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What You Always Wanted To Know About Mechanical Ventilation …But Were Afraid To Ask

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Course Objectives

- At the conclusion of this course, you will be able to:

1. Correctly identify the indication for mechanical ventilation in their patients.
2. Independently differentiate at least two differences between conventional and alternative modes of ventilation in their patients.
3. Accurately identify at least two standard ventilator settings on a standard ventilator.
4. Identify at least two complications of mechanical ventilation given a case scenario.
5. Describe at least three factors to consider when weaning a patient off of a ventilator.
6. Integrate current evidence about early mobility into the care of patients on mechanical ventilation.

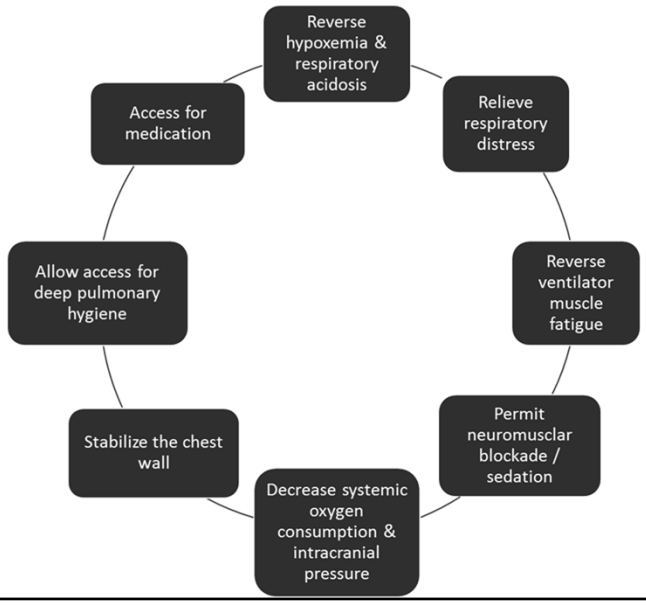
Objectives, Indications, & Types

Overview of Mechanical Ventilation

Objectives of Mechanical Ventilation

- Basic goal
  - Provide positive pressure to keep lungs inflated
- Physiologic goals
  - Support pulmonary gas exchange
  - Increase lung volume
  - Reduce work of breathing (WOB)

Clinically, what is the aim of mechanical ventilation?



Indications for Mechanical Ventilation

- Apnea
- Acute hypercapnia
- Partial pressure of arterial O2 <50 mmHg w/supplemental O2
- Vital capacity <10 L/min
- Protect airway from gastric contents
- Reversal of respiratory muscle fatigue

Types of Mechanical Ventilation

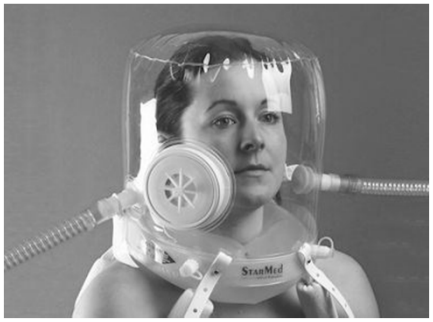
NONINVASIVE

- External interface to ventilator tubing

INVASIVE

- Artificial airway in trachea to ventilator tubing

Noninvasive Mechanical Ventilation Interfaces



- Full-face mask (i.e., oronasal)
- Total face mask
- Mouthpieces
- Nasal mask
- Nasal pillows or plugs
- Helmet

- Primarily used with
  - COPD exacerbation
  - Cardiogenic pulmonary edema

Invasive Mechanical Ventilation Interface: Intubation

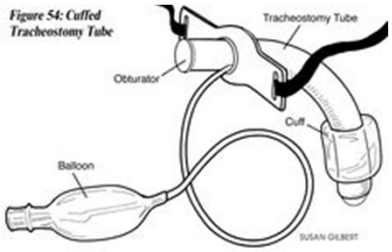
- Indications for intubation
  - Upper airway obstruction
  - Protect lower airway from aspiration
  - Inability to clear pulmonary secretions
  - Respiratory acidosis
  - Progressive general fatigue
    - Including mental status deterioration
  - Positive pressure ventilation needed

- Process
  - Putting the tube in = intubation
  - Taking the tube out = extubation

