I. Pharmacology Simulation Scenarios: Respiratory Failure due to Asthma Exacerbation

II. Target Audience: 1st and 2nd year medical students

III. Learning Objectives
   A. Primary
      1. Develop a plausible differential diagnosis from the history and physical examination findings for the scenario and be able to explain how each diagnosis in the differential is consistent with the findings.
      2. Identify and discuss the pathophysiologic mechanisms that are most likely responsible for the patient-simulator’s findings.
      3. Choose a treatment plan that utilizes medications and/or intravenous fluids to resolve the patient-simulator’s condition.
      4. Determine what the most likely physiologic responses will be after the administration of select medications to the patient-simulator.
   B. Secondary
      1. Demonstrate the ability to rapidly assess a patient with respiratory failure due to status asthmaticus
      2. Manage respiratory failure in a patient in status asthmaticus
      3. Describe the mechanism of action of various pharmacologic agents used in the treatment of status asthmaticus
      4. Understand the progression of pharmacologic therapy in treating an acute asthma exacerbation
      5. Understand the importance of and the indications for supplemental O₂ and mechanical ventilation in patients with respiratory emergencies.
   C. Critical Actions Checklist
      1. Perform a rapid primary survey assessment (ABC’s).
      2. Obtain vitals, including pulse oximetry.
      3. Obtain IV access and connect patient to continuous cardiorespiratory monitoring.
      4. Perform a focused history
      5. Perform a focused physical examination
      6. Recognize the patient’s initial respiratory distress due to status asthmaticus
      7. Initiate treatment with supplemental oxygen
      8. Order tests: CXR
      9. Access dosing and route information from standard pocket pharmacology guide
      10. Initiate pharmacologic treatment (beta-agonist, ipratropium)
      11. Order pharmacologic agents (solumedrol, heliox, magnesium sulfate, terbutaline, aminophylline, epinephrine)
      12. Perform bag-valve-mask ventilation
      13. Perform rapid sequence intubation using appropriate
pharmacologic agents
14. Disposition to ICU

Duration to critical actions: resuscitation to be completed within 20-30 minutes of starting the scenario

IV. Environment
A. Lab Setup: 2 spaces, an Emergency Department examination room with an adjacent conference room with live audio video feed. There was an instructor in each room.
B. Adult human patient simulator with available monitoring devices including cardiorespiratory monitor and pulse oximeter.
C. Props:
   1. IV lines
   2. Oxygen tank
   3. Nebulizer set-up
   4. Stethoscope
   5. Nasal cannula
   6. Face mask
   7. Non-rebreather mask
   8. Ambu-bag
   9. CXR: pre and post hyper inflated intubation films (Appendix A and B)
   10. Standard pocket pharmacology guide
   11. Faux medications
   12. Airway supplies x 2 (set for each room)
      a. Laryngoscope with blades of various sizes/types
      b. Endotracheal tubes of various sizes
      c. End tidal Co2 detector
   13. Intubating head for conference room

V. Actors
A. None

VI. Case Narrative
A. Scenario Background (given freely)
   1. Chief complaint: A 22 year-old male presents to the ED with progressive shortness of breath. He was seen in clinic 4 hours ago and was given one nebulized treatment of albuterol and one dose of oral prednisone. En route, the patient decompensates and requires further intervention.
   2. Hx: Asthma w/ three Intubations, second hand smoke exposure, cat at home, non-compliant with Albuterol MDI (ran out)
   3. Meds: Albuterol MDI, fluticasone, uses salmeterol for Rescue

B. Scenario condition initially
   1. V/S: Afebrile, RR 46, HR 160, BP 160/90, O2: 83%
   2. Gen: Patient not speaking, eyes are closed
3. Airway: Patent
4. Breathing: Tachypnea, breath sounds diminished, faint wheezing
5. Circulation: Tachycardia, symmetric pulses

C. Scenario branch points
1. Treatment with doses of nebulized albuterol +/- ipratropium do not result in significant improvement
2. New V/S: RR 20 HR 144, BP 150/75, O2: 83%
3. Gen: Responds only to noxious stimuli
4. Breathing: Shallow respirations, minimal breath sounds related to decreased tidal volume
5. Students may choose additional medications (solumedrol, magnesium sulfate, terbutaline, aminophylline, heliox, epinephrine) however patient continues to deteriorate
6. New V/S: RR 10, HR 110, BP 120/70, O2: 78%
7. Bag/mask ventilation with 100% oxygen
8. Rapid sequence intubation for respiratory failure
9. Disposition to the ICU

VII. Instructor Tips
A. Instructor must be able to highlight key teaching points as the scenario develops. Possible questions include:
   1. What may have led to the patient entering status asthmaticus? Patient may not have received proper education. A discussion with primary care physician on avoidance of smoke exposure, cat dander, and importance of always having albuterol may have prevented the status asthmaticus.
   2. Is there an upper limit to amount of Albuterol that can be used? No, unless significant side effects develop such as hypokalemia, hyperglycemia, and tachycardia.
   3. What other pharmacologic treatments can you use? Solu-medrol, magnesium sulfate, terbutaline, aminophylline, heliox, epinephrine.
   4. How can you evaluate a patient’s respiratory status? Mental status, respiratory rate, oxygen saturation, accessory muscle use, ABG.
   9. A 3 page handout contains key teaching points. (Appendix C)
B. Laminated cue cards which contain the case narrative, suggested questions, and detailed information on the medications used in each scenario can be held by instructor (Appendix D)
C. Use of Socratic method (comfortable with silence).
D. Instructor must make it interactive by encouraging participation with all 4 participants
   a. Connect simulator to cardiorespiratory monitor and pulse oximeter
   b. Connect oxygen tubing
   c. Assess mental status, work of breathing, auscultation, color, and respiratory rate
d. Correct bag-valve-mask technique

e. Select correct intubation equipment

f. Perform intubation using correct technique

g. Access dosing information from standard pocket pharmacology guide

VIII. Debriefing Method

A. Group debriefing consisted of two separate, simultaneous real time discussions amongst observers in the conference room (max of 10) and simulation participants in the simulation room (max of 4).

B. Key learning points outlined in the learning objectives were intentionally highlighted by the instructor in both rooms.

C. After each scenario, a brief joint discussion involving both observers and participants was held. Some potential questions include:
   1. What did the simulation participants do well?
   2. What was the one take home point from this case?
   3. What was discussed in the conference room that was not mentioned in the simulation room?

IX. Pilot Testing and Revisions

A. The initial class involved up to 15 students in the simulation room with one faculty member. This inhibited individual participation. The quality of interaction was significantly improved when the class was divided into two smaller groups, each led by a separate faculty facilitator. While there was significant overlap in the content discussed during the 2 real time discussions, material that was not addressed in both rooms was explored in the joint debriefing session. Students were given the opportunity to teach the other group members advanced knowledge not addressed by the other group, which promoted active learning. At the end of the simulation experience, students were asked to complete an online evaluation. Overall, student feedback was very favorable (Appendix F).

B. The group in the simulation room emphasized clinical skills in more detail while the group in the conference room used the clinical assessment time to focus on pharmacologic principles.

C. Number of participants: 4 in Simulation Room, 10 watching live feed

D. Performance expectations: review lecture material prior to simulation experience

E. Evaluation form #1 completed by each learner (Appendix E)

F. Evaluation form #2 completed by each learner (Appendix G)

G. Evaluation form completed for each student by both faculty facilitators (Appendix H)

X. References


**XI. Author Affiliations**

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Loma Linda University School of Medicine  
Loma Linda, Ca
Appendix A – Pre-intubation CXR
Appendix B – Post-intubation CXR
Appendix C

Key Teaching Points for Faculty Facilitators

General Topics

**Asthma:** A chronic, partially reversible inflammatory disorder of the airways. The obstruction is caused by airway edema, inflammatory cells, mucous, smooth muscle contraction.

**Differential diagnosis:** COPD, tumor, pneumonia, pulmonary edema, pulmonary embolus, foreign body, and bronchiectasis

**Calcium:** Main cation responsible for airway smooth muscle contraction

**cAMP:** Responsible for relaxation by decreasing calcium release from sarcoplasmic reticulum in airway smooth muscle cells.

**Pertinent physical exam findings**
1) Tachypnea: > 25 in adults
2) Bradypnea: < 8 in adults
3) Chest shape: normal thoracic ratio is 0.7. It is increased in old age, emphysema, severe bouts of asthma
4) Respiratory paradox: chest and abdominal move asynchronously. Chest wall moves outward during inspiration and abdominal wall moves inward. Sign of diaphragm paralysis or weakness or tiring.
5) Percussion: hyper-resonance
6) E:I ratio: may exceed 3:1

**Poor prognostic indicators**
1) Use of accessory muscles
2) Inability to lie supine
3) Pulsus paradoxus > 15 (fall in systolic blood pressure during inspiration, due to exaggerated negative pressure during inspiration in asthmatics)
4) No breath sounds
5) Normal or High Co2
6) Cyanosis
7) Acidosis from lactic acid buildup
8) Peak Flow < 200

**Symptoms of mild hypoxemia:** Similar to ethanol intoxication (confusion, loss of judgment, or coma)

**Signs of moderate hypoxemia:** Increased sympathetic nervous system activity by activation of carotid body chemoreceptors → increased HR and cardiac output, hypertension, and vasoconstriction

**Signs of severe hypoxemia:** Loss of sympathetic tone (bradycardia, decreased cardiac output, and vasodilation)
V/Q mismatch: Albuterol produces vasodilation in lung segments that have poor ventilation. Atrovent is NOT a vasodilator and therefore doesn’t cause V/Q mismatch

When to obtain a blood gases: Check peak flow, if < 200, will probably see abnormal VBG findings (due to C02 retention).

Signs of hypercapnea: Similar to a general anesthetic: mild sedation, drowsiness.

Drugs (1st line for acute exacerbations)

Albuterol: Beta 2 agonist, increases cAMP, which in turn leads to
1) Smooth muscle relaxation
2) Inhibition of mediator release from mast cells
3) Increased mucociliary clearance
4) Side effects: tremor, tachycardia, hypokalemia

Atrovent: Blocks cholinergic induced bronchoconstriction
1) There are 3 muscarinic receptors in our airways, atrovent blocks M3 → decreases IP3 and DAG → decreases amount of available cytosolic calcium needed to initiate contractions
2) Side effects: poorly absorbed, so very few systemic side effects. Can worsen mucous plugging, dry mouth, blurry vision, glaucoma
3) Efficacy: in combination with albuterol, improves lung function by 10%. In kids and adults, 3 doses of atrovent decreases hospitalization rate from ER by 30% in severe asthmatics.

Systemic Corticosteroids:
1) Decrease inflammatory cell invasion (neutrophils, macrophages, eosinophils, mast cells)
2) Sensitization of beta receptors
3) Upregulation of beta receptors (but takes a long time since this requires new gene expression)
4) Decrease mucous secretion
5) Less leaky endothelial cells
6) Clinically apparent affects take about 6 hrs
7) IV = oral forms

Drugs (2nd line for acute exacerbations)

Terbutaline: IV form of beta 2 agonist. Side effects: tremor, tachycardia, nausea

Magnesium Sulfate: Mechanism not well understood. It competes with calcium, acts as a calcium antagonist. Inhibits calcium uptake in smooth muscle cells: causes relaxation. Side effects: flushing, hypotension

Heliox: The effects of heliox relates to its low density and its ability to reduce turbulent air flow. This decreases airway resistance, resulting in improved ventilation and reduces the work of breathing (can get the medications down more distally). There are no evidence-based guidelines on its use. No significant side effects with heliox therapy.
Not very expensive compared to plain oxygen (4X cost). Usually 80:20 or 70:30 ratio of helium to oxygen.

**Aminophylline(IV)/Theophylline:** Mild bronchodilator and anti-inflammatory properties.
1) Thought to be due to phosphodiesterase inhibition which increases cAMP and adenosine receptor antagonism
2) Also enhances diaphragmatic contractility, relaxes smooth muscle, decreases secretions. Works well and is inexpensive.
3) Small therapeutic index. Side effects: nausea, then neurologic changes (agitation, dizziness, headaches) then arrhythmias, hypotension.

**Ketamine:** Anesthetic
1) Decreases vagal tone
2) Direct muscle relaxation
3) Causes release of endogenous catecholamines which increase sympathetic tone which causes bronchodilation
4) Side effects: hallucinations, increased secretions, laryngospasm

**Drugs (for chronic maintenance therapy)**

**Salmeterol:** Long acting beta 2 agonist
1) Black box warning due to possible increased mortality with its use. However, if combined with steroids, probably beneficial (salmeterol + fluticasone)
2) Side effects: may actually worsen respiratory status, via negative feedback mechanism. Chronic stimulation may desensitize and down regulate beta 2 gene expression.

**Leukotriene receptor antagonist:** Decreases inflammation (not as effective as steroids) and prevents airway remodeling.

**Cromolyn Sodium:** Mast cell stabilizer, no bronchodilator response
Appendix D

Facilitator Cue Card #1

Patient Name: Al Uterol  Scenario: Status Asthmaticus

22 year-old male complaining of shortness of breath and a “tight chest”. The paramedics bring him to the Emergency Department from home. This patient initially was seen in clinic earlier today but now has decompensated and requires further pharmacologic treatment and intubation. His eyes are closed, he has labored breathing, and he is not speaking anymore.

Hx: Asthma w/ three Intubations, second hand smoke exposure, cat at home, non-compliant with Albuterol MDI (ran out)

Meds: Albuterol MDI (ran out), flovent (ICS), uses salmeterol for rescue

RR 35  HR 140  BP 160/90  O2: 83%

Questions: What may have led to the patient entering status asthmaticus? Patient may not have received proper education. A discussion with primary care physician on avoidance of smoke exposure, cat dander, and importance of always having albuterol may have prevented the status asthmaticus.

Is there an upper limit to amount of Albuterol that can be used? No, unless significant side effects develop such as hypokalemia, hyperglycemia, and tachycardia.

What other pharmacologic treatments can you use? Steroids, epinephrine, terbutaline, magnesium sulfate.

How can you evaluate a patient’s respiratory status? Mental status, respiratory rate, oxygen saturation, accessory muscle use, ABG.

Scenario Meds: Terbutaline, epinephrine, ketamine

Facilitator Cue Card #2

Terbutaline:
Action: Beta-2 Agonist: Relaxes bronchial smooth muscle by action on beta-2 receptors with less effect on heart rate

Onset: 6-15 minutes. Half life: 11 hours

Dosage: 0.25 mg/dose; may repeat in 15-30 minutes (maximum: 0.5 mg/4-hour period)

Side Effects: Palpitations, tachycardia, agitation, trembling
**Facilitator Cue Card #3**

**Epinephrine:**

**Action:** Stimulates alpha-1, alpha-2, beta-1, and beta-2 adrenergic receptors resulting in relaxation of smooth muscle of the bronchial tree, cardiac stimulation, and dilation of skeletal muscle vasculature.

**Onset:** Bronchodilation: within minutes

**Dosage:** 0.3-0.5 mg (1:1000) every 20 minutes for 3 doses

**Side Effects:** Palpitations, tachycardia, flushing, trembling

**Facilitator Cue Card #4**

**Ketamine:**

**Action:** Produces a cataleptic-like state in which the patient is dissociated from the surrounding environment by direct action on the cortex and limbic system. Releases endogenous catecholamines (epinephrine, norepinephrine) which maintain blood pressure and heart rate.

**Onset:** 30 seconds. T1/2 Alpha: 10-15 minutes. T1/2 Beta: 2.5 hours

**Dosage:** 1-2 mg/kg infuse over 0.5 mg/kg/minute

**Side Effects:** Emergence reaction, tachycardia, increase BP, increased CSF pressure
Appendix E

Pharmacology Simulation Evaluation Form #1

1-strongly disagree  2-disagree  3-neutral  4-agree  5-strongly agree

The following questions pertain solely to the Pharmacology Simulation Lab:

1) The pharmacology lab helped me apply the basic science of medicine to clinical practice.

2) Pharmacology simulation lab is more effective in helping me understand basic science knowledge than pharmacology lecture.

3) The pharm simulation experience helped me learn the appropriate pharmacologic and nonpharmacologic interventions to stabilize acute patients in cardiopulmonary emergencies.

4) Overall, the experience of pharmacology simulation lab was a worthwhile component of the 2nd year medical school curriculum.
Pharmacology Simulation Evaluation Form #1 Results

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<th>D</th>
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<td>Q3. The pharmacology simulation experience helped me learn the appropriate pharmacologic and non-pharmacologic interventions to stabilize acute patients in cardiopulmonary emergencies.</td>
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<td>Q4. Overall, the experience of pharmacology simulation lab was a worthwhile component of the 2nd year medical school curriculum.</td>
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Appendix G
Pharmacology Simulation Evaluation Form #2

Name_________________________ Date____________________

1) List two strengths of today’s lab?
   --
   --

2) List two things that we as facilitators could do differently to improve this experience?
   --
   --

3) Self-assessment: Do you believe you performed as well as your peers, better than your peers, or worse than you peers? Please explain your response.

4) Overall comments on the lab
Pharmacology Simulation Lab Faculty Evaluation

Student Name____________________  Date____________________

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<th>Evidence</th>
<th>Rating (1-3)</th>
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<td>-Actively participated during debrief sessions</td>
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<td>-Facilitated peer involvement</td>
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General Comments________________________________________________________________________
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Faculty_______________________  Faculty_______________________