Aerosol Medications
Learning Objectives

* Define the term “aerosol.”
* Describe how particle size, motion, and airway characteristics affect aerosol deposition.
* Describe how aerosols are generated.
* List the hazards associated with aerosol drug therapy.
* Describe how to select the best aerosol drug delivery system for a given patient.
Learning Objectives (cont.)

* Describe how to initiate and modify aerosol drug therapy.
* State the information patients need to know to properly self-administer drug aerosol therapy.
* Describe how to assess patient response to bronchodilator therapy at the point of care.
The aim of medical aerosol therapy is to deliver a therapeutic dose of the selected agent (drug) to the desired site of action.

For patients with pulmonary disorders, administration of aerosol provides higher therapeutic index:

* Higher local drug concentration in lung
* Lower systemic effects
Aerosol Medications

- Aerosol output: amount of drug that is delivered by nebulizer
- Particle size: determines where in airway particle will be deposited
- MMAD (mass median aerodynamic diameter): expressed average particle size
Characteristics of Therapeutic Aerosols

* Aerosol Output
  * Mass of fluid or drug contained in aerosol
  * Output rate is mass of aerosol generated per unit of time
    * Varies depending on different nebulizers & inhalers used
  * Emitted dose describes mass of drug leaving mouthpiece as aerosol
    * Measured by collecting aerosol that leaves nebulizer on filters:
      * Gravimetric analysis measures aerosol weight
      * Assay measures quantity of drug
Characteristics of Therapeutic Aerosols (cont.)

* Particle size
  * Depends on 3 factors
    1. Substance being nebulized
    2. Method used
    3. Environmental conditions
  * Methods to measure medical aerosol particle distribution include:
    * Cascade impaction
    * Laser diffraction
Characteristics of Therapeutic Aerosols (cont.)

- **Deposition**
  - Only fraction of emitted aerosol (emitted dose) will be inhaled
  - Only fraction of inhaled (respirable dose) is deposited in lungs
  - Amount of drug inhaled called “inhaled mass.”
  - Portion of inhaled mass that can reach lower airways is “respirable mass”
Aerosol Medications

- Aerosol particles that are inhaled into the lung are deposited in the respiratory tract depends on the size, shape, and motion of the particles and on the physical characteristics of the airways and breathing pattern.

- Key mechanisms of aerosol deposition include:
  1. Inertial impaction
  2. Gravimetric sedimentation
  3. Brownian diffusion
Aerosol Medications (Cont.)

1. Inertial impaction
   - Occurs when aerosol in motion collides with and are deposited on surface
   - Primary deposition mechanism for larger particles (>5 μm).

2. Sedimentation
   - Occurs when aerosol particles settle out of suspension & are deposited due to gravity
   - Represents primary mechanism for deposition of small particles (1-5 μm
   - Occurs mostly in the central airways and increases with time, affecting particles 1 μm in diameter.
   - Breath holding enhances distribution across the lungs and sedimentation.
Characteristics of Therapeutic Aerosols (cont.)
Characteristics of Therapeutic Aerosols (cont.)
3. Brownian motion/diffusion
   - Primary deposition mechanism for very small particles (<3 µm) deep within lung
   - Particles between 1 & 0.5 µm have very low mass & are so stable that most remain in suspension & are exhaled back into environment
   - Particles <0.5 µm have greater retention rate in lungs
Aging: aerosol particles grow, shrink, and coalesce as they move down airway passage

- How aerosol ages depends on:
  - Composition of aerosol
  - Initial size of its particles
    - Particle size can change due to evaporation or hygroscopic water absorption
  - Time in suspension
  - Ambient condition
Aerosol Therapy (Cont.)

Deposition is affected by:

1. Inspiratory flow rate
2. Flow pattern
3. Respiratory rate
4. I:E ratio
5. Breath hold
6. Presence of airway obstruction
Hazards of Aerosol Therapy

1. Infection
2. Airway reactivity
3. Pulmonary and systemic effects
4. Drug concentration changes
5. Eye irritation
6. Exposure to secondhand aerosol drugs
Aerosol Delivery Systems

- Methods of aerosol drug administration:
  - Metered-dose inhaler
  - Dry powder inhaler
  - Jet Nebulizer (Large and small volume)
  - Ultrasonic nebulizer
  - Hand-bulb atomizer (e.g., nasal spray)
  - Vibrating mesh nebulizer
* Most common method of aerosol drug administration
* Used for administration of short-acting beta agonists, long-acting beta agonists, anticholinergic agents, and inhaled corticosteroids
Pressurized canister containing propellant and drug

- Propellants
  - Chlorofluorocarbons (CFCs): no longer used due to damage to ozone layer
  - Hydrofluoroalkane (HFA): only propellant used in currently available MDIs
Technique for Administration of MDI

- Patient teaching critical for effective use of MDI
- Optimum technique for use of MDI:
  1. Shake inhaler well before each use
  2. Remove cap from actuator mouthpiece
  3. Inspect mouthpiece and clear any debris
  4. Shake inhaler and prime it with test spray away from face (done with new MDI and one that has not been in use for the past 24 hours)
  5. Breathe out fully through mouth
  6. Insert mouthpiece into mouth and seal lips around it. (An alternative technique is to place mouthpiece about 4 cm from open mouth)
Optimum technique for use of MDI (Cont.):

* Press down on canister at beginning of breath; breathe in slowly and deeply
* Perform an inspiratory hold for up to 10 seconds
* Repeat procedure at 30- to 60-second intervals
* Replace cap on mouthpiece
* Clean actuator mouthpiece at least 1 time per week; shake out excess water and let air dry
* Discard canister when canister has delivered number of doses indicated on label
* Activate during inspiration; decreasing need for coordination
* Only available in United States as pirbuterol; used with other drugs in other countries
* Decreases amount of drug deposited in pharynx and improves lung deposition
Breath-Actuated MDI (Cont.)

* Inhaler is activated when inspiratory flow rate exceeds 30 L/min
* Patients with severe exacerbations of asthma may not be able to actuate MDI
MDI Accessory Devices

- Dose counters
  - Indicate number of doses remaining in MDI
  - No longer recommended to place canister in water to determine amount of contents remaining
Determining the Contents of an MDI

* With dose counter:
  * Determine number of puffs available in MDI when full
  * Learn how to read counter
  * Dispose of MDI after last dose has been administered
Without dose counter:

- Read instructions to determine number of doses contained in MDI
- Calculate number of days MDI will last (total doses/number of puffs per day)
- Determine date MDI will be empty; record on canister or calendar
- Track number of doses; record on daily log
- Dispose of MDI after last dose has been administered
Accessory Devices

- Spacers or holding chambers
  - Decrease amount of oropharyngeal deposition and need for hand-breath coordination
  - Add distance between MDI and mouth; allow aerosol to expand and propellants to evaporate before inhalation
  - Minimize effects of cold propellants
  - One-way valve used to prevent exhalation into spacer
Spacers and Holding Chambers

* Electrostatic charge builds up on surface of spacer
* This decreases effectiveness of spacer; effects of charge can be eliminated by washing spacer
* Available with mouthpieces and masks
* Can be used with infants and children
Technique for Using MDI with Spacer

1. Remove caps from boot of MDI and spacer
2. Shake MDI and chamber
3. Actuate one dose from MDI while breathing through spacer
4. Take slow, deep breath and perform an inspiratory hold for 10 seconds, if possible
5. If spontaneous breathing through spacer is not possible, remove spacer from mouth
6. Repeat actuation of MDI in 30- to 60-second intervals
7. Remove MDI from spacer and replace caps on both
8. Store MDI and spacer properly
9. Periodically wash spacer in warm soapy water; rinse; allow to air dry
Dry Powder Inhalers

- Deliver drug in powder form
- Is a breath-actuated system
- Delivery of drug is dependent on patient’s ability to generate adequate inspiratory flow rate
- Types of dry powder inhalers (DPIs):
  - Unit dose DPI
  - Multiple unit dose DPI
  - Multiple dose DPI
Unit Dose DPI

