
Synchrony

Asynchrony



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Independent Vs. Dependent Variables

- ✓ Independent Variable
  - ✓ What you set/fix
  - ✓ Does not change
- ✓ Dependent Variable
  - ✓ Is not set/fixed
  - ✓ Changes (Response to the control)

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Variables

Mode	Independent Variable	Dependent Variable
S-CMV		
P-CMV		
Spontaneous (PSV)		

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Variables (Examples)

	Less Flexibility	More Flexibility
Mode	**Independent Variable**	**Dependent Variable**
S-CMV	Volume Flow I-time	Pressure
P-CMV	Pressure I-time	Volume
Spontaneous (PSV)	Pressure	Volume Flow I-time

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Systematic Process

1. Utilize the Pressure and Flow/Time Scalars
2. Eliminate Independent Variables
3. Confirm Dependent Variables
4. Assess matching to patient neural I-time & effort

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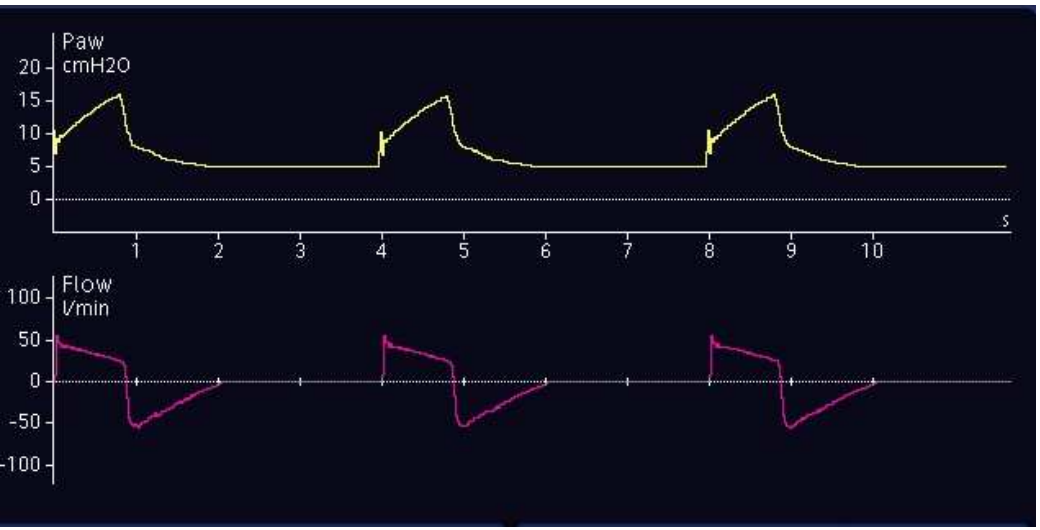
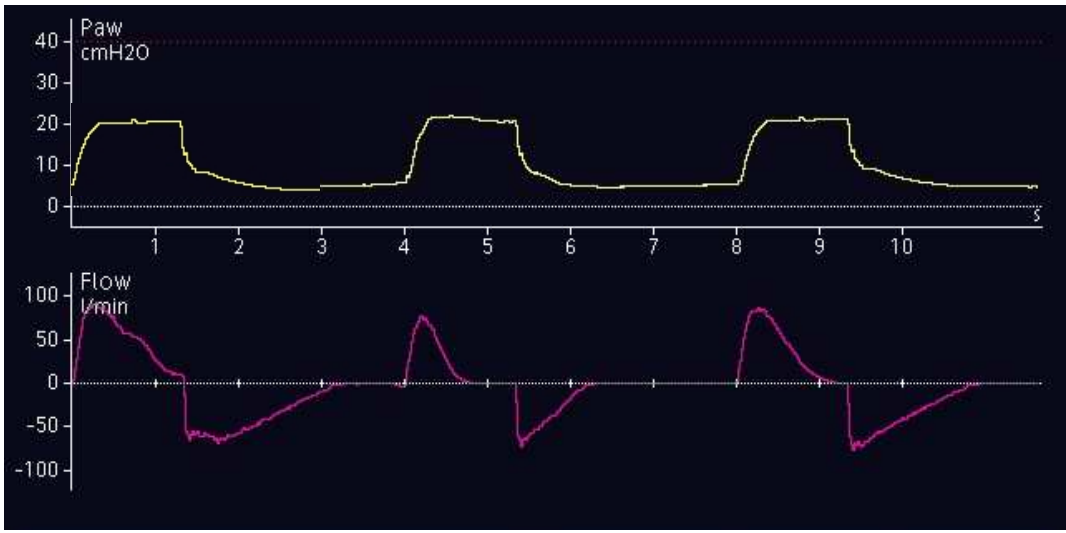
Use Pressure & Flow/Time waveforms

Volume Control



Pressure Control



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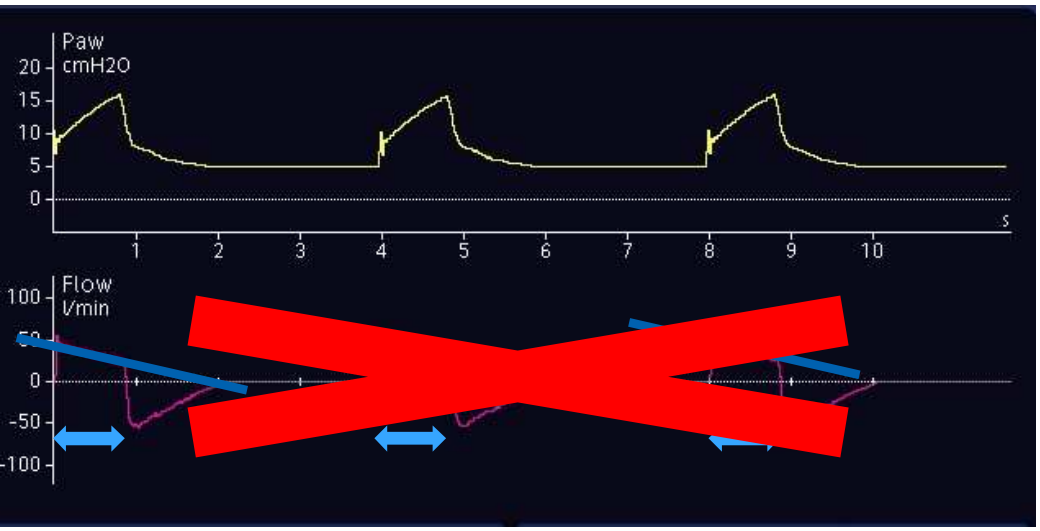
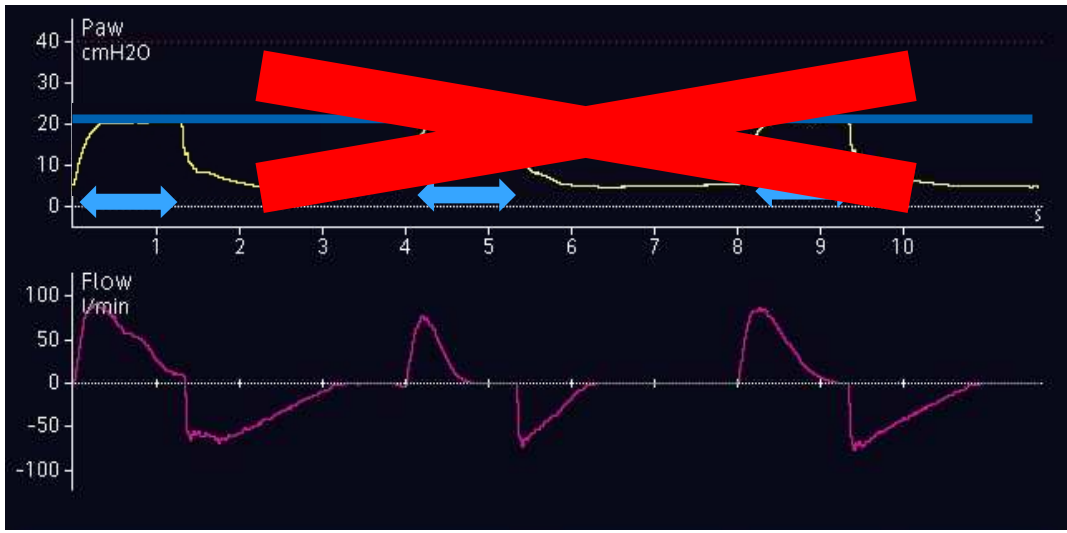
Eliminate Independent Variables. What is fixed?

Volume Control



Pressure Control



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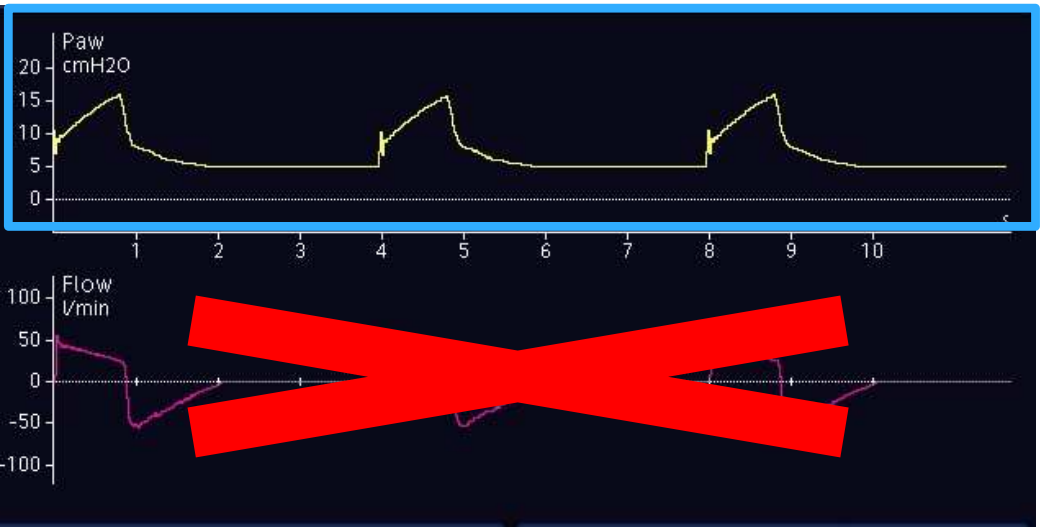
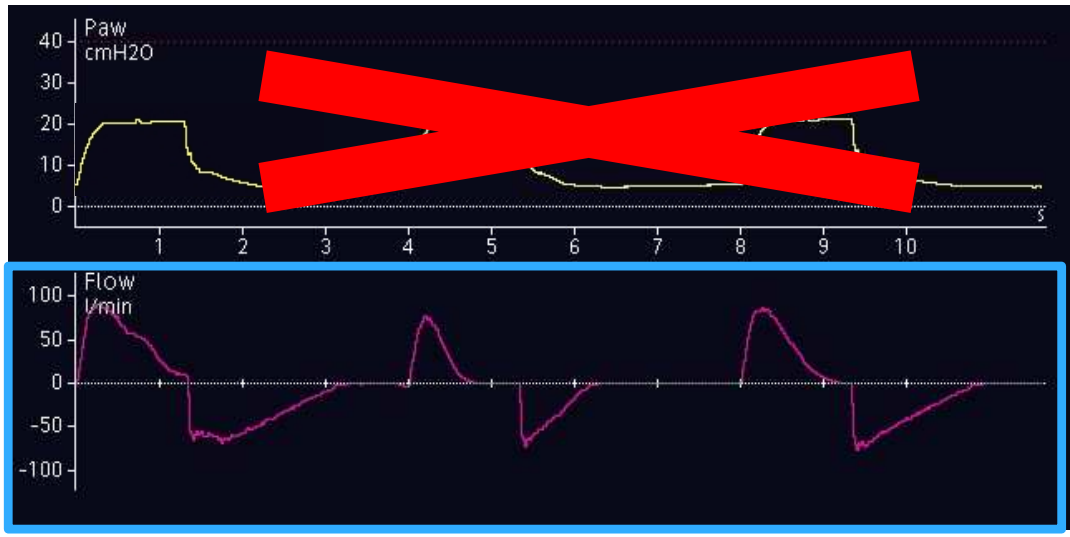
Confirm Dependent Variable Curve

Volume Control



Pressure Control



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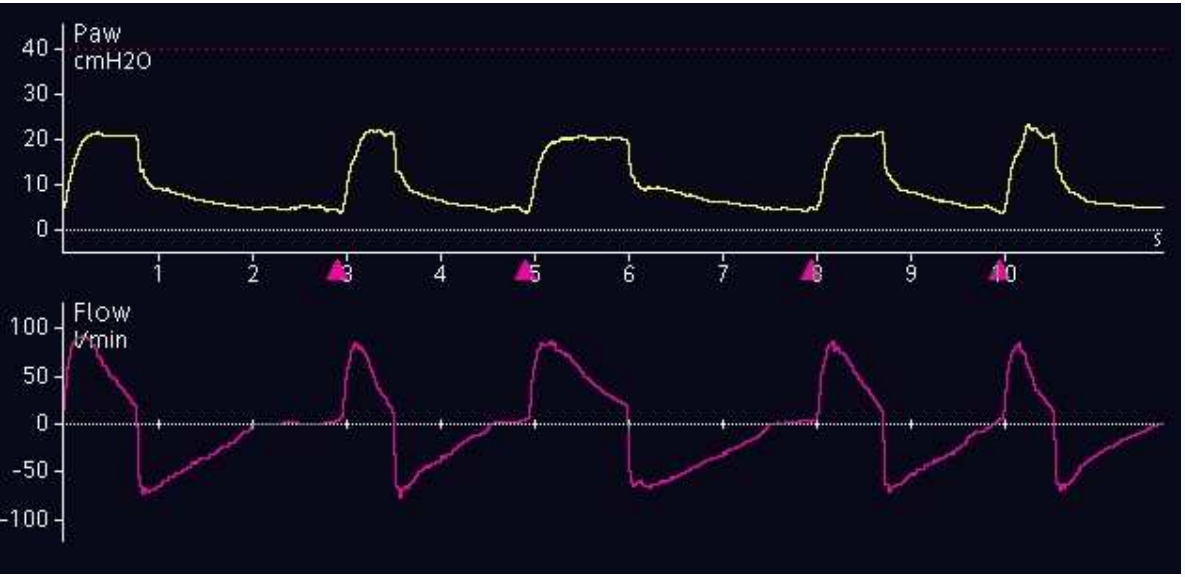
#4



What mode is this?

