**Mechanical Ventilation, Sedation and Paralysis in Critically Ill Patients**

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**Content Questions**

1. List the normal ranges for the following arterial blood gas indices: pH, PaCO₂, PaO₂, HCO₃⁻.
2. What acid-base disturbance is represented by the following arterial blood gases?
   - pH 7.24, PaCO₂ 51 mm Hg, PaO₂ 83, HCO₃⁻ 22
   - pH 7.53/40/100/32
   - pH 7.60/35/120/34
   - pH 7.26/22/68/10
3. What are the advantages/disadvantages of the Assist Control mode of ventilation?
4. What settings should be manipulated on the ventilator to adjust PaO₂? PaCO₂?
5. What are the pharmacokinetic differences observed between lorazepam and midazolam?
6. Describe a method by which sedation should be initially started, and then maintained in a patient that is mechanically ventilated.
7. What is the Ramsey Sedation Score goal for a patient that is mechanically ventilated?
8. What are the signs/symptoms of benzodiazepine withdrawal?

**Content Questions cont.**

9. What are complications of therapeutic paralysis?
10. A nurse who is paralyzing a patient for the first time asks you how the train-of-four monitor works. Describe the appropriate procedure for monitoring therapeutic paralysis.
11. What drugs prolong blockade when used concomitantly with a neuromuscular blocking agent?

**ICU Types**

- NICU - neonatal
- PICU - pediatric
- CCU - coronary care unit
- SICU - surgical
- NNICU - neurological & neurosurgical
- MICU - medical

**Common Reasons for ICU Admission**

- Respiratory compromise
- Hemodynamic compromise
- Myocardial ischemia or infarction
- Neurological compromise
- Gastrointestinal
- Renal and metabolic
- Postoperative
ICU Equipment

- Bedside monitors
  - HR, BP, RR, SaO2, ETCO2
  - PAC: PAP, CVP, PCWP, CO
- Mechanical ventilators
- Intravenous medication pumps
- Other devices
  - foley catheter
  - sequential compression devices
  - dialysis machines

ICU Rounds

- Purpose
  - communicate patient’s present status
  - establish goals and plans
- ICU team
  - physicians, nurses, respiratory therapists, nutritional support, social work, pharmacists
Critical Care Pharmacy Services

- Prospective drug therapy evaluation
  - dosage, drug interactions, drug allergies, ADE prevention
- Pharmacokinetic monitoring
- Education regarding drug-related procedures, policies, guidelines, and pathways
- cost-containment

Mechanical Ventilation

Patient Case #1

A 22 yo male with no past medical history is admitted to the hospital after being found down at a party where he reportedly ingested a fifth of whiskey over a 20 minute period of time. Upon arrival to the ER, he was neurologically unresponsive and had the following ABG: pH 7.23, PaCO₂ 58, PaO₂ 111, HCO₃ 24, SaO₂ 100% on 2L/min of oxygen by nasal cannula.

Should this patient be intubated? Why or why not?
Patient Case #1

Should this patient be intubated? Why or why not?
- Ventilation disorder 2°/2 EtOH coma
- EtOH abolishes hypercarbic drive to respiration
- PaCO₂ 58 mm Hg

Patient Case #2

A 55 yo female with a significant history of asthma and COPD is admitted after several days of worsening SOB. She was recently discharged from the hospital after a similar episode, and was doing fine until 3 days PTA when she developed a productive cough, requiring more home O₂ and more frequent use of her MDI’s. She has been hospitalized multiple times in the past, but never required intubation. Upon admission to the ICU, she was anxious and markedly distressed with rapid shallow breaths. She was hypertensive (160/80), tachycardic (140), and tachypneic (28). Her ABG was 7.30/59/50/28, SaO₂ 83% on 4 L/min oxygen by face mask and she was immediately intubated.

