Oxygen Devices
Objectives

- Assess the need for oxygen therapy.
- Describe what precautions and complications are associated with oxygen therapy.
- Compare low-flow and high flow oxygen delivery systems
- Name several commonly used low-flow oxygen delivery systems.
- Discuss the advantages and disadvantages of oxygen devices.
- Explain the operational theory of air entrainment devices.
- Select an oxygen delivery system appropriate for the respiratory care plan.
Learning Objectives (cont.)

- Describe how to administer oxygen to adults, children, and infants.
- Describe how to check for proper function and to identify and correct malfunctions of oxygen delivery systems.
- Explain how to evaluate and monitor a patient’s response to oxygen therapy.
- Describe how to modify or recommend modification of oxygen therapy on the basis of patient response.
- Review how to implement protocol-based oxygen therapy.
- Identify what indications, complications, and hazards apply to hyperbaric oxygen therapy.
- Describe the physiologic effects of hyperbaric oxygen therapy.
- List the indication and contraindications of NO therapy.
- Describe the appropriate use of mixed gas (e.g., heliox, carbogen) therapy.
Oxygen Therapy

- General Goals & clinical objectives of O2 therapy
  - Correct documented or suspected acute hypoxemia
  - Decrease symptoms associated with chronic hypoxemia
  - Decrease workload hypoxemia imposes on cardiopulmonary system
All of the following are the major clinical goals and objectives for oxygen therapy, except:

A. Decrease the workload hypoxemia imposes on the cