SEVA™-CrashCourse

Standardized Education for Ventilatory Assistance

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Conflict of Interest

Royalties
- Jones & Bartlett Learning
- Elsevier

Patents
- U.S. Patent 8,550,077

Consulting Agreements
- Ingmar Medical Inc
- Inovytec Medical Solutions Ltd
- Vyaire Medical Inc
- Aires Medical Inc
- Ventis Medical Inc
- ProMedic LLC (for Timpel)
- AutoMedx

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Introduction

SEVA Program

Standardized
Education for
Ventilatory
Assistance

3

What is SEVA?

- **S**tandardized **E**ducation for **V**entilatory **A**ssistance

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What is SEVA?

- **Standardized Education for Ventilatory Assistance**
- **Vision**
  - SEVA is a unique platform for standardizing training by unifying the concepts of, physics, physiology and technology of mechanical ventilation
  - SEVA will provide a globally available program, supported by peer-reviewed articles, to help health care professionals master the skills of mechanical ventilatory support

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  - SEVA will provide a globally available program, supported by peer-reviewed articles, to help health care professionals master the skills of mechanical ventilatory support
- **Mission**
  - SEVA provides a universal and standardized education program in the theory and practice of mechanical ventilation.
  - SEVA uses online and simulation-based instruction that is both self-directed and instructor-led to elevate the competency of health care professionals to a mastery level

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Motivation for SEVA

- **Better understanding of available technology**
  - New ventilators offer new capabilities and challenges

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- **Better application of new ventilators**
  - New modes and new monitoring tools

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  - New modes and new monitoring tools
- **Better communication among caregivers**
  - Clearer orders and charting in Epic
  - More efficient decision making at the bedside
  - Enhanced training for MDs, NPs, and PAs
  - Improved engagement of RCPs in care decisions

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  - Enhanced training for MDs, NPs, and PAs
  - Improved engagement of RCPs in care decisions
- **Better patient outcomes**
  - Shorter duration of ventilation
  - Fewer adverse events

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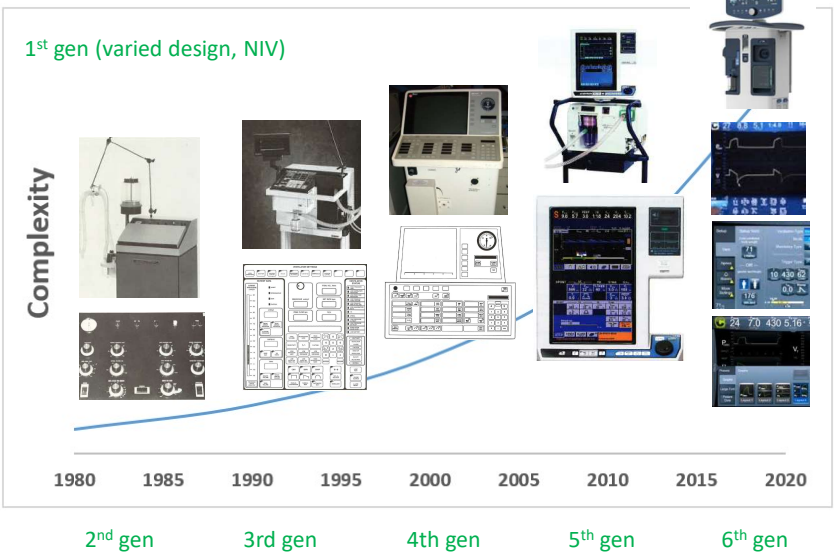
Growth in Ventilator Complexity



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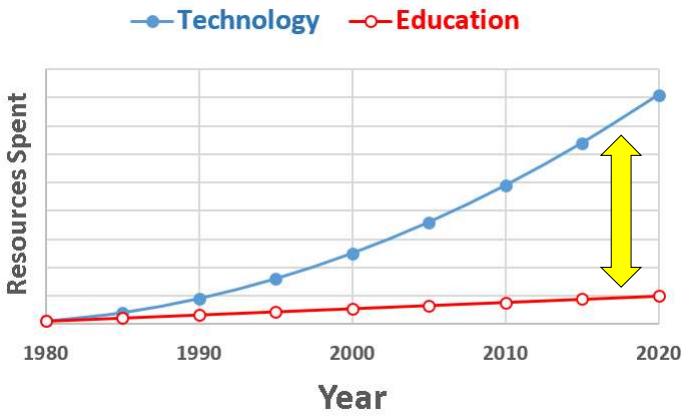
Growing Knowledge Gap



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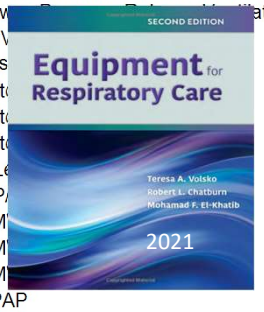
Common Mode Names

AC PCV
Adaptive Flow
Adaptive Support Ventilation
Airw… …ation
APV
Ass
Aut
Aut
Aut
BiL
BiP
CM
CM
CM
CPAP
DuoPAP
Flow Adaptive Volume Control
Mandatory Minute Ventilation
PC-A/C
PCV+



Pressure Control
Pressure Regulated Volume
Pressure Support
Proportional Assist Ventilatio
SIMV

VC-A/C
VC-SIMV
Volume Assured Pressure Support
Volume Augment
Volume Control
Volume Support
VV+SIMV

496 unique modes!

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SEVA Founders

Eduardo Mireles-Cabodevila, MD
Cleveland Clinic
Director Medical Intensive Care Unit
Director Simulation and Advanced Skills Center
Lerner College of Medicine of CWRU
Associate Professor of Medicine

Robert L. Chatburn, MHHS, RRT-NPS, FAARC
Cleveland Clinic
Enterprise Program Manager Respiratory Care Research
Lerner College of Medicine of CWRU
Professor of Medicine

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Landmark Papers Establishing SEVA

Determining the Basis for a Taxonomy of Mechanical Ventilation

Robert L Chatburn MHHS RRT-NPS FAARC, Teresa A Volsko MHHS RRT FAARC, John Hazy PhD, Louis N Harris EdD RRT, and Salvatore Sanders PhD RRT CPFT

RESPIRATORY CARE • APRIL 2012 VOL 57 NO 4

A Taxonomy for Mechanical Ventilation: 10 Fundamental Maxims

Robert L Chatburn MHHS RRT-NPS FAARC, Mohamad El-Khatib PhD MD RRT FAARC, and Eduardo Mireles-Cabodevila MD

RESPIRATORY CARE • NOVEMBER 2014 VOL 59 NO 11

A Rational Framework for Selecting Modes of Ventilation

Eduardo Mireles-Cabodevila MD, Umur Hatipoğlu MD, and Robert L Chatburn MHHS RRT-NPS FAARC

RESPIRATORY CARE • FEBRUARY 2013 VOL 58 NO 2

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All these books have chapters based on SEVA-theory

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SEVA Curriculum Levels

SEVA levels

COURSES	INTRO	ADVANCED	MASTER
SEVA-basic	●	●	●
SEVA-theory		●	●
SEVA-lab		●	●
SEVA-team		●	●
SEVA-sim			●
SEVA-master			●
SEVA VentRounds	5	10	15

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SEVA Curriculum Topics

TOPICS	SEVA Basic	Theory	Lab	Team	Sim	Master	VentRounds
Ventilator Taxonomy	X	XX	XX	XX			X
Waveform anatomy	X	XX		XX			X
How to choose modes	X			XX	XX		
Patient ventilator interactions	X			XXX	XX		X
Knobology and Screenology					XX	X	X
Ventilation of specific clinical conditions					XX		
Application of Modes of ventilation		X			XX	XX	X
Advanced physiological monitoring						XXX	

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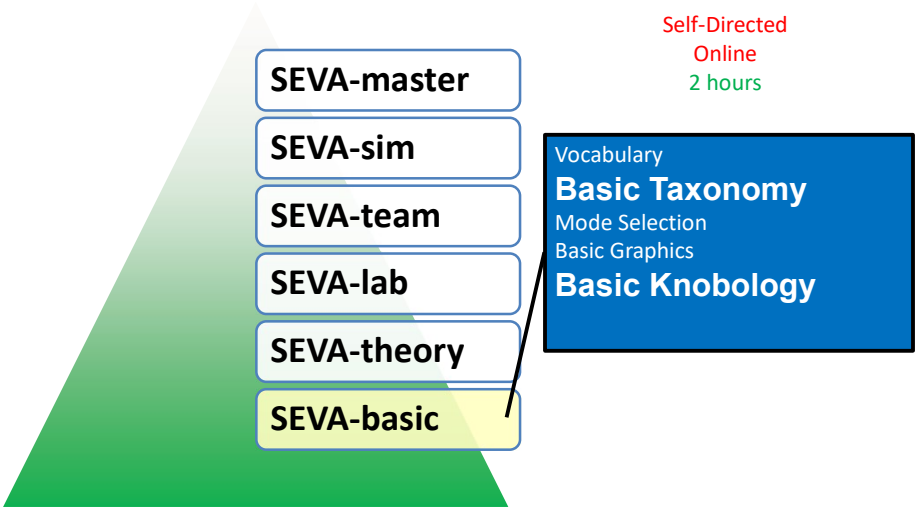
SEVA Curriculum Descriptions



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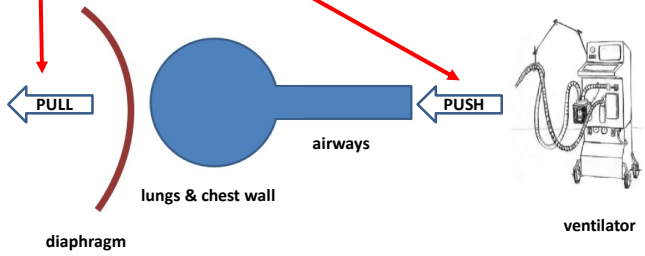
SEVA-basic

$$P_{mus} + P_{vent} = E \times V + R \times \dot{V}$$



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SEVA-basic

- **Taxonomy**
  - A classification system
  - Identifies generic modes (similar to generic vs brand names for drugs)
- **TAG**
  - Abbreviation for mode: Control Variable, Breath Sequence, Targeting Scheme
- **Breath Control Variable**
  - What is pre-set (either pressure or volume/flow)
- **Breath Sequence**
  - Pattern of mandatory vs spontaneous breaths
- **Targeting scheme**
  - Software that achieves pre-set values (targets)

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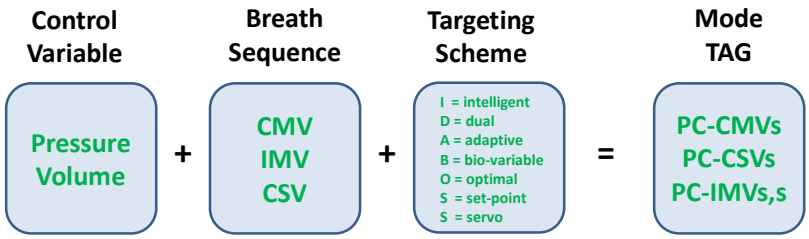
SEVA-basic



All modes have these 3 components

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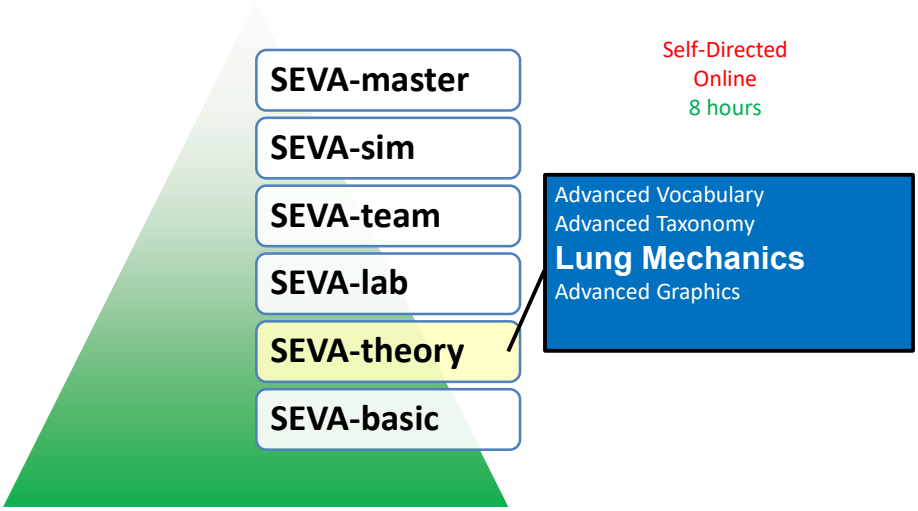
SEVA Curriculum Descriptions



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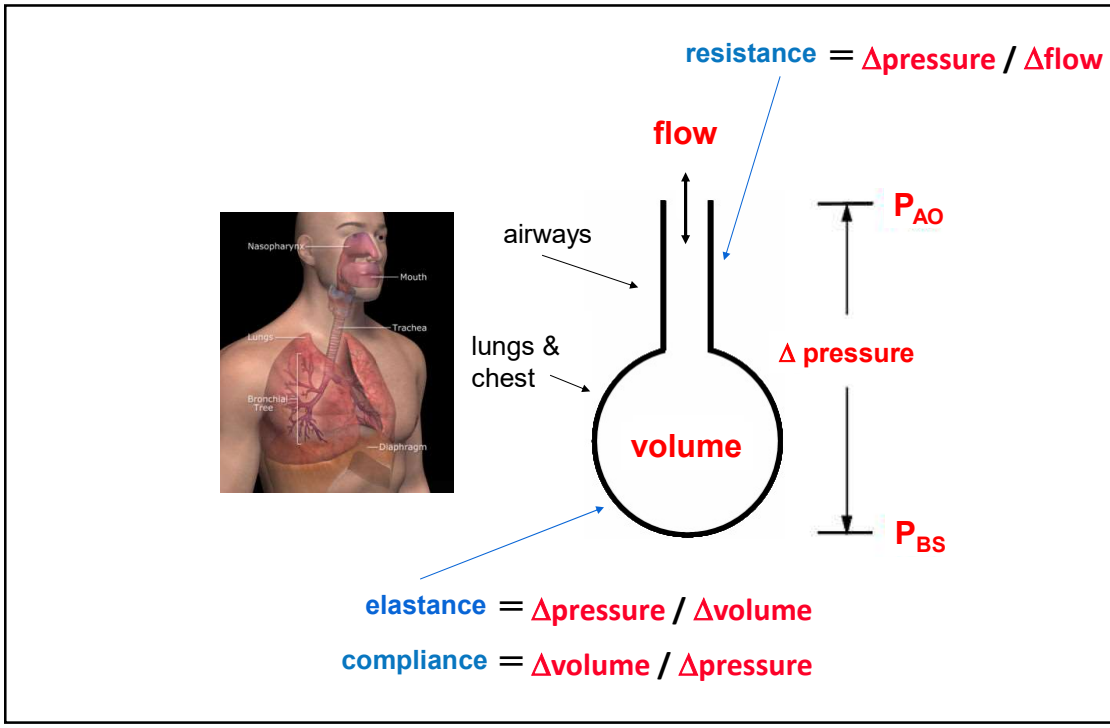

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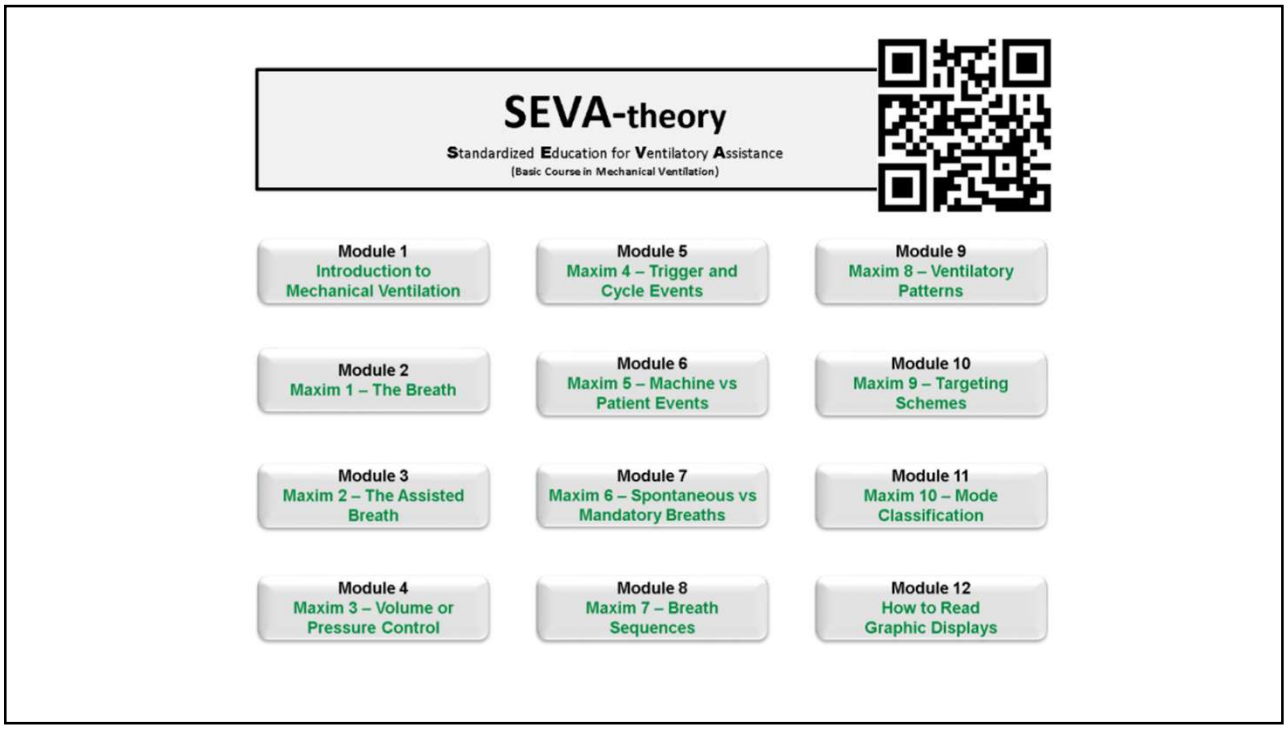

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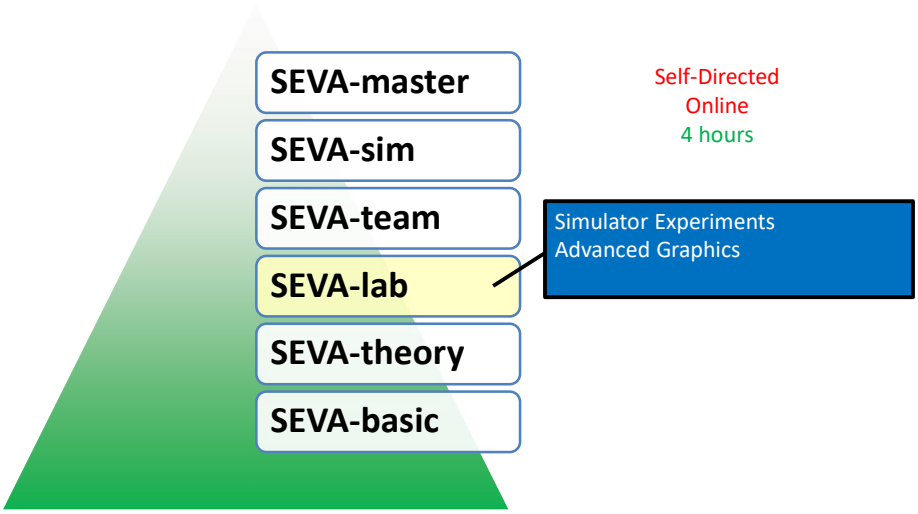
SEVA Curriculum Descriptions



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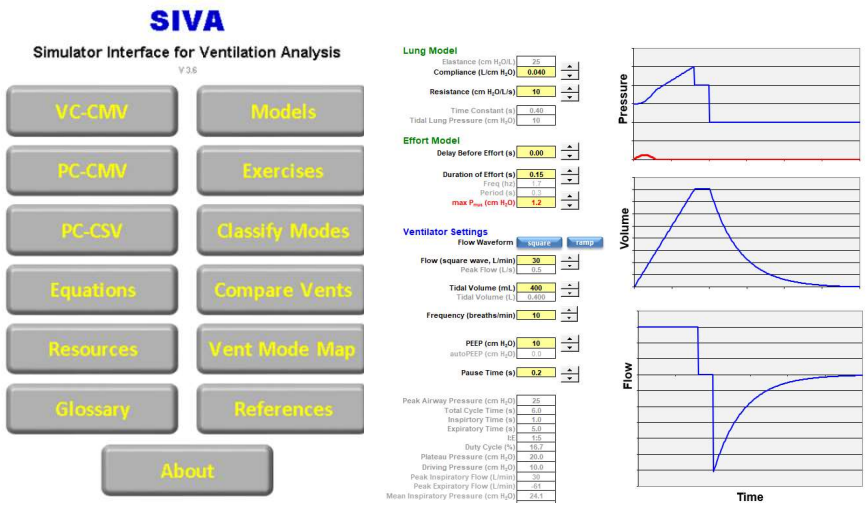
Course tool: Patient-vent simulator



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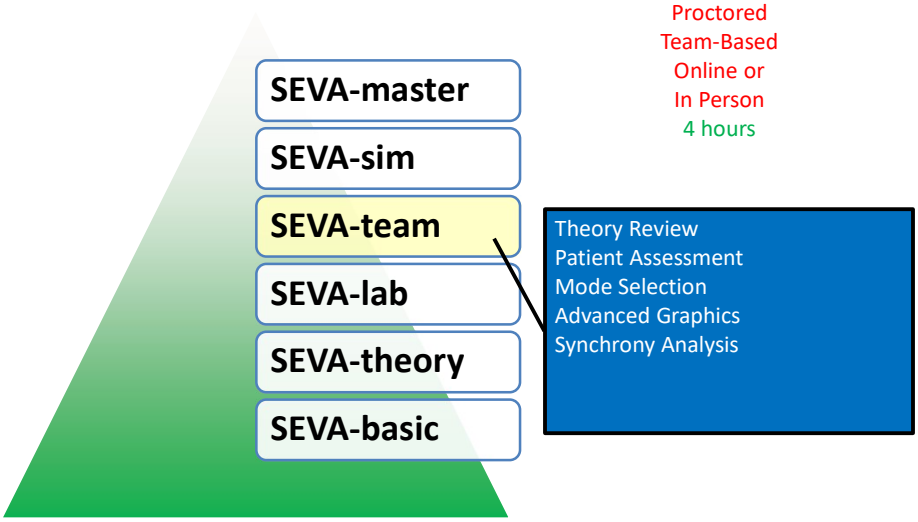
SEVA Curriculum Descriptions



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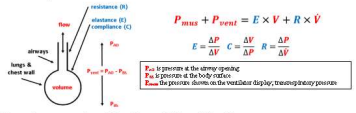
SEVA-team Workbook

- Review of theory

The Equation of Motion



$$P_{mus} + P_{vent} = E \times V + R \times \dot{V}$$

$$E = \frac{\Delta P}{\Delta V} \quad C = \frac{\Delta V}{\Delta P} \quad R = \frac{\Delta P}{\Delta V}$$

P_{ao} is pressure at the airway opening
P_{bs} is pressure at the body surface
P_{mus} the pressure shown on the ventilator display, transrespiratory pressure

Anatomy of a Mode of Ventilation

1. The Control Variable (the variable in the equation of motion that the ventilator controls during inspiration)
   a. Volume Control means that tidal volume and inspiratory flow are preset
      i. *Volume and flow are independent variables, pressure is dependent on elastance, resistance, and inspiratory effort (if present)*
   b. Pressure Control means that inspiratory pressure is preset or proportional to inspiratory effort
      i. *Pressure is the independent variable, volume and flow are dependent on elastance, resistance, and inspiratory effort (if present)*
2. The Breath Sequence is a sequence of mandatory and spontaneous breaths
   a. Spontaneous Breath: inspiration is both triggered (starts it) and cycled (stopped) by the patient
   b. Mandatory Breath: inspiration is triggered or cycled by the machine independent of the patient
      - CMV = [illegible] mandatory ventilation • spontaneous breath: an effort (event: patient) triggers a breath
      - IMV = intermittent mandatory ventilation • spontaneous breath: an effort (event: patient) triggers a breath
      - CSV = [illegible] mandatory ventilation • all breaths are spontaneous
3. The Targeting Scheme: The way the ventilator interacts with the patient. It is preprogrammed by the manufacturer. We enter all or some of the targets.
   a. Set-point (s): all targets are set by the operator (most basic, we set the volume and flow, or we set pressure)
   b. Dual (d): ventilator switches between volume controlled pressure control within a breath (for safety)
   c. Bio-variable (b): ventilator randomly varies tidal volume or pressure (to simulate natural breathing)
   d. Servo (r): inspiratory pressure is proportional to inspiratory effort (to allow synchrony and balanced work)
   e. Adaptive (a): ventilator adjusts one target (eg. pressure) to maintain an operator-set target (eg. average tidal volume)
   f. Optimal (o): ventilator adjusts targets to maximize or minimize some desired function (eg. tidal volume)
   g. Intelligent (i): ventilator adjusts targets using tools of artificial intelligence (eg. rule based expert systems)

TAG

Volume Assist/Control

1. Operator sets tidal volume and inspiratory flow: volume control (VC)
2. Patient efforts generate volume (machine) cycled inspirations: continuous mandatory ventilation (CMV)
3. All targets are operator set: set point (s)

VC-CMVs
- control variable: =
- primary targeting scheme: breath sequence

SIMV Pressure Control

1. Operator sets inspiratory pressure: pressure control (PC)
2. Some breaths are machine cycled (mandatory) and some are both patient triggered and cycled (spontaneous): IMV
3. All targets are operator set: set point (s)
   a. Need to specify targeting scheme for mandatory (primary) and spontaneous (secondary)

PC-IMVs,s
- control variable: =
- secondary targeting scheme
- primary targeting scheme: breath sequence

1

Exercise: Classify Modes

INSTRUCTIONS
1. Follow the instructions on the screen
2. Fill in the blanks
   a. YOU is YOU ALONE
   b. TEAM is after discussion with the TEAM
   c. FINAL ANSWER is what we reveal

	YOU	YOUR TEAM	FINAL ANSWER
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Notes

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SEVA-team

Duration of Ventilation

VC-CMVs | **PC-IMV(1)s,s** | **PC-CSVs**

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SEVA-team (in person)

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SEVA-team (online)

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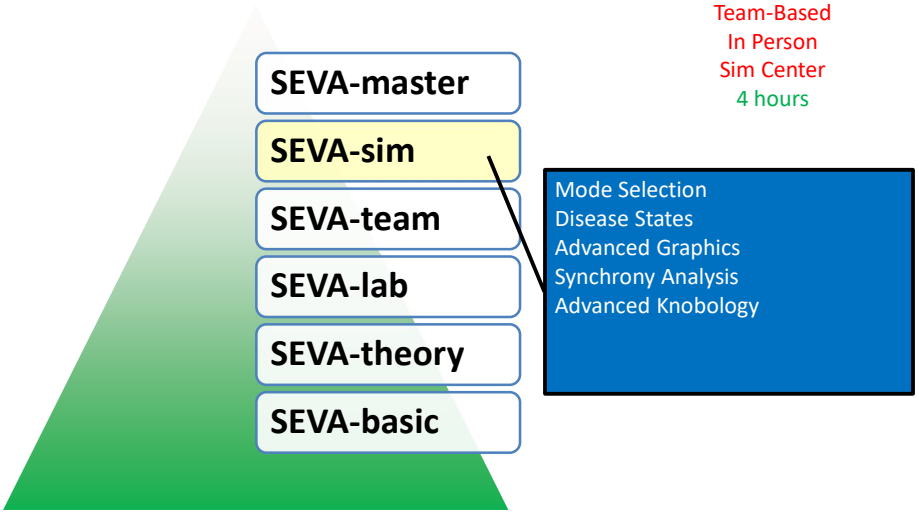
SEVA Curriculum Descriptions



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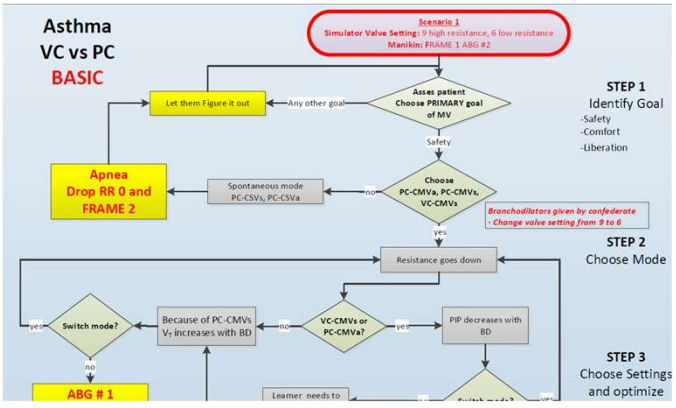
SEVA-sim

- **Awakening from anesthesia**
- ARDS
- **Asthma/COPD**



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SEVA-sim Class

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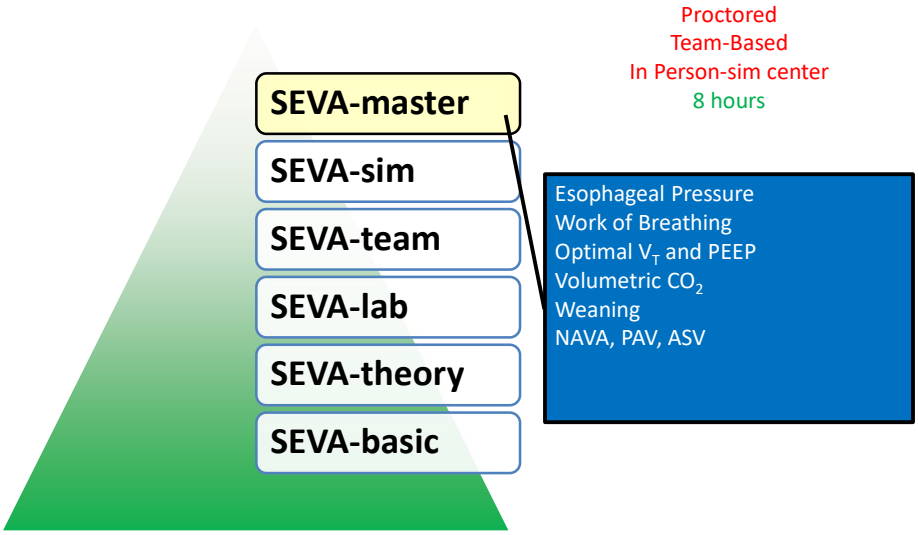
SEVA Curriculum Descriptions



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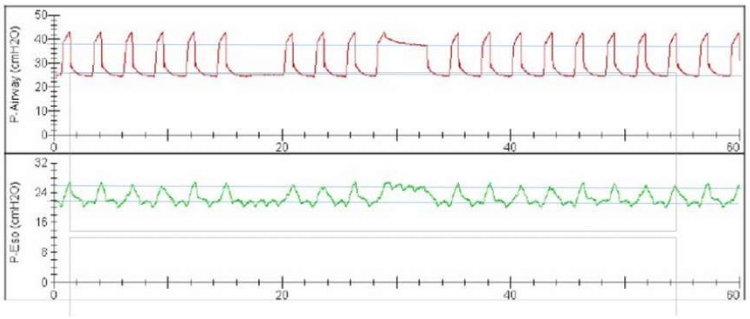
SEVA-master

- **Esophageal pressure monitoring using**
  - **Patient BP monitor adapted for Pes**
  - **Ventilators equipped with Pes capabilities**



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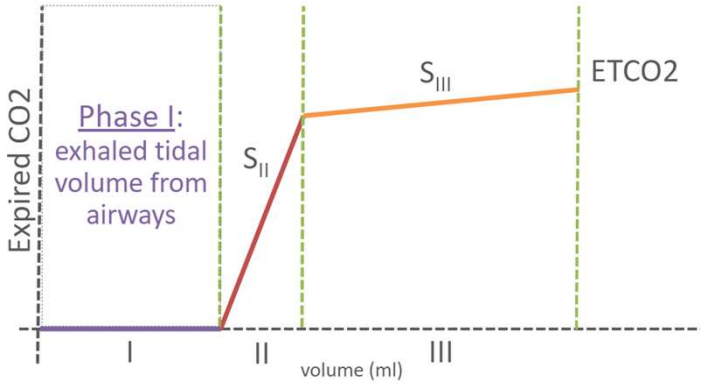
SEVA-master

- Stand-alone and ventilator monitors for volumetric capnography



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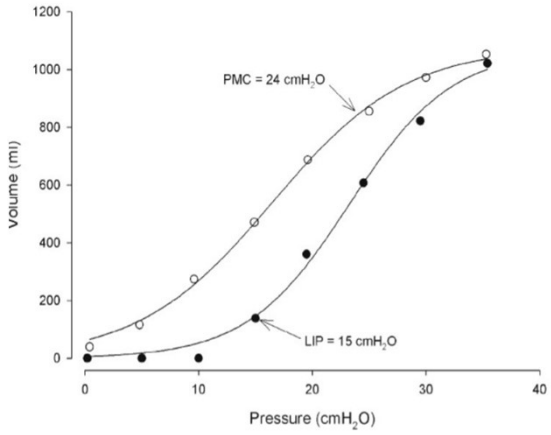
SEVA-master

- **Recruitment maneuver and PV curves**



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Educational Aspects

1. SEVA-basic
   - Required for all RTs working ICUs
   - 2 CEUs
2. SEVA-theory
   - Optional for staff, required for Fellows, Clin Specs
   - 8 CEUs
3. SEVA-lab
   - Optional for staff, required for Fellows, Clin Specs
   - 4 CEUs
4. SEVA-team
   - Optional for staff, required for Fellows, Clin Specs
5. 4 CEUs SEVA-sim
   - Optional for staff, required for Fellows, Clin Specs
   - 4 CEUs
6. SEVA-master
   - Optional for staff, required for Fellows, Clin Specs
   - 8 CEUs

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Every other Tuesday 2:00 – 2:30 pm EST

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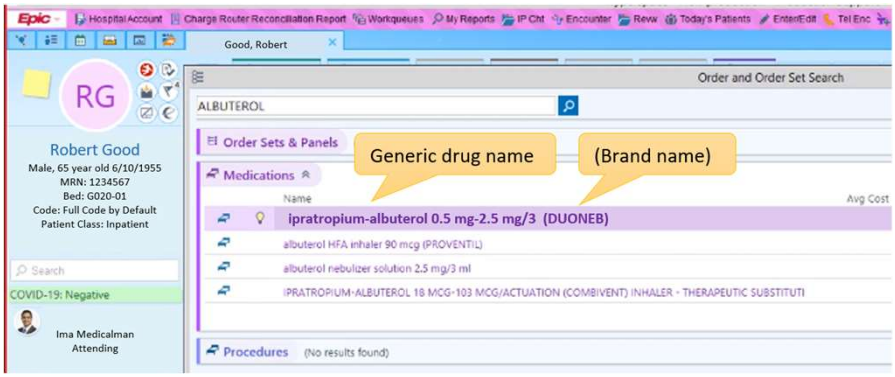
Epic Order Entry Screen for Drugs

- Drug lookup by generic name (brand name)



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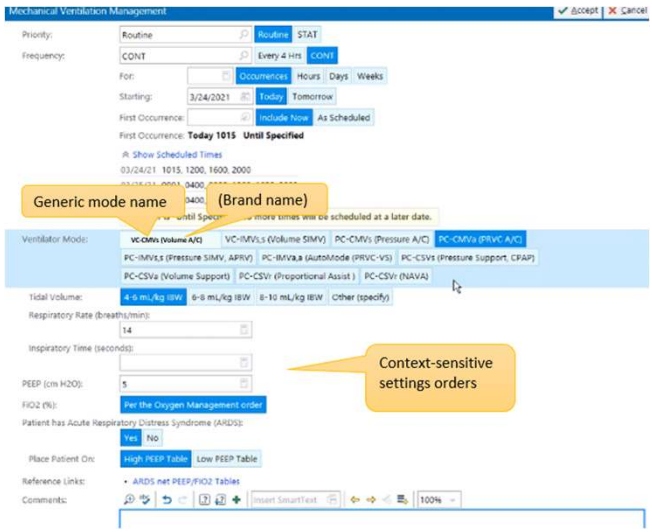
Epic Order Entry for Ventilator Mode

- Vent modes ordered by generic mode name (brand name)



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Epic Order Entry for Ventilator Mode

Standardizing electronic health record ventilation data in the pediatric long-term mechanical ventilator-dependent population

Lara J. Kanbar PhD[1,2] | Judith W. Dexheimer PhD[3] | Janet Zahner BS[4] | Evanette K. Burrows MPH[5] | Robert Chatburn MHHS, RRT-NPS, FAARC[6] | Amanda Messinger MD[7] | Christopher D. Baker MD[7] | Christine L. Schuler MD, MPH[1,8,9] | Dan Benscoter DO[1,3] | Raouf Amin MD[1,9] | Nathan Pajor MD[1,2,9]

Abstract

Background: Sharing data across institutions is critical to improving care for children who are using long-term mechanical ventilation (LTMV). Mechanical ventilation data are complex and poorly standardized. This lack of data standardization is a major barrier to data sharing.

Objective: We aimed to describe current ventilator data in the electronic health record (EHR) and propose a framework for standardizing these data using a common data model (CDM) across multiple populations and sites.

Methods: We focused on a cohort of patients with LTMV dependence who were weaned from mechanical ventilation (MV). We extracted and described relevant EHR ventilation data. We identified the minimum necessary components, termed "Clinical Ideas," to describe MV from time of initiation to liberation. We then utilized existing resources and partnered with informatics collaborators to develop a framework for incorporating Clinical Ideas into the PEDSnet CDM based on the Observational Medical Outcomes Partnership (OMOP).

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Phone App

Ventilator Mode Map for Android and iPhone

Ventilator Mode Map
Cleveland Clinic • Medical

Description

This app is designed to implement the taxonomy (classification system) for modes of mechanical ventilation described by Chatburn et al in *Respir Care 2014;59(11):1747-1763.* It has photographs, model names, and manufacturer names for over 35 ventilators. Nearly 300 modes of ventilation are named and classified exactly as described in recent textbooks:

Respiratory Care Equipment *Volsko et al; Jones and Bartlett Learning,2016.*
Respiratory Care Principles and Practice, 3rd edition*, Hess et al; Jones and Bartlett Learning, 2016*
Egan's Fundamentals of Respiratory care 11th edition, *Kacmarek et al; Elsevier (in press)*

With this app you can do:

1. Identify ventilator name and manufact
2. List all mode names on every ventilato
3. Show the classification of any mode
4. Determine which modes are the same
5. List all mode names associated with a

This app is the perfect tool for physician
care workers who need to identify and us

Screen Shots

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Curriculum

SEVA-CrashCourse

Standardized
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Assistance

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Outline

- **The equation of motion (**simplified**)**
- **Taxonomy (**simplified**)**
  - what a TAG is and why we need it
- **Choosing a mode of ventilation based clinical goals**
- **Basic ventilator waveform interpretation**
- **Outline of patient ventilator interactions**

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The Equation of Motion

Basic Model of
Patient-Ventilator Interaction

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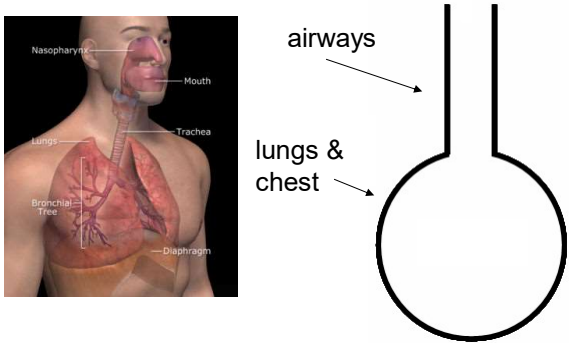

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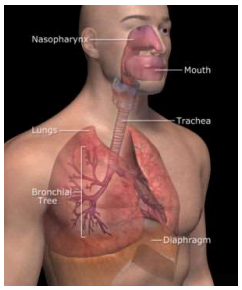

Δ flow

airways

lungs & chest

P_{AO}

Δ pressure

Δ volume

P_{BS}

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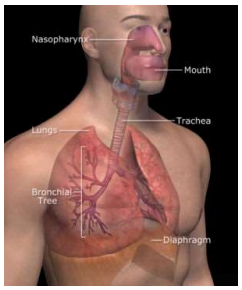
resistance = Δpressure / Δflow



flow

airways

lungs & chest

P_{AO}

Δ pressure

volume

P_{BS}

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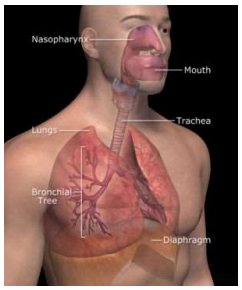

resistance = Δpressure / Δflow

flow

airways

lungs & chest

P_{AO}

Δ pressure

volume

P_{BS}

elastance = Δpressure / Δvolume

compliance = Δvolume / Δpressure

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The Equation of Motion

$$P_{action} = P_{reaction}$$

$$P = P_{elastance} + P_{resistance}$$

elastic load resistive load

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The Equation of Motion

$$P = P_{elastance} + P_{resistance}$$

elastic load resistive load

$$= E \times V + R \times \dot{V}$$

elastance (constant) resistance (constant)

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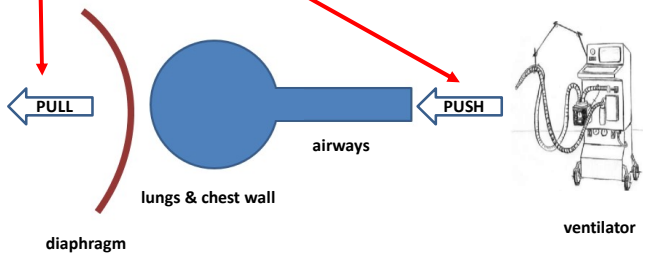
Equation of Motion

$$P_{mus} + P_{vent} = E \times V + R \times \dot{V}$$



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Taxonomy of Modes

Using the Same Vocabulary

https://pubmed.ncbi.nlm.nih.gov/25118309/

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Why Use a Mode Taxonomy?

- **Over 500 unique names of modes on US ventilators alone**

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Why Use a Mode Taxonomy?

- **Over 500 unique names of modes on US ventilators alone**
- **Same need as for generic drug names in pharmacology**
  - Improve communication
  - Improve patient safety
  - Improve patient care through better use of technology

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Why Use a Mode Taxonomy?

- **Over 500 unique names of modes on US ventilators alone**
- **Same need as for generic drug names in pharmacology**
  - Improve communication
  - Improve patient safety
  - Improve patient care through better use of technology
- **Taxonomy is essential for ordering modes just like for drugs**
  - Epic now uses mode taxonomy at Cleveland Clinic
  - Other electronic medical record products will follow

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Key Words

- **Taxonomy**
  - A classification system
  - Identifies generic modes (similar to generic vs brand names for drugs)

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  - Abbreviation for mode: Control Variable, Breath Sequence, Targeting Scheme

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  - A classification system
  - Identifies generic modes (similar to generic vs brand names for drugs)
- **TAG**
  - Abbreviation for mode: Control Variable, Breath Sequence, Targeting Scheme
- **Breath Control Variable**
  - What is pre-set (either pressure or volume/flow)

63

Key Words

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  - Identifies generic modes (similar to generic vs brand names for drugs)
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  - What is pre-set (either pressure or volume/flow)
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  - Pattern of mandatory vs spontaneous breaths

64

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  - Identifies generic modes (similar to generic vs brand names for drugs)
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  - Abbreviation for mode: Control Variable, Breath Sequence, Targeting Scheme
- **Breath Control Variable**
  - What is pre-set (either pressure or volume/flow)
- **Breath Sequence**
  - Pattern of mandatory vs spontaneous breaths
- **Targeting scheme**
  - Software that achieves pre-set values (targets)

65

Key Words

- **Target**
  - A parameter set by you or automatically by the ventilator (eg, inspiratory pressure, tidal volume, flow, minute ventilation, SpO_2, $ETCO_2$, etc) that is a goal of the ventilator's targeting scheme

66

Key Words

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- Trigger
  - To start inspiration
    - Initiated by patient or machine

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Key Words

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- Trigger
  - To start inspiration
    - Initiated by patient or machine
- Cycle
  - Top end inspiration
    - Initiated by patient or machine

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Key Words

- **Spontaneous Breath**
  - Inspiration is both patient triggered (started) and patient cycled (ended)

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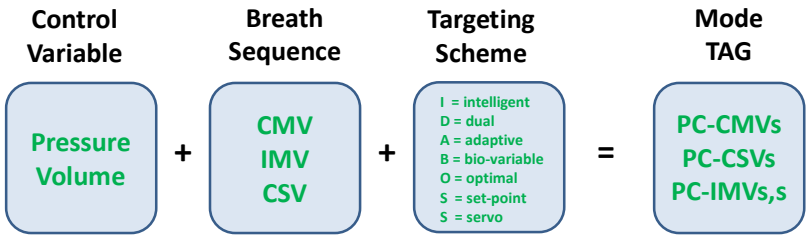
Key Words

- **Spontaneous Breath**
  - Inspiration is both patient triggered (started) and patient cycled (ended)
- **Mandatory Breath**
  - A breath for which inspiration is either machine triggered, or machine cycled (or both)

70

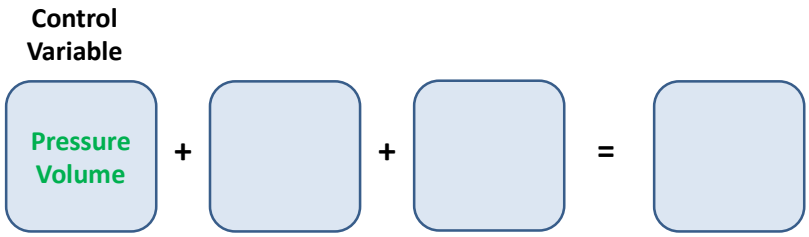
The Components of a Mode of Ventilation



All modes have these 3 components

71

The Components of a Mode of Ventilation



72

Pressure Control Modes

$$\underbrace{P_{vent}}_{\text{pressure control}} = E \times V + R \times \dot{V}$$

- **Preset values**
  - Inspiratory pressure target
    - Constant inspiratory pressure, or
    - Inspiratory pressure is proportional to inspiratory effort
  - Inspiratory time

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Volume Control Modes

$$P_{vent} = \underbrace{E \times V + R \times \dot{V}}_{\text{volume control}}$$

- **Preset values**
  - Inspiratory volume (tidal volume)
  - Inspiratory flow (peak and waveform)

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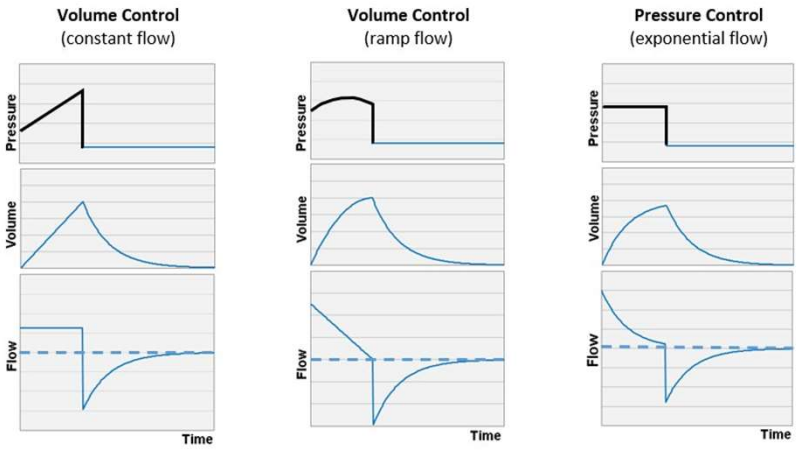
Ideal Waveforms



75

What is a Mode of Ventilation?

Control Variable		Breath Sequence				
Pressure Volume	+	CMV IMV CSV	+		=	

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Key Idea – 4 Kinds of IMV

IMV(1): mandatory rate delivered independent of patient action

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Key Idea – 4 Kinds of IMV

IMV(1): mandatory rate delivered independent of patient action

IMV(2): mandatory breaths suppressed if spontaneous breath rate higher that set mandatory breath rate

78

Key Idea – 4 Kinds of IMV

IMV(1): mandatory rate delivered independent of patient action

IMV(2): mandatory breaths suppressed if spontaneous breath rate higher that set mandatory breath rate

IMV(3): mandatory breaths suppressed if spontaneous minute ventilation higher than set mandatory minute ventilation

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Key Idea – 4 Kinds of IMV

IMV(1): mandatory rate delivered independent of patient action

IMV(2): mandatory breaths suppressed if spontaneous breath rate higher that set mandatory breath rate

IMV(3): mandatory breaths suppressed if spontaneous minute ventilation higher than set mandatory minute ventilation

IMV(4): individual mandatory breaths suppressed if inspiratory effort high enough

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Five Basic Ventilatory Patterns

Control Variable	Breath Sequence	Symbol
Volume	Continuous Mandatory Ventilation	VC-CMV
	Intermittent Mandatory Ventilation	VC-IMV
Pressure	Continuous Mandatory Ventilation	PC-CMV
	Intermittent Mandatory Ventilation	PC-IMV
	Continuous Spontaneous Ventilation	PC-CSV

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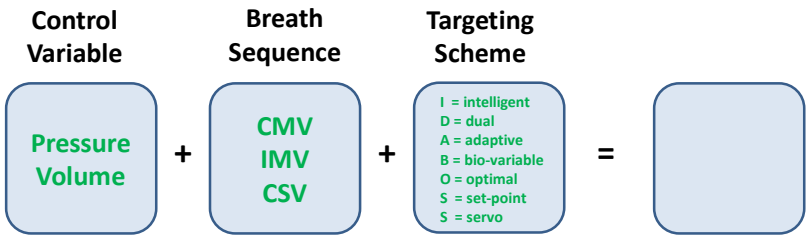
What is a Mode of Ventilation?