A. Volume SIMV

B. Pressure Control

C. Volume Control

D. Pressure Support

E. I still have no clue!

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Lung Protective vs Diaphragmatic Protective Ventilation

- ✓ Lung Protective Ventilation
  - ✓ Only on passive patients
  - ✓ Optimize PEEP
  - ✓ Minimize Driving Pressure
- ✓ Diaphragmatic Protective Ventilation
  - ✓ Only on active patients
  - ✓ Focus on patient comfort
  - ✓ Optimize diaphragmatic energy expenditure

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Diaphragmatic myotrauma: a mediator of prolonged ventilation and poor patient outcomes in acute respiratory failure

Ewan C Goligher, Laurent J Brochard, W Darlene Reid, Eddy Fan, Olli Saarela, Arthur S Slutsky, Brian P Kavanagh, Gordon D Rubenfeld, Niall D Ferguson

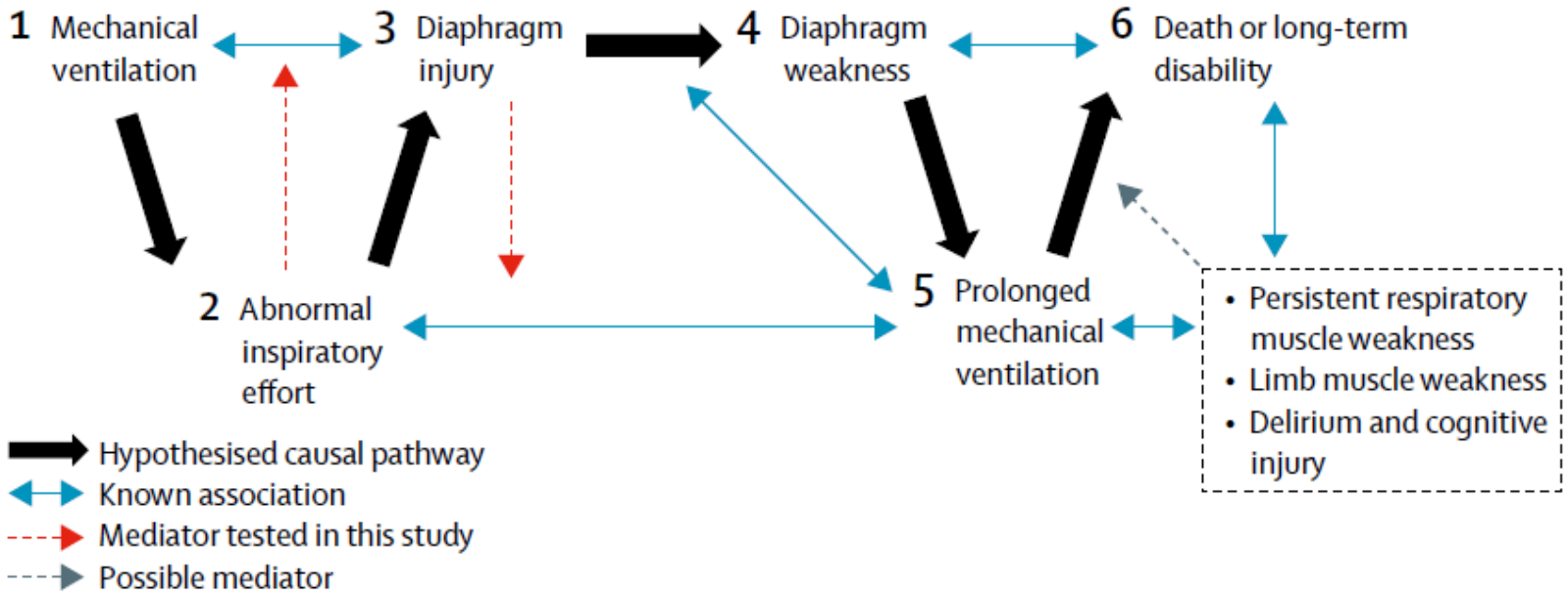
Asynchronies during mechanical ventilation are associated with mortality

Received: 29 October 2014
Accepted: 6 February 2015

L. Blanch · B. Sales · J. Montanya · O. García-Esquirol · J. C. Oliva · J. Lopez-Aguilar
Fundació Parc Taulí, Corporació Sanitaria Universitària Parc Taulí, Universitat Autònoma de Barcelona, Sabadell, Spain

J. Villar
Research Unit, Multidisciplinary Organ Dysfunction Evaluation Research Network (MODERN), Hospital Universitario Dr. Negrín, Las Palmas De Gran Canaria, Spain

Causal Pathway



Gallagher. LRM. 2019

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Asynchrony Classification

- ✓ Trigger Asynchrony
- ✓ Flow Asynchrony
- ✓ Termination Asynchrony

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Asynchrony Classification & Learning Approach

- ✓ Trigger Asynchrony
- ✓ Flow Asynchrony
- ✓ Termination Asynchrony

- ✓ Approach to understand
  - ✓ Asynchrony title
  - ✓ Asynchrony example
    - ✓ Basic
    - ✓ Advanced
  - ✓ Asynchrony Causes
  - ✓ Resolutions

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Triggering Asynchrony

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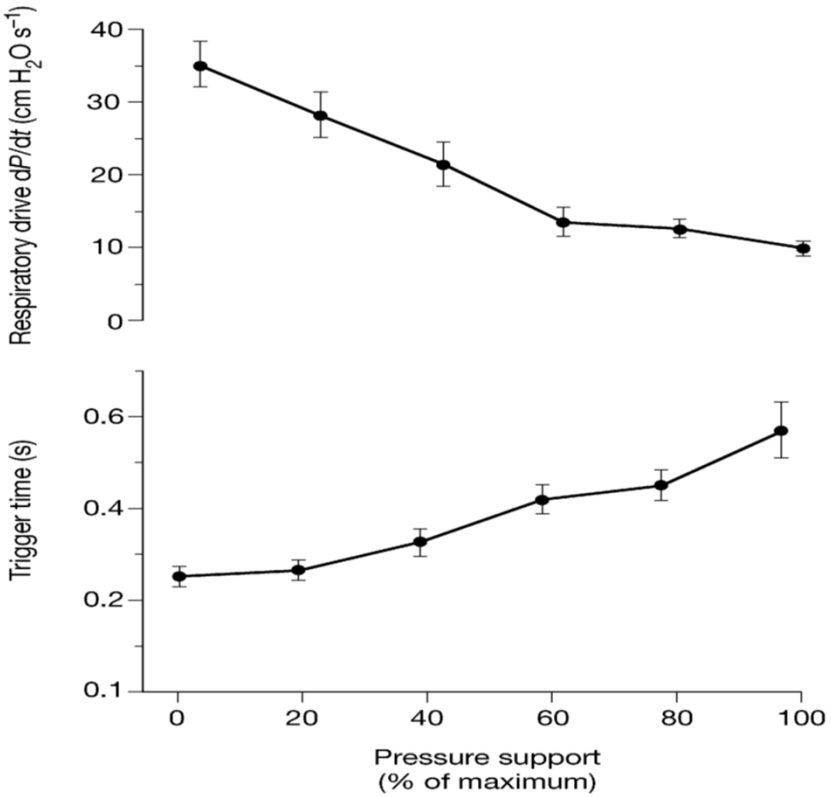
Delayed triggering

- ✓ Delay in reaching trigger threshold
- ✓ Inspiratory Flow occurs too long after trigger signal



Leung. AJRCCM. 1997

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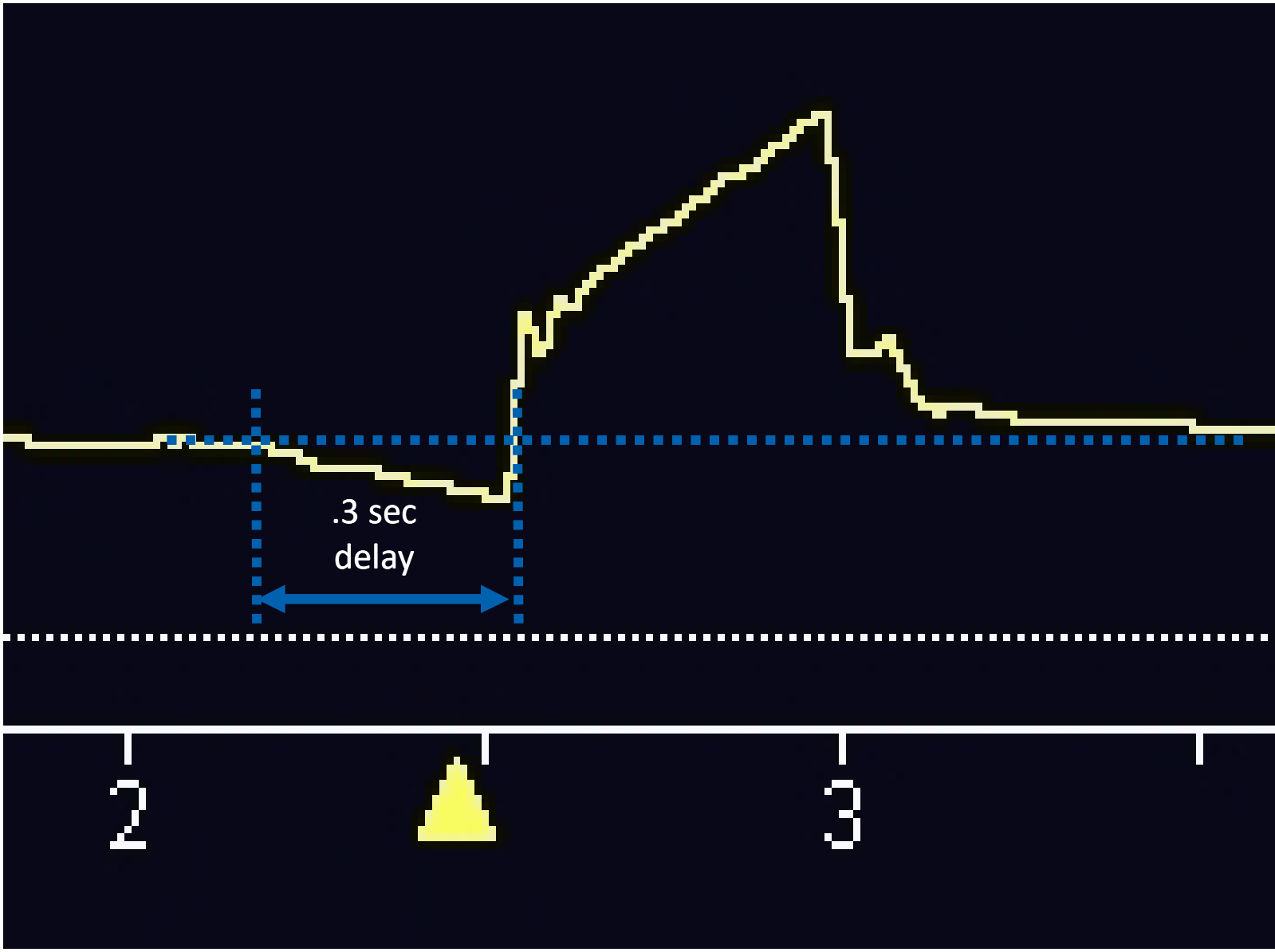
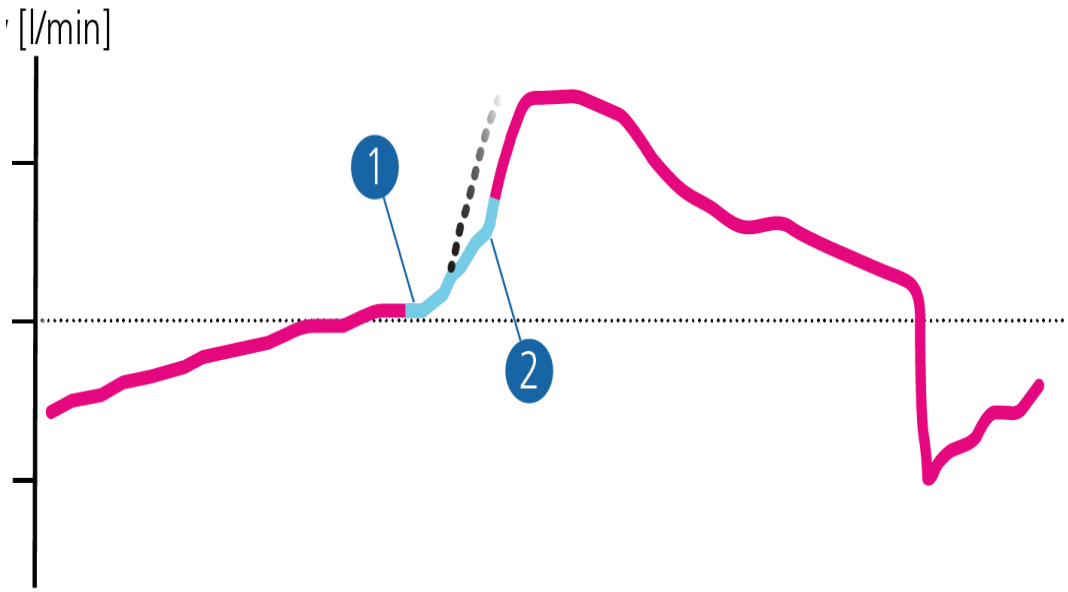
Delayed triggering

Delayed triggering



Delayed Triggering- Flow waveform

- ✓ Flow Waveform
  - ✓ Extended time between positive deflection in flow (1) and delivery of support (2)



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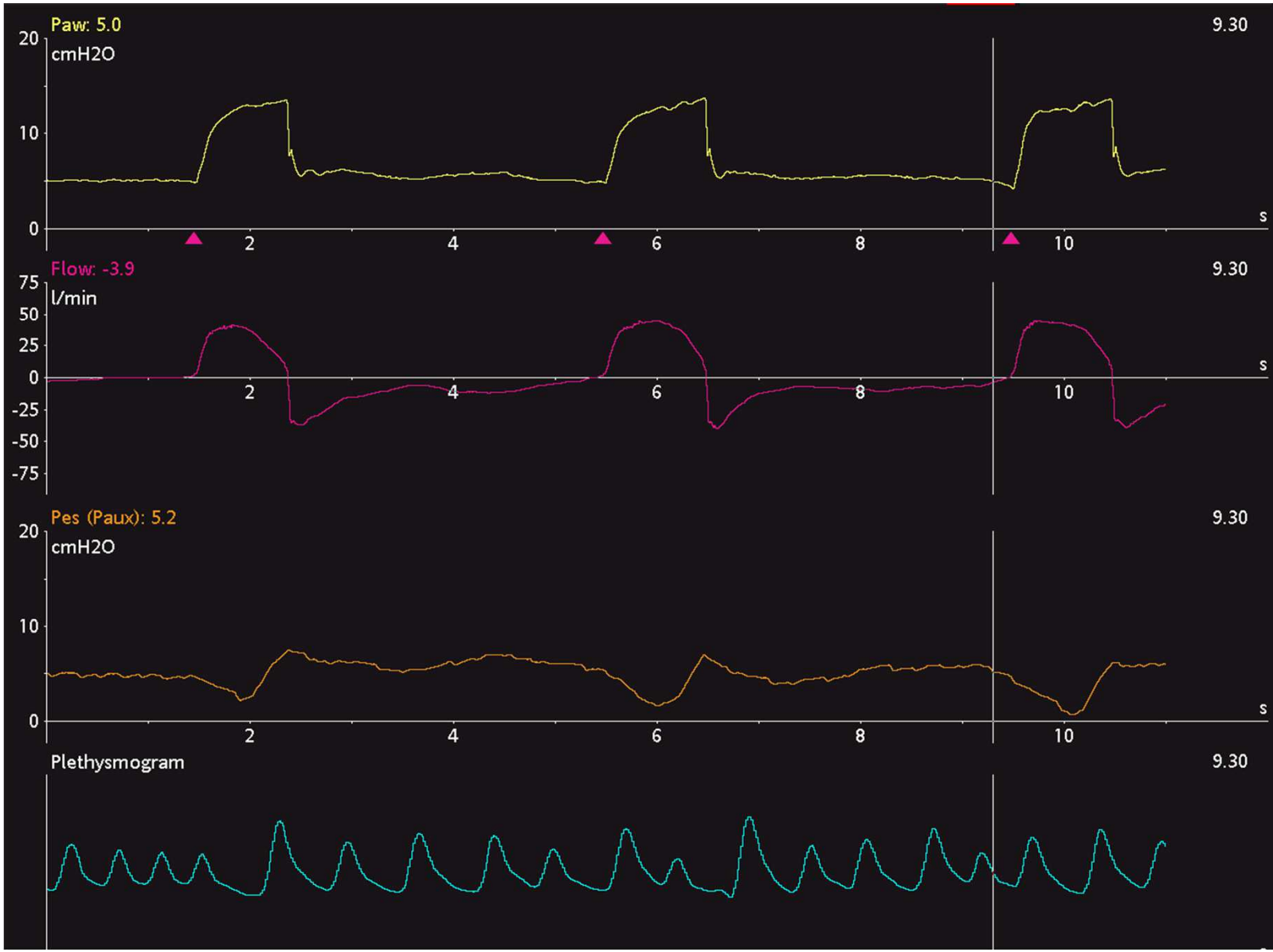
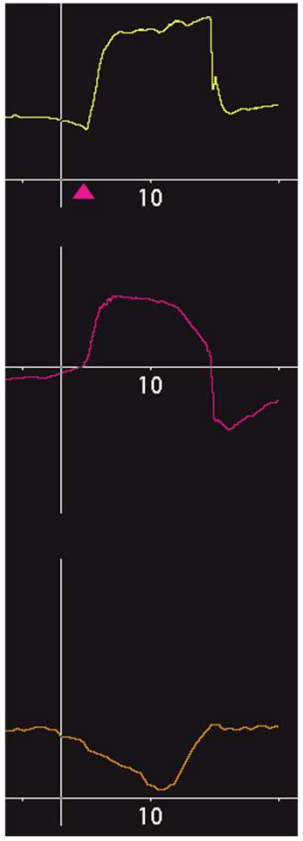
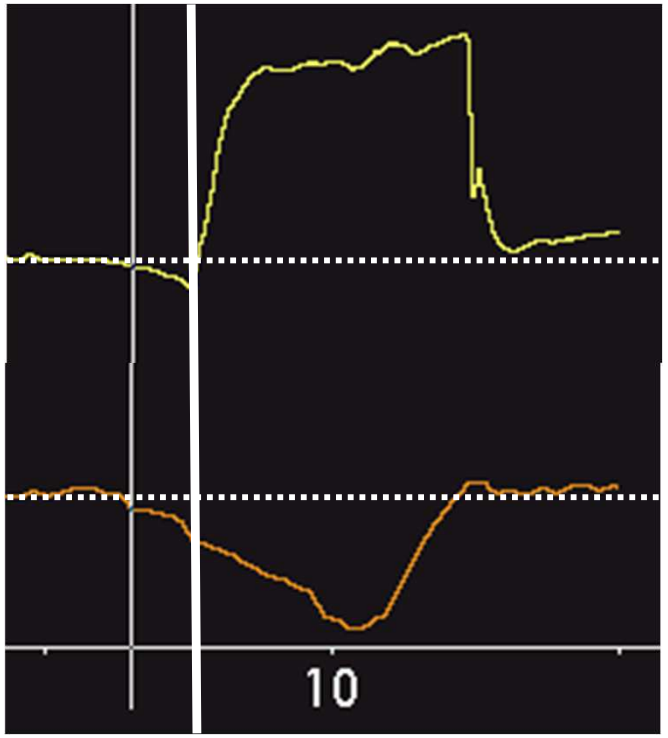
Delayed Trigger



Delayed Trigger





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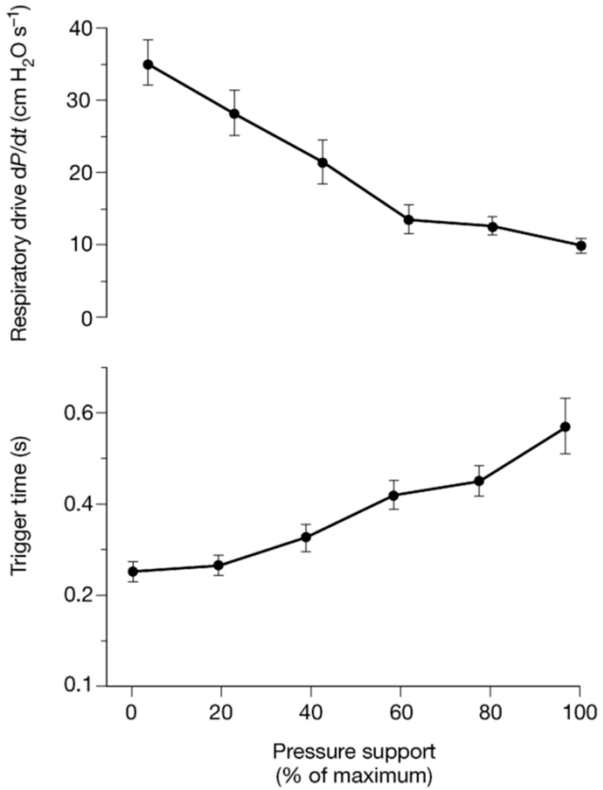
Delayed Trigger Possible Causes

- ✓ Trigger sensitivity too high
- ✓ Ventilator Pneumatics
- ✓ AutoPEEP
- ✓ Weak respiratory drive
- ✓ Poor effort
- ✓ Too much inspiratory support



Leung. AJRCCM. 1997

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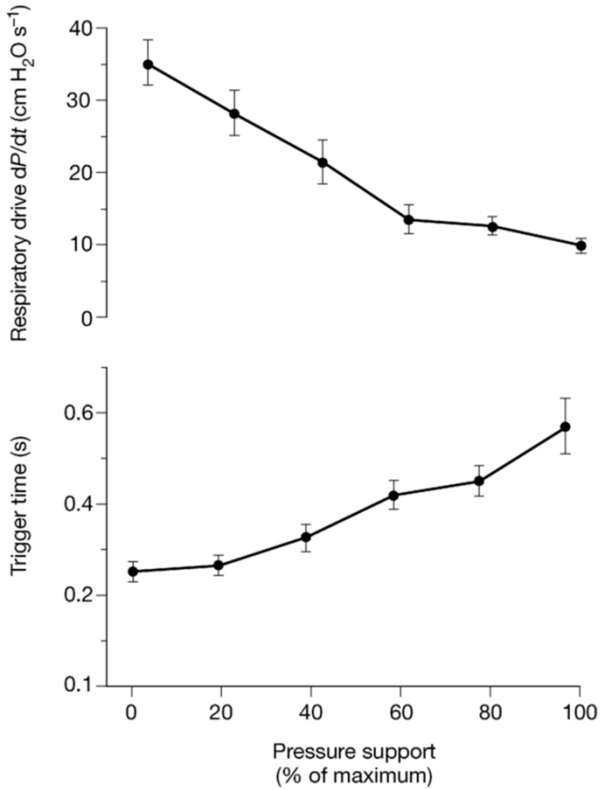
Delayed Trigger Resolution

- ✓ Adjust trigger sensitivity
- ✓ Ventilator tubing/ remove restrictions
- ✓ Reduce autoPEEP
- ✓ Reduce level of inspiratory support



Leung. AJRCCM. 1997

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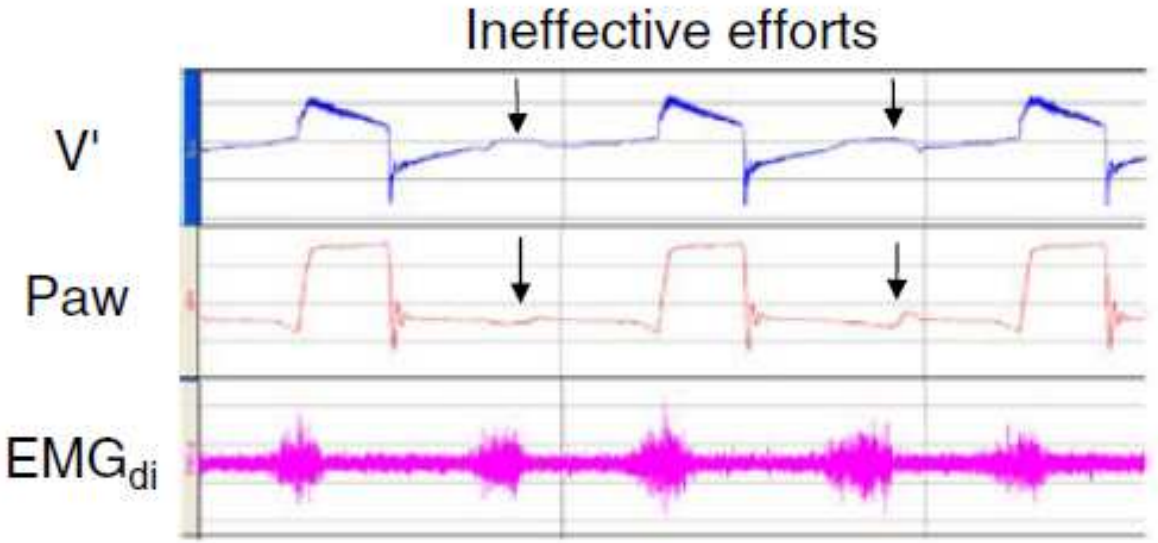
Ineffective Effort

- ✓ Inspiratory effort does not trigger a mechanical breath



Vignaux. ICM. 2006

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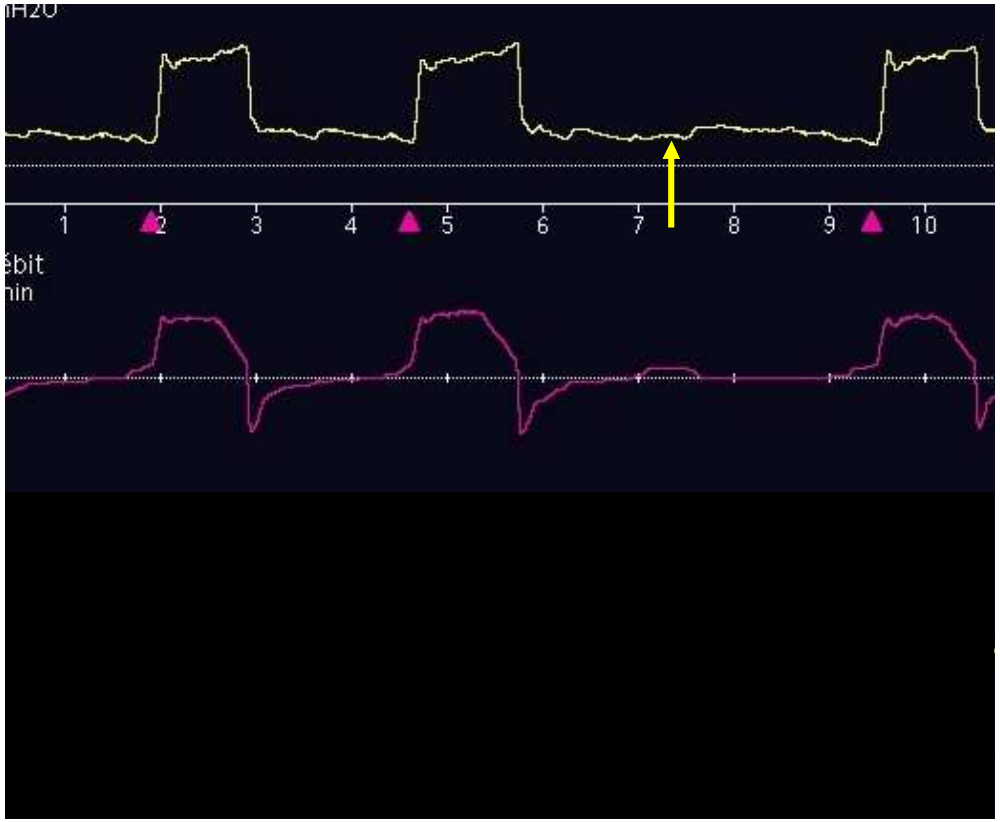
Ineffective Effort



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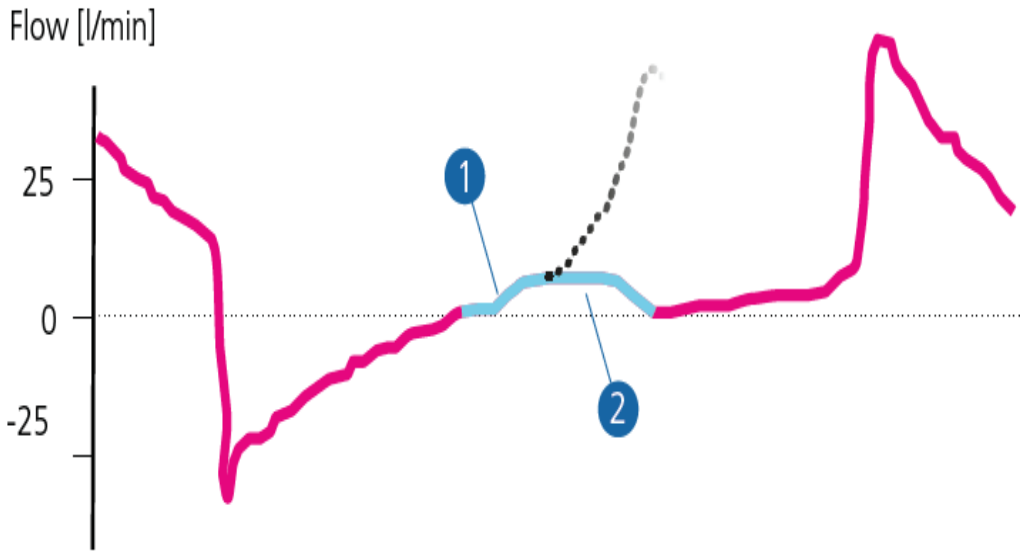
Ineffective Effort

- ✓ Flow waveform
  - ✓ Look for an abrupt change in the steepness of the waveform (1) not followed by delivery of ventilator support



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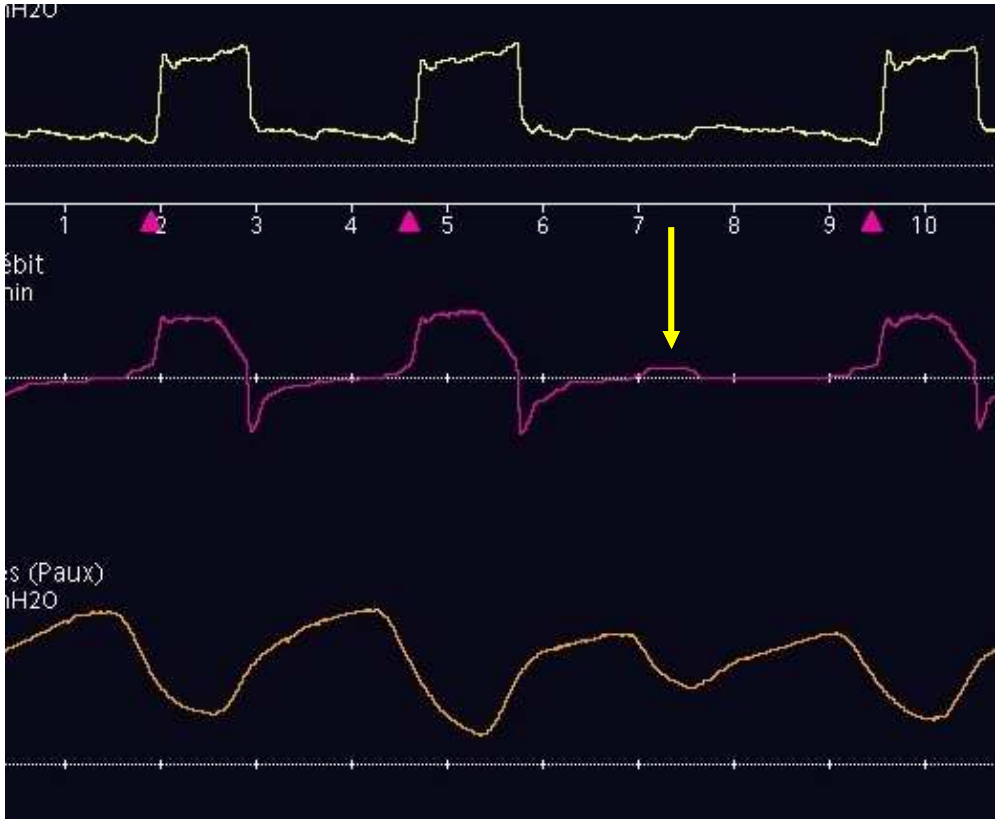
Ineffective Effort



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Ineffective Effort Possible Causes

- ✓ Trigger threshold set too high
- ✓ Pressure support too high
- ✓ Set frequency and/or inspiratory time too high (in controlled modes)
- ✓ Tidal volume set too high
- ✓ Presence of AutoPEEP
- ✓ Low respiratory drive
- ✓ Weak inspiratory effort
- ✓ Sedation

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Ineffective Effort Resolution

- ✓ Adjust trigger to be more sensitive
- ✓ Reduce support
- ✓ Increase PEEP
- ✓ Other- reduce sedation, increase patient strength

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Double Triggering (Multiple Triggering)

- ✓ Two or more patient triggered breaths separated by minimal expiratory flow
- ✓ Mismatch of “machine” and “neural I-time”

Vignaux. ICM. 2006

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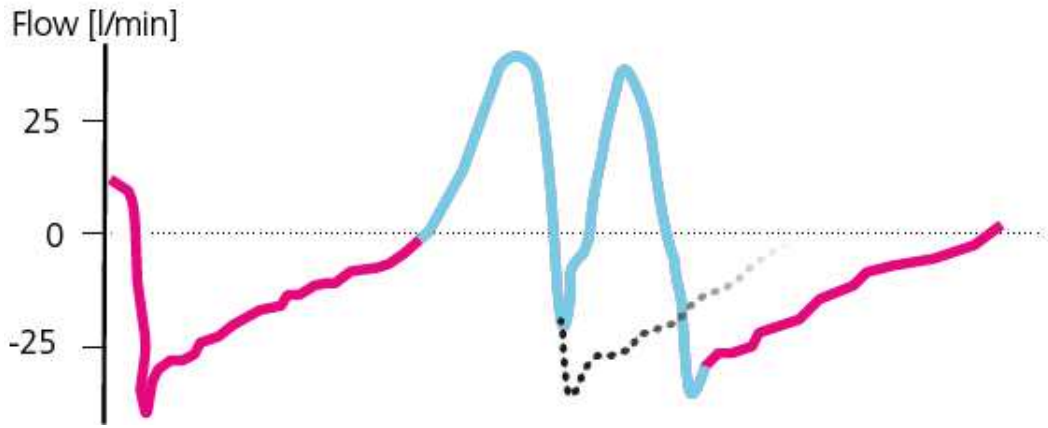
Double Triggering

Double Triggering

- ✓ Flow waveform
  - ✓ Two assisted breaths without expiration between them or with an expiration interval of less than half of the mean inspiratory time



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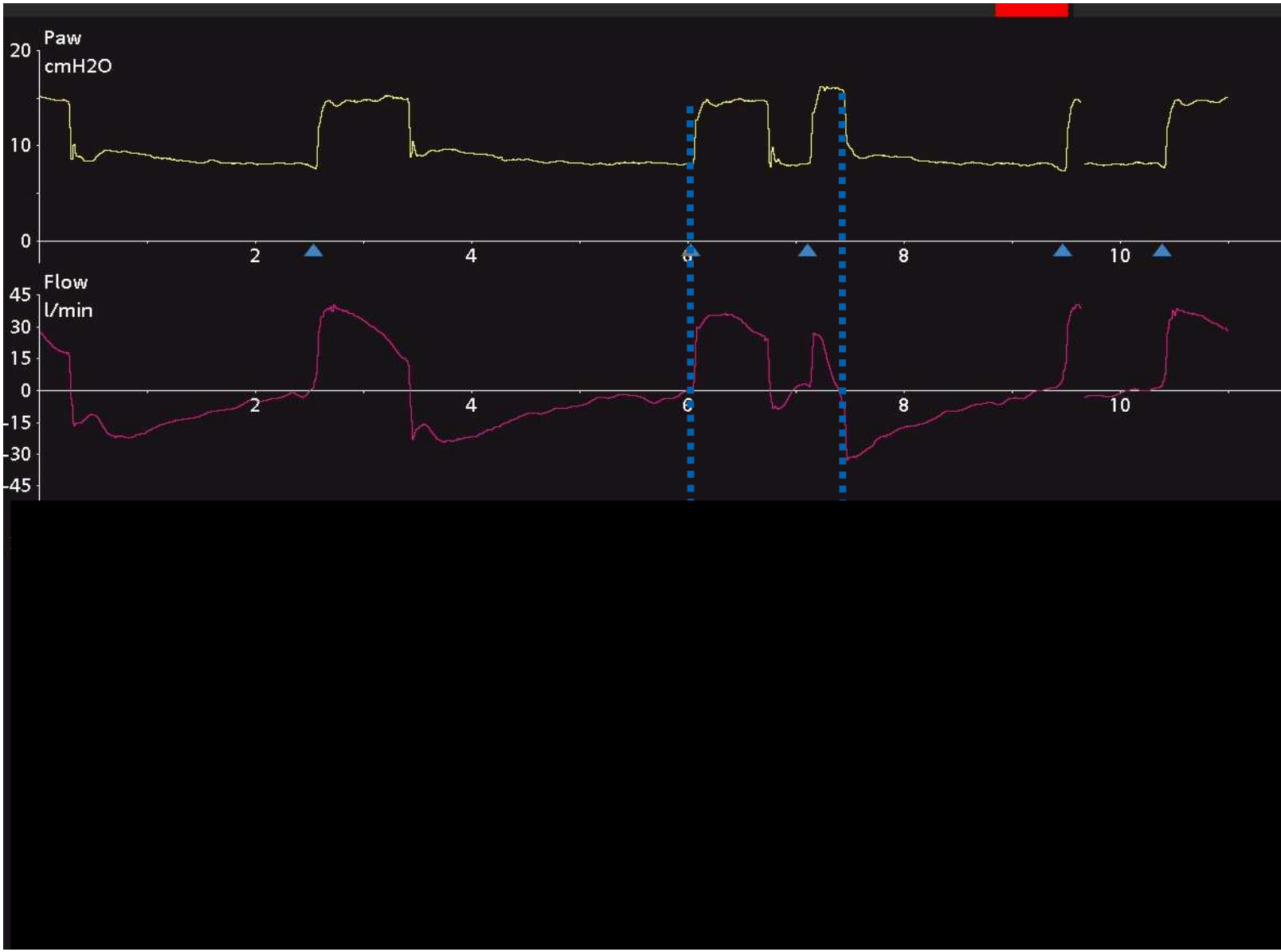
Double Triggering



Double Triggering Possible Causes

- ✓ Cycling criteria (ETS, Esens%, FlowTerm%, Flowcycle) set too high (PS)
- ✓ I-time too short (VC & PC)
- ✓ Insufficient support

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Double Triggering Resolution

- ✓ Adjust ETS, Esens%, FlowTerm%, Flowcycle
- ✓ Lengthen I-time
- ✓ Increase inspiratory support

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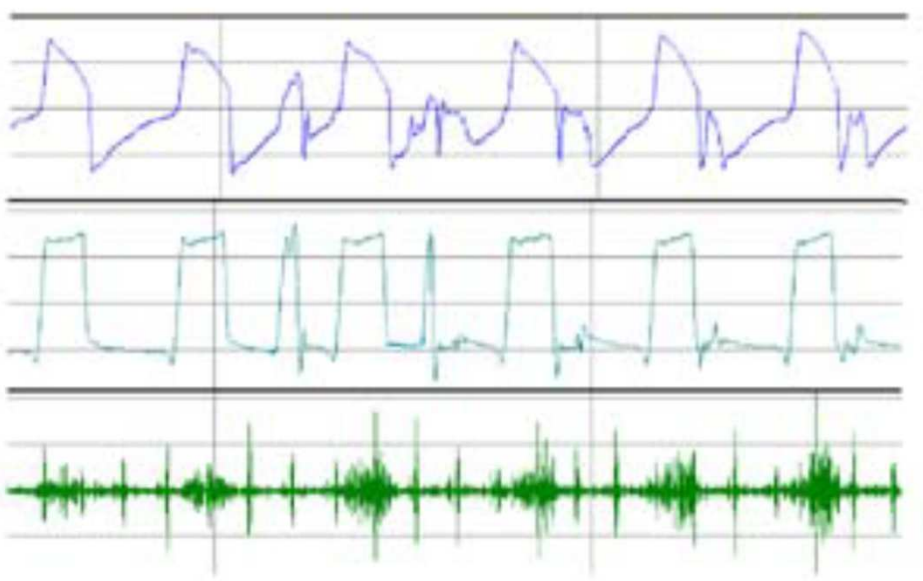
Autotriggering

- ✓ A mechanical breath delivered without an inspiratory effort



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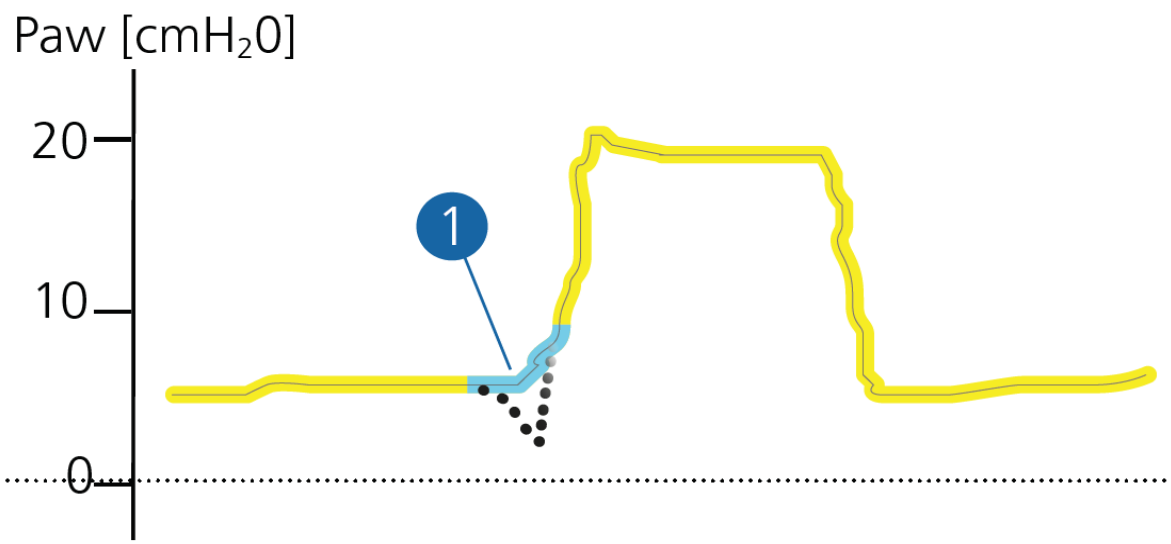
Autotriggering

- ✓ Pressure waveform
  - ✓ Delivered breath showing no drop in airway pressure (1) at beginning of inspiratory phase



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Autotriggering

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Autotriggering Possible Causes

- ✓ Trigger Sensitivity too low
- ✓ Leaks
- ✓ Oscillations in the tubing-secretions, water, cardiac

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Autotriggering Resolutions

- ✓ Adjust Sensitivity
- ✓ Resolve leak
- ✓ Clear environment causing autotrigger (secretions/water)
- ✓ Switch to a pressure trigger for cardiac oscillations

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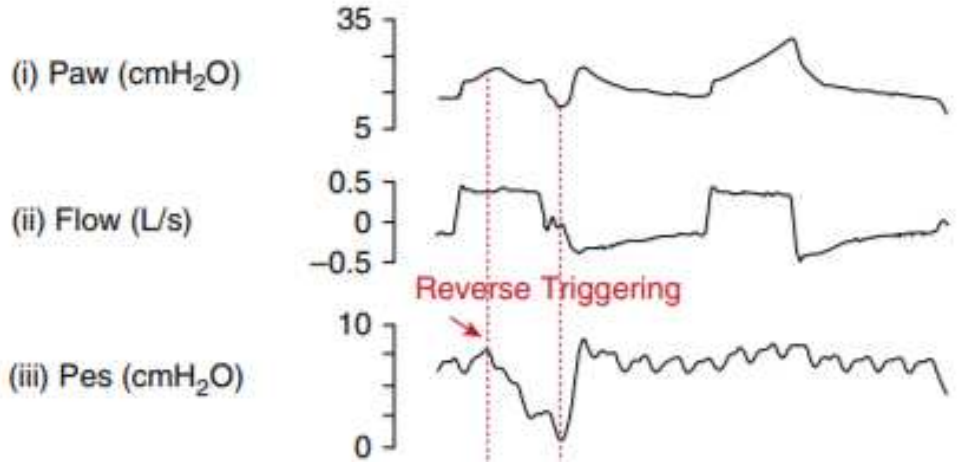
Reverse Triggering

- ✓ Inspiratory effort begins after machine trigger



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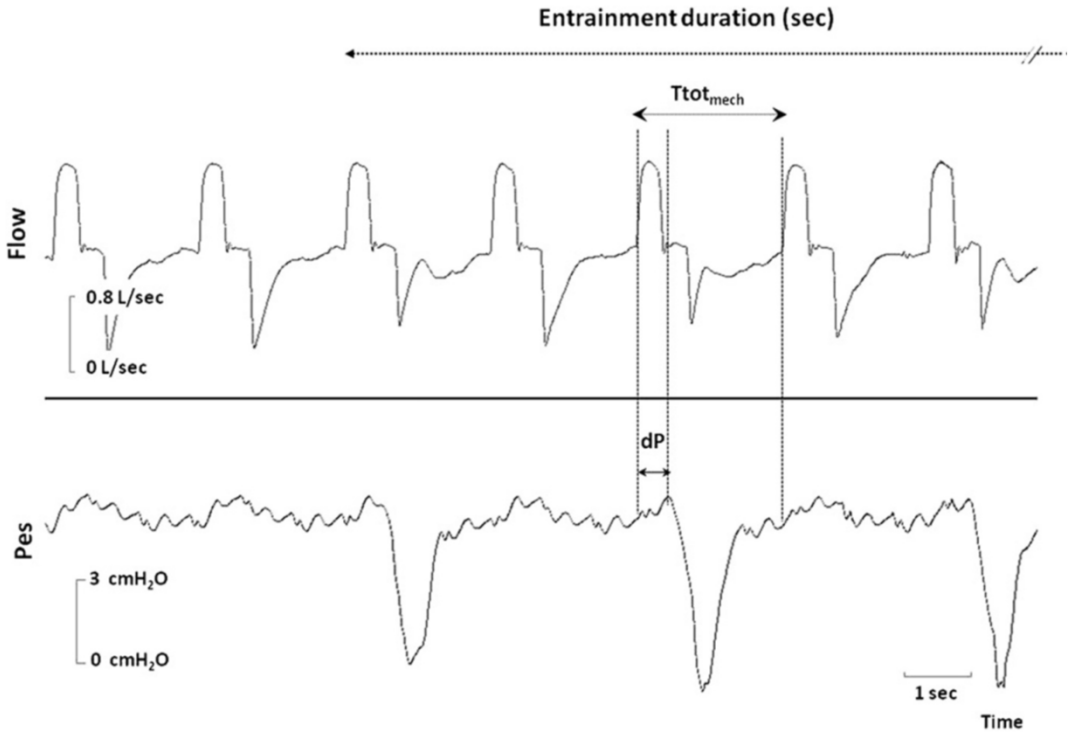
Reverse Triggering

- ✓ Inspiratory effort begins after machine trigger



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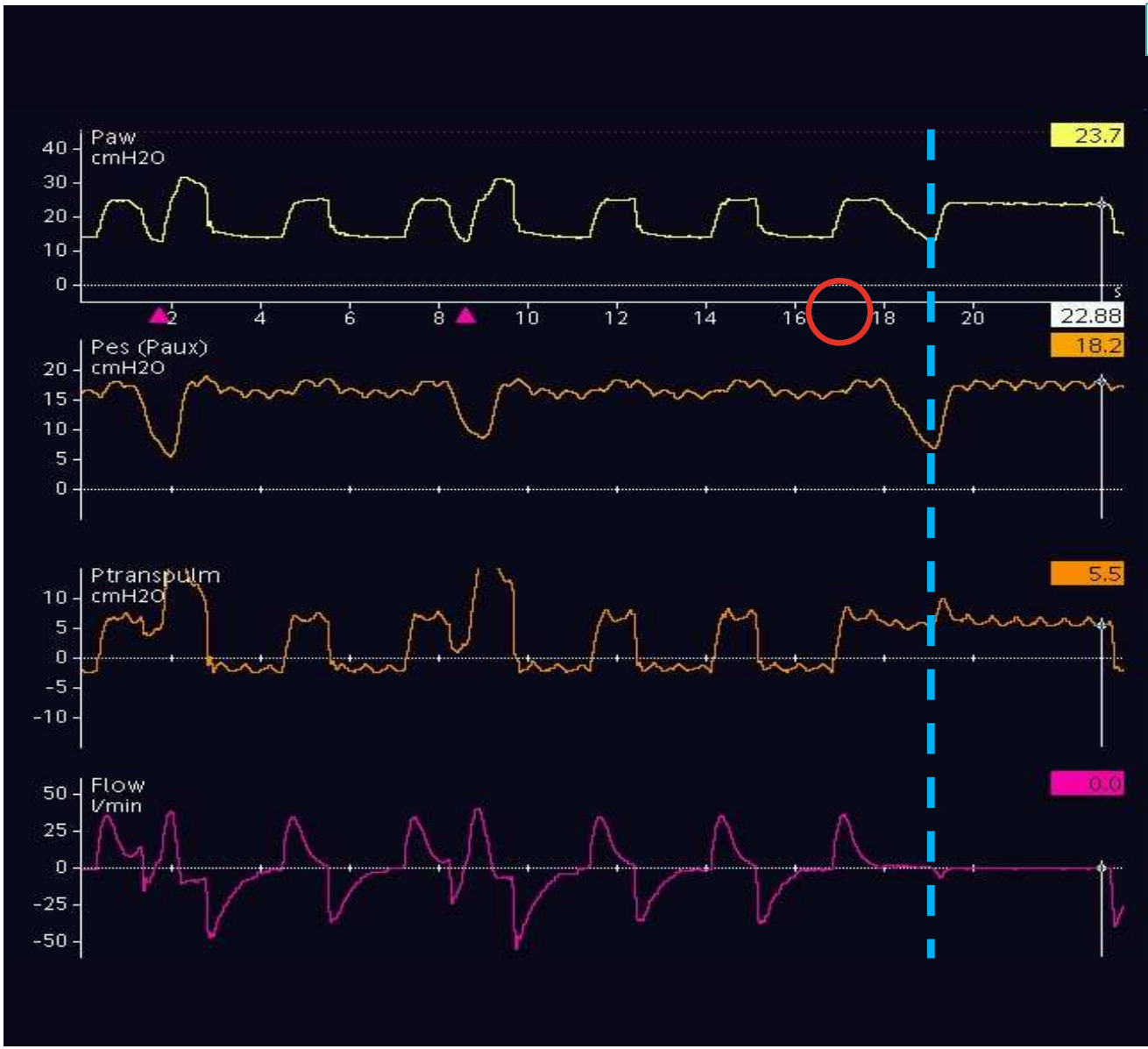
45
5
32 Ppeak cmH2O
12.0
3.0
7.6 ExpMinVol l/min
850
120
512 VTE ml
40
8
25 fTotal b/min
19 Pmean cmH2O
Paw cmH2O
40
30
20
10
0
2
4
8
10
12
14
16
18
20
s
Pes (Paux) cmH2O
20
15
10
5
0
Ptranspulm cmH2O
10
5
0
-5
-10
Flow l/min
50
25
0
-25
32 Ppeak cmH2O
31 Pplateau cmH2O
19 Pmean cmH2O
14 PEEP/CPAP cmH2O
2 / 9
IntelliCuff
22 b/min
Rate
10 cmH2O
Pcontrol
14 cmH2O
PEEP/CPAP
40 %
Oxygen
Controls