- Types of intubation
  - Endotracheal tube
  - Nasotracheal tube

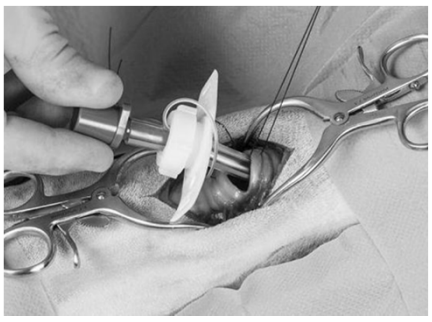
Intubation Considerations: Cuff

- Cuff inflated
  1. All supplemental 02 is delivered to lungs
  2. Holds the artificial airway in place
- Inflation pressure
  - Ensure no air leaks
  - Not to exceed 20 mm Hg
    - Increased risk of tracheal damage and scarring
    - Increased long term risk of tracheal stenosis
  - Phonation or audible sounds = cuff leak
    - Contact nursing or RT



Tracheostomy

- Indications for when to consider replacing intubation with tracheostomy
  - 1 week of endotracheal intubation, if extubation in next week seems unlikely
  - Transfer out of ICU
- Benefits of trach
  - Comfort
  - Reduced laryngeal injury
  - Decreased resistance to airflow
  - Increase airway effectiveness
  - Oral feeding possible
  - Vocalization possible with PMV



Modes & Settings

Mechanical Ventilation Basics

Ventilators

- Modern mechanical ventilators are positive pressure ventilators
- Classification based on method used to stop the inspiratory phase and allow expiration to occur
  - Pressure cycled
  - Volume cycled
  - Time cycled
- Can also classify ventilators by control mode
  - Volume controlled
  - Pressure controlled
  - Dual controlled

Ventilator Settings

- Parameters established to provide needed support to both oxygenation and ventilation needs
  - Oxygenation: ensure gas exchange occurs at alveoli
  - Ventilation: ensure adequate lung volumes related to moving air in/out of lungs
- Dependent on patient's
  - Arterial blood gas levels
  - Vital signs
  - Airway pressures
  - Lung volumes
  - Pathophysiology, including spontaneous breathing ability

Ventilator Settings: Oxygenation

FRACTION OF INSPIRED OXYGEN (FiO2)

- Percentage of inspired air that is oxygen
- Room air at sea level FiO2=21%
  - Yields partial pressure of O2 of 95-100 mmHg
- Can increase % of O2 inspired to increase availability of O2 in alveoli, drive more diffusion into blood
- FiO2 of 60% threshold value for toxicity with prolonged use

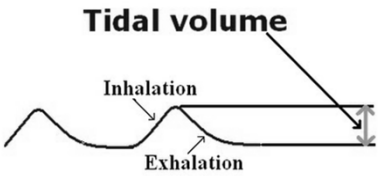
POSITIVE END-EXPIRATORY PRESSURE (PEEP)

- Pressure maintained in airways by mechanical ventilator at the end of expiration
- Normal is 5 cm H_2O
- Adjusted to maintain functional residual capacity above closing capacity to avoid alveoli closure
- Alveoli closure shunts blood past alveoli before gas exchange resulting in decreased oxygenation

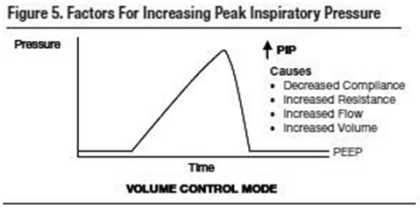
Ventilator Settings: Ventilation

- Respiratory Rate (RR)
  - Number of breaths/minute
  - Set depending on spontaneous breathing abilities
  - No spontaneous breaths, set at 12-20
  - Used in conjunction with volume to control PaCO2
- Tidal Volume (V_T)
  - Volume of air delivered from normal inspiration through normal expiration without extra force
  - Monitored closely to prevent barotrauma, may use permissive hypercapnia to prevent
  - Approx 500 mL normally or 7 mL/kg

- Sensitivity or Negative Inspiratory Force (NIF)
  - Airway pressure required to trigger breath by ventilator
  - Normal = -1 to -3 cm H_2O