82

Targeting Schemes (abbreviations)

1. **Set-point** (s)
   - All targets are operator pre-set
     Example: Volume Assist/Control

83

Targeting Schemes (abbreviations)

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2. **Dual** (d)
   - Ventilator switches between VC and PC
     Example: "flow adaptation" (Servo-U)

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Targeting Schemes (abbreviations)

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   - Ventilator randomly changes inspiratory pressure
     Example: variable pressure support (Dräger V500)

85

Targeting Schemes (abbreviations)

1. **Set-point** (s)
   - All targets are operator pre-set
     Example: Volume Assist/Control
2. **Dual** (d)
   - Ventilator switches between VC and PC
     Example: "flow adaptation" (Servo-U)
3. **Bio-variable** (b)
   - Ventilator randomly changes inspiratory pressure
     Example: variable pressure support (Dräger V500)
4. **Servo** (r)
   - Inspiratory pressure proportional to effort
     Example: NAVA (Servo-U) or PAV+ (PB980)

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Targeting Schemes (abbreviations)

5. **Adaptive** (a)
   - Ventilator adjusts target with changing patient condition
     Example: Pressure Regulated Volume Control (Servo-U)

87

Targeting Schemes (abbreviations)

5. **Adaptive** (a)
   - Ventilator adjusts target with changing patient condition
     Example: Pressure Regulated Volume Control (Servo-U)
6. **Optimal** (o)
   - Ventilator adjusts target to maximize or minimize some desired parameter
     Example: Adaptive Support Ventilation (Hamilton C6)

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Targeting Schemes (abbreviations)

5. **Adaptive** (a)
   - Ventilator adjusts target with changing patient condition
     Example: Pressure Regulated Volume Control (Servo-U)
6. **Optimal** (o)
   - Ventilator adjusts target to maximize or minimize some desired parameter
     Example: Adaptive Support Ventilation (Hamilton C6)
7. **Intelligent** (i)
   - Ventilator adjusts target using artificial intelligence tools
     Example: SmartCare (Dräger V500) or IntelliVent (Hamilton C6)

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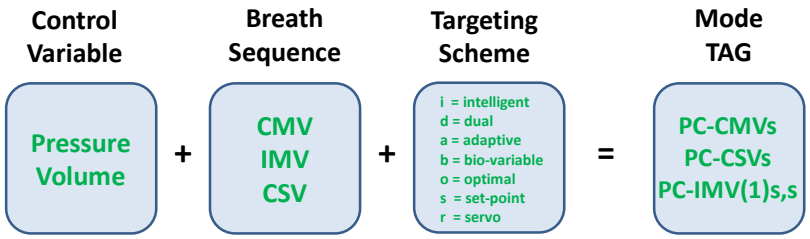
The Components of a Mode of Ventilation



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Choosing the Right Mode

Goals of Mechanical Ventilation

https://pubmed.ncbi.nlm.nih.gov/22710796/

91

What is your Goal?

- **There are only 3 basic goals of mechanical ventilation:**
  - **Safety**
    - ensure adequate gas exchange
    - minimize risk lung injury

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What is your Goal?

- **There are only 3 basic goals of mechanical ventilation:**
  - **Safety**
    - ensure adequate gas exchange
    - minimize risk lung injury
  - **Comfort**
    - maximize patient-ventilator synchrony
    - minimize work shifting (balance work of breathing)

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What is your Goal?

- **There are only 3 basic goals of mechanical ventilation:**
  - **Safety**
    - ensure adequate gas exchange
    - minimize risk lung injury
  - **Comfort**
    - maximize patient-ventilator synchrony
    - minimize work shifting (balance work of breathing)
  - **Liberation**
    - minimize duration of ventilation
    - minimize risk of adverse events

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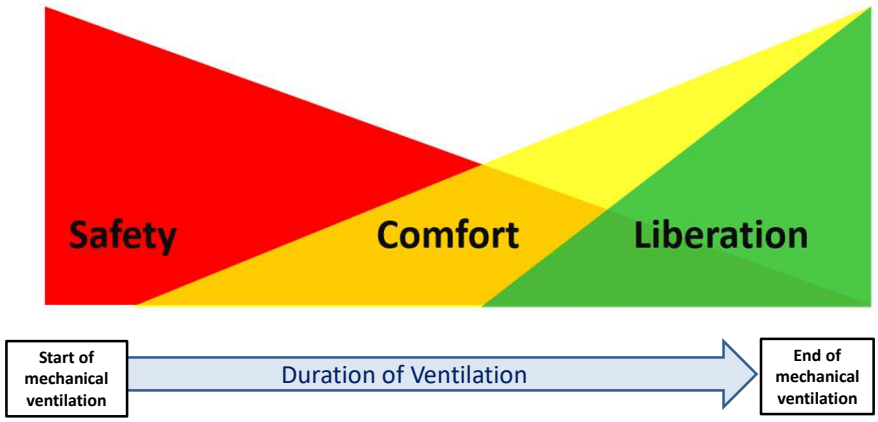
Safety, Comfort *or* Liberation

There can be only one…



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Safety Goal

Clinical Objective

- **Provide adequate gas exchange**
- **Protect the lung**

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Safety Goal

Clinical Objective	Mode Capabilities
• Provide adequate gas exchange	• Manual adjustment rate and V_T targets
• Protect the lung	• Automatic adjustment of pressure to achieve average V_T = target

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Safety Goal

Clinical Objective	Mode Capabilities	Mode Examples
• Provide adequate gas exchange	• Manual adjustment rate and V_T targets	• VC-CMVs – Volume A/C
• Protect the lung	• Automatic adjustment of pressure to achieve average V_T = target	• PC-CMVa – PRVC

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Comfort Goal

Clinical Objective

- **Optimize synchrony**

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Comfort Goal

Clinical Objective

- **Optimize synchrony**

Mode Capabilities

- **Spontaneous breaths allowed**
- **Unrestricted flow**
- **Coordination of mandatory and spontaneous breaths**

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Comfort Goal

Clinical Objective	Mode Capabilities	Mode Examples
• **Optimize synchrony**	• **Spontaneous breaths allowed** • **Unrestricted flow** • **Coordination of mandatory and spontaneous breaths**	• **PS-CSVs** – Pressure Support • **PC-IMV(2)a,a** – Automode (PRVC-VS)

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Comfort Goal

Clinical Objective	Mode Capabilities	Mode Examples
• **Optimize synchrony**	• **Spontaneous breaths allowed** • **Unrestricted flow** • **Coordination of mandatory and spontaneous breaths**	• **PS-CSVs** – Pressure Support • **PC-IMV(2)a,a** – Automode (PRVC-VS)
• **Adequate support of work of breathing**		

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Comfort Goal

Clinical Objective	Mode Capabilities	Mode Examples
• Optimize synchrony	• Spontaneous breaths allowed • Unrestricted flow • Coordination of mandatory and spontaneous breaths	• PS-CSVs – Pressure Support • PC-IMV(2)a,a – Automode (PRVC-VS)
• Adequate support of work of breathing	• Automatic adjustment of support proportional to effort	

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Comfort Goal

Clinical Objective	Mode Capabilities	Mode Examples
• Optimize synchrony	• Spontaneous breaths allowed • Unrestricted flow • Coordination of mandatory and spontaneous breaths	• PS-CSVs – Pressure Support • PC-IMV(2)a,a – Automode (PRVC-VS)
• Adequate support of work of breathing	• Automatic adjustment of support proportional to effort	• PC-CSVr – PAV or NAVA

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Liberation Goal

Clinical Objective

- **Minimize duration of ventilation**
- **Minimize adverse events**

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Liberation Goal

Clinical Objective

- **Minimize duration of ventilation**
- **Minimize adverse events**

Mode Capabilities

- **Automatic reduction of support**
- **Automatic initiation of SBT**
- **Automatic messaging on readiness to breath unassisted**

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Liberation Goal

Clinical Objective	Mode Capabilities	Mode Examples
• **Minimize duration of ventilation** • **Minimize adverse events**	• **Automatic reduction of support** • **Automatic initiation of SBT** • **Automatic messaging on readiness to breath unassisted**	• **PC-CSVa** – Volume Support ? • **PC-CSVi** – Smart Care • **PC-IMVoi,oi** – INTELLiVENT ASV

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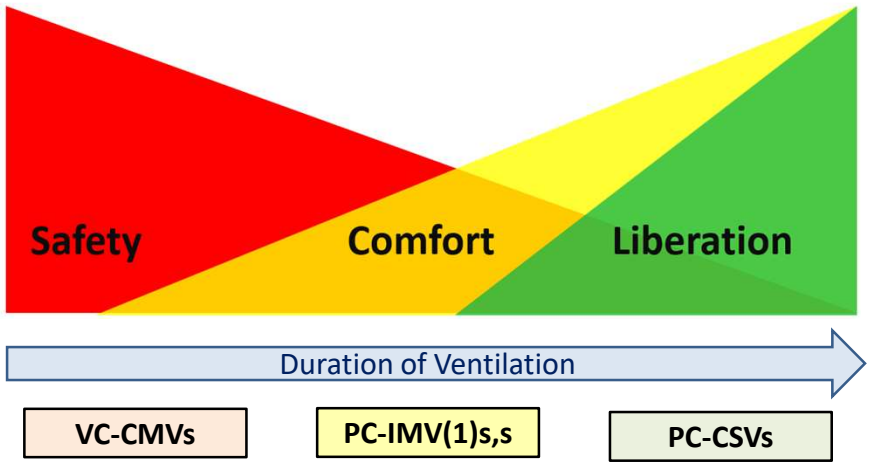
Choose the mode to serve the goal



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Pick Mode Based on Goal and Objectives

	Mandatory Breaths Only			Spontaneous Breaths Only		
CLINICAL OBJECTIVE	PC-CMVs	VC-CMVs	PC-CMVa[1]	PC-CSVs	PC-CSVa[1]	PC-CSVr
Minute Ventilation	unlimited V_T	set rate & V_T	set rate & V_T	uncontrolled MV	uncertain rate	uncertain rate
Prevent VILI	passive only	active & passive	active? & passive	unlimited V_T	active? & passive	unlimited V_T
Synchrony	flow synchrony	flow dyssynchrony	flow synchrony	flow & cycle sync	flow & cycle sync	flow & cycle sync
WOB	WOB sync?	work shifting	work shifting	WOB sync?	work shifting	WOB synchrony
Liberation	no features	no features	auto-wean?	no features	auto-wean?	no features

[1] *contraindicated if increased respiratory drive (eg, metabolic acidosis)*

Green = OK, Yellow = caution, Red = not recommended

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Pick Mode Based on Goal and Objectives

	Mandatory Breaths Only			Spontaneous Breaths Only		
CLINICAL OBJECTIVE	PC-CMVs	VC-CMVs	PC-CMVa[1]	PC-CSVs	PC-CSVa[1]	PC-CSVr
Minute Ventilation	unlimited V_T	set rate & V_T	set rate & V_T	uncontrolled MV	uncertain rate	uncertain rate
Prevent VILI	passive only	active & passive	active? & passive	unlimited V_T	active? & passive	unlimited V_T
Synchrony	flow synchrony	flow dyssynchrony	flow synchrony	flow & cycle sync	flow & cycle sync	flow & cycle sync
WOB	WOB sync?	work shifting	work shifting	WOB sync?	work shifting	WOB synchrony
Liberation	no features	no features	auto-wean?	no features	auto-wean?	no features