- DPIs hold only one dose of drug
- Examples: Aerolizer and Handihaler
Multiple Unit Dose DPI

- Unit contains multiple, individually packaged doses of drug
- Example: Diskhaler
Multiple Dose DPI

* DPI has reservoir of medication dispensed in appropriate dose with each activation
* Examples: Twinthalar and Flexhaler
1. Assemble apparatus
2. Load dose following manufacturer’s instructions
3. Exhale slowly, down to functional residual capacity; be sure to exhale away from mouthpiece
4. Seal lips around mouthpiece
5. Inhale deeply and rapidly (inspiratory flow rates must exceed 60 L/min)
6. If more than one dose is required, repeat previous steps
Technique for DPI Administration (Cont.)

* Monitor for adverse effects
* Replace cover of DPI
* Keep device clean and dry at all times
* Keep device at controlled room temperature
DPI Administration

- Most significant factor in DPI administration is inspiratory flow rate
- Patient must be able to generate inspiratory flow rates of 40 to 60 L/min
- Patients who may not be able to use DPI:
  - Children under 5 years of age
  - Patients with severe airway obstruction
Jet Nebulizer

- Delivers dose of drug in aerosol form
- Types of small-volume nebulizers:
  1. Pneumatic jet nebulizers
  2. Ultrasonic nebulizers
  3. Vibrating mesh nebulizer
Factors Affecting Nebulizer Performance

* Nebulizer Design
* Residual Drug Volume
* Flow
* Gas Source: Hospital vs. Home
* Gas Density
Jet Nebulizer with Reservoir

* Large bore tube collects some of exhaled medication
* Significant amount of medication lost during exhalation
Jet Nebulizer with Collection Bag

- Collection bag is attached to expiratory side of nebulizer
- Patient inhales from reservoir through one-way valve and exhales through exhalation port
Breath-Actuated Nebulizer

- Delivers an aerosol during inspiration
- AeroEclipse uses spring-loaded, one-way valve drawing flow during inspiration
Residual Drug Volume

- Also referred to as “dead volume”
- Volume in small-volume nebulizer that cannot be nebulized
- Amount of residual volume is affected by the angle in which the nebulizer is held
As flow is increased through the nebulizer, particle size is decreased and treatment time is decreased.
Gas Source for Nebulizer

* Higher driving pressure will deliver smaller particles, higher aerosol outputs, and shorter treatment times
* Home compressors have lower driving pressure than wall oxygen or air
  * Produces larger particles and requires longer times to deliver drug
Gas Density

* Lower density gas reduces amounts of turbulent flow
* Helium concentrations of 40% have been shown to increase delivery of aerosol by 50%
Vibrating Mesh Nebulizers

- Pumps push fluid through vibrating mesh to create aerosol
- Passive mesh nebulizers use ultrasonic vibrations to move fluid through static mesh
- Produce particle sizes ranging from 3 to 6 microns
Vibrating Mesh Nebulizers (Cont.)

- Active mesh nebulizers use dome shape that contains 1000 to 4000 apertures
- Use funnel-shaped apertures forming a mesh
- As fluid is pumped through apertures, particles are produced
- Electricity is applied to mesh causing size of apertures to go up and down by 1 to 2 microns, producing very fine mist delivered to patient
- Particle sizes range from 2 to 5 microns
Vibrating Mesh Nebulizers (Cont.)

- Do not require propellants or gas to produce an aerosol; no gas is added to aerosol stream
- Shown to be more efficient than jet nebulizers
**Small-Volume Ultrasonic Nebulizers**

- Medication is placed directly on transducer
- Medication is drawn into lungs by patient’s inspiratory flow
Large-Volume Ultrasonic Nebulizers

- Primary use is administration of bland aerosol therapy
- Produce small aerosol particles
- Use blower to deliver aerosol particles
- Provide continuous nebulization
- Deliver particles ranging from 2.2 to 3.5 microns
- Used to deliver drugs over longer period of time
Small-Particle Aerosol Generator

* For infants with RSV: ribavirin (Virazole)
Technique for Using Small-Volume Nebulizer

* Assemble tubing or cable, nebulizer, and mouthpiece or mask
* Place medication into nebulizer’s reservoir
* For pneumatic nebulizer:
  * Connect tubing to flowmeter or compressor
  * Set flow to manufacturer’s recommendation
Technique for Using Small-Volume Nebulizer (Cont.)

* For vibrating mesh or small ultrasonic nebulizer:
  * Connect clean nebulizer/medication reservoir to mask or mouthpiece
  * Attach nebulizer/medication reservoir to electronic controller
  * Attach nebulizer to power source; make sure battery has adequate charge
  * Instruct patient to sit in an upright position, as tolerated
Technique for Using Small-Volume Nebulizer (Cont.)

* Apply mouthpiece or mask and encourage patient to breathe through mouth
  * If artificial airway is used, ensure nebulizer is positioned appropriately and does not place pressure on airway
* Encourage normal breathing and low inspiratory rates with occasional deep breaths
Technique for Using Small-Volume Nebulizer (Cont.)

* Operate nebulizer in an upright position, 45 degrees from vertical
* Run nebulizer until “sputtering” occurs or aerosol is no longer produced
* When treatment is complete, rinse, disinfect, and air dry nebulizer or dispose
* Do not submerge electronic controller or compressor in water or disinfectant
* Store nebulizer in clean, dry location
Selecting Aerosol Drug Delivery System

* RT must understand advantages and disadvantages of each system.
Selecting Aerosol Drug Delivery System (Cont.)

* MDI with spacer is most convenient and cost-effective method
* In adults, patient’s preference must be considered
* Small-volume ultrasonic nebulizer or vibrating mesh nebulizer may be preferred because of short treatment time
Aerosol Delivery in Infants and Children

- Due to decreased minute volumes, they inhale at lower percentage of nebulizer output
- Using mask is preferred method of administration in this population
- “Blowby” is not recommended because so little of drug enters patient’s lungs
Aerosol Delivery with Mechanical Ventilation

1. Use of small-volume nebulizer with mechanical ventilation:
   * Only simple-set nebulizer can be used in ventilator circuits
   * Breath-actuated nebulizers cannot be used with mechanical ventilation
   * About 1.5% to 3% of nebulizer output is deposited in lungs (with optimal ventilator settings, this may reach 15%)
   * If external gas source is used to power nebulizer, alarms must be reset
Aerosol Delivery with Mechanical Ventilation (Cont.)

- Nebulizer is placed in inspiratory line; this usually interrupts mechanical ventilation
- If ventilator is used as power source, alarms do not need to be reset
- Increased treatment time is required since nebulization only occurs during inspiration
2. Metered-dose inhaler
  * Special adaptor must be placed in inspiratory line
  * Increased deposition of medication when spacer is placed in line
  * Establish ventilator dose (usually double normal dose)
  * Leave humidifier on; if HME is used, it must be removed during treatment
Patients with diseases such as tuberculosis (TB), severe acute respiratory syndrome (SARS), or avian flu require that caregivers protect themselves.

- Patient should be placed in respiratory isolation.
- Caregiver should wear N-95 mask when entering patient’s room.
Hazards of Aerosols

- Pentamidine and Virazole both can cause complications to person administering aerosol.
- These patients must be in private room or protective booth during administration.
1. Negative Pressure Room

* Negative pressure is applied to room air; this prevents air from leaving room when door is opened
* High-efficiency particulate air (HEPA) filters are used for all air that is vented from room
* There must be at least six air changes per hour
* Recommended if patient has airborne infection
2. Booths or Stations
   * Use negative pressure to pull exhaled air away from patient
   * Exhaled air forces through high-efficiency particulate air filters before it is vented into atmosphere
   * Used for sputum induction or administration of pentamidine treatment
3. Personal Protective Equipment
   - Required for any patient with airborne infection
   - Effectiveness of surgical masks has never been documented
   - OSHA recommends use of N-95 mask to protect caregiver