Initiation & Management of Mechanical Ventilation

Live Broadcast

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This Presentation is Approved for
2 CRCE Credit Hours

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Learning Objectives

- Identify reasons for initiation of mechanical ventilation.
- Describe intubation techniques.
- Explain mechanical ventilation management strategies .
- Discuss patient monitoring.
- Describe a spontaneous breathing trial.
- Recommending extubation vs. tracheostomy.

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Reasons to Intubate

- Respiratory failure
- Disordered control of breathing
- Airway protection
- Airway obstruction
- Therapeutics

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Types of Respiratory Failure

- Type 1 - Hypoxemic
  - (PaO_2 < 60 mmHg)
- Type 2 - Hypercapnic
  - ($PaCO_2$ > 50 mmHg with acidosis)
- Mixed failure

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Respiratory Failure – Type 1
Hypoxemic (PaO_2 < 60 mmHg)

- V/Q mismatch
- Shunt
- Diffusion impairment/defect
- Low inspired oxygen

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Respiratory Failure – Type 1

- Oxygen/HFNC
- NIV
- CPAP/PEEP
- Recruitment maneuvers
- Proning
- Treat cause
  - Diuresis
  - ABX
  - Anticoagulation
  - Steroids

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Respiratory Failure – Type 2
Hypercapnic ($PaCO_2$ > 50 mmHg) with Acidosis

- **Pump failure**
- **Central drive failure/disordered control**
- **Airflow obstruction**
- **Increased dead space**

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Respiratory Failure Type 2

- **Improve ventilation**
- **Reduce CO_2 load**
- **Treat underlying cause**

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Respiratory Failure Mixed

- Oxygen problem is severe
- Exhaustion/hypoventilation

- Severe COPD exacerbation
- Status asthmaticus
- PNA/ARDS
- CNS depression + lung disease
- Neuromuscular disorder + lung disease

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Respiratory Failure Mixed

- Fix oxygenation
- Fix ventilation
- Treat cause

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Airway Obstruction

- Airway securement

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Therapeutics

- Tracheal suctioning
- Bronchoscopy
- Lung lavage
- Biopsy

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Airway Protection in Special Populations

- Stroke / GCS < 8
- Seizures
- Head trauma with vomiting
- AMS
- Pediatrics: small airway, higher obstruction risk

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Minute Ventilation (Ve)

$Ve = V_T \times f$

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Alveolar Ventilation (VA)

VA = (VT - VD) × f

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Driving Pressure (ΔP)

ΔP = Pplat – PEEP

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Static Compliance (Cstat)

$$C_{stat} = \frac{V_T}{P_{plat} - PEEP}$$

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Resistance (Raw)

Raw = (PIP - Pplat) / Flow

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Resistance (Raw)

Before bronchodilator:
PIP = 38
Pplat = 22
Flow = 60 L/min (1 L/sec)

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Resistance (Raw)

$$R = \frac{38 - 22}{1} = 16\ cmH_2O/L/sec\ (high)$$

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Resistance (Raw)

After bronchodilator:
PIP = 28
Pplat = 22

$R = 6$ cmH₂O/L/sec (improved)

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P/F Ratio

$P/F = PaO2 / FiO2$

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Alveolar Gas Equation

$$PAO_2 = \left(F_{iO_2} \times \left(P_B - P_{H_2O}\right)\right) - \left(\frac{PaCO_2}{R}\right)$$

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Alveolar Gas Equation

$$PAO_2 = \left(F_{iO_2} \times \left(P_B - P_{H_2O}\right)\right) - \left(\frac{PaCO_2}{R}\right)$$

$$0.21 \times (760 - 47) = 0.21 \times 713 = 150 \ mmHg$$

150 - 50 = 100

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A–a Gradient

A–a = PAO2 - PaO2

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Respiratory Failure

- pCO_2 = 50 pO_2 = 82.5
- pCO_2 = 60 pO_2 = 75
- pCO_2 = 70 pO_2 = 62.5

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Dead Space Ratio (VD/VT)

$$\frac{VD}{V_T} = \frac{PaCO_2 - PETCO_2}{PaCO_2}$$

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I:E Ratio

I:E = I / (TCT - I)

$$I - time = \frac{V_T}{Flow}$$

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Intubation

- BVM – PEEP valve
  - Oral or nasal airway
- Airway tray
  - Suction
  - ETT / syringe
  - Stylet
  - Laryngoscope
    - Mac
    - Miller
    - Video assisted

  - Bougie or Airway exchanger
  - Magill forceps – nasal intubation
  - End-tidal CO2
  - CXR

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Hazards of Intubation

- Dental trauma
- Aspiration
- Laryngeal injuries
- Esophageal intubation

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Rapid Sequence Intubation (RSI)

- Preparation
- Preoxygenation
- Pretreatment (optional)
- Induction
- Paralysis
- Intubation
- Post-intubation management
- Plan B

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Post Intubation CXR

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Modes

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Ventilation Modes

- Volume-Controlled Modes
  - A/C
  - SIMV
  - CMV

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Ventilation Modes

- Volume-Controlled Modes
  - A/C
  - SIMV
  - CMV
- Pressure-Controlled Modes
  - PCV
  - PSV
  - APRV

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Ventilation Modes

- Dual-Controlled modes
  - PRVC
  - ASV
- Spontaneous
  - CPAP
  - BiPAP
- Other/Misc
  - NAVA
  - PAV

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Initial Settings

- **AC-VC or equivalent**
- **4-8 ml/kg IBW**
- **Rate 10-16 (maybe 18-20)**
- **Flow 40-60 lpm**
- **FiO2 40-60% (maybe 100%)**
- **PEEP – depends, but probably 8-10.**

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IBW Calculation kg

- Male 50 + (2.3 x inches above 60)
- Female 45.5 + (2.3 x inches above 60)

NIH PREDICTED BODY WEIGHT (PBW) / TIDAL VOLUME CHART

MALES

HEIGHT Feet	Inches	PBW Male	4 ml/kg	5 ml/kg	6 ml/kg	7 ml/kg	8 ml/kg
4' 10"	58	45.4	180	230	270	320	360
4' 11"	59	47.7	190	240	290	330	380
5' 0"	60	50	200	250	300	350	400
5' 1"	61	52.3	210	260	310	370	420
5' 2"	62	54.6	220	270	330	380	440
5' 3"	63	56.9	230	280	340	400	460
5' 4"	64	59.2	240	300	360	410	470
5' 5"	65	61.5	250	310	370	430	490
5' 6"	66	63.8	260	320	380	450	510
5' 7"	67	66.1	260	330	400	460	530
5' 8"	68	68.4	270	340	410	480	550
5' 9"	69	70.7	280	350	420	490	570
5' 10"	70	73	290	370	440	510	580
5' 11"	71	75.3	300	380	450	530	600
6' 0"	72	77.6	310	390	470	540	620
6' 1"	73	79.9	320	400	480	560	640
6' 2"	74	82.2	330	410	490	580	660
6' 3"	75	84.5	340	420	510	590	680
6' 4"	76	86.8	350	430	520	610	690
6' 5"	77	89.1	360	450	530	620	710
6' 6"	78	91.4	370	460	550	640	730

FEMALES

HEIGHT Feet	Inches	PBW Female	4 ml/kg	5 ml/kg	6 ml/kg	7 ml/kg	8 ml/kg
4' 7"	55	34	140	170	200	240	270
4' 8"	56	36.3	160	180	220	250	290
4' 9"	57	38.6	150	190	230	270	310
4' 10"	58	40.9	160	200	250	290	330
4' 11"	59	43.2	170	220	260	300	350
5' 0"	60	45.5	180	230	270	320	360
5' 1"	61	47.8	190	240	290	330	380
5' 2"	62	50.1	200	250	300	350	400
5' 3"	63	52.4	210	260	310	370	420
5' 4"	64	54.7	220	270	330	380	440
5' 5"	65	57	230	290	340	400	460
5' 6"	66	59.3	240	300	360	420	470
5' 7"	67	61.6	250	310	370	430	490
5' 8"	68	63.9	260	320	380	450	510
5' 9"	69	66.2	260	330	400	460	530
5' 10"	70	68.5	270	340	410	480	550
5' 11"	71	70.8	280	350	420	500	570
6' 0"	72	73.1	290	370	440	510	580
6' 1"	73	75.4	300	380	450	530	600
6' 2"	74	77.7	310	390	470	540	620
6' 3"	75	80	320	400	480	560	640