What signs/symptoms of respiratory failure did this patient exhibit?
- PacO₂ 59 mm Hg
- PaO₂ 50 mm Hg
- SaO₂ 83% on 4 L/min nasal cannula

Oxygen Delivery Systems

- Nasal Cannula
- Face masks
  » simple masks
  » partial rebreathing masks
  » nonrebreathing masks

Noninvasive Ventilatory Support Modes

- Continuous Positive Airway Pressure (CPAP)
  » elevates airway pressure above atmospheric pressure throughout spontaneous inhalation and exhalation
  » pneumatic splint – literally an air splint to hold your throat open.
  » offers the benefit of positive end-expiratory pressure
Noninvasive Ventilatory Support Modes

- **Bilevel Positive Airway Pressure (BiPAP)**
  - works by delivering two different levels of positive air pressure: a higher level of pressure when you inhale and a lower level of pressure when you exhale
  - IPAP = inspiratory positive airway pressure
  - EPAP = expiratory positive airway pressure
  - bilevel devices deliver "assisted breaths," not continuous pressure, so they fall into the category of ventilation
  - bilevel devices have a back-up rate, which means that the machine can provide extra breaths as necessary for those patients who require it

Patient Case #2 (continued)

The initial ventilator settings include Assist Control at a rate of 20 breaths/minute (although the patient is breathing 36 times/minute) with a tidal volume of 700cc and an FiO2 of 1.0. Thirty minutes later an ABG reveals a pH 7.54, PaCO2 34, PaO2 49, HCO3 28, SaO2 82%.

What changes to the ventilator could be made at this time?

Positive Pressure Ventilation Modes

- **Assist Control (AC)**
  - every patient breath is supported by the ventilator
  - delivers the full tidal volume on every breath
  - assist = breath triggered by the patient
  - control = independent trigger
  - ventilator rate = minimum number of machine breaths delivered per minute
  - advantage: “Rests” the patient
  - disadvantage: may result in respiratory alkalosis

- **Intermittent Mandatory Ventilation (IMV)**
  - combines a preset number of ventilator-delivered mandatory breaths with patient-generated spontaneous breaths
  - ventilator rate = maximum number of machine breaths delivered
  - usually combined with pressure support ventilation (PSV) which augments spontaneous breaths and offsets the imposed work

- **Inverse Ratio Ventilation**
  - uses inhalation times greater than exhalation
  - normal ratio of 1:2 or 1:3 is reversed to 2:1 or 3:1
  - generally reserved for patients with poor oxygenation despite maximal FiO2 and PEEP
  - usually requires therapeutic paralysis

- **Oxygenation (PaO2)**
  - FiO2
  - PEEP
  - IRV

- **Ventilation (PaCO2)**
  - Tidal Volume (VT)
  - Respiratory rate

Adjusting mechanical ventilatory support
Adjusting mechanical ventilatory support

- FiO₂ - initially 100%
- Minute Ventilation (VT x RR)
  - VT: 6 - 12 ml/kg
  - RR: 10-15 breaths/min
- PEEP - hypoxic respiratory failure
  - 3 - 5 cm H₂O increments

Weaning from mechanical ventilation

- Weaning Parameters
  - Correction of underlying cause of respiratory failure
  - Stable cardiovascular function
  - Good neurological function (awake, alert, etc)
  - PaO₂ >60 mmHg on FiO₂ < 0.6
  - PEEP < 10 cm H₂O
  - Minute Ventilation < 10-12 L/min
  - Negative inspiratory force (NIF) > -20 cm H₂O

Patient Case #2 (continued)

What changes to the ventilator could be made at this time?

- AC: VT 700 cc, RR 20 (36), FiO₂ 1.0
- ABG: pH 7.54, PaCO₂ 34, PaO₂ 49, HCO₃ 28
- Respiratory alkalosis → decrease VT or RR
- Sedation
- PEEP

Complications of mechanical ventilation

- Oxygen toxicity
- Barotrauma (pneumothorax, subcutaneous emphysema)
- Reduced cardiac output
- Stress ulceration
- Aspiration
- Pneumonia
- Upper airway trauma

Weaning from mechanical ventilation

- Weaning techniques
  - Conventional weaning
  - CPAP trial (PSV + PEEP)
  - T-piece trial
  - IMV weaning
    - step-wise reduction in the number of machine breaths

Weaning from mechanical ventilation

- Factors that should terminate weaning attempt
  - Heart rate increases > 20-30% baseline or >140 bpm
  - Respiratory rate > 35-40 breaths/minute
  - SaO₂ < 90%
  - SBP > 180 mmHg
  - Sustained anxiety, agitation, diaphoresis
Patient Case #2 (continued)

The patient was receiving 4 puffs of albuterol and ipratropium every 4 hours prior to intubation. Since intubation, the respiratory therapist has recommended increasing the patient’s MDI regimen to 10 puffs of albuterol and ipratropium per endotrachial tube every 4 hours. The package insert for ipratropium says not to exceed 12 puffs per day.

Did the respiratory therapist make an appropriate recommendation? Why or why not?

Goals of ICU sedation

- Attenuate fear, anxiety, agitation
  - Improve ventilator interaction
  - Allow completion of invasive patient care
  - Avoid self-injury
- Promote normal sleep wake cycles
- Reduce unnecessary recall

Sedation of Mechanically Ventilated Patients

After making the changes you recommended above, the patient continued to breathe rapidly and began pulling at her endotrachial tube; her last ABG revealed a PaO$_2$ 55 and SaO$_2$ 89%. The intern wants to sedate the patient to help coordinate her breathing with the ventilator and reduce oxygen consumption. She asks you if there are any important differences between midazolam and lorazepam.

What is your response?

Fear

- Anxiety: innate sense of life-threatening illness
- Agitation: motor restlessness that accompanies anxiety
- Pain: amplifies the experience of fear
- Sleep deprivation

BZD Pharmacokinetics

<table>
<thead>
<tr>
<th></th>
<th>Midazolam</th>
<th>Lorazepam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipophilicity</td>
<td>high</td>
<td>low-intermed</td>
</tr>
<tr>
<td>Onset of sedation</td>
<td>2-4 min</td>
<td>20-40 min</td>
</tr>
<tr>
<td>T1/2$\alpha$ (min)</td>
<td>6-15 min</td>
<td>3-20 min</td>
</tr>
<tr>
<td>Duration - bolus</td>
<td>1-2 hr</td>
<td>4-6 hr</td>
</tr>
<tr>
<td>T1/2$\beta$ (hr)</td>
<td>1.5-2.5 hr</td>
<td>a 10-20 hr</td>
</tr>
<tr>
<td>Prolonged in renal failure</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Prolonged in hepatic failure</td>
<td>maybe</td>
<td></td>
</tr>
<tr>
<td>Vd (L/kg)</td>
<td>1.1-1.7</td>
<td>b 1.1-1.3</td>
</tr>
</tbody>
</table>

*a* elimination half-life prolonged in critically-ill patient on cont. infusions  
*b* Vd may increase 2- to 3-fold in patients with congestive heart failure and 1.5- to 2-fold in chronic renal failure
**BZD Pharmacokinetics**

- Lipophilicity
  - Central
  - Brain
  - Tissue
  - Fat
  - $t_{1/2} \alpha$
  - $t_{1/2} \beta$

**Opioid Analgesics**

- Morphine
  - trade name: Versed
  - dosing: intermittent bolus inj., continuous infusion, drip titration
  - adverse effects: hypotension, metabolic acidosis
  - drug interactions: CYP3A4 substrate

- Fentanyl
  - trade name: Sublimaze
  - pharmacokinetics: onset (minutes), duration of effect (hours), prolonged in renal failure, prolonged in hepatic failure
  - dosing: intermittent bolus inj., continuous infusion
  - adverse effects: hypotension, constipation

- Propofol
  - trade name: Diprivan
  - pharmacokinetics: onset (minutes), duration (minutes), prolonged in renal failure, prolonged in hepatic failure
  - dosing: maintenance titration
  - adverse effects: hypotension, bradycardia, hypertriglyceridemia

- Haloperidol
  - trade name: Haldol
  - pharmacokinetics: onset (minutes), duration (hours), prolonged in renal failure, prolonged in hepatic failure
  - dosing: 2-5 mg IVP; if not effective, double the dose q 20 min until desired effect, then give 1/2 the effective dose q 4 hours (max: 40 q 4 hours)
  - adverse effects: EPS - rare, QTc prolongation

**Benzodiazepines**

- Midazolam
  - acute, intermittent inj.
  - rapid onset
  - short duration
  - chronic, cont. infusion
  - long duration
  - potential accumulation

- Lorazepam
  - acute, intermittent inj.
  - slow onset
  - long duration
  - chronic, cont. infusion
  - long duration
  - less accumulation potential

**Patient Case #2 (continued)**

- What is your response?
  - Midazolam
  - Lorazepam

**Drug Interactions**

- CYP3A4 substrate
  - azole antifungals
  - macrolides
  - protease inhibitors

**Drug Interactions**

- none
**Dexmedetomidine**

**Trade Name** Precedex

**Pharmacokinetics**

- Onset (minutes)
- Duration (minutes)
- Prolonged in renal failure
- Prolonged in hepatic failure
- Elimination half-life (hours)
  - 5-10
  - 20-30

**Dose**

- Infuse no longer than 24 hours
- Loading dose: 1mcg/kg over 10 min
- Maint infusion: 0.2-0.7mcg/kg/hour
- Titrate 0.1 mcg/kg/hr q 15 min

**Adverse effects**

- Bradycardia
- Hypotension
- Hypertension
- Atrial fibrillation

**Induction of sedation**

- Remove all correctable causes of agitation (tube placement, vent settings, pain, etc) prior to pharmacologic intervention

- Address pain management before initiating a sedative agent

- Achieve desired level of sedation with boluses BEFORE initiating a maintenance infusion of a bolus dose regimen

**Maintenance of sedation**

- Continuous infusion regimen
  - Minimizes “peak and valley” effect
  - Preferred in patients requiring therapeutic paralysis
  - Increases risk of accumulation
  - Increases risk of tolerance
  - Increases cost

- Bolus dose regimen
  - makes patient assessment easier
  - minimizes risk of accumulation
  - minimizes access limitations
  - requires repeated administration

**Ramsey Sedation Scale**

<table>
<thead>
<tr>
<th>Clinical Score</th>
<th>Characteristics of Sedated Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anxious and agitated or restless or both</td>
</tr>
<tr>
<td>2</td>
<td>Cooperative, accepting ventilation, oriented and tranquil</td>
</tr>
<tr>
<td>3</td>
<td>Sedated, but responsive to commands</td>
</tr>
<tr>
<td>4</td>
<td>Asleep, brisk response to light glabellar tap or loud auditory stimulus</td>
</tr>
<tr>
<td>5</td>
<td>Asleep, sluggish response to light glabellar tap or loud auditory stimulus</td>
</tr>
<tr>
<td>6</td>
<td>Asleep, no response to painful stimulus</td>
</tr>
</tbody>
</table>

**Maintenance of sedation**

- Regain desired level of sedation with boluses BEFORE increasing the maintenance infusion of bolus dose regimen

- Evaluate adequacy of sedation using Ramsey sedation scale, and titrate drip to minimum effective dose at least every 8 hours
  - Protocol-directed sedation (Crit Care Med 1999;27:2609-2615)
  - Daily interruption of sedative infusions (NEJM 2000;342:1471-1477)
**Sedation-Agitation Scale (SAS)**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Dangerous</td>
<td>Agitation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pulling at ETT, trying to remove catheters, thrashing side-to-side</td>
</tr>
<tr>
<td>6</td>
<td>Very agitated</td>
<td>Requires restraints, biting ETT</td>
</tr>
<tr>
<td>5</td>
<td>Agitated</td>
<td>Anxious, attempting to sit up, calms to verbal instructions</td>
</tr>
<tr>
<td>4</td>
<td>Calm</td>
<td>Calm, easily awakens, follows commands</td>
</tr>
<tr>
<td>3</td>
<td>Sedated</td>
<td>Difficult to arouse, awakens to verbal stimuli or gentle shaking, but drifts off again</td>
</tr>
<tr>
<td>2</td>
<td>Very sedated</td>
<td>Arouses to physical stimuli but does not communicate or follow commands</td>
</tr>
<tr>
<td>1</td>
<td>Unarousable</td>
<td>Minimal or no response to noxious stimuli</td>
</tr>
</tbody>
</table>

**Complications of ICU sedation**

- Prolonged ICU Stay
- Prolonged mechanical ventilation
- Respiratory Depression
- Physiologic dependence (withdrawal rxns)

**Patient Case #2 (continued)**

The patient was given bolus doses of lorazepam and started on a continuous infusion at 1mg/hr. The next morning, she appeared to be resting comfortably and was tolerating mechanical ventilation without difficulty. Overnight, the physicians had been able to reduce her FiO₂ requirement from 1.0 to 0.6. When you ask the nurse about the patient’s level of sedation, you hope she says:

a. The patient has been sleeping and is easily aroused with verbal stimulation
b. The patient doesn’t become agitated even with suctioning and turning
c. The patient has not required bolus doses or increases in drip rate
d. all of the above
e. a and c

What factors should you consider when weaning sedatives?

Describe an appropriate method for weaning this patient’s sedation regimen including monitoring parameters

**Benzodiazepine withdrawal**

- **Signs and Symptoms**
  - dysphoria
  - tremor
  - sweating
  - ↑ light/sound sensitivity
  - agitation
  - insomnia
  - myoclonus
  - seizures
- **Highest Risk**
  - ≥ 35 mg/day lorazepam or ≥ 70 mg/day midazolam
- **Time Course**
  - 6-24 hours

**Opioid withdrawal**

- **Signs and Symptoms**
  - pupil dilation
  - lacrimation/rhinorrhea
  - sweating
  - vomiting/diarrhea
  - tachycardia
  - hypertension
  - fever
  - tachypnea
- **Highest Risk**
  - ≥ 5000 mcg/day fentanyl
- **Time Course**
  - 6-24 hours
**Patient Case #2 (continued)**

What factors should you consider when weaning sedatives?

- Duration of sedation
- Dose requirements
- Hemodynamic status

**Indications for neuromuscular blockade**

- Poor oxygenation or patient-ventilator interaction that persists despite adequate sedation
- Potentially dangerous movements in an instrumented patient that persists despite adequate sedation

**Therapeutic Paralysis**

Describe an appropriate method for weaning this patient’s sedation regimen including monitoring parameters

- Reduce the infusion rate by 50% decrements per day
- Monitor for tachycardia, fever, agitation, etc
- Withdrawal - titrate infusion to adequate sedation and reduce the infusion rate by 10% decrements per day

**Neuromuscular Blocking Agents**

**Depolarizing**
- Succinylcholine

**Nondepolarizing**
- Atracurium (Tracrium ®)
- Cisatracurium (Nimbex ®)
- Doxacurium (Nuromax ®)
- Mivacurium (Mivacron ®)
- Pancuronium (Pavulon ®)
- Pipecuronium (Arduan ®)
- Rocuronium (Zemuron ®)
- Vecuronium (Norcuron ®)

**Patient Case #3**

A 42 yo female with a significant history of alcohol and tobacco abuse is transferred to the MICU from an outside hospital with adult respiratory distress syndrome (ARDS). She presented to the outside hospital after one week of productive cough, fevers, chills and increasing SOB. On admission to the MICU she is hypotensive (80/60), tachycardic (130) and febrile (39.0). Her ABG shows 7.10/56/49 with an SaO2 of 76% on FiO2 1.0. The only other significant labs were a Scr 1.5, WBC 16,000. She appears to be adequately sedated with lorazepam 3mg/hr, fentanyl 200mcg/hr. In an attempt to improve her oxygenation, she is paralyzed and placed on inverse ratio ventilation. Which of the following statements about therapeutic paralysis is true?

a. sedatives can be discontinued after paralysis is initiated
b. doxacurium is best administered by a continuous infusion
c. depth of paralysis should be monitored using a peripheral nerve stimulator
d. once paralysis is initiated, it should not be stopped until the patient is extubated
Neuromuscular Blocker Pharmacology

NMB Adverse Effects

Drug | Histamine release | Vagolytic action
--- | --- | ---
pancuronium | + | +++
pipecuronium | + | ++
rocuronium | | +
vecuronium | | ++

Benzylisoquinolinium

Drug | Histamine release | Vagolytic action
--- | --- | ---
atracurium | +++ | +
cisatracurium | | +
doxacurium | | ++
mivacurium | | +++

NMB Pharmacokinetics

Drug | Duration of effect (min) | Elimination
--- | --- | ---
pancuronium | 120-180 | renal 60-80%, hepatic*
pipecuronium | 80-100 | renal >80%
rocuronium | 30-70 | biliary 50%, renal
vecuronium | 20-60 | biliary/hepatic 80-90%*

Benzylisoquinolinium

Drug | Duration of effect (min) | Elimination
--- | --- | ---
atracurium | 30-40 | Hofmann, ester hydrolysis
cisatracurium | 30-70 | Hofmann, ester hydrolysis
doxacurium | 90-120 | renal
mivacurium | 12-18 | plasma cholinesterase

NMB Dosing

Drug | Loading dose | Maintenance dose
--- | --- | ---
pancuronium | 0.08 mg/kg | 0.1 mg/kg
pipecuronium | 0.1 mg/kg | 0.02-0.04 mg/kg prn
rocuronium | 0.6-1.0 mg/kg | 0.3-0.6 mg/kg/hr
vecuronium | 0.1 mg/kg | 0.02-0.04 mg/kg/hr

Benzylisoquinolinium

Drug | Loading dose | Maintenance dose
--- | --- | ---
atracurium | 0.4 mg/kg | 0.4-0.6 mg/kg/hr
cisatracurium | 0.2 mg/kg | 0.3-0.6 mg/kg/hr
doxacurium | 0.05 mg/kg | 0.025 mg/kg prn
mivacurium | 0.1 mg/kg | 0.05 mg/kg/hr

Patient Case #3 (continued)

The patient was paralyzed as instructed and appeared to be doing well until about one hour after her 3rd dose of pancuronium when she began to violently move around in bed. At this time she was tachycardic (120), appeared very agitated, her $\text{SaO}_2$ fell to 80%, and the nurse reported that the patient had regained all four twitches on TOF. Which of the following is most appropriate?

a. administer a pancuronium bolus dose
b. administer a fentanyl bolus dose
c. increase the lorazepam drip rate
d. change the pancuronium to vecuronium

Monitoring therapeutic paralysis

• Adequate sedation and analgesia must be achieved before starting a paralytic agent
• Sedation should be ordered around-the-clock (e.g. not prn)
• Paralytic dosage should be monitored using a Peripheral Nerve Stimulator (PNS)
Peripheral Nerve Stimulator

Monitoring therapeutic paralysis

- When performing TOF, hold the fingers down and only observe thumb twitches
- Goal for paralysis: 1-2/4 twitches
- 0/4 twitches: “over-paralyzed”
  » withhold the paralytic agent until at least 1/4 twitches is observed

Monitoring therapeutic paralysis

- Baseline “Train of Four” (TOF) should be documented prior to paralysis
- Place two EKG patches near the wrist along the ulnar nerve
- Attach the alligator clips to the electrodes, turn on the PNS, and press the TOF button.
  » 4 strong thumb adductions should be seen in the non-paralyzed patient
  » If 4 equal twitches are not seen, increase the current on the dial on the side of the PNS and repeat TOF at 10-20 second intervals until seen. Continue increasing the current until the strength of contraction is supramaximal. Use this current for all subsequent TOFs

Monitoring therapeutic paralysis

- Monitor and record depth of paralysis every 15 minutes for the first hour, then hourly x 4 hours
- If paralysis is needed beyond this time, TOF should be monitored at least every 4 hours
- Paralysis should be stopped at least once daily to ensure adequate sedation and assess the need for continued paralysis.

Monitoring therapeutic paralysis

- Estimate the depth of paralysis using the tetany mode
  » hold the tetany button for 5 seconds, wait 3 more seconds then push the twitch button
  » extreme paralysis is present if the single twitch fails to elicit a response following application of tetany
  » Do not apply tetany more frequently then every 5-10 minutes, may yield a false result

Patient Case #3 (continued)

After that event, the patient did poorly throughout the rest of the night. A Swan-Ganz catheter was placed, confirming the diagnosis of sepsis (e.g., high CO, low SVR) and she required 60mcg/min of norepinephrine to maintain an adequate blood pressure. Other medications included clindamycin, cefepime, and gentamicin. By morning, her SCr had increased to 2.8, and the night shift nurse charted that the patient had 0/4 twitches on TOF for the last 8 hours.

List some possible reasons why the TOF is consistently 0/4 in this patient.
Complications of therapeutic paralysis

- Prolonged paralysis
- ICU myopathy
- Masked problems
  - abdominal infections
  - pain
  - seizures

Factors affecting neuromuscular blockade

<table>
<thead>
<tr>
<th>Drugs</th>
<th>Potentiate block</th>
<th>Antagonize block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aminoglycosides</td>
<td>Clindamycin</td>
<td>Tetracyclines</td>
</tr>
<tr>
<td>CCB</td>
<td>β-blockers</td>
<td>Aminophylline</td>
</tr>
<tr>
<td>Theophylline</td>
<td>Carbamazapine</td>
<td>Phenytoin</td>
</tr>
</tbody>
</table>

Electrolyte Disorders
- Hypermagnesemia
- Hypocalcemia
- Hypokalemia
- Hypercalcemia
- Hyperkalemia

Acid-Base Disorder
- Acidosis
- Alkalosis

Patient Case #3 (continued)

List some possible reasons why the TOF is consistently 0/4

- Clindamycin, gentamicin
- Acute renal failure
- Electrolytes, acid-base status

Supplemental Reading

Mechanical Ventilation

Sedation


Neuromuscular Blockade

Clinical Practice Guidelines

Sedation

Neuromuscular Blockade