[1] *contraindicated if increased respiratory drive (eg, metabolic acidosis)*

Green = OK, Yellow = caution, Red = not recommended

	Mandatory and Spontaneous Breaths					
	VC-IMVs,s		PC-CMVs,s		PC-IMVa,a	
CLINICAL OBJECTIVE	Mandatory	Spontaneous	Mandatory	Spontaneous	Mandatory	Spontaneous
Minute Ventilation	set rate & V_T	MV uncertain	Uncontrolled MV	MV uncertain	set rate & V_T	Uncertain rate
Prevent VILI	Active breaths	No protection	Passive only*	no protection	Active? & passive	Active? & passive
Synchrony	flow & cycle dyssynch	flow/cycle synch	flow synch	flow/cycle synch	flow synch	flow/cycle synch
WOB	Work shifting	WOB-vent constant	WOB synch	WOB-vent constant	Work shifting	Work shifting
Liberation	no features	no features	no features	no features	possible auto-wean	possible auto-wean

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Waveform Analysis

Know the Lingo

https://pubmed.ncbi.nlm.nih.gov/34470804/

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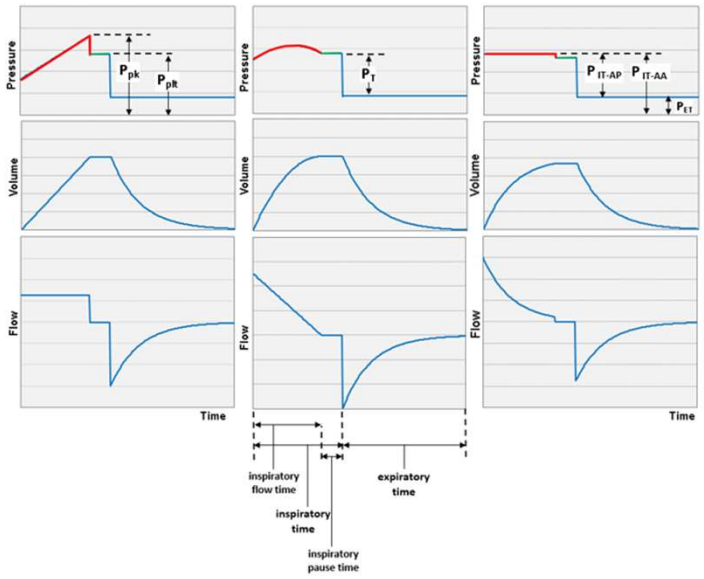
P_{IT-AP} = inspiratory pressure target above PEEP
P_{IT-AA} = inspiratory pressure target above atmospheric pressure
P_{ET} = expiratory pressure target (PEEP)
P_{pk} = peak airway pressure
P_{plt} = plateau pressure
P_T = tidal pressure (aka, driving pressure)

inflation pressure
pause pressure
inspiratory pressure
expiratory pressure
airway pressure



112

Key Terms

- **total-PEEP**
  - Static end-expiratory pressure above atmospheric pressure
    - during expiratory hold maneuver

113

Key Terms

- **total-PEEP**
  - Static end-expiratory pressure above atmospheric pressure
    - during expiratory hold maneuver
- **auto-PEEP or intrinsic PEEP**
  - Static end-expiratory pressure above set PEEP
    - during expiratory hold maneuver

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Key Terms

- **total-PEEP**
  - Static end-expiratory pressure above atmospheric pressure
    - during expiratory hold maneuver
- **auto-PEEP or intrinsic PEEP**
  - Static end-expiratory pressure above set PEEP
    - during expiratory hold maneuver
- **Plateau Pressure**
  - Static end-inspiratory pressure above atmospheric pressure
    - during inspiratory hold maneuver

115

Key Terms

- **total-PEEP**
  - Static end-expiratory pressure above atmospheric pressure
    - during expiratory hold maneuver
- **auto-PEEP or intrinsic PEEP**
  - Static end-expiratory pressure above set PEEP
    - during expiratory hold maneuver
- **Plateau Pressure**
  - Static end-inspiratory pressure above atmospheric pressure
    - during inspiratory hold maneuver
- **Tidal Pressure or Driving Pressure (**E x V_T**)**
  - Static end-inspiratory pressure above total PEEP
    - during inspiratory hold maneuver

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Key Terms

- **Work Shifting**
  - Any $P_{mus} > 0$ results in some work shifting
    - work by vent is shifted to patient

117

Key Terms

- **Work Shifting**
  - Any $P_{mus} > 0$ results in some work shifting
    - work by vent is shifted to patient
  - If $P_{vent} > 0$ then work shifting may be acceptable
    - $P_{aw} >$ PEEP

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Key Terms

- **Work Shifting**
  - ***Any P_{mus} > 0 results in some work shifting***
    - work by vent is shifted to patient
  - ***If P_{vent} > 0 then work shifting may be acceptable***
    - P_{aw} > PEEP
  - ***If P_{vent} < 0 (VC modes) work shifting is inappropriate***
    - P_{aw} < PEEP
    - This is also called flow starvation
    - No mode or setting can fix this
    - May need to sedate and paralyze

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Key Terms

- **Patient-Ventilator Synchrony**
  - P_{vent} and P_{mus} start and end at the same time
  - P_{mus} is the reference signal
  - P_{mus} surrogates
    - esophageal pressure, P_{es}
    - diagphragmatic electromyogram, Edi

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Key Terms

- **Synchrony**
  - P_{vent} and P_{mus} start and end at the same time
  - P_{mus} is the reference signal
- **Asynchrony**
  - Absence of one signal (P_{vent} or P_{mus})
  - Examples:
    - Failed trigger: P_{mus} without P_{vent}
    - False trigger: P_{vent} without P_{mus}

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Key Terms

- **Synchrony**
  - P_{vent} and P_{mus} start and end at the same time
  - P_{mus} is the reference signal
- **Asynchrony**
  - Absence of one signal (P_{vent} or P_{mus})
    - Failed trigger: P_{mus} without P_{vent}
    - False trigger: P_{vent} without P_{mus}
- **Dyssynchrony**
  - P_{vent} and P_{mus} start and end at different times
    - Early trigger or cycle: P_{vent} before P_{mus}
    - Late trigger or cycle: P_{vent} after P_{mus}

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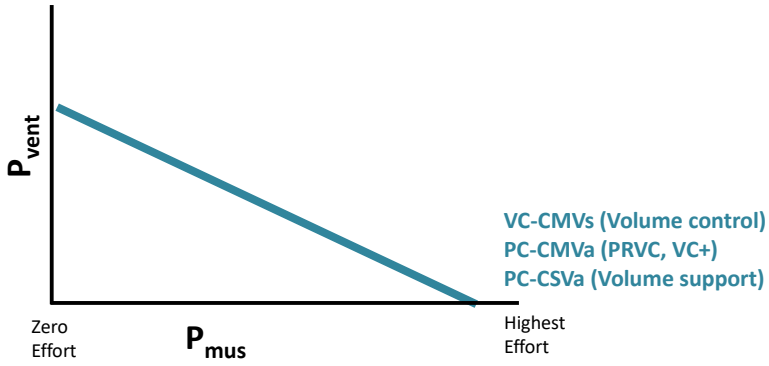
Work Shifting



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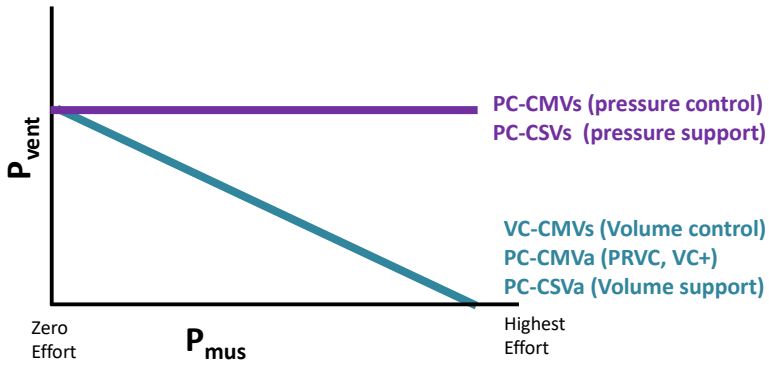
Work Shifting



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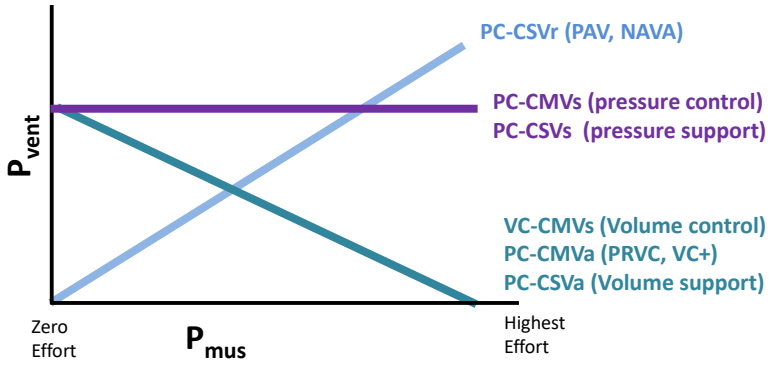
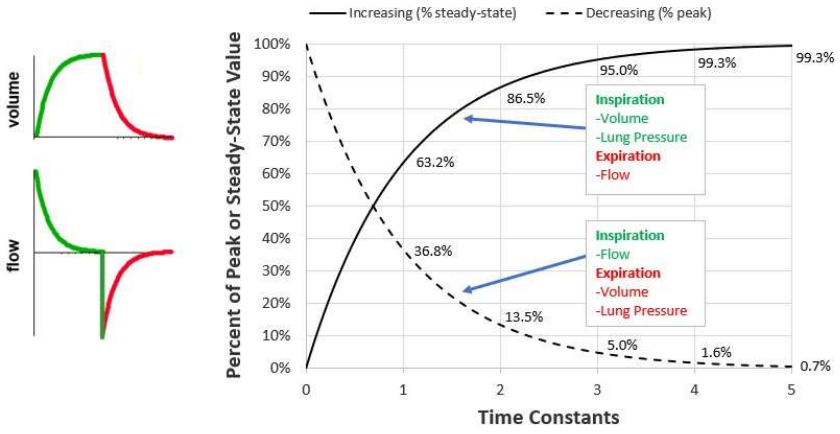
Work Shifting



125

Time Constant

- **Time Constant = Resistance x Compliance** (units: seconds)
  - time to change 63%



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Basic
Waveform Interpretation
Standardized Procedure

https://pubmed.ncbi.nlm.nih.gov/34470804/

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Step 1 – Define the TAG

Standardized Ventilator Waveform Analysis

1. **Define the TAG**

- ☐ PC-CMVs
- ☐ PC-CMVa
- ☐ VC-CMVs
- ☐ VC-CMVd
- ☐ PC-CSVs
- ☐ PC-IMVa,a
- ☐ PC-CSVa
- ☐ PC-CSVr
- ☐ VC-IMVs,s
- ☐ VC-IMVd,d
- ☐ PC-IMVs,s
- ☐ Other_____

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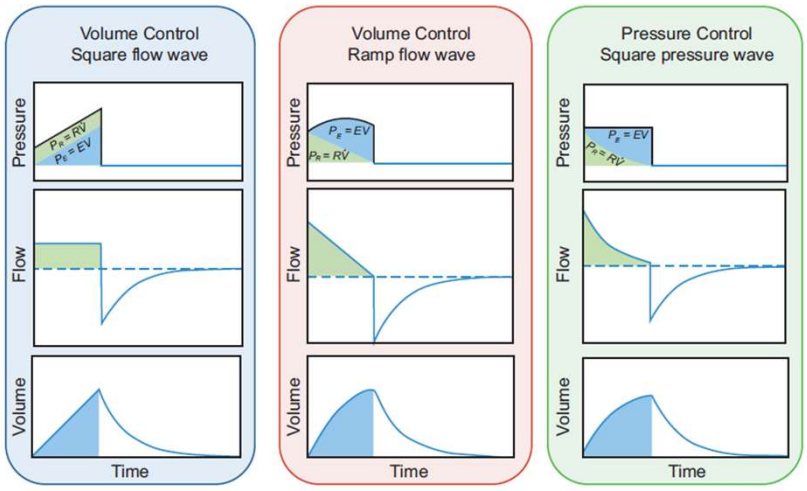
Ideal Waveforms



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Step 2 – Define the Load

2. Define the load

Inspiration	Expiration
☐ Elastic load	☐ Elastic load
☐ Resistive load	☐ Resistive load
☐ P_{mus}	☐ P_{mus}