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Generic VT Settings

- Male 450
- Female 385

Initial Settings

- Male Rate 14 VT 450 PEEP 8 FiO2 40-50%
- Female Rate 14 VT 385 PEEP 8 FiO2 40-50%
- ABG – 20-30 minutes
- Measure actual height

Initial Settings

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Alarms

- High pressure
- Low pressure / low VT
- High VT
- High RR
- Apnea
- High PEEP
- Low PEEP
- High FiO2
- High/Low VE

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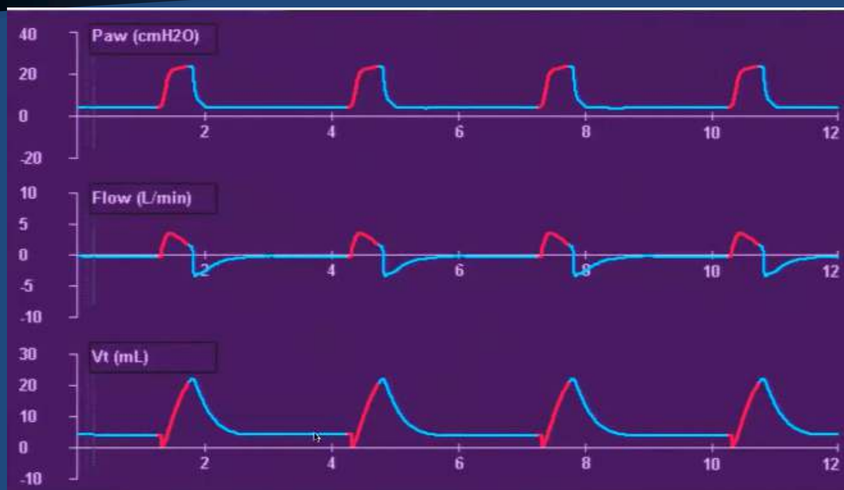
Initial Settings



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Ensure Proper Ventilator Management

- Ensure adequate ventilation
- Ensure proper oxygenation
- Protect the lung
- Are we satisfying the patient's neural drive to breathe?
- Is the patient getting better or worse?

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Adjust pH

(current) Ve x CO2 = Ve x CO2 (future)

$Ve = V_T \times f$

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Adjust pH

(current) Ve x CO2 = Ve x CO2 (future)

pH 0.1 = 12 CO2

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Adjustments

Adjust — Adjust mode as necessary

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Fix — Fix asynchronies

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Common Asynchronies

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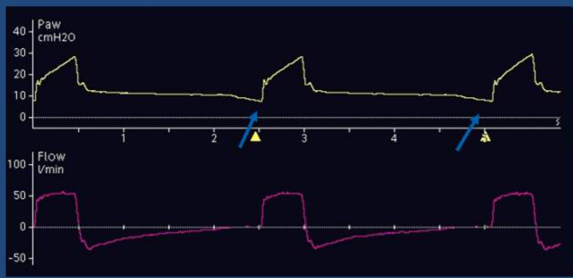
Trigger Asynchronies

- Ineffective/Missed
- Auto-triggering
- Double-triggering



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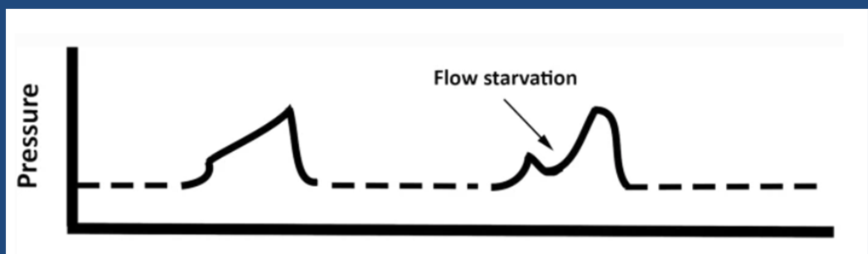
Flow Asynchronies

