How a Breath is Delivered

Chapter 4
Method of breath delivery:

- What energy is required to deliver the breath and is this energy provided by the ventilator or the patient?
- What factors does the ventilator control?
- How are the phases of a breath accomplished?

*Answers to these questions determine the mode of ventilation*
Mechanics of Breathing

- Muscle Pressure
  - Action of the respiratory muscles

- Ventilation Pressure
  - Produced by the ventilator

These pressures produce motion (flow) to deliver a volume of gas to the lung; the volume delivered depends on the lung’s characteristics.
EQUATION OF MOTION

Describes pressure, flow, and volume delivery

Resistance = $\frac{\Delta \text{Transairway pressure}}{\Delta \text{Flow}}$

Compliance = $\frac{\Delta \text{Volume}}{\Delta \text{Transthoracic pressure}}$

Elastance = $\frac{\text{Transthoracic pressure}}{\text{Volume}}$

Equation of motion for the respiratory system:

$P_{\text{vent}} + P_{\text{muscles}} = \text{Elastance} \times \text{volume} + \text{resistance} \times \text{flow}$

(From Wilkins RL, Stiller JK, Scanlan CL, editors: Egan's fundamentals of respiratory care, ed 9, St Louis, 2003, Mosby)
EQUATION OF MOTION

Muscle pressure + ventilator pressure = Elastic recoil + flow resistance pressure

\[ P_{\text{mus}} + P_{\text{tr}} = V/C + (\text{Raw} \times \text{flow}) \]
Inspiration during Mechanical Ventilation

- Delivery of the inspiratory volume
  - Ventilator design
  - Operator setting

- Control Variable
  - Pressure
  - Volume
  - Flow
  - Time

- Only controls one at a time!
Pressure Controlled Breathing

- Maintains the pressure waveform in a specific pattern
- Pressure waveform is unaffected by changes in lung characteristics
- Volume and flow waveforms vary with changes in lung characteristics

Volume Controlled Breathing

- Maintains the volume waveform in a specific pattern
- Volume and flow waveforms remain unchanged
- Pressure waveform varies with changes in lung characteristics

Control Variables
Flow Controlled Breathing

- Flow and volume waveforms remain unchanged
- Pressure waveform changes with alterations in lung characteristics
- Volume and pressure delivery are more relevant than flow

Time Controlled Breathing

- Used less often than pressure and volume control (HFHV, HFO)
- Both volume and pressure vary with changes in lung characteristics

Control Variables
Defining the breath

- Does the pressure waveform change with changes in the patient's lung characteristics?
  - Yes: The ventilator maintains or controls the pressure waveform.
  - No: Does the volume waveform change with changes in the patient's lung characteristics?
    - Yes: The ventilator maintains or controls the time.
    - No: Is the volume measured and used for determining the volume waveform?
      - Yes: The ventilator maintains or controls the volume waveform.
      - No: The ventilator maintains or controls the flow waveform.

(Modified from Chatburn RL: Respir Care 37:1009, 1992.)
Essentially comes down to Volume and Pressure

Volume Ventilation
- Volume targeted
- Volume limited
- Volume controlled

Pressure Ventilation
- Pressure targeted
- Pressure limited
- Pressure controlled
Pressure Control vs Volume Control

Pressure-controlled ventilation

Inspiration

Expiration

Pressure

Time (s)

Volume

Pressure (elastic)

Flow

Volume-controlled ventilation

Inspiration

Expiration

Pressure (elastic)

Pressure (resistive)

\[ P_{\text{total}} = P_{\text{elastic}} + P_{\text{resistive}} \]

\[ P_{\text{elastic}} = \frac{\text{Volume}}{\text{Compliance}} \]

\[ P_{\text{resistive}} = \text{Resistance} \times \text{Flow} \]

(From Wilkins RL, Stoller JK, Scanlan CL, editors: Egan’s fundamentals of respiratory care, ed 8, St Louis, 2003, Mosby.)
4 Phases of a Breath

- Change from exhalation to inspiration
- Inspiration
- Change from inspiration to exhalation
- exhalation
Phase Variable

- Signal measured by the ventilator
- Begins, sustains and ends each of the four phases of the breath
  - Trigger variable
  - Limit variable
  - Cycle variable
Trigger Variable

- Mechanism used to end exhalation and begin inspiration
- Two ways this occurs
  - Time
  - Patient
- Also allows operator to trigger manually
**Time Trigger**

- Breath begins after an elapsed amount of time.
- Rate of breathing is controlled by the ventilator.
- \( f = 12/\text{min} \) a breath occurs every ____ seconds.
Patient Trigger

- Senses patient’s effort to breathe
- Specify sensitivity setting
Sensitivity

- Pressure triggering
- Flow triggering
- Volume triggering
- Manual triggering
A patient is receiving volume ventilation. Whenever the patient makes an inspiratory effort, the pressure indicator shows a pressure of -5 cmH2O from the baseline before the ventilator triggers into inspiration. What does this indicate?
The machine is not sensitive enough to the patient’s effort. The clinician needs to increase sensitivity.
A patient appears to be in distress while receiving volume ventilation. The ventilator is cycling rapidly from breath to breath. The actual rate is much faster than the set rate. No discernable deflection of the pressure indicator occurs at the beginning of inspiration. The ventilator panel indicates that every breath is an assisted, or patient triggered breath. What does this indicate?

The machine is set too sensitive and is auto-triggering into inspiration. The clinician needs to reduce the sensitivity.
Limit Variable

- Maximum value a variable can attain
- Limits the variable during inspiration
- Does NOT end the inspiratory phase
- Pressure limiting
- Volume limiting
- Flow limiting
- Maximum safety pressure
Cycle Variable

- Determines the end of inspiration
- Once cycling occurs, expiratory gas flow begins
- Volume cycled
- Time cycled
- Flow cycled
- Pressure cycled
Clinical Rounds 4-2

A patient on volume ventilation suddenly coughs during the inspiration phase of the ventilator. A high pressure alarm sounds, and inspiration ends. Although the set tidal volume is 0.8L, the measured delivered volume for that breath is 0.5L. What variable ended inspiration in this example?

The ventilator pressure cycled when the patient coughed.
Maintains air in the lungs at the end of inspiration
Measures plateau pressure
Changes operation of normal cycling mechanism

INFLATION HOLD OR INSPIRATORY PAUSE

Plateau pressure

Airway pressure

Time

Copyright © 2009, Mosby Inc.
Mandatory

- Ventilator determines start time
- Ventilator determines tidal volume
- Ventilator determines both
- Machine triggers and/or cycles the breath

Spontaneous

- Patient determines start of breath
- Patient determines tidal volume delivery

Types of Breaths
Baseline Variable

- Expiratory phase
- Baseline pressure: ZEEP or PEEP
- Gas flow
- NEEP/ATC
- Expiratory hold/expiratory pause
- Expiratory retard
NEEP

Airway pressure

Inspiration

Expiration

NEEP

Peak pressure

Passive exhalation to zero

Pressure drops below zero
Expiratory Retard

[Graph showing airway pressure over time]
CPAP and PEEP

- Improve oxygenation
- CPAP = spontaneous breaths
- PEEP = machine breaths
Inspiration is pressure triggered

Does inspiration start because a preset pressure is detected?

Yes

Inspiration is pressure limited

Does peak pressure reach preset value before inspiration ends?

Yes

Inspiration is pressure cycled

Does expiratory flow start because a preset pressure is met?

Yes

No variables are limited during inspiration

No

Inspiration is volume triggered

Does inspiration start because a preset volume is detected?

Yes

Inspiration is volume limited

Does peak volume reach preset value before inspiration ends?

Yes

Inspiration is volume cycled

Does expiratory flow start because a preset volume is met?

Yes

No variables are limited during inspiration

No

Inspiration is flow triggered

Does inspiration start because a preset flow is detected?

Yes

Inspiration is flow limited

Does peak flow reach preset value before inspiration ends?

Yes

Inspiration is flow cycled

Does expiratory flow start because a preset flow is met?

Yes

No variables are limited during inspiration

No

Inspiration is time triggered

Inspiration starts because a preset time interval has elapsed

No

Expiration flow begins because a preset time interval has elapsed

(From Wilkins RL, Stoller JK, Scanlan CL, editors: Egan’s fundamentals of respiratory care, ed 8, St Louis, 2003, Mosby.)