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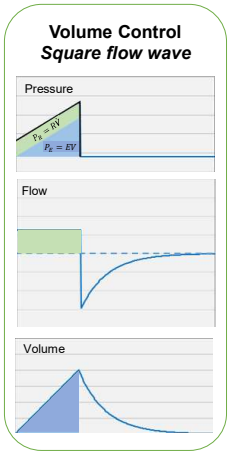
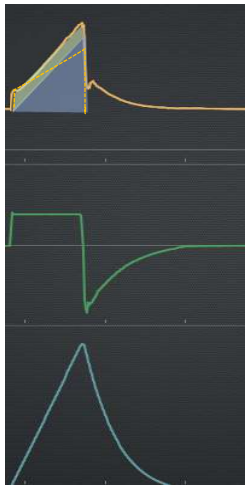
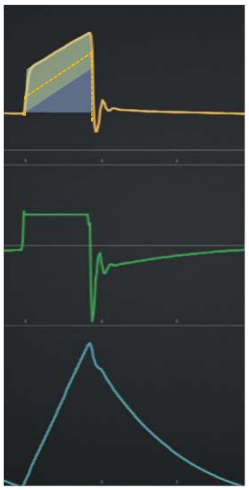
Effects of Increased Loads



Increased Elastic Load



Increased Resistive Load



$$P_{vent} = EV + R\dot{V}$$
$$= P_R + P_E$$

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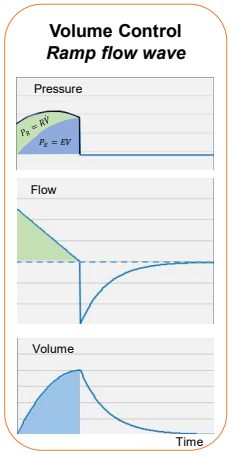
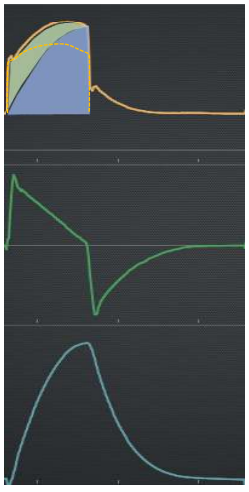
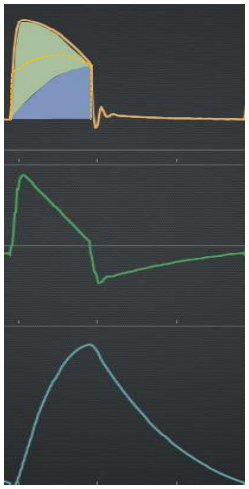
Effects of Increased Loads



Increased Elastic Load



Increased Resistive Load



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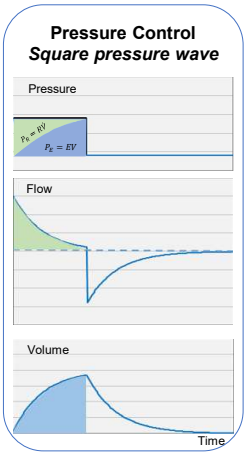
$$= P_R + P_E$$

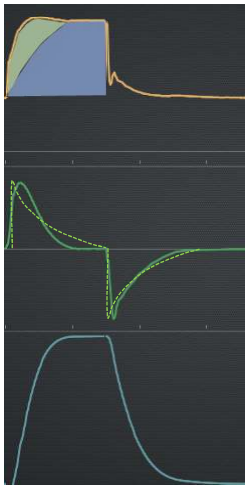
132

Effects of Increased Loads

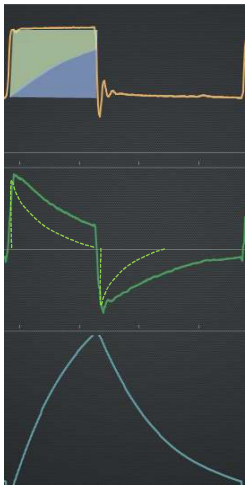


$$P_{vent} = EV + R\dot{V}$$
$$= P_R + P_E$$

Increased Elastic Load



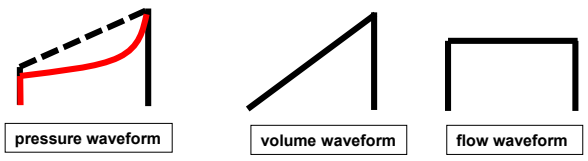
Increased Resistive Load



133

Effects of Insipratory Effort (P_{mus})

$$P_{vent} + P_{mus} = E \times V + R \times \dot{V}$$

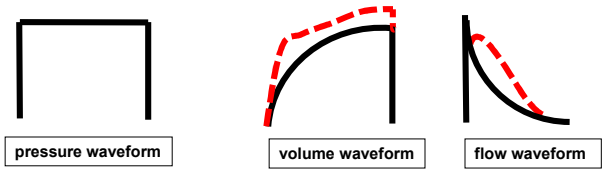


Volume Control
this side preset

134

Effects of Insipratory Effort (P_{mus})

$$P_{vent} + P_{mus} = E \times V + R \times \dot{V}$$



Pressure Control
this side preset

135

Step 3 – Define the PVI

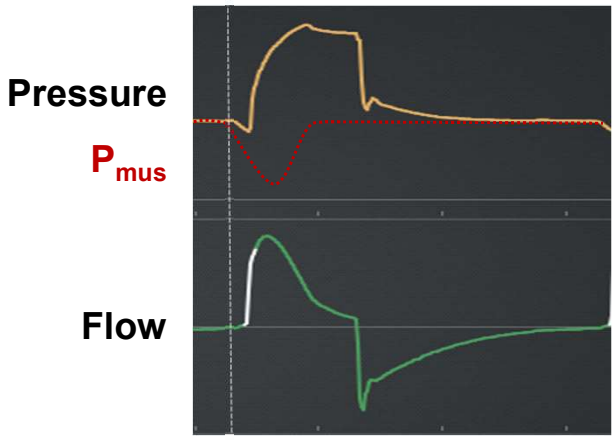
3. Define Patient-Ventilator Interaction

Trigger

- ☐ Normal
- ☐ Early
- ☐ Late
- ☐ False
- ☐ Failed

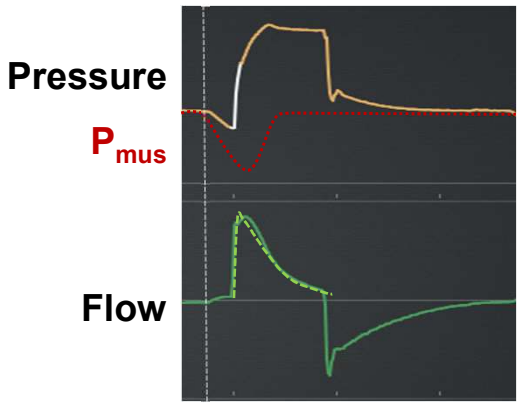
136

Trigger Synchrony - Normal



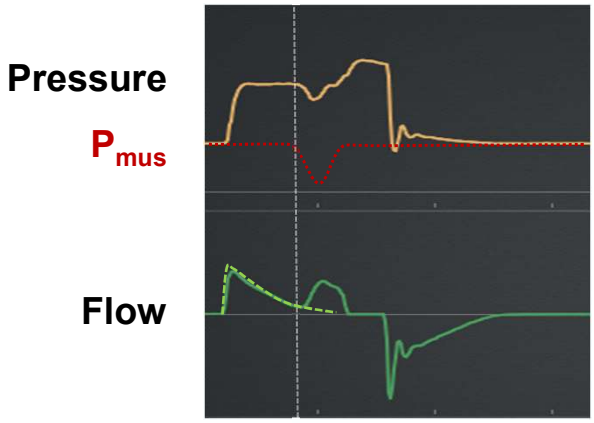
137

Trigger Synchrony - Late



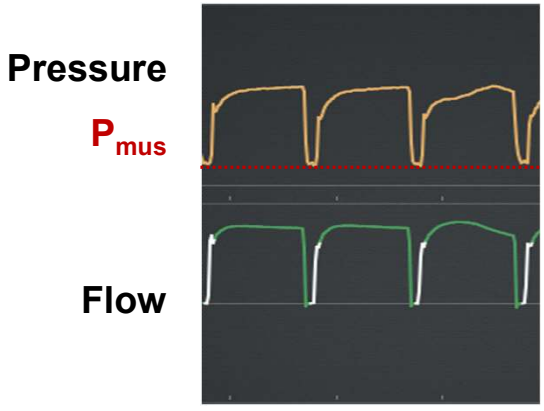
138

Trigger Synchrony - Early



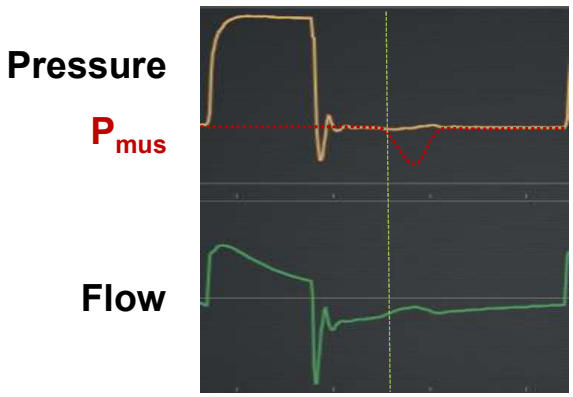
139

Trigger Synchrony - False



140

Trigger Synchrony - Failed



141

Step 3 – Define the PVI

3. Define Patient-Ventilator Interaction

Trigger

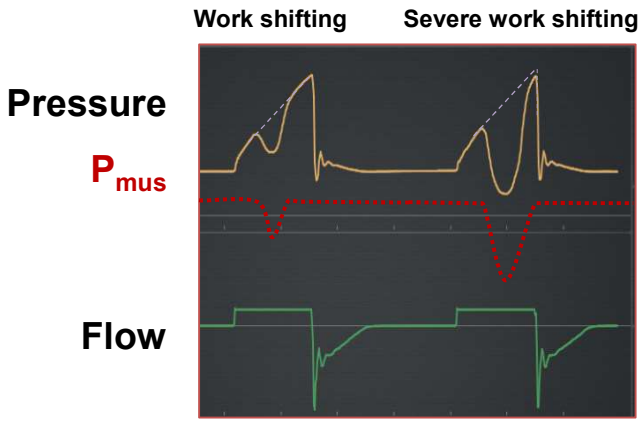
- ☐ Normal
- ☐ Early
- ☐ Late
- ☐ False
- ☐ Failed