- Flow starvation
- Excessive flow



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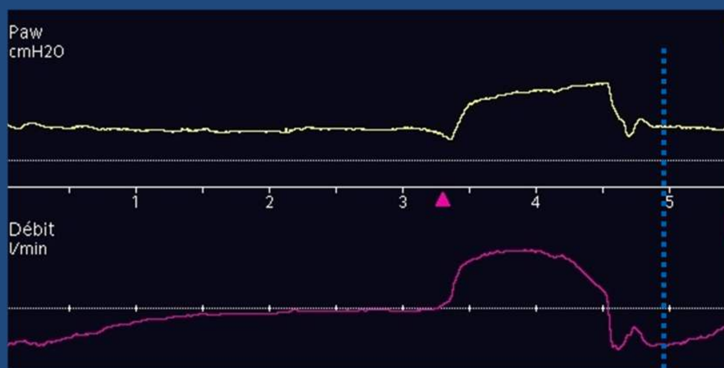
Cycle Asynchronies

- **Premature cycling**
- **Delayed cycling**



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Mode Asynchronies

- **Wrong mode**
- **Inadequate rise time**

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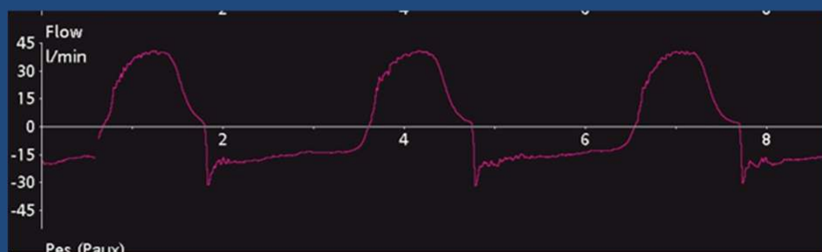
Expiratory Asynchronies

- Auto-PEEP



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Most Common Asynchronies

- Ineffective trigger
- Double Triggering
- Flow starvation

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Adjustments

Check	Check Peak Pressure

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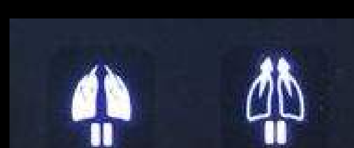
Adjustments

Check	Check Plateau pressure < 30
Check	Total PEEP



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Adjustments

Check	Check driving pressure < 15

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Driving Pressure (ΔP)

ΔP = 28-12

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Reducing Driving Pressure

- Lower VT
- Increase PEEP -maybe
- Optimize
- Treat underlying issues

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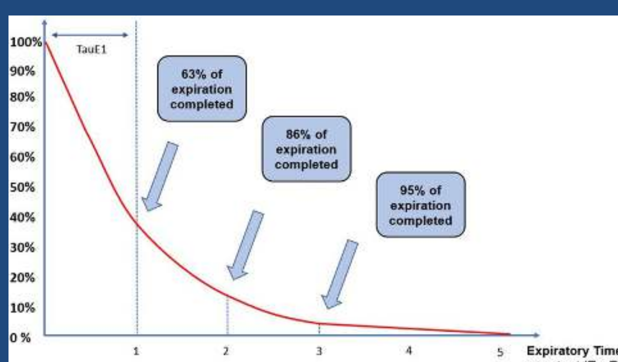
Expiratory Time Constant



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Time Constants

- 1 time constant = the time it takes for **63%** of the volume to move in or out
  2 time constants = 86%
  3 time constants = 95%
  4 time constants = 98%
  5 time constants = 99%
- **3 time constants for inspiration → ~95% full**
- **5 time constants for expiration → near-complete emptying**

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Adjustments

Optimize	Optimize PEEP

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Adjustments

Optimize | Optimize PEEP – FiO2 Tables

Lower PEEP/higher FiO2

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7
PEEP	5	5	8	8	10	10	10	12

FiO_2	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	14	14	14	16	18	18-24

Higher PEEP/lower FiO2

FiO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5
PEEP	5	8	10	12	14	14	16	16

