Respiratory Care in PICU
Aerosol Therapy
Aerosol

liquid droplets or solid particles
suspended in a gas (air)
visible like fog
Aerosol vs Humidity

Humidity
water in gas status (vapor),
invisible
Goals of Aerosol Therapy

drug be inhaled and deposit in targeted site of respiratory system:
  deposit in lungs (lung dose),
responsible for pharmacologic effects at targeted site
Advantages of Aerosol Therapy

- direct delivery of drug to site of action
- rapid onset of action
- lower dose to produce desired effects (than systemic administration)
- minimizes systemic adverse effects
Indication of Aerosol Therapy

1. bronchial hygiene
2. humidification
3. medication
   - bronchodilator, vasoconstrictor,
   - corticosteroids, mucoregulators,
   - antimicrobial agents, surfactant,
   - insulin, prostaglandin, vasopressin
   - etc.
Aerosol deposition in airway

**aerosol size**

**mass median aerodynamic diameter (MMAD)**
Median value of particle of aerosol mass, output from nebulizer, suspended in the gas flow
## aerosol deposition in airway

<table>
<thead>
<tr>
<th>Size / MMAD (µm)</th>
<th>Site of aerosol deposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.5</td>
<td>no deposition, exhaled with exp. flow</td>
</tr>
<tr>
<td>0.5-2</td>
<td>alveoli</td>
</tr>
<tr>
<td>2-5</td>
<td>bronchi, bronchiole</td>
</tr>
<tr>
<td>5-100</td>
<td>mouth, nose, upper airway</td>
</tr>
<tr>
<td>&gt;100</td>
<td>filtered by upper respiratory tract</td>
</tr>
<tr>
<td>MMAD (µm)</td>
<td>Aerosol deposition</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------</td>
</tr>
<tr>
<td>2-5</td>
<td></td>
</tr>
<tr>
<td>0.5-2</td>
<td></td>
</tr>
</tbody>
</table>
Aerosol Therapy

How are infants/children different?

- lung deposition
- weight-dose
- physiologic effect of pharmacologic aerosol
respiratory flow pattern-aerosol output from continuous jet nebulization-inhaled drug

In infants/ children
peak inspiratory flow rate- low
tidal volume, vital capacity,
functional residual capacity-low
respiratory rate –high
respiratory cycle -short

Inspired dose vs aerosol output from nebulizer

Lung deposition, the percentage of the dose delivered and the percentage of initial nebulizer dose for the nebulizers.


amount of albuterol deposited in the lungs
Lung deposition of albuterol with MDI / chamber vs jet nebulizer in nonventilated children

Lung deposition of aerosol in nonintubated patient

- **Infant**: 0.1-1%  
- **Children < 4 y**: 5%  
- **Children > 4 y**: 10%  
- **Adult**: 8-22% (SVN 10-14%)
Aerosol Therapy
How are infants/children different?

- Lung deposition
  - Neonate: < 1% of nominal dose
  - Adult: 8-22% of nominal dose

- Weight-dose

- Physiologic effect of pharmacologic aerosol
lung dose / body weight

salbutamal 1 dose = 2500 microgm./ dose

**infant 2 kg**
- lung deposition 1%
- lung dose = 12.5-25 microgm. = 6.25 microgm./ kg

**Adult 70 kg**
- lung deposition 10%
- lung dose = 250 microgm. = 3.6 microgm./ kg
% change in total resistance ($R_{rs}$) and total compliance ($C_{rs}$) of the respiratory system following administration of albuterol MDI and nebulizer

Aerosol: particle size & physical characteristics

Aerosol output

Airway anatomy & pathology

Aerosol deposition depend on

Patient Ventilatory pattern
Aerosol: particle size & physical characteristics

Aerosol output depend on:
- MMAD size
- Density of gas
- Temperature
- Humidity

Airway anatomy & pathology

Patient Ventilatory pattern
Aerosol deposition depend on

- Device
- Fill volume
- Gas flow/ pressure
- Nebulization time

Aerosol output

- Aerosol: particle size & physical characteristics

Airway anatomy & pathology

Patient Ventilatory pattern
Aerosol: particle size & physical characteristics

Aerosol output

Congenital stenosis of airway obstructive airway disease BPD, bronchiectasis Secretion Artificial airway

Airway anatomy & pathology

Aerosol deposition depend on

Patient Ventilatory pattern
Aerosol: particle size & physical characteristics

Aerosol output

Airway anatomy & pathology

Inspiratory flow rate - slow 0.5 L/min-laminar flow
Inspiratory volume -deep inspiration
Breath holding 4 sec
Inspiratory time -at beginning
Mouth breathing
deposition in sedated pt. > non-sedated pt.