Ventilator Settings: Ventilation

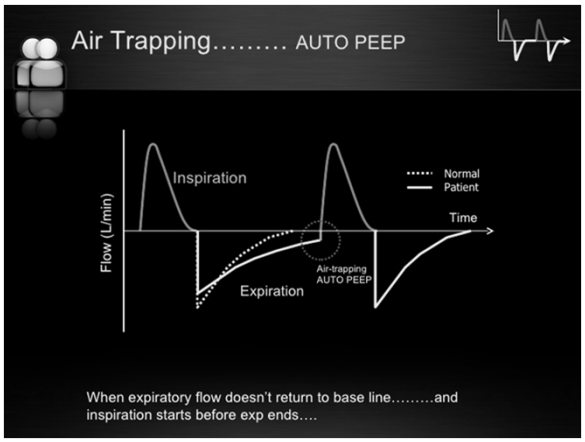


- Inspiratory Flow Rate
  - Matched to peak inspiratory demands otherwise uncomfortable
  - If high may allow longer expiratory times & prevent hyperinflation, but can increase pressure and risk of barotrauma
  - Too slow may cause respiratory muscle fatigue
- Inspiratory-to-Expiratory Ratio
  - Set for max synchronicity with patient
  - Without spontaneous breathing, set for adequate ventilation and oxygenation

www.ebmedicine.net/topics.php?paction=showTopicSeg&topic_id=89&seg_id=1700

Complications of Mechanical Ventilation: Auto PEEP

- Dynamic hyperinflation
- Increases air trapping
- Results
  - Physiologic dead space
  - Decreases gas exchange
  - Increases work of breathing due to higher respiratory demand
  - Alters length-tension relationship in inspiratory muscles



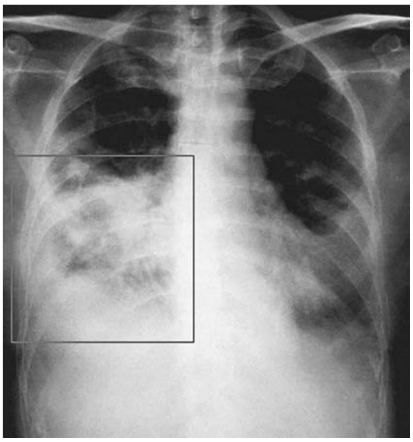
www.slideshare.net/vbuche/ventilator-graphics

Complications of Mechanical Ventilation: Barotrauma

- Damage to lungs by excessive airway pressure
- Causes stress fractures in walls of alveoli, can exacerbate lung conditions
  - Infants on mechanical ventilation 5 times more likely to have bronchopulmonary dysplasia
  - Barotrauma though to exacerbate ARDS
- Pneumothorax
- Subcutaneous emphysema

- Normally
  - Spontaneous inhalation occurs due to negative pressure
  - Volume limited because intrapulmonary pressure = atmospheric pressure
- In mechanical ventilation
  - Delivered with positive inspiration, which can exceed normal pressures
  - Conditions don't affect lungs uniformly; inhalation volumes delivered to normal areas can cause high pressure

Complications of Mechanical Ventilation: Ventilator-Associated Pneumonia (VAP)



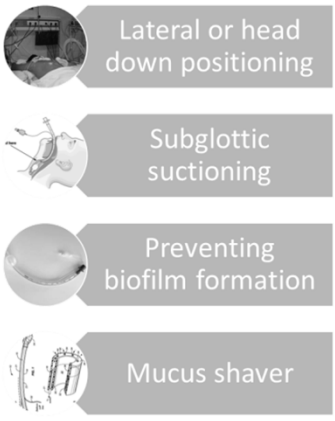
- Health care associated infection in mechanically ventilated patient (>48 hrs)
- Risk factors:
  - Immunosuppression
  - Underlying lung disease/conditions
  - Body position
  - Altered LOC
  - Endotracheal tubing
  - Laxity with standard precautions

www.ondineblog.com/tag/ventilator-associated-pneumonia/

VAP Prevention

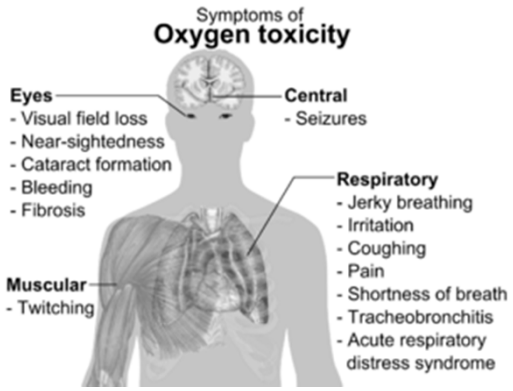
INSTITUTE FOR HEALTHCARE IMPROVEMENT VENTILATOR BUNDLE

NOVEL STRATEGIES NOT IN BUNDLE (JAMA, 2012)



Complications of Mechanical Ventilation: Oxygen Toxicity

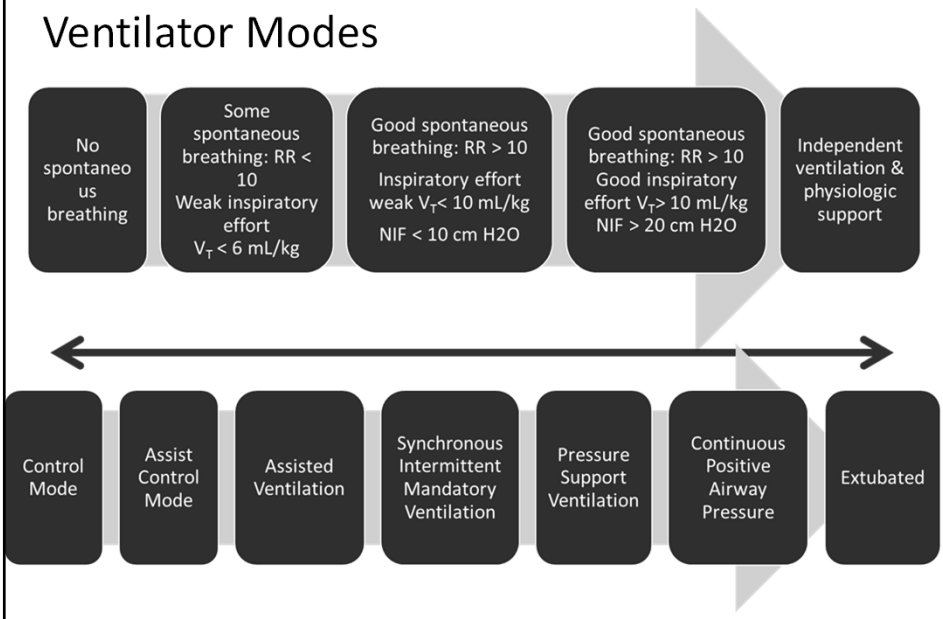
- O2 levels too high & maintained for too long
  - Substernal chest pain
    - Increased with deep breathing
  - Dry cough
  - Tracheal irritation
  - Pleuritic pain on inspiration
  - Dyspnea
  - Nasal stiffness/congestion
  - Sore throat
  - Eye and ear discomfort



Complications of Mechanical Ventilation: Esophageal or tracheal tears

- Improper intubation with tube in esophagus

Ventilator Modes



Adapted from Collins & Paz

Control Ventilation

- Control Mode
- Total control of ventilation
  - Preset rate, FiO2, V_T, flow rate, I:E ratio
- Requires sedation or medically induced coma
- No active respiratory muscle activity required

Assist Ventilation

- Patient controls respiratory pattern and rate
- Patient generated inspiratory pressure creates negative airway pressure in circuit, once initiated the volume is delivered
  - Either preset volume or pressure and flow rate
- Respiratory muscles must work to generate inspiratory pressure
- Patient can select high RR
  - Respiratory alkalosis or auto PEEP

Assist Control Mode

- Combo of CV and AV
- Delivers predetermined V_T with the patient's inspiratory effort
- If patient doesn't trigger via inspiratory effort within a set time period, ventilator delivers breath to maintain a set RR

Synchronized Intermittent Mandatory Ventilation

- SIMV
- Delivers breath intermittently at preset times with preset RR, V_T, and flow rate
- Patient can breath spontaneously through a separate circuit between the ventilator delivered breaths
- Like AV, it will assist patient initiated breaths
- Mandatory breaths occur only when patient is not initiating enough breaths to hit preset minute ventilation targets
- Can be used as a weaning setting

Video Comparing Assist Control to SIMV

- Assist Control uses a set volume for every breath
- SIMV allows variable volumes for breaths selected by patient
  - Only augments this if minute ventilation volume does not hit the target
  - Too many shallow breaths by patient will lead to ventilator augmenting the volume
- www.youtube.com/watch?v=wx6Dkjri0bc

Pressure Support Ventilation

- Patient initiated breaths get boost with a preset flow to maintain constant inspiratory pressure
  - If patient generates the target inspiratory pressure, ventilator doesn't assist
- Patient controls RR, inspiratory time, and flow
- Patient and ventilator determine V_T and minute ventilation
- V_T from ventilator is not only related to the patient's effort but also the amount of pressure provided by the ventilator
- Used as a weaning mode

Continuous Positive Airway Pressure

- CPAP
- Decreases work of breathing by reducing airway pressure needed to generate inspiration throughout cycle while patient is spontaneously breathing
- Positive pressure > atmospheric pressure
- Can be used as a weaning setting
- Can be used to postpone intubation via noninvasive face mask
- Commonly used at night for sleep apnea

High-Frequency Oscillation Ventilation

- Uses frequencies of 100-300 breaths per minute with small V_T of 1-4 mL/kg
- Dramatically reduces airway pressure
  - Neonates
  - ARDS if conventional modes are not yielding good results

- www.youtube.com/watch?v=IrTAo5GAVrw

Mandatory Minute Ventilation

- Minimum minute ventilation or augmented minute ventilation
- Only parameter controlled by ventilator is the minute ventilation
- If spontaneous breathing doesn't meet that minute ventilation, ventilator will supply mechanical breaths to make up the difference
- Primarily used in weaning

Pressure Control Ventilation

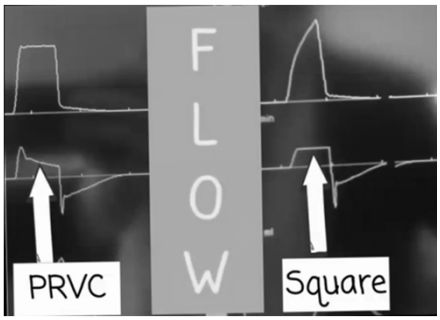
- Delivers preset airway pressure for a predetermined inspiratory time interval
- Usually increased inspiratory time, which can be uncomfortable
  - Sedation usually required
- V_T determined by lung compliance
  - Very useful if barotrauma may exacerbate acute lung injury, as in ARDS
- Also available with Assist Control Ventilation and SIMV modes

Pressure-Regulated Volume Control

- PRVC
- Provides volume support while keeping peak inspiratory pressure low
  - Alters inspiratory time and peak flow
- Good for patient's with changing airway compliance

Video comparing PRVC and Assist Control modes

- Assist Control has higher peak inspiratory pressures overall
- PRVC lowers the peak inspiratory pressure
- PRVC allows the inspiration to have a more normal decrease in pressure over the time of inspiration



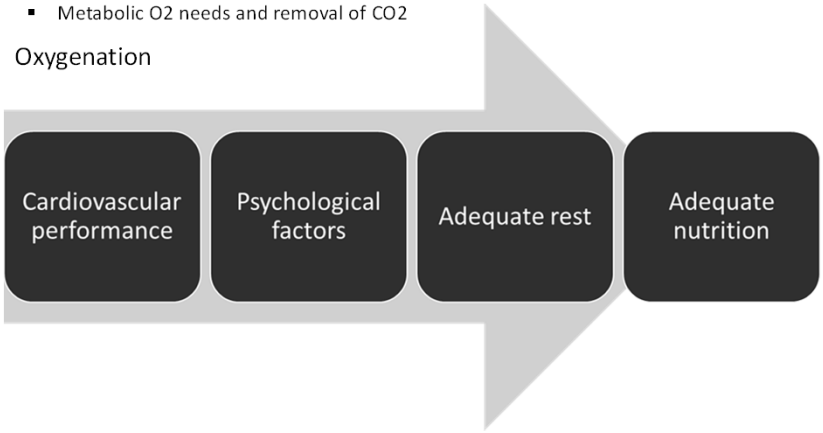
- www.youtube.com/watch?v=iCeDnlou04Y

Considerations & Complications

Weaning from Mechanical Ventilation

Weaning Considerations

- Respiratory demand & ability of patient to cope with the demand
  - Metabolic O2 needs and removal of CO2
- Oxygenation



Weaning Criteria

- Spontaneous breathing
  - SBT recommended daily as a check
- FiO2 < 50% and PEEP < 5 cm H2O with an O2 saturation > 90%
- Max inspiratory pressure > -30 cm H2O
  - Pressures greater than -15 but less than -30 cm H2O are associated with inability to maintain spontaneous breathing
- Respiratory rate < 35 breaths/minute
- Tidal volume > 325 mL
- Respiratory rate/tidal volume ratio < 105

Signs of Increased Distress During Weaning

- Increasing tachypnea (> 30 breaths/min)
- Drop in pH to less than 7.25 with increasing PaCO2
- Paradoxical breathing pattern
- O2 saturation < 90%
- Change in heart rate > 20 bpm
- Change in blood pressure > 20 mmHg
- Agitation, panic, diaphoresis, cyanosis, angina, or arrhythmias

Weaning Methods

T-PIECE

- Breathing off the ventilator while still intubated for ever increasing time periods
- All-or-none method
- Requires spontaneous breathing drive & adequate tidal volume
- Aims primarily at strength & endurance of respiratory muscles

PRESSURE SUPPORT VENTILATION

- Ever increasing periods of pressure support ventilation with ever decreasing amounts of pressure
- Aim to increase spontaneous ventilation
- Can increase strength load via reducing the pressure of PSV
- Can increase endurance via increased length of time that PSV is at reduced pressure

SIMV method is less superior to either of these based on current consensus unless used immediately post-anesthesia & no pre-existing lung problems

PT role in ventilator weaning

- Weaning is exercise!
- Optimize conditions for patient
  - Time of day, activities before and after, scheduling of other therapies
- Position during weaning: seated with ability to lean forward with arms supported
- Biofeedback to augment relaxation and increase tidal volume
- Inspiratory muscle resistive training to increase strength and endurance

PT in Mechanically Ventilated Patients

- Multiple studies show this is safe, effective, and beneficial

Early Mobility is Safe (ARF)

- Respiratory Failure Patients (Bailey et al, 2007)
- Prospective RCT in US (n=103)
  - Early activity (sit on bed, sit on chair, ambulate) in intubated respiratory failure patients in RICU
  - No significant activity-related adverse events (<1% of all activity events)
    - Fall to knees
    - Feeding tube removal
    - Systolic BP <90mmHg
    - Systolic BP <200mmHg
    - Desaturation <80%
    - Extubation (no extubations)
  - 69% could ambulate >100 ft at RICU discharge

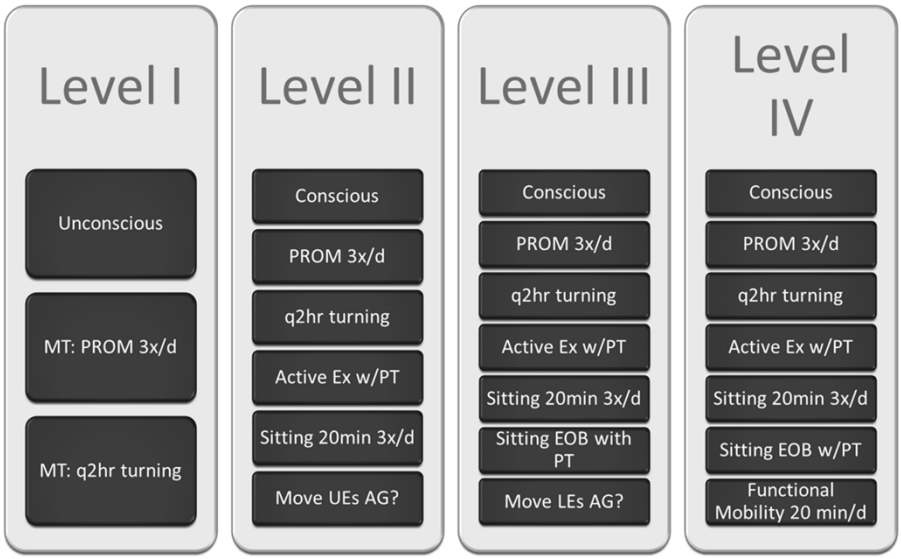
Early Mobility is Safe (Mech Vent)