CB6

Reverse triggering identification

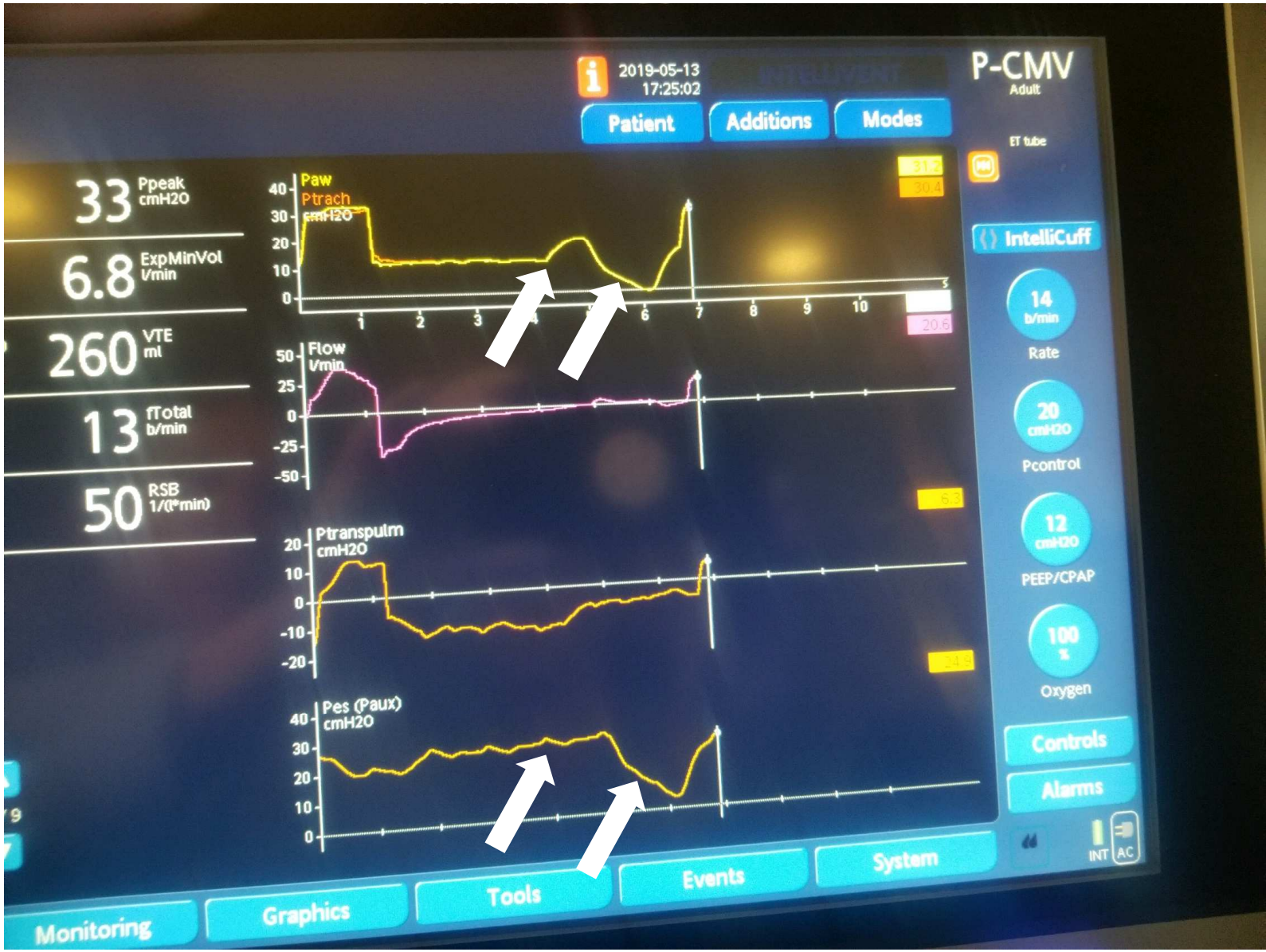


Slide 54

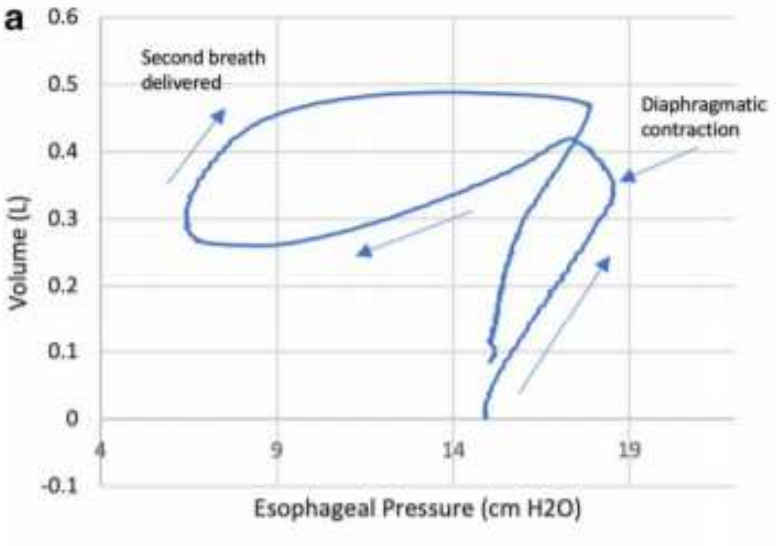
CB6 I would probably say
Identifying reverse triggering
Caroline, 4/20/2022

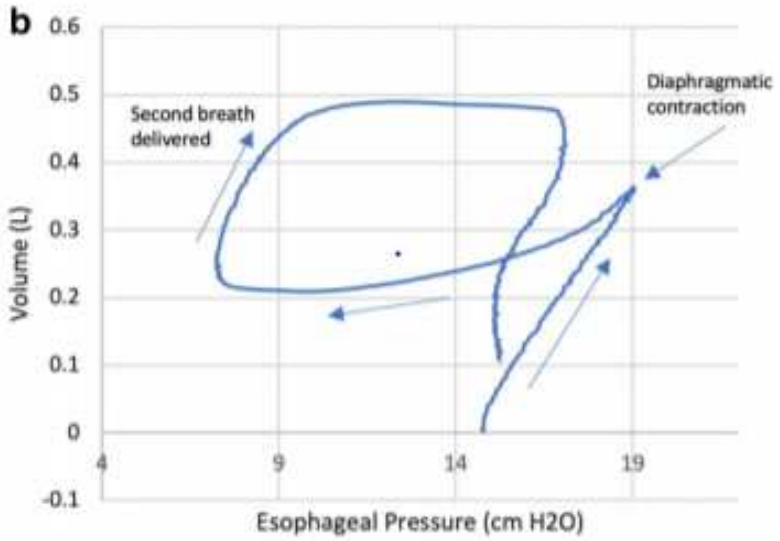
CB8 I have added this black background to make the image go from top to bottom so the slide matches our presentation template slides.
Caroline, 4/21/2022

Reverse Triggering



Reverse Triggering





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Reverse Trigger Resolutions

- ✓ Neuromuscular Blockade
- ✓ Increase PEEP
- ✓ Increase support (Vt, Pcontrol, iTime)
- ✓ Frequency increases should be taken with serious considerations for breath stacking
- ✓ Some instances of Reverse Trigger benefit from decrease in frequency with concurrent increase in inspiratory support

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Why increase PEEP?

Volume-controlled Ventilation Does Not Prevent Injurious Inflation during Spontaneous Effort

Takeshi Yoshida[1,2], Susumu Nakahashi[1,3], Maria Aparecida Miyuki Nakamura[4], Yukiko Koyama[1], Rollin Roldan[4,5], Vinicius Torsani[4], Roberta R. De Santis[4], Susimeire Gomes[4], Akinori Uchiyama[1], Marcelo B. P. Amato[4], Brian P. Kavanagh[2], and Yuji Fujino[1]

[1]Intensive Care Unit, Osaka University Hospital, Suita, Japan; [2]Translational Medicine, Department of Critical Care Medicine and Department of Anesthesia, Hospital for Sick Children, University of Toronto, Toronto, Ontario, Canada; [3]Emergency and Critical Care Center, Mie University Hospital, Tsu, Japan; [4]Laboratório de Pneumologia LIM-09, Disciplina de Pneumologia, Instituto do Coração (Incor), Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, Brazil; and [5]Unidad de Cuidados Intensivos, Hospital Rebagliati, Lima, Peru

Why increase PEEP?

Journal of *Clinical Medicine*

MDPI

Review

Patient-Self Inflicted Lung Injury: A Practical Review

Guillaume Carteaux [1,2,3,*], Mélodie Parfait [1,2,†], Margot Combet [1,2,†], Anne-Fleur Haudebourg [1,2], Samuel Tuffet [1,2,3] and Armand Mekontso Dessap [1,2]

Why increase PEEP?

Medizinische Klinik
Intensivmedizin und Notfallmedizin

Pflege

Med Klin Intensivmed Notfmed 2021 · 116: 614–623
https://doi.org/10.1007/s00063-021-00823-2
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Online publiziert: 7. Mai 2021

Benjamin Neetz[1] · Thomas Flohr[2] · Felix J. F. Herth[1] · Michael M. Müller[1]

[1]Thoraxklinik am Universitätsklinikum Heidelberg, Pneumologie und Beatmungsmedizin, Translational Lung Research Center Heidelberg (TLRC), Heidelberg, Deutschland
[2]Medizinische Klinik und Poliklinik I, Universitätsklinikum Würzburg, Würzburg, Deutschland

„Patient self-inflicted lung injury" (P-SILI)

Von der Pathophysiologie zur klinischen Evaluation mit differenziertem Management

Benjamin Neetz, Flohr, Herth, et al: Patient self-inflicted lung injury (P-Sili)

Flow Asynchrony

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Flow Asynchrony (Flow Starvation, Work Shifting)

- ✓ The delivered flow does not meet the patient's inspiratory flow demands

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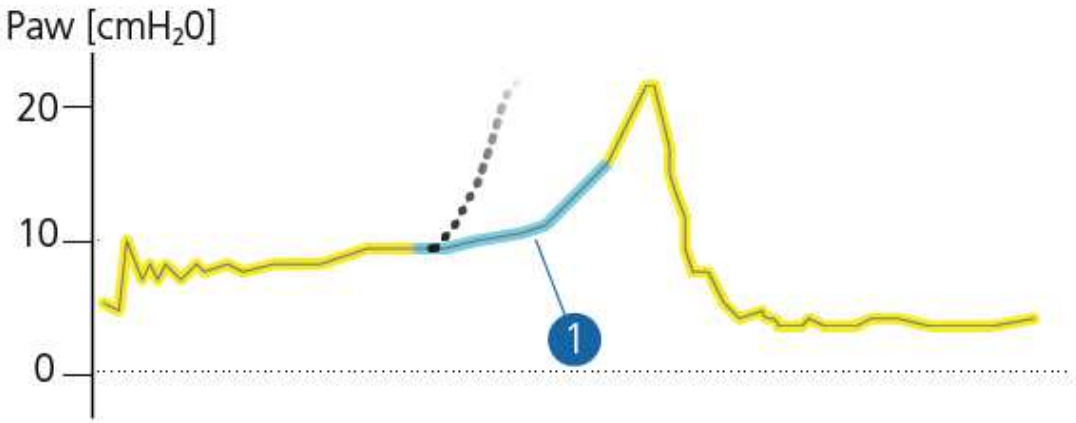
Flow Asynchrony

- ✓ Pressure waveform
  - ✓ Upward concavity (1) preceding the end of the mechanical breath



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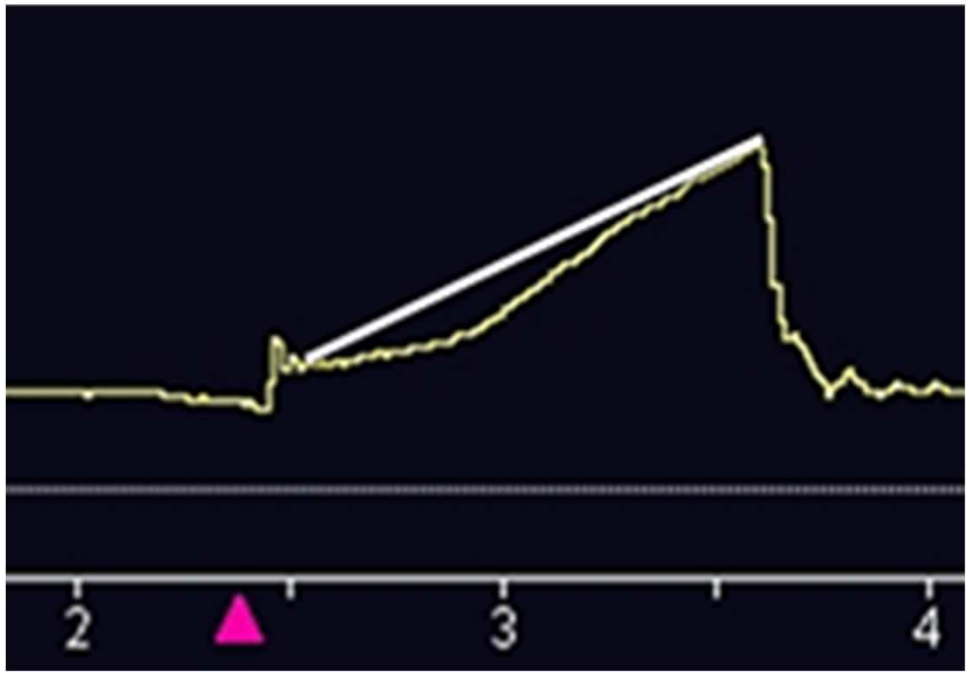
Flow Asynchrony

- ✓ Pressure waveform
  - ✓ Upward concavity (1) preceding the end of the mechanical breath



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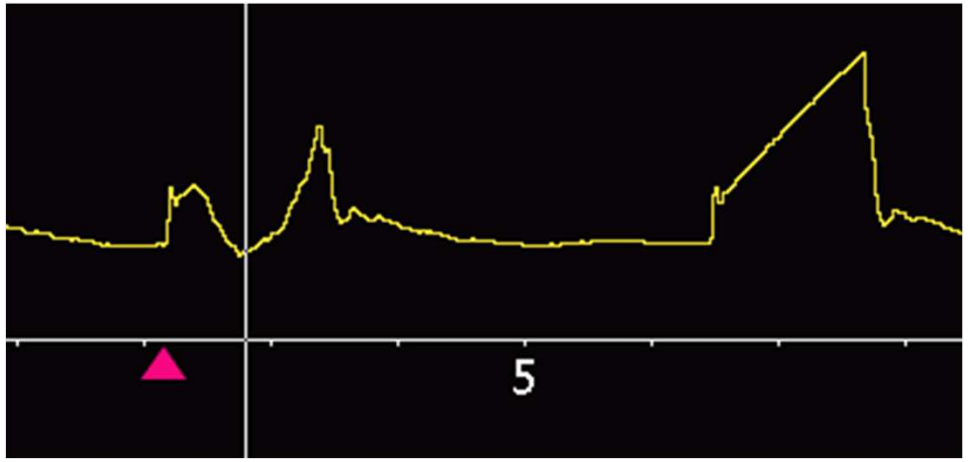
Flow Starvation

- ✓ The delivered flow does not meet the patient's inspiratory flow demands



$$P_{AW} = (Vt/Cstat) + (flow\ X\ Raw) - (P_{MUS}\text{-}PEEP_{TOT})$$

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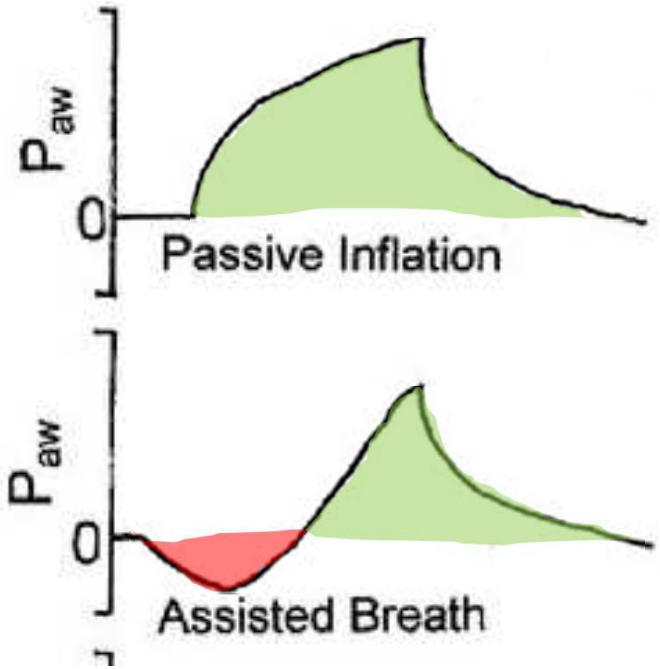
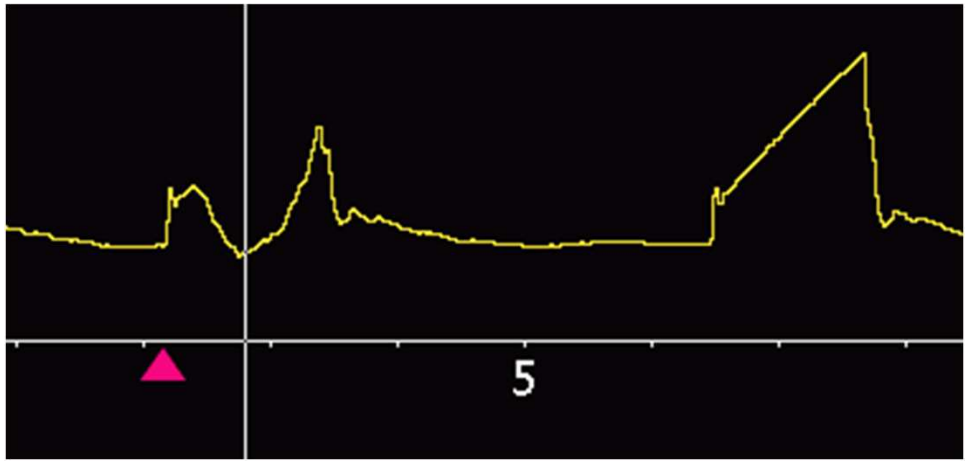
Flow Asynchrony and Work Shifting





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Flow Asynchrony Possible Causes

- ✓ Inappropriate selection of ventilation mode
- ✓ High inspiratory effort

In volume-controlled modes:

- ✓ Inappropriate flow settings
- ✓ Decreased tidal volume
- ✓ I-time too long

In pressure-controlled modes:

- ✓ Inappropriate P-ramp, Slope, Rise settings
- ✓ Decreased PC
- ✓ I-time too short

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Flow Asynchrony Resolution

- ✓ Select a more appropriate mode
- ✓ Increase flow or Vt

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Termination asynchronies

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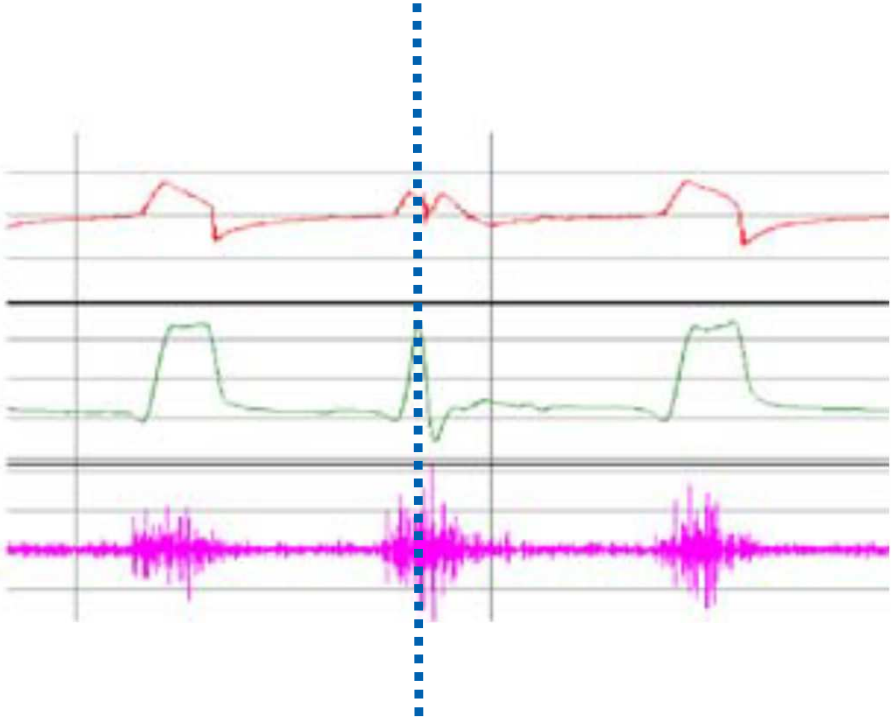
Early Cycling

- ✓ Neural inspiratory time longer than set inspiratory time
- ✓ Termination of inspiratory phase before relaxation of respiratory muscles.



Vignaux. ICM. 2006

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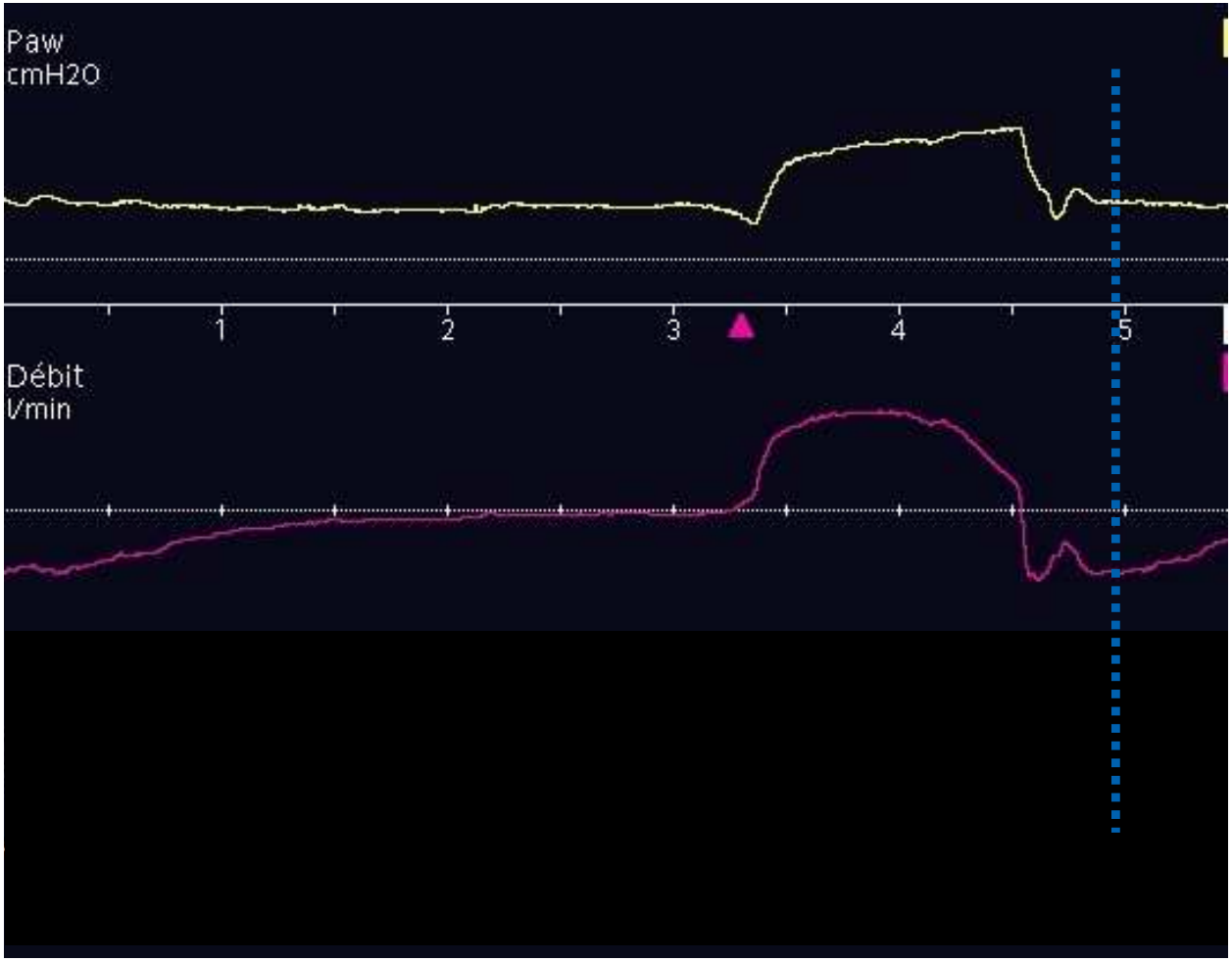
Early Cycling



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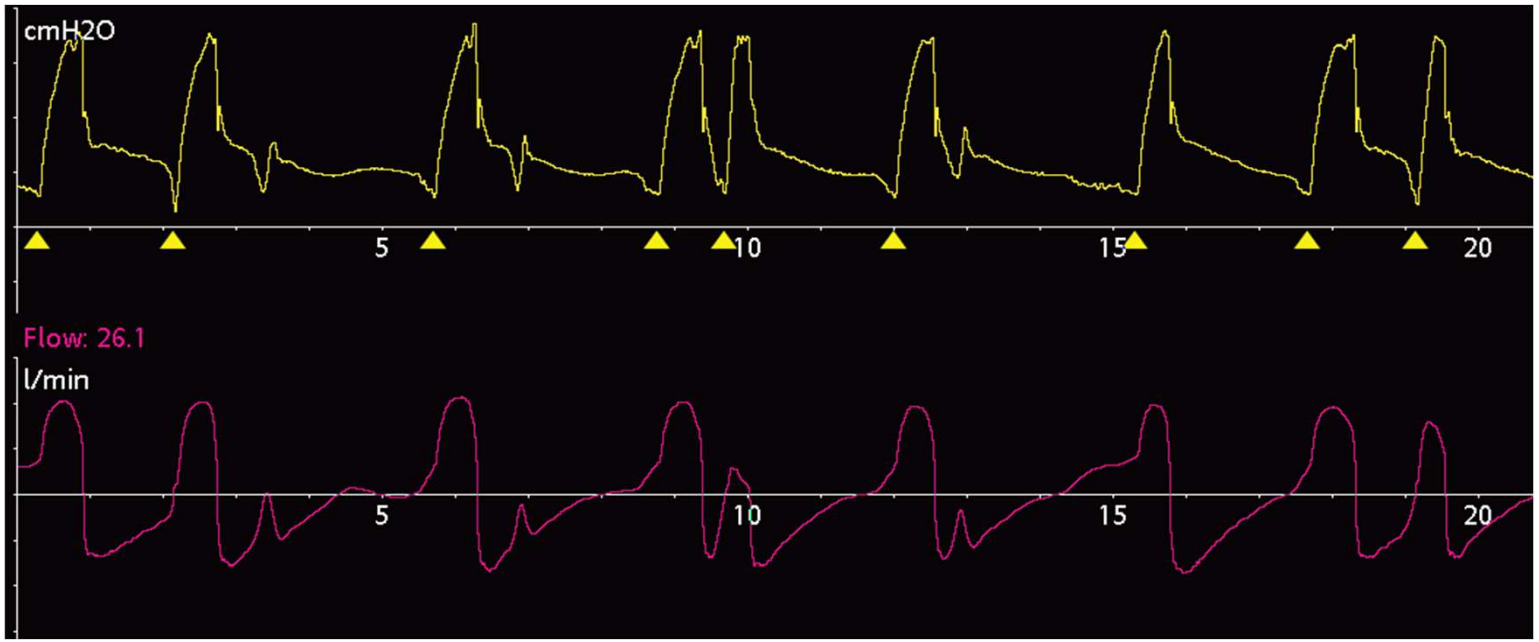
Early Cycling



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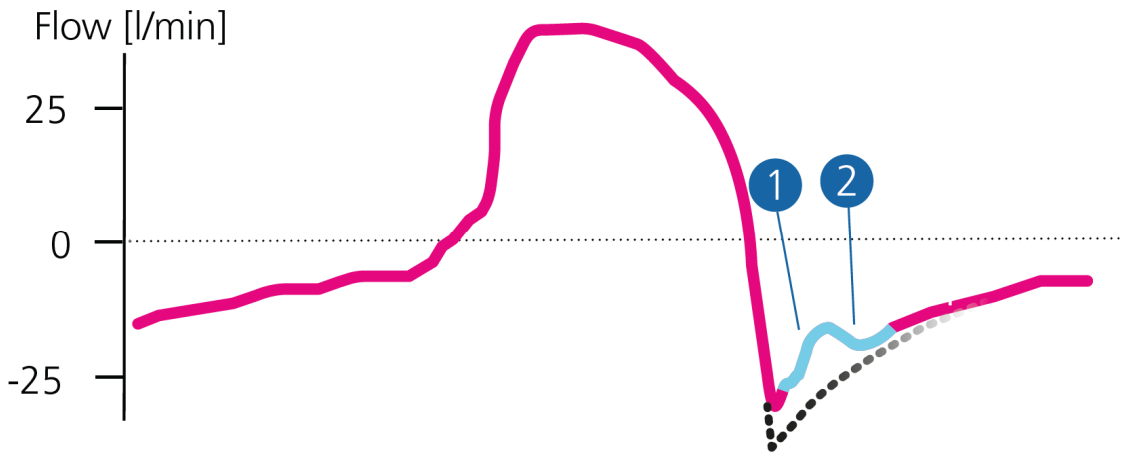
Early Cycling

- ✓ Flow waveform
  - ✓ Small bump at the beginning of expiration (1) (after peak expiratory flow) followed by an abrupt initial reversal in the expiratory flow (2)



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Early Cycling Possible Causes

In pressure support ventilation:

- ✓ Cycling criteria (ETS, Esens%, FlowTerm%, Flowcycle) set too high
- ✓ Low levels of ventilator pressure support

In time-cycled ventilation:

- ✓ Short inspiratory time setting

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Early Cycling Resolution

In pressure support ventilation:

- ✓ Lower the Cycling criteria (ETS, Esens%, FlowTerm%, Flowcycle)
- ✓ Increase ventilator pressure support

In time-cycled ventilation:

- ✓ Increase inspiratory time setting
- ✓ Increase Support (Vt, Pcontrol)

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Lengthen I-time to match Neural I-time

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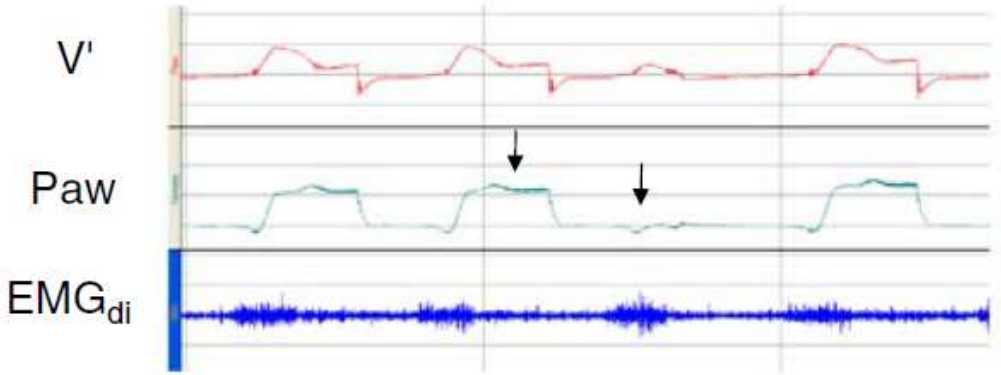
Delayed Cycling

- ✓ Failure of breath to terminate in proportion to neural-I time.



Vignaux. ICM. 2006

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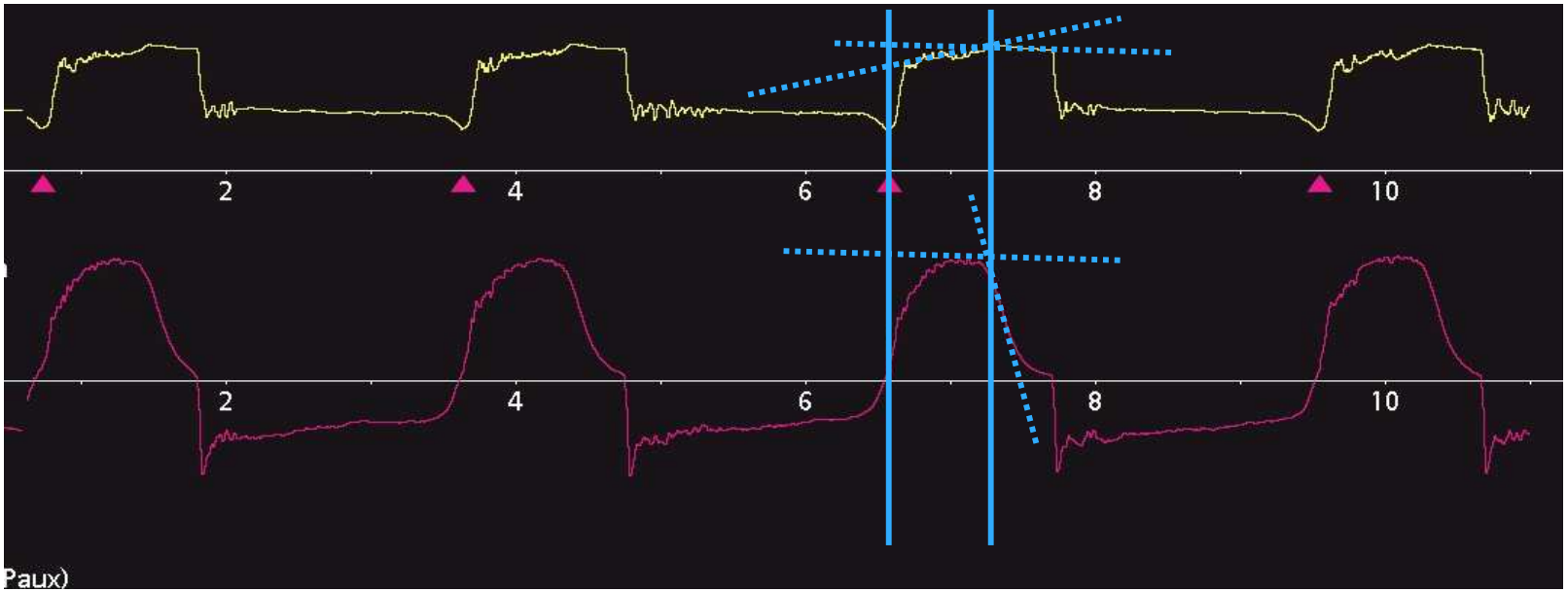
Delayed Cycling



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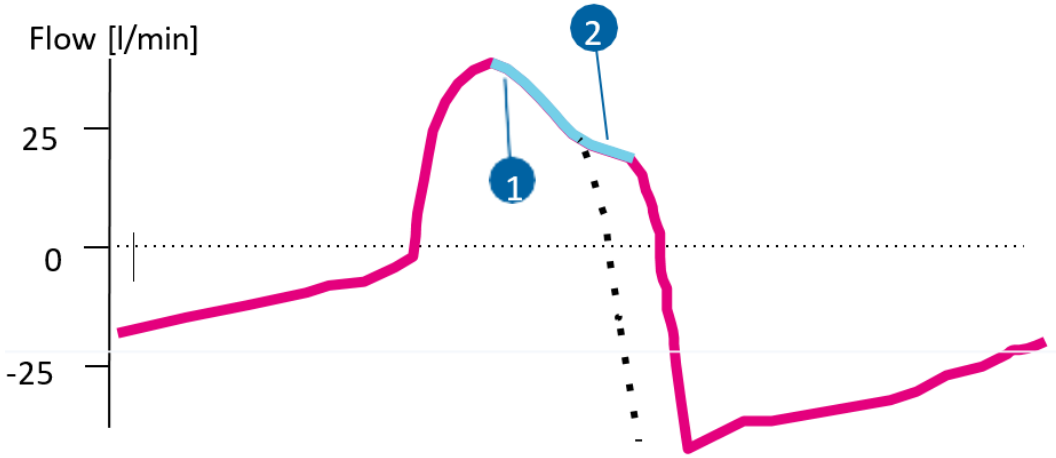
Delayed Cycling

Flow waveform: look for a change in the slope of the inspiratory flow:

- ✓ a fast decrease (1) followed by an exponential (less steep) decline (2)



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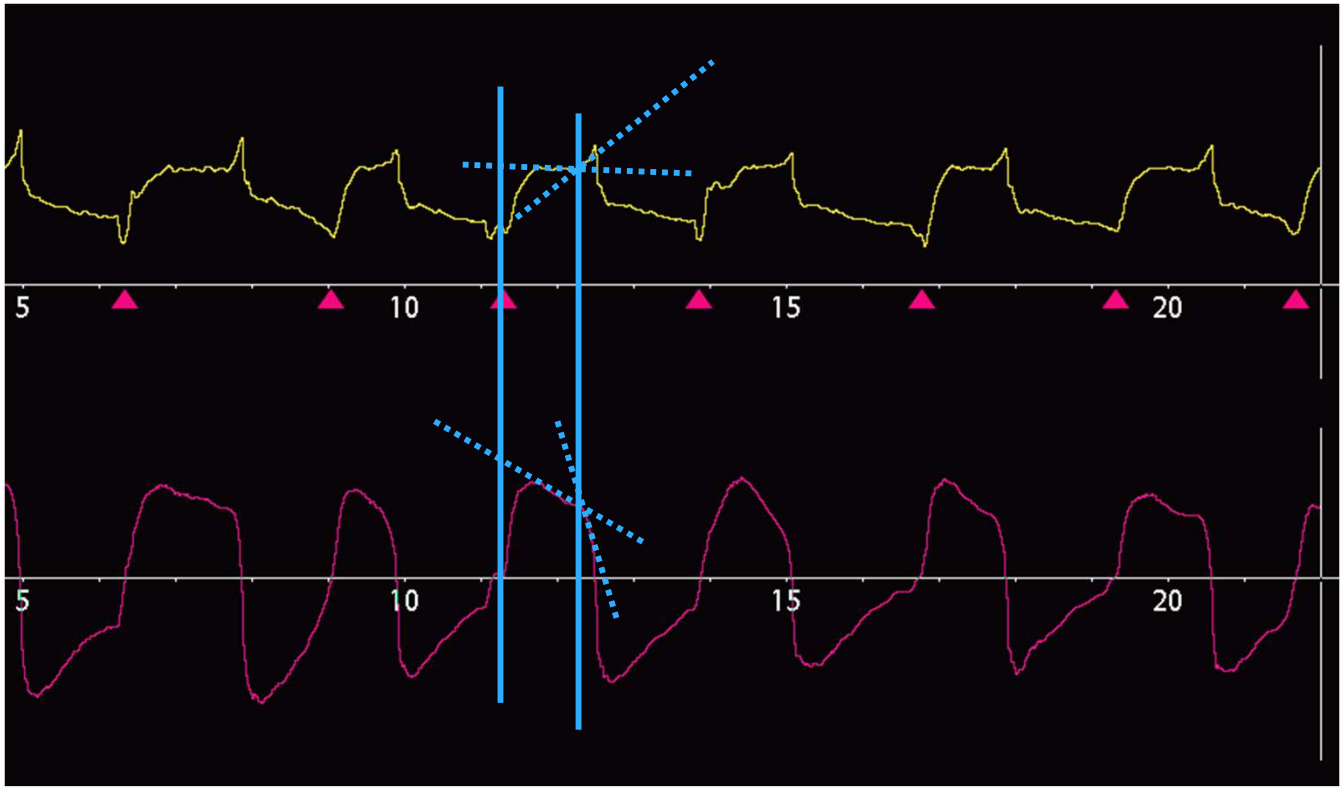
Delayed Cycling



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Delayed Cycling

Delayed Cycling Causes

- ✓ In pressure support ventilation:
  - ✓ Cycling criteria (ETS, Esens%, FlowTerm%, Flowcycle) set too low
  - ✓ Pressure support too high
  - ✓ P-ramp/Rise Time/Slope too long
- ✓ In pressure control ventilation:
  - ✓ I-time too long
- ✓ In volume control ventilation:
  - ✓ Low flow
  - ✓ Inspiratory time too long
  - ✓ High tidal volume

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Delayed Cycling Resolutions:

In pressure support ventilation:

- ✓ Raise Cycling criteria (ETS, Esens%, FlowTerm%, Flowcycle)
- ✓ Reduce Pressure support
- ✓ Reduce (P-ramp, Rise Time, Slope)

In pressure control ventilation:

- ✓ Shorten inspiratory time

In volume control ventilation:

- ✓ Increase flow
- ✓ Decrease inspiratory time
- ✓ Reduce Vt

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Lets See what you Learned?

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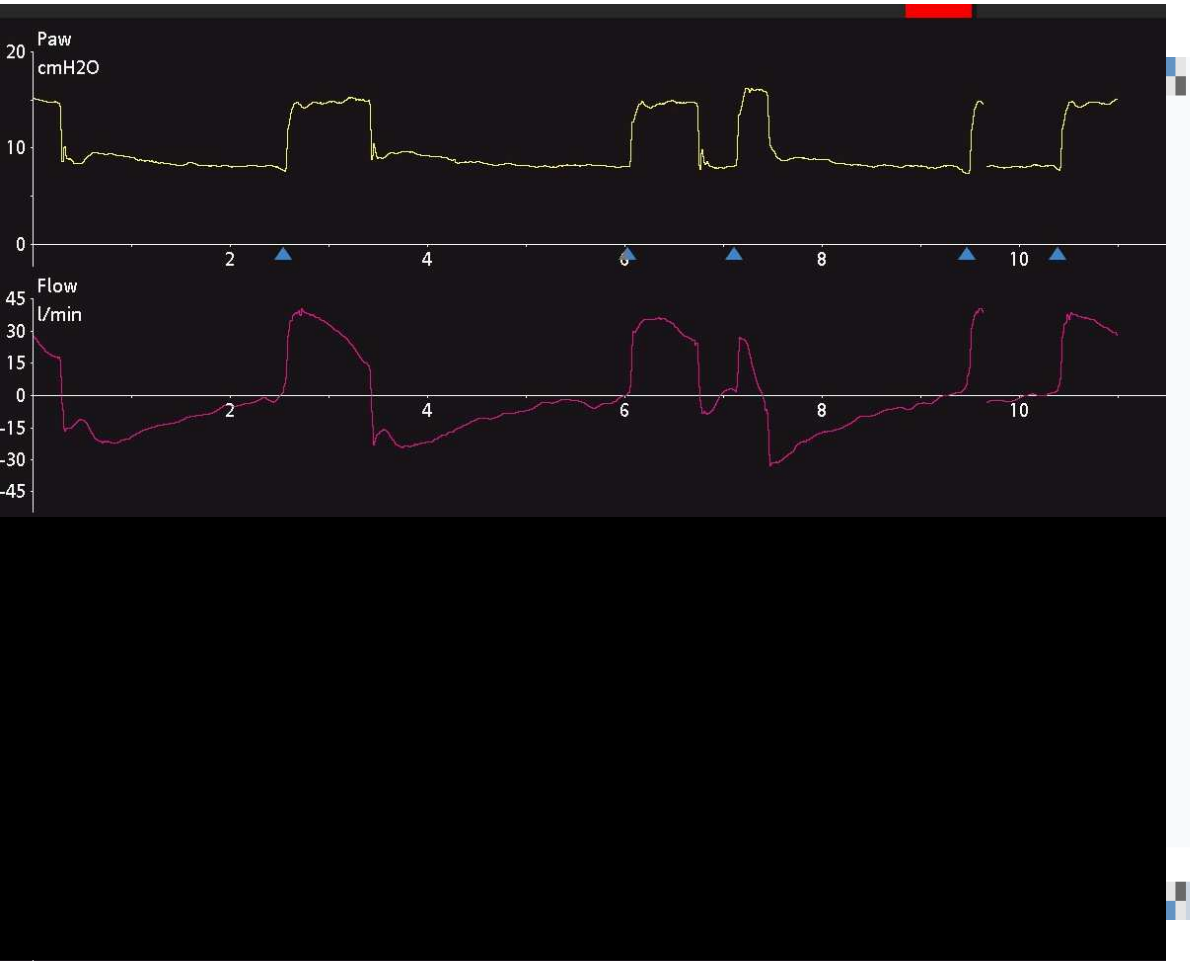

What is going on here? (Round 2)

A. Flow Starvation

B. Delayed Cycling

C. Double Trigger

D. Reverse Trigger

E. I have no clue!

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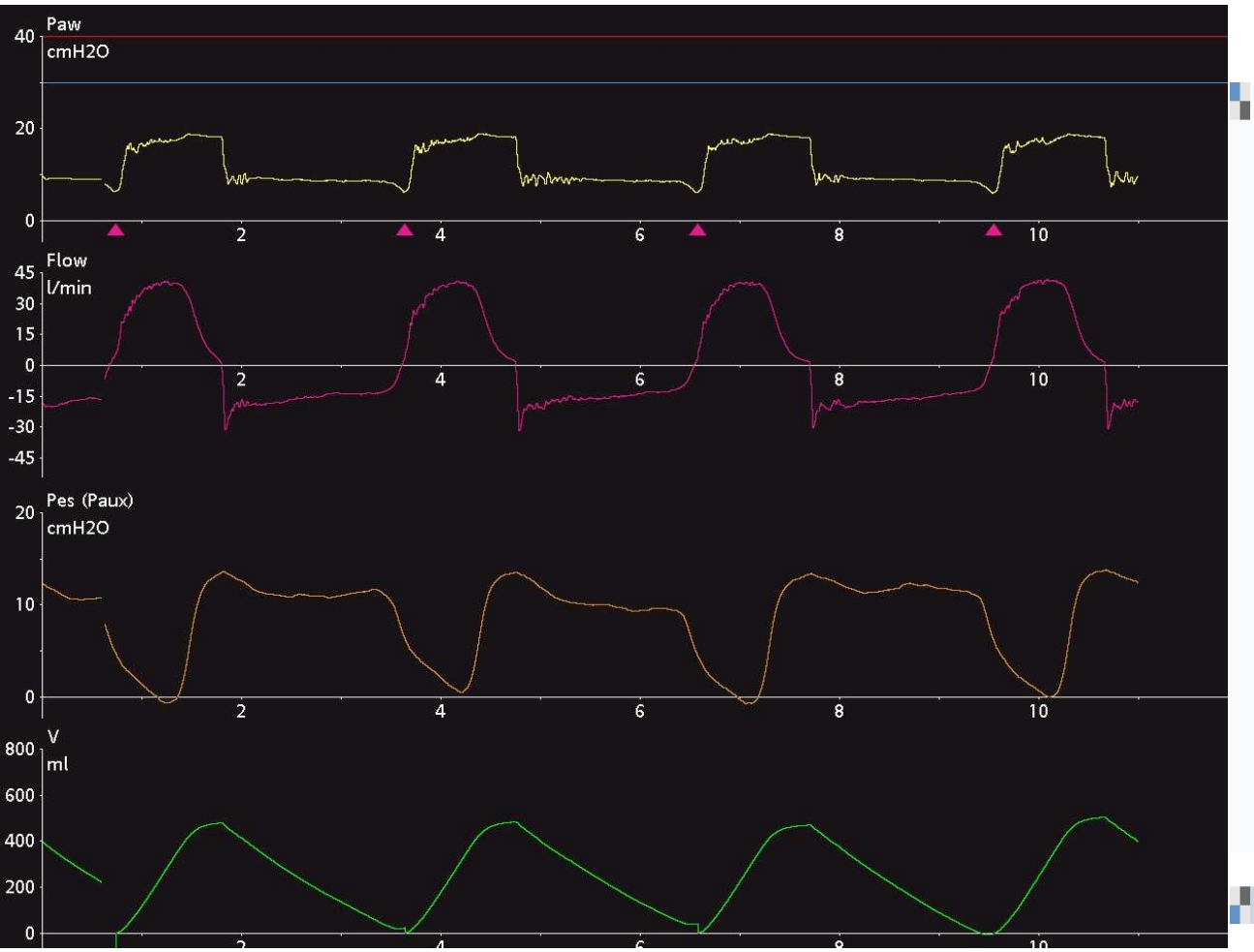

What is happening here?

A. Early Cycling

B. Delayed Cycling

Trick question. Normal Waveform

Flow Starvation

I don't know, can I pass?

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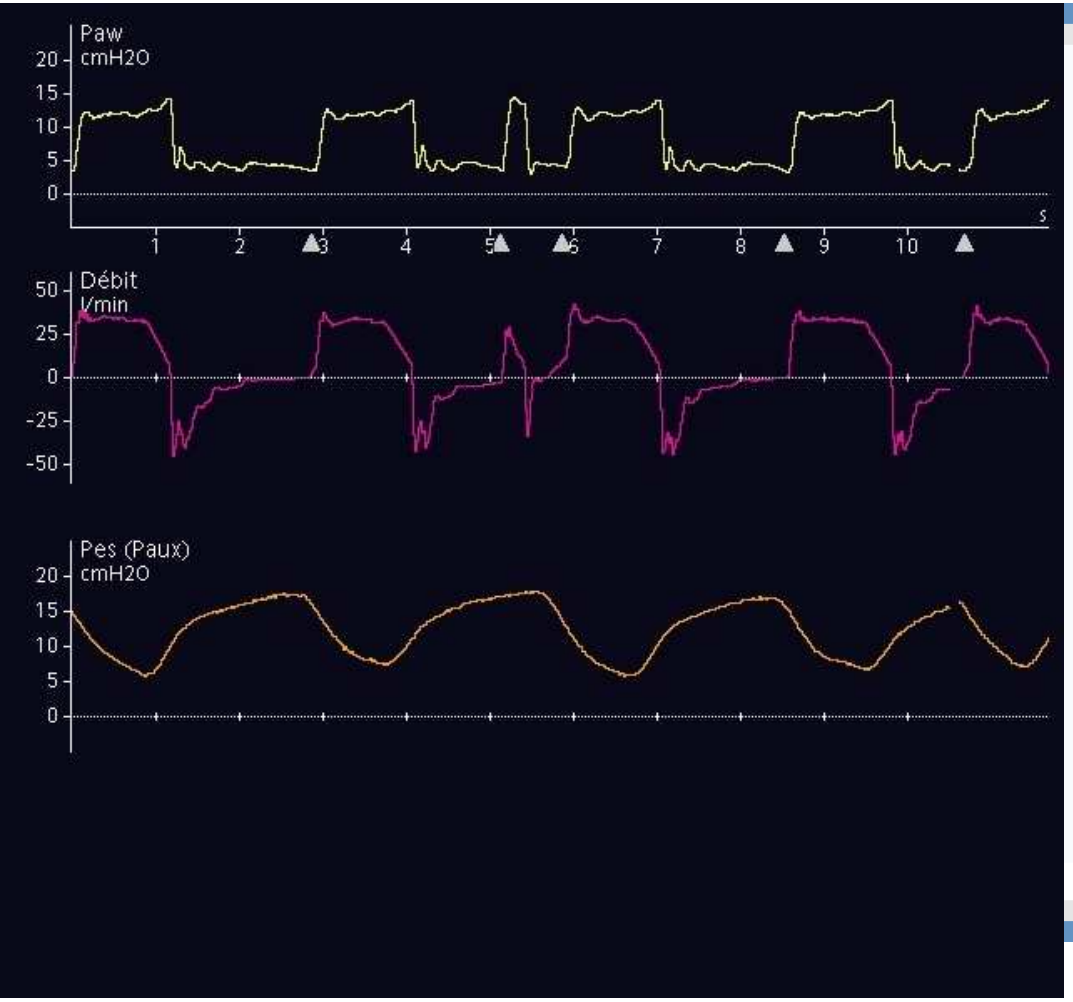


What is going on here? (Round 2)

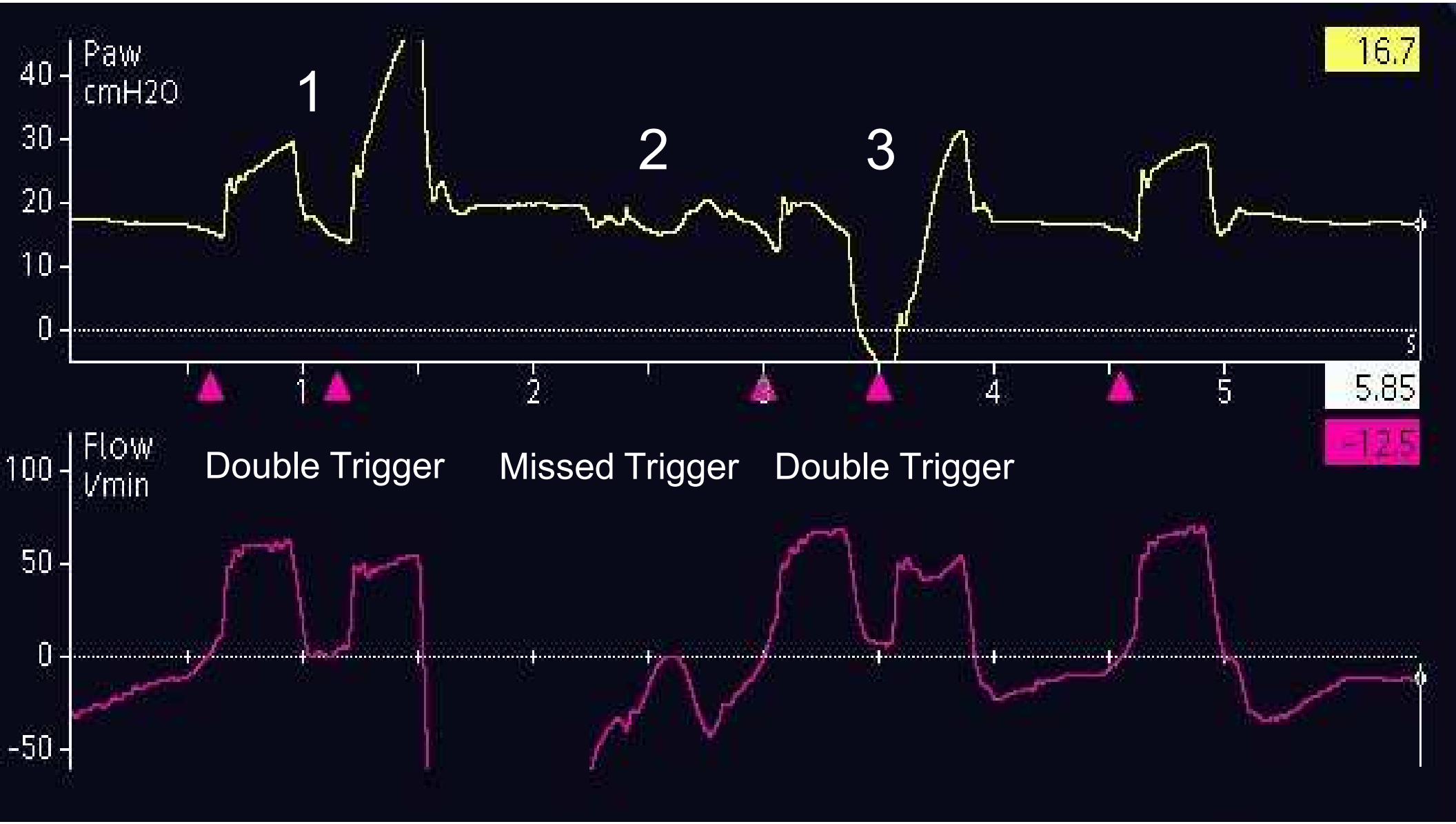
A. Patient Breath

B. Machine Breath

C. Reverse Trigger

D. AutoTrigger

E. I still don't know! I'm out!


Paw
cmH2O
40
30
20
10
0
1
2
3
16.7
5.85
-12.5
Flow
l/min
100
50
0
-50
Double Trigger
Missed Trigger
Double Trigger

Summary

- ✓ Dysyncrhonies/Asynchronies are common
- ✓ Ineffective effort and double trigger most common
- ✓ Usually a result of Ventilator/Neural I-time mismatching
- ✓ ..\HMI Asynchrony Reference Card 2019.pdf

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Thank you for your attention!

J. Beno Thompson MSrt, RRT-NPS

Clinical Applications Specialist

Beno.thompson@hamiltonmedical.com

Hamilton Medical AG
Via Crusch 8, 7402 Bonaduz, Switzerland
☎ +41 58 610 10 20
info@hamilton-medical.com
www.hamilton-medical.com

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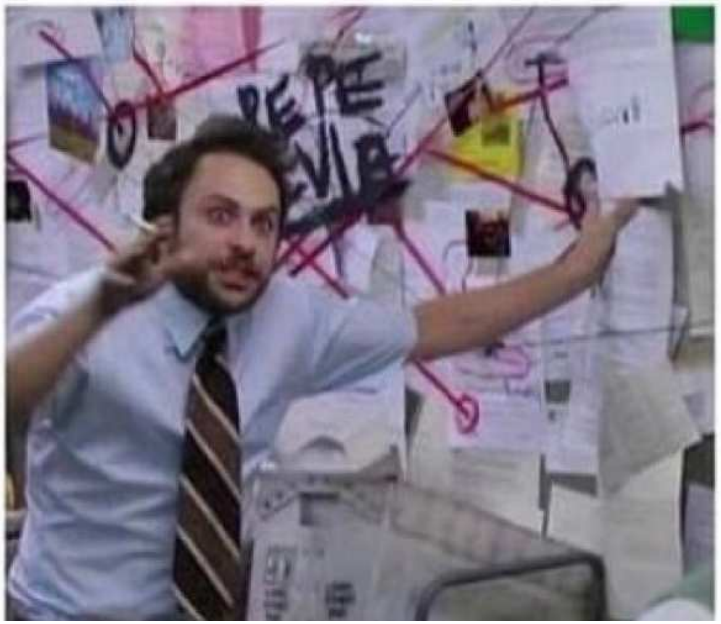
Questions?

What I think I look like talking about Mechanical Ventilation vs what I actually look like



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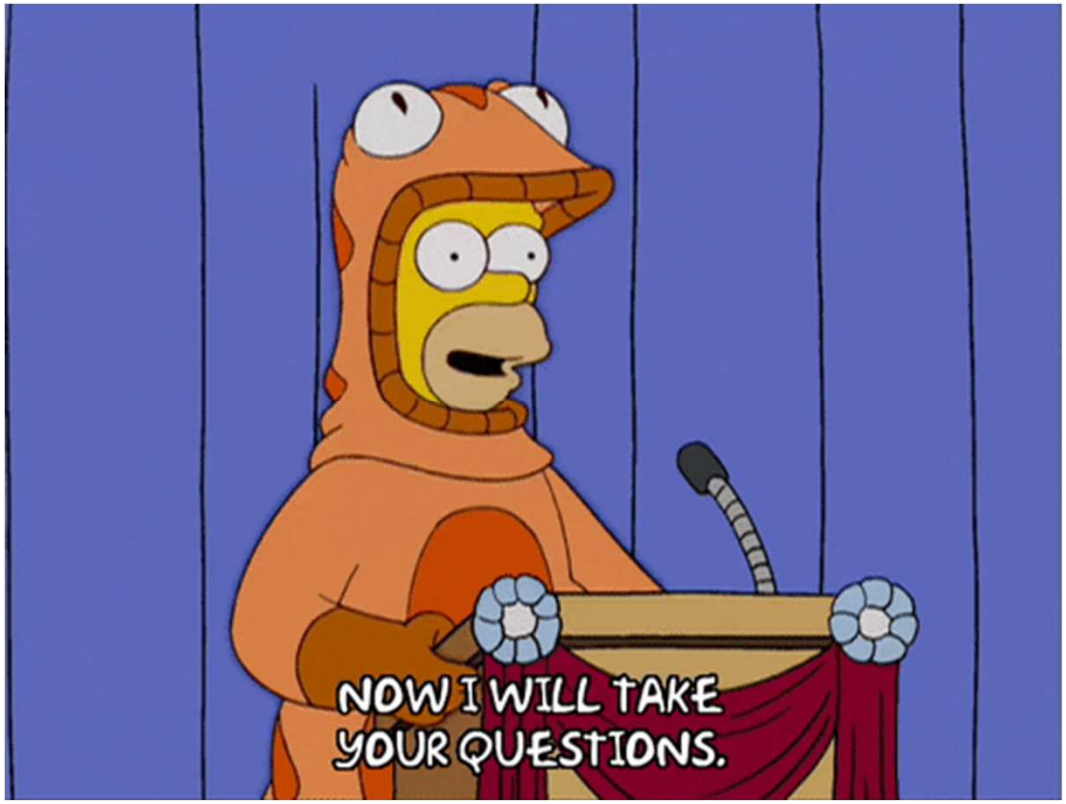
Questions?



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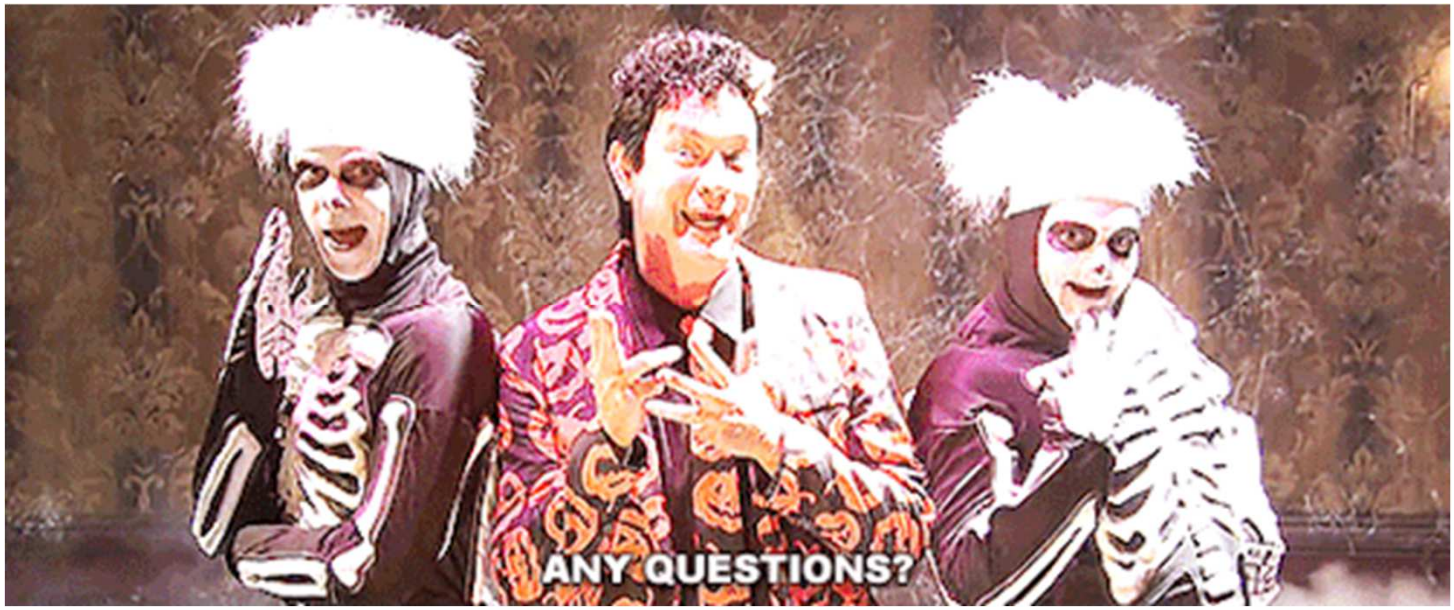
Questions???



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