FiO_2	0.5	0.5-0.8	0.8	0.9	1.0	1.0
PEEP	18	20	22	22	22	24

http://www.ardsnet.org/files/ventilator_protocol_2008-07.pdf

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Adjustments

Optimize | Optimize PEEP – C_{STAT} or Driving Pressure

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Adjustments

Optimize	Optimize PEEP - Decremental

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Adjustments

Optimize	Optimize PEEP - Incremental

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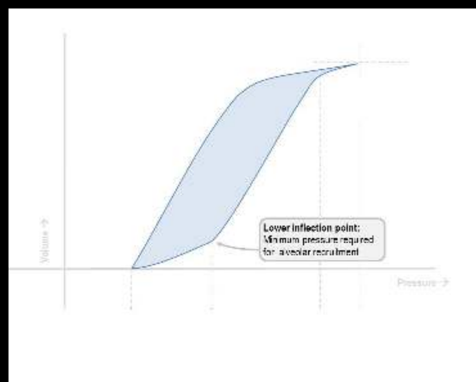
Adjustments

Optimize	Optimize PEEP – P-V Loop



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Adjustments

Optimize	Optimize PEEP – WOB

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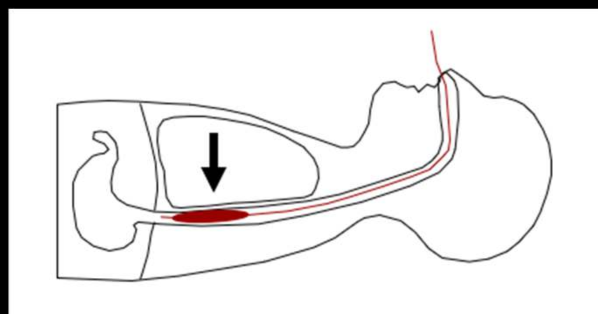
Adjustments

Optimize | Optimize PEEP – Esophageal Balloon



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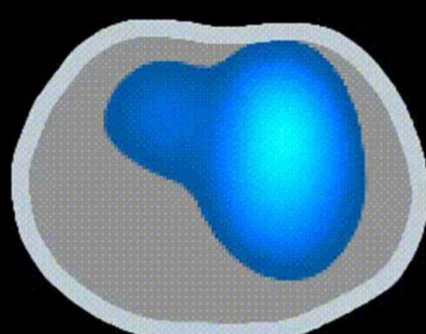
Adjustments

Optimize | Optimize PEEP – Image-Based



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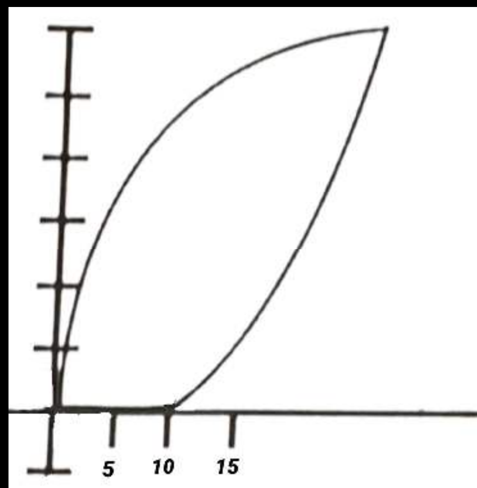
P-V Loop



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Adjustments

Titrate	Oxygen

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Predicting PaO2 with P/F Ratio

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Predicting PaO2 with P/F Ratio

$$PaO_2 = (P/F\ ratio) \times FiO_2$$

$$P/F = \frac{80}{0.40} = 200$$

$$PaO_2 = 200 \times 0.50 = 100$$

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Predicting PaO2 with P/F Ratio