- ICU patients prescribed OT/PT within 48 h of mech ventilation (Pohlman et al, 2010)
- Detailed descriptive study in US (n=49)
  - AROM→ADLs→sitting→ standing→gait as able
  - Variety of interventions during OT/PT sessions
    - EOB 69%
    - Transfer to chair 33%
    - Stood 33%
    - Ambulation 15%
- Daily sedation interruption with PT/OT sessions
- 1 barrier present 89% of time
  - Acute lung injury
  - Vasoactive medication
  - Delirium
  - Renal replacement therapy
  - BMI >30kg/m
- Stopped only 4% of sessions
  - Pt-vent asynchrony
  - Agitation

Mobility Protocol & LOS (ARF)

- Acute Respiratory Failure Patients (Morris et al, 2008)
- Prospective Cohort Study in US (n=230)
  - Mobility Protocol to increase proportion of ICU pt receiving PT vs. usual care
  - Mobility Team initiated protocol within 48 hr of admit
    - 4 levels of intervention based on patient response
    - Similar low complication rates
    - No adverse events
    - No cost difference, including mobility team costs
  - Mobility Protocol outcomes
    - At least 1 more PT session
    - Out of bed earlier (5 d vs. 11 d)
    - PT initiated more frequently (91% vs. 13%)
    - ICU LOS decreased (5.5 d vs. 6.9 d)
    - Hospital LOS decreased (11.2 d vs. 14.5 d)

Mobility Team Protocol



Morris et al, 2008

It does take a village…

Evidence Based Guidelines

- Responsive to verbal stimulation
- FiO2 < 60% or 0.60
- PEEP < 10 cm H2O
- No orthostasis with sitting or standing
- No catecholamine drips
- Keep O2 sat > 90%
- Monitor RR, HR, & BP
- No excessive anxiety, diaphoresis

Other Considerations

- Skin
  - Reported ulcer development in 8-40% of critically ill patients
  - Medications and APACHE II score not related to development of ulcer
  - Level of consciousness, activity*, cooperation, LOS*, & C-reactive protein level correlated with skin breakdown (Sayar, 2009)
  - Frequency of turning/repositioning and emergent ICU admission prognostic of developing skin ulcers (Kaitani 2010)
- ROM/joint integrity
  - More than 1/3 of pt with prolonged ICU stay had a "significant contracture of a major joint…persisted until d/c home" (Clavet, 2008)

Case: JM

- 23 y/o male
- s/p MVA 1 d ago, unrestrained driver
- Open TBI, blunt abdominal trauma
  - s/p craniotomy w/ventriculostomy, splenectomy, repair of liver laceration
- What do you want to know?

Can JM mobilize?

- Sedated? Sedation holiday soon?
- Currently weaning? Weaning schedule?
- Ventilator settings
  - Assist Control
  - FiO2 56%
  - PEEP 8 cm H2O
  - HR 103
  - BP 102/76, not on pressors
  - RR 15
- What else do you want to know?

Graded Mobility

- Recall the Morris study (mentioned earlier)
- For PT
  - Passive to active bed exercise
  - Sitting edge of bed to transfers
  - Standing to marching in place
  - Ambulation
- Remember your team!
  - Nursing can mobilize
  - Use equipment as needed

In Summary

- Just like you check the patient's vitals before PT session, you should check also their CURRENT vent settings & specific values:
  - FiO2
  - PEEP
  - RR
  - O2 saturation
  - HR
  - BP
  - May want to check ABGs
- Work with your interprofessional team!
  - Know guidelines
  - Understand weaning plan

jama.jamanetwork.com/article.aspx?articleid=182682

Learn More…

PEER-REVIEWED JOURNALS

- Journal of Cardiovascular & Pulmonary Physical Therapy
- Journal of Acute Care Physical Therapy
- Critical Care
  - www.ccforum.com

SOCIETIES OR ACADEMIES

- Society for Critical Care Medicine
  - www.sccm.org
- American Trauma Society
  - www.amtrauma.org
- American Thoracic Society
  - www.thoracic.org

Questions?

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