Inspiration

- ☐ Normal
- ☐ Work shifting
- ☐ Work shifting, severe

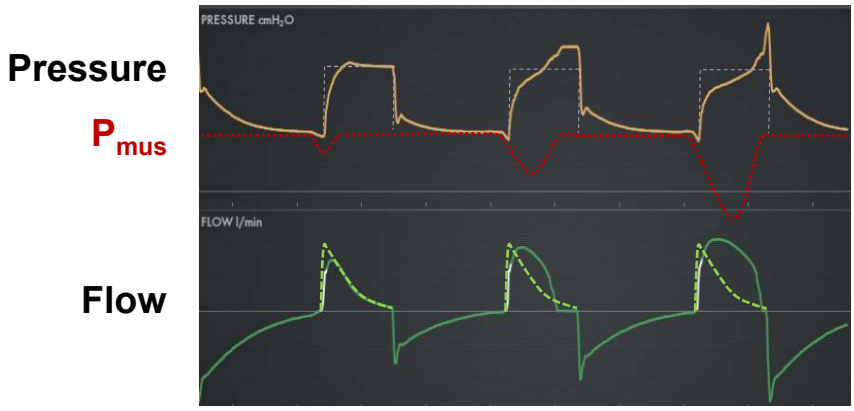
142

Work Shifting in Volume Control



143

Work Shifting in Pressure Control



144

Step 3 – Define the PVI

3. Define Patient-Ventilator Interaction

Trigger

- ☐ Normal
- ☐ Early
- ☐ Late
- ☐ False
- ☐ Failed

Cycle

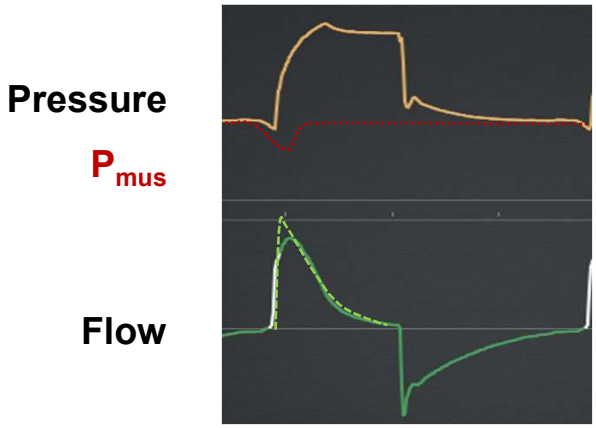
- ☐ Normal
- ☐ Early
- ☐ Late

Inspiration

- ☐ Normal
- ☐ Work shifting
- ☐ Work shifting, severe

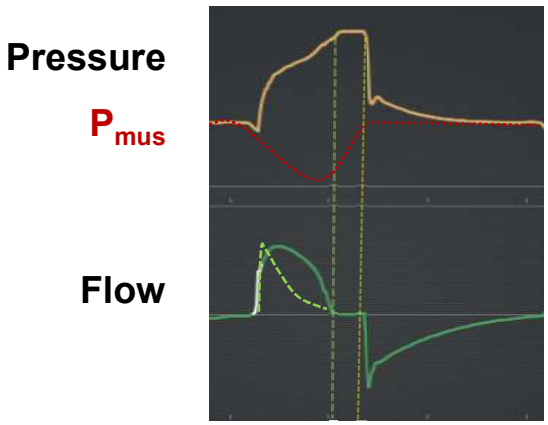
145

Cycle Synchrony - Normal



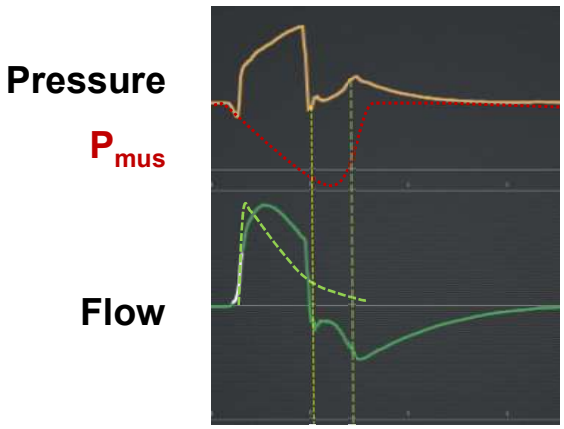
146

Cycle Synchrony - Late



147

Cycle Synchrony – Early



148

Step 3 – Define the PVI

3. Define Patient-Ventilator Interaction

Trigger
- ☐ Normal
- ☐ Early
- ☐ Late
- ☐ False
- ☐ Failed

Inspiration
- ☐ Normal
- ☐ Work shifting
- ☐ Work shifting, severe

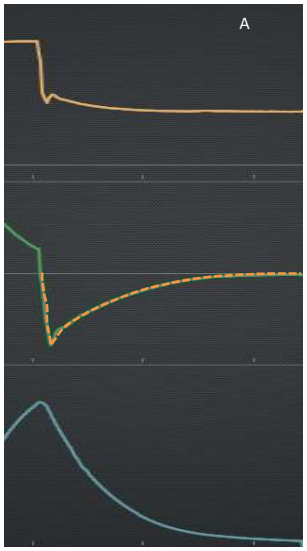
Cycle
- ☐ Normal
- ☐ Early
- ☐ Late

Expiration
- ☐ Normal
- ☐ Expiratory work

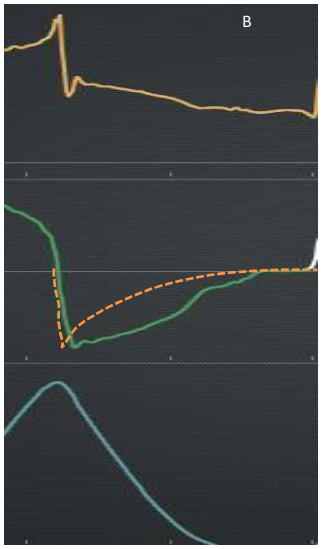
149

Expiratory Work

Passive, normal load



P_{mus} present, exp work



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Step 4 – Recommend Interventions

4. Interventions

What is the main goal (choose one only)?

☐ Safety ☐ Comfort ☐ Liberation.

☐ Adjusted Settings: which?_____

☐ Changed mode: To what?_____

☐ None

☐ Other_____

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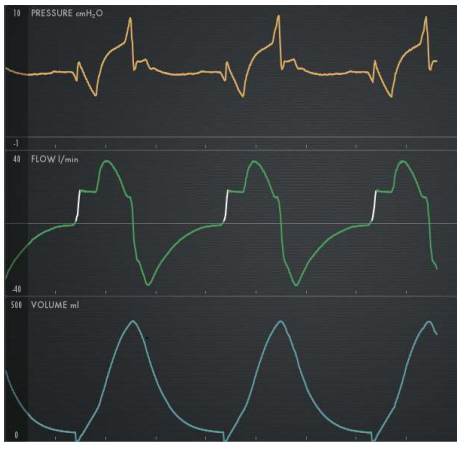
Example

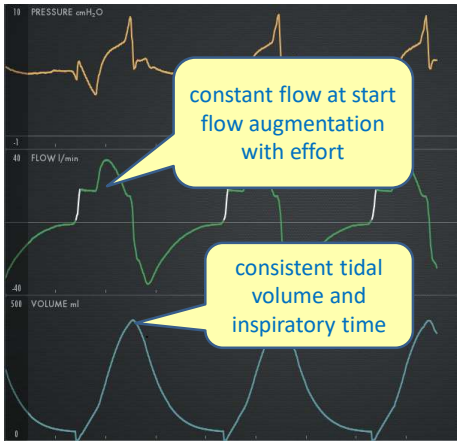
1. **What is the mode TAG**



152

Example

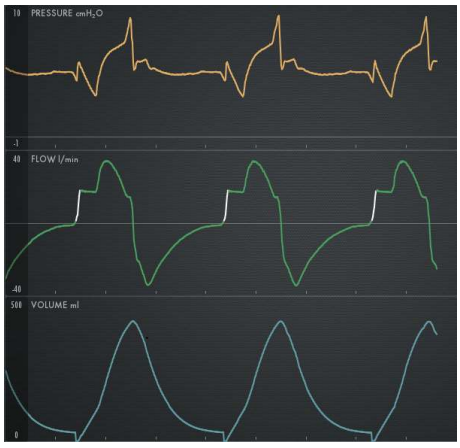
1. **What is the mode TAG**
   - VC-CMVd



153

Example

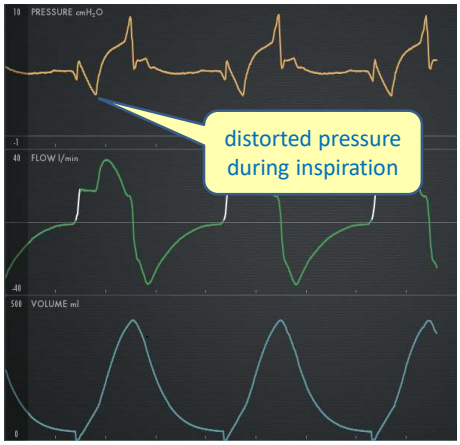
1. **What is the mode TAG**
   - VC-CMVd
2. **What is the load**



154

Example

1. **What is the mode TAG**
   - VC-CMVd
2. **What is the load**
   - Inspiratory Pmus



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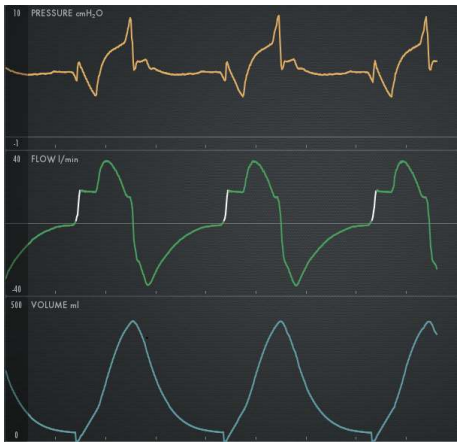
Example

1. **What is the mode TAG**
   - VC-CMVd
2. **What is the load**
   - Inspiratory Pmus
3. **What is the patient-ventilator interaction status**



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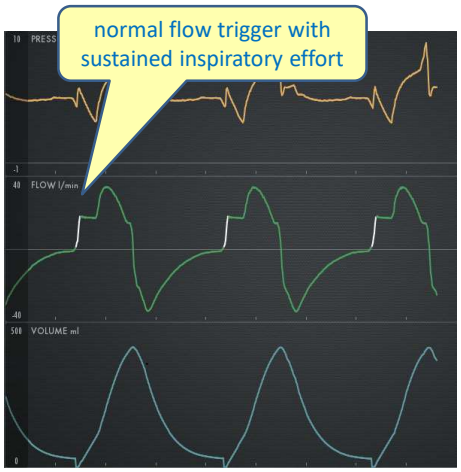
Example

1. **What is the mode TAG**
   - VC-CMVd
2. **What is the load**
   - Inspiratory Pmus
3. **What is the patient-ventilator interaction status**
   A. Trigger: normal flow trigger



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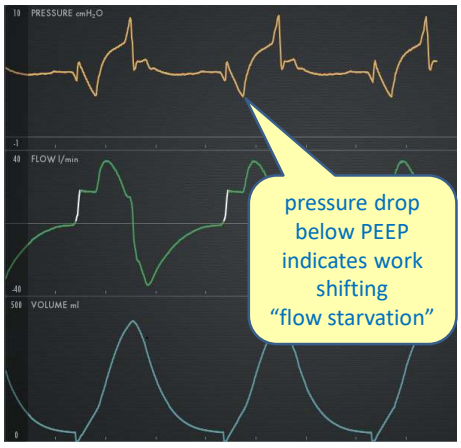
Example

1. **What is the mode TAG**
   - VC-CMVd
2. **What is the load**
   - Inspiratory Pmus
3. **What is the patient-ventilator interaction status**
   A. Trigger: normal flow trigger
   B. Inspiratory phase: work shifting



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Example

1. **What is the mode TAG**
   - VC-CMVd
2. **What is the load**
   - Inspiratory Pmus
3. **What is the patient-ventilator interaction status**
   A. Trigger: normal flow trigger
   B. Inspiratory phase: work shifting
   C. Cycle: normal

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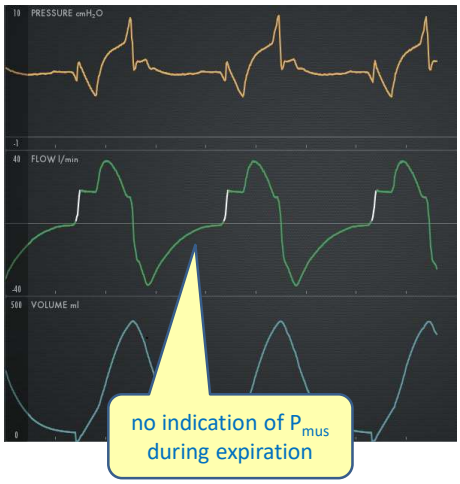
Example

1. **What is the mode TAG**
   - VC-CMVd
2. **What is the load**
   - Inspiratory Pmus
3. **What is the patient-ventilator interaction status**
   A. Trigger: normal flow trigger
   B. Inspiratory phase: work shifting
   C. Cycle: normal
   D. Expiratory phase: normal



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Summary

- The equation of motion is essential to understand mechanical ventilation

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Summary

- The equation of motion is essential to understand mechanical ventilation
- We now have taxonomies for
  - Modes of ventilation
  - Patient-ventilator interactions

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Summary

- **The equation of motion is essential to understand mechanical ventilation**
- **We now have taxonomies for**
  - Modes of ventilation
  - Patient-ventilator interactions
- **Learning to interpret ventilator waveforms is just as important as learning to interpret ECG waveforms**
  - This skill helps us optimize the mode and settings required to serve the goal of ventilation and meet the patient's needs

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Simulator – Hamilton C6 Ventilator

- **Free**
- **Fully simulated user interface with most modes**
- **Real-time waveforms and digital displays**
- **Standard patient models (normal, ARDS, COPD)**
- **Monitoring parameters for the patient's oxygenation and ventilation, including a simulated BGA**
- **Responds to recruitment maneuvers and changes in PEEP**

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Next steps

- **Attend SEVA-VentRounds, online (free)**
  - We review ventilator waveforms live, applying the SEVA method

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