Required FiO2 = Desired PaO2 / P/F

$$P/F = \frac{80}{0.40} = 200$$

$$FiO2 = \frac{100}{200} = 0.50$$

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Minor Adjustments

- Check — Rise time
- Check — Expiratory Trigger
- Check — Sensitivity

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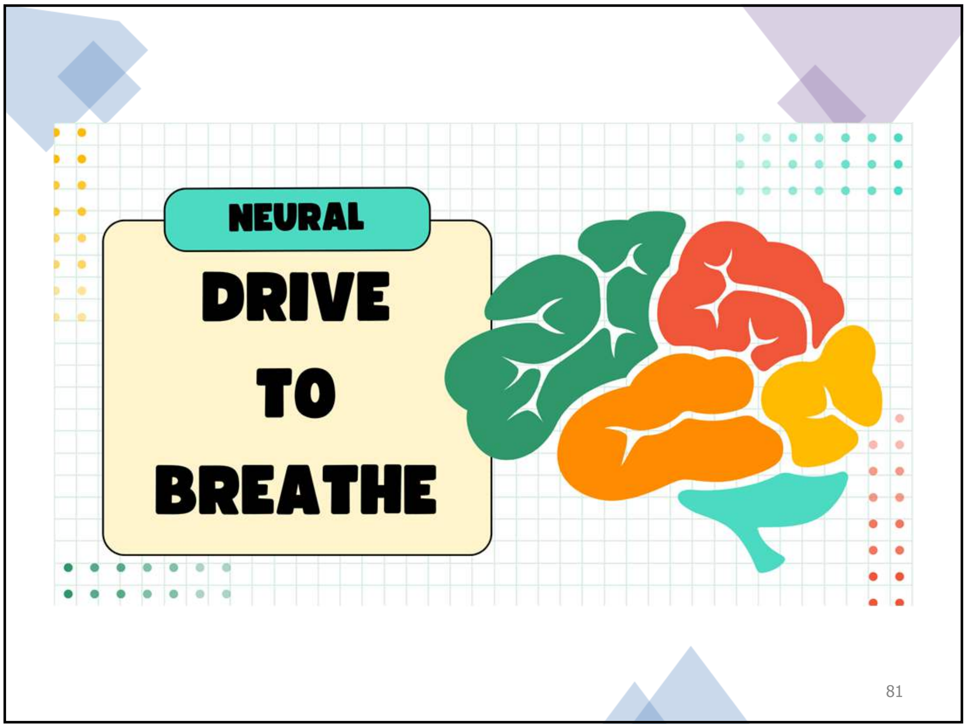

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Check for updates

ORIGINAL ARTICLE

Airway Occlusion Pressure As an Estimate of Respiratory Drive and Inspiratory Effort during Assisted Ventilation

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Abstract

Rationale: Monitoring and controlling respiratory drive and effort may help to minimize lung and diaphragm injury. Airway occlusion pressure (P0.1) is a noninvasive measure of respiratory drive.

Objectives: To determine *1*) the validity of "ventilator" P0.1 (P0.1*vent*) displayed on the screen as a measure of drive, *2*) the ability of P0.1 to detect potentially injurious levels of effort, and *3*) how P0.1*vent* displayed by different ventilators compares to a "reference" P0.1 (P0.1*ref*) measured from airway pressure recording during an occlusion.

Methods: Analysis of three studies in patients, one in healthy subjects, under assisted ventilation, and a bench study with six ventilators. P0.1*vent* was validated against measures of drive (electrical activity of the diaphragm and muscular pressure over time) and P0.1*ref*. Performance of P0.1*ref* and P0.1*vent* to detect predefined potentially injurious effort was tested using derivation and validation datasets using esophageal pressure–time product as the reference standard.

Measurements and Main Results: P0.1*vent* correlated well with measures of drive and with the esophageal pressure–time product (within-subjects $R^2 = 0.8$). P0.1*ref* >3.5 cm H_2O was 80% sensitive and 77% specific for detecting high effort (≥ 200 cm $H_2O \cdot s \cdot min^{-1}$); P0.1*ref* ≤ 1.0 cm H_2O was 100% sensitive and 92% specific for low effort (≤ 50 cm $H_2O \cdot s \cdot min^{-1}$). The area under the receiver operating characteristics curve for P0.1*vent* to detect potentially high and low effort were 0.81 and 0.92, respectively. Bench experiments showed a low mean bias for P0.1*vent* compared with P0.1*ref* for most ventilators but precision varied; in patients, precision was lower. Ventilators estimating P0.1*vent* without occlusions could underestimate P0.1*ref*.

Conclusions: P0.1 is a reliable bedside tool to assess respiratory drive and detect potentially injurious inspiratory effort.

Keywords: artificial respiration; airway occlusion pressure; P0.1; myotrauma; diaphragm

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Clinical Improvement

- Intubation reason resolved
- Respiratory rate < 30
- Minute ventilation < 10 L/min
- PEEP requirements
- Oxygenation
- Imaging
- Mental status
- Ventilator mode
- Team input

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Troubleshooting

- Tube position
- ABG
  - CO2 – use minute ventilation
  - O2 – use p/f ratio
- Circulation

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Pneumothorax

- Increased PIP
- Falling SAT
- Absent BS
- Sub Q
- Low VT return
- Tracheal deviation away
- Hypotension

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VAP Prevention

- Elevate head of bed 30-45 degrees
- Oral care q 2-4 hours
- Cuff pressure management
- Daily sedation vacation
- Suctioning of oral and subglottic secretions
- Hand hygiene
- Minimize circuit breaks
- Humidification
- Early mobility and position changes
- ET tube care & securement

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RSBI

- RSBI < 105
- Mental status
- Hemodynamics
- Secretions
- Gag
- Overall clinical course

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SBT

- FiO2 ≤ 40-50%
- PEEP ≤ 5-8 cnH2O
- SpO2 ≥ 90%
- PaO2/FiO2 > 150 (>200)

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SBT – Pass

- Stable vitals
- No respiratory distress
- Adequate VT
- Stable pH & CO2
- Acceptable O2
- Gag reflex
- Cough/Secretions

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SBT – Fail

- RR > 35
- SAT < 88
- Accessory muscle use
- Agitated
- Hyper/hypotension
- Arrythmias
- Acidosis

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Tracheostomy

- Early trach > 7–10 days
- Benefits
- Risks

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Tracheostomy Benefits

- Improved airway security
- Improved long-term access
- Reduced airway resistance
- Enhanced patient comfort
- Facilitates communication
- Facilities nutrition & swallowing assessment
- Reduced sedation
- Potentially shorter vent duration
- Secretion management

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Tracheostomy Risks

- Procedure-related complications
- Infection
- Tracheal complications
- Tube-related hazards
- Impact on speech and swallowing
- Bias toward prolonged vent use
- Cosmetic concerns

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Report

Give a good report

What's the plan?

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Report

- Patient ID & reason for intubation
- Airway information
- Current vent settings
- Recent vent trends
- ABG & O2 status

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Report

- Lung assessment
- Sedation and neuro status
- Hemodynamics & perfusion
- Secretions and humidification
- Lines, tubes, & misc.
- Plans, concerns, & guidance

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Ethics in Ventilation

- Withdrawal vs. withholding
- DNR/DNI discussions
- Futility and family expectations

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Future of Ventilation

- Automation and closed-loop intelligence
- Precision ventilation
- Advanced monitoring at bedside
- AI-supported clinical decision making

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Future of Ventilation

- Automation and closed-loop intelligence
- Precision ventilation
- Advanced monitoring at bedside
- AI-supported clinical decision making
- Improvements in patient comfort & human factors
- Expansion of tele-ventilation & remote respiratory care
- Hybrid Ventilation strategies & novel therapies

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Case Review

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Case 1 – Severe COPD

- 68 y/o male
- pCO_2 80, pH 7.20
- Hypoxemia despite NRB
- Which mode/settings would you choose?

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Case 1 – Severe COPD

- Inability to protect airway
- Obtunded
- Hemodynamics
- Secretions
- Refractory hypoxemia
- Verify DNR/DNI

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Case 1 – Severe COPD

- AC-VC
- VT 6-8 ml/kg IBW
- RR 16-20
- PEEP 5-8
- FiO2 high – then titrate down
- I:E 1:3-1:4
- Watch waveforms

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Case 2 – ARDS from Sepsis

- $PaO_2/FiO_2 = 90$

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Case 2 – ARDS from Sepsis

- A/C
- VT 6 ml/kg IBW – $\downarrow$ to 4-5 if high plateau
- RR 18-30
- PEEP 12-20+
- FiO2 60-100%
- Watch Plateau & driving pressure
- Proning
- Neuromuscular blockade

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Case 3 – Post-Op Patient

- 58 y/o male
- CABG x 4

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Case 3 – Post-Op Patient

- A/C
- RR 14
- VT 450 ml
- PEEP 5-8
- FiO2 40%
- Quickly extubate

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Summary & Review

- Respiratory Failure
- Medical math
- Intubation procedures
- Vent modes
- Initial settings
- Ensuring proper management
- Asynchronies
- Optimal PEEP
- Troubleshooting
- SBT/Trach
- Report
- Ethics
- Future
- Case review

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The End

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