Mechanical Ventilation

SCALARS

Graphics

LOOPS
SCALARS

Flow/Time

Pressure/Time

Volume/Time
LOOPS

- Pressure-Volume
- Flow-Volume
SCALARS

Flow/Time

Pressure/Time

Volume/Time
Spontaneous Breath

- Inspiration
- Expiration

Flow (L/min)

Time (sec)
Mechanical Breath

Flow (L/min)

Inspiration

Expiration

Time (sec)
Typical Flow Patterns

- Square
- Decelerating
- Accelerating
- Sine
Inspiratory Flow Pattern

- Peak inspiratory flow rate (PIFR)
- Inspiration
- Expiratory Time ($T_E$)
- Total cycle time (TCT)
- Beginning of inspiration
  - Exhalation valve closes
- Beginning of expiration
  - Exhalation valve opens

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Expiratory Flow Pattern

- Inspiration
- Expiration
- Beginning of expiration
- Exhalation valve opens
- Peak Expiratory Flow Rate (PEFR)
- Duration of expiratory flow
- Expiratory time
- $T_E$
Inadequate Inspiratory Flow

Active Inspiration or Asynchrony

Flow (L/min)

Patient’s effort

Normal Abnormal

Time (SEC)
Obstruction vs Active Expiration

<table>
<thead>
<tr>
<th>Obstruction</th>
<th>Active Expiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>Abnormal</td>
<td>Abnormal</td>
</tr>
</tbody>
</table>

Flow (L/min)

Time (sec)
Air Trapping

Inspiration

Expiration

Flow (L/min)

Time (sec)

Normal

Patient

Air Trapping Auto-PEEP

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Response to Bronchodilator

Before

Flow (L/min)

PEFR

Long $T_E$

After

Higher PEFR

Shorter $T_E$

Time (sec)
SCALARS

Flow/Time

Pressure/Time

Volume/Time
Volume vs Time

- Inspiration
-Expiration

Inspiratory Tidal Volume

Time (sec)
Volume Ventilation breaths are Volume Cycled

Volume (ml)

Inspiratory Tidal Volume

Inspiration

Expiration

Time (sec)

Volume Cycling

$T_1$
Air Leak

Volume (ml) vs Time (sec) graph illustrating air leak.
Active Exhalation

Volume (ml) vs. Time (sec)
SCALARS

- Flow/Time
- Pressure/Time
- Volume/Time
Spontaneous Breath

\[ P_{aw} \text{ (cm H}_2\text{O)} \]

Inspiration

Expiration

Time (sec)
CONTROLLED BREATH (Time Triggered)
Assisted Breath (Patient Triggered)

Patient Triggered Breath

$P_{aw}$ (cm H$_2$O)

Mechanical

Time (sec)
Spontaneous vs. Mechanical

**Spontaneous**

- Inspiration
- Expiration

**Mechanical**

- Inspiration
- Expiration

$P_{aw}$ (cm H$_2$O)

Time (sec)
Components of Inflation Pressure

- $P_{aw}$ (cm H$_2$O)
- $P_{plateau}$ (Palveolar)
- PIP
- Transairway Pressure ($P_{TA}$)
- Exhalation Valve Opens
- Inspiratory Pause
- Expiration

Time (sec)

Begin Inspiration

Begin Expiration
PIP vs $P_{plat}$

**Normal**

- PIP
- $P_{plat}$

**High $R_{aw}$**

- PIP
- $P_{plat}$

**High Flow**

- PIP
- $P_{plat}$

**Low Compliance**

- PIP
- $P_{plat}$

Paw (cm H$_2$O)

Time (sec)
Increased Airway Resistance

- Normal P_{Plat}
- Increased P_{Plat} (increased Airway Resistance)
- Normal P_{Plat} (Normal Compliance)
- Increased P_{IP}
- High R_{AW}
Effect of increased Flow

- **Normal PIP**
- **PIP High Flow**

**Paw (cm H$_2$O)**

- **Dynamic Inspiratory Time**
  - Decreased Inspiratory Time (Due to High Inspiratory Flow)
  - Dynamic Inspiratory Time
DECREASED COMPLIANCE

Paw (cm H₂O)

Normal

PIP

Pplat

Low Compliance

Increased Pplat
(Decreased Compliance)

Normal Pplat
(Normal Compliance)

Time (sec)
Inadequate Inspiratory Flow

- Adequate Flow
- Inadequate Flow

$P_{aw}$ (cm H$_2$O)

Time (sec)
LOOPS

Pressure-Volume

Flow-Volume
Pressure-Volume Loop (Type of Breath)

- Controlled
- Assisted
- Spontaneous

Vol (ml)

I: Inspiration
E: Expiration

$P_{aw}$ (cm H$_2$O)
FRC and PV Loop

Normal Compliance

FRC

TLC

FRC

VOLUME

DISTENDING PRESSURE

Negative 0 Positive

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Components of Pressure-Volume Loop

- Volume (mL)
- P_{aw} (cm H_2O)
- PIP
- VT

Expiration
Inspiration
PEEP and P-V Loop

Volume (mL)

PEEP

P_{aw} (cm H_{2}O)

V_{T}

PIP
Work of Breathing

A: Resistive Work
B: Elastic Work

Pressure (cm H₂O)
Volume (ml)
Inflection Points

Upper Inflection Point

Lower Inflection Point

Volume (mL)