Patient
Ventilatory pattern
Aerosol devices

1. nebulizer
   - Jet nebulizer
     - small volume nebulizer-SVN
     - large volume nebulizer-LVN
   - Ultrasonic nebulizer
   - Small particle aerosol generator

2. Metered dose inhaler (MDI)

3. Dry powdered inhaler (DPI)
   - turbuhaler, diskhaler, swinghaler
Aerosol therapy in non-intubated children in PICU

Aerosol therapy with small volume nebulizer (SVN)
Continuous nebulization therapy (CNT)
Aerosol therapy with EzPAP
Aerosol therapy with noninvasive positive pressure ventilation (NPPV)
Jet nebulizer: small volume nebulizer-SVN
Continuous nebulization therapy (CNT)

Indication of CNT

1. Severe asthma with asthma score > 5
2. Asthma patient who need nebulization frequently (every 15 min-1 hr)
Continuous nebulization therapy (CNT)

- Efficiency not different from intermittent nebulization
  (more efficiency in severe airway obstruction case)
- Benefit in cost effectiveness
- Benefit for personnel in drug administration
- Decrease patient disturbance
### Continuous nebulization therapy (CNT)

<table>
<thead>
<tr>
<th>ชนิด CNT</th>
<th>ตัวอย่างผลิตภัณฑ์</th>
<th>ขนาดบรรจุ Fill volume</th>
<th>Gas flow</th>
<th>Nebulization output</th>
<th>Nebulization time</th>
</tr>
</thead>
<tbody>
<tr>
<td>low flow</td>
<td>miniHEART Lo-Flo</td>
<td>30 มล.</td>
<td>2 ลิตร/ นาที</td>
<td>8 มล./ ชม.</td>
<td>3 ชม.</td>
</tr>
<tr>
<td>high flow</td>
<td>HEART</td>
<td>240 มล.</td>
<td>10 ลิตร/ นาที</td>
<td>30 มล./ ชม.</td>
<td>8 ชม.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15 ลิตร/ นาที</td>
<td>50 มล./ ชม.</td>
<td>4 ชม.</td>
</tr>
<tr>
<td></td>
<td>miniHEART Hi-Flo</td>
<td>30 มล.</td>
<td>8 ลิตร/ นาที</td>
<td>20 มล./ ชม.</td>
<td>1.5 ชม.</td>
</tr>
</tbody>
</table>
Jet nebulizer: large volume nebulizer-LVN

continuous nebulization therapy

HEART nebulizer- high flow
Jet nebulizer: large volume nebulizer-LVN

HEART nebulizer- high flow

<table>
<thead>
<tr>
<th>Dose (mg/hr)</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>5</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate = Output</td>
<td>10 L/min = 30 mL/hr</td>
<td>15 L/min = 50 mL/hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medicine 5 mg/mL (mL)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Saline (mL)</td>
<td>29</td>
<td>28</td>
<td>27</td>
<td>49</td>
<td>48</td>
<td>47</td>
</tr>
<tr>
<td>Dose (mg/hr) decreased after reducing flow from 15 to 10 L/min</td>
<td>15 L/min</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 L/min</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Jet nebulizer: large volume nebulizer-LVN

Flo-Mist
Jet nebulizer: large volume nebulizer-LVN

- miniHEART high flow
- miniHEART low flow
Aerosol therapy with EzPAP
EzPAP with nebulizer
EzPAP with nebulizer
Jet nebulizer with NPPV

Aerosol delivery 5-25%
Jet nebulizer with NPPV

High aerosol delivery by

High inspiratory press. 20 cmH2O
Low expiratory press. 5 cmH2O
Low breath frequency
Position in circuit near patient, between leak port-patient connector
Aerosol therapy in intubated children

pressurized metered dose inhaler (pMDI)
jet nebulizer
dry powder inhaler (DPI)
Lung deposition, the percentage of the dose delivered and the percentage of initial nebulizer dose for nebulizers.

Factors that influence aerosol delivery

- Ventilator-Related
  - Ventilation mode
  - Tidal volume
  - Respiratory rate
  - Duty cycle
  - Inspiratory waveform
  - Breath-triggering mechanism

- Device-Related - MDI
  - Type of spacer or adapter
  - Position of spacer in circuit
  - Timing of MDI actuation
  - Type of MDI

- Drug-Related
  - Dose
  - Formulation
  - Aerosol particle size
  - Targeted site for delivery
  - Duration of action

- Device-Related - Nebulizer
  - Type of nebulizer
  - Fill volume
  - Gas flow
  - Cycling: inspiration vs continuous
  - Duration of nebulization
  - Position in the circuit

- Circuit-Related
  - Endotracheal tube size
  - Humidity of inhaled gas
  - Density of inhaled gas

- Patient-Related
  - Severity of airway obstruction
  - Mechanism of airway obstruction
  - Presence of dynamic hyperinflation
  - Patient-ventilator synchrony

Factors that affect aerosol delivery and deposition

**Ventilator related**
- Mode: Pressure-limited vs volume-limited
- Continuous flow of gas through circuit
- Respiratory rate
- Tidal volume
- Inspiratory flow rate
- Inspiratory-expiratory ratio

**Circuit related**
- Diameter
- Length
- Adapters
- Density of gas
- Endotrachael tube Size
- Type
- Humidification
ventilator modes and setting
with nebulizer

Aerosol delivery with nebulizer
IMV mode = A/C mode = A/C flow synchronize mode
PC mode < VC mode
ventilator modes and setting with pMDI

Aerosol delivery with pMDI

SIMV mode > CMV mode
PC mode = VC mode
Aerosol delivery from MDI during mechanical ventilation, at different inspiratory air-flows and duty cycles (inspiratory time to total breathing cycle time [TI/Ttot])

Serum albuterol levels after MDI administration in mechanically ventilated patients and healthy subjects

MDI with chamber spacer had the highest drug-delivery efficiency.
aerosol delivery with helium-oxygen mixtures during mechanical ventilation

Efficiency of aerosol delivery to the lower respiratory tract in mechanical ventilation with dry and humidified ventilator circuits

The delivery of aerosol to the major airways is reduced by about 40% when the circuit is humidified.