Pressure (cm H₂O)
Inadequate Sensitivity

- Volume (mL)
- $P_{aw}$ (cm H$_2$O)

Increased WOB
Air Leak

Volume (ml) vs. Pressure (cm H₂O)

Air Leak

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Inadequate Inspiratory Flow

Volume (ml)

P_{aw} (cm H_{2}O)

Inappropriate Flow

Active Inspiration

Normal Abnormal
Increased $R_{aw}$

- Higher $P_{TA}$
- Normal Slope
- Lower Slope

$Vol\ (mL)$

$Pressure\ (cm\ H_2O)$
Hysteresis

Volume (ml) vs. Pressure (cm H$_2$O)

Normal Hysteresis

Abnormal Hysteresis
Lung Compliance Changes and the P-V Loop

Volume Targeted Ventilation

Preset $V_T$

Volume (mL)

$P_{aw}$ (cm H$_2$O)

PIP levels

COMPLIANCE
Increased
Normal
Decreased
Lung Compliance Changes and the P-V Loop

**COMPLIANCE**
- Increased
- Normal
- Decreased

**Pressure Targeted Ventilation**

**Volume (mL)**

**P_{aw} (cm H_{2}O)**

**Preset PIP**
Overdistension

With little or no change in $V_T$, $P_{aw}$ rises.

Normal
Abnormal
LOOPS

- Pressure-Volume
- Flow-Volume
Flow-Volume Loop

- Inspiration
  - PIFR
  - FRC

- Expiration
  - PEFR
  - VT

Flow (L/min) vs Volume (ml)
Air Leak

Inspiration

Expiration

Flow (L/min)

Volume (ml)

Air Leak in mL

Normal

Abnormal

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Air Trapping

Inspiration

Expiration

Flow (L/min)

Volume (ml)

Does not return to baseline

Normal

Abnormal
Increased Airway Resistance

Flow (L/min)

Inspiration

Volume (ml)

Expiration

“Scooped out” pattern

Decreased PEFR

Normal

Abnormal

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Airway Secretions/Water in the Circuit

- **Flow (L/min)**
- **Volume (ml)**

Normal
Abnormal
Modes of Ventilation

- Spontaneous
- Mechanical
  - Volume
    - Targeted
  - Pressure
    - Targeted
Modes of Ventilation

Spontaneous

Volume
Targeted

Pressure
Targeted

Mechanical
Spontaneous Breath

- Flow: L/min
- Pressure: cm H₂O
- Volume: mL

Time (sec)
PSV

Patient Triggered, Flow Cycled, Pressure limited Mode

Flow
L/m

Pressure
cm H$_2$O

Volume
mL

Time (sec)
CPAP + PSV

Flow Cycling

Flow
L/m

Pressure
cm H₂O

Set PS level

CPAP level

Volume
mL

Time (sec)
Modes of Ventilation

- Spontaneous
  - Volume
    - Targeted
- Mechanical
  - Pressure
    - Targeted
Controlled Mode
(Volume-Targeted Ventilation)

Time triggered, Flow limited, Volume cycled Ventilation

Preset Peak Flow

Flow
L/m

Pressure
cm H₂O

Volume
mL

Dependent on
Cₗ & Rₐw

Preset Vₜ
Volume Cycling

Time (sec)
Assisted Mode (Volume-Targeted Ventilation)

Patient triggered, Flow limited, Volume cycled Ventilation

Flow
L/m

Pressure
cm H$_2$O

Volume
mL

Time (sec)

Preset $V_T$

Volume Cycling
SIMV
(Volume-Targeted Ventilation)

Flow
L/m

Pressure
cm H$_2$O

Volume
mL

Spontaneous Breaths
Controlled Mode
(Pressure-Targeted Ventilation)

Time Triggered, Pressure Limited, Time Cycled Ventilation

- Flow (L/min)
- Pressure (cm H₂O)
- Volume (ml)

Time-Cycled
Set PC level
Assisted Mode
(Pressure-Targeted Ventilation)

Patient Triggered, Pressure Limited, Time Cycled Ventilation

Flow (L/min)

Pressure (cm H₂O)

Volume (ml)

Time (sec)

Set PC level

Time-Cycled

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SIMV Mode
(Pressure-Targeted Ventilation)

Flow (L/min)

Pressure (cm H₂O)

Volume (ml)

Set PC level

Spontaneous Breath

Time (sec)
SIMV + PS
(Pressure-Targeted Ventilation)

Flow (L/min)

Pressure (cm H₂O)

Volume (ml)

Time (sec)

Time-Cycled

Flow-Cycled

Set PC level

Set PS level

PS Breath

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SIMV+PS
(Volume-Targeted Ventilation)

Flow
(L/min)

Pressure
(cm H₂O)

Volume
(ml)

Flow-cycled

Set PS level

PS Breath
SIMV + PS + CPAP
(Pressure-Targeted Ventilation)

Flow (L/min)

Pressure (cm H₂O)

Volume (ml)

Set PC level

Set PS level

CPAP level

Time (sec)
SIMV+PS + CPAP (Volume-Targeted Ventilation)

Flow (L/min)

Pressure (cm H$_2$O)

Volume (ml)

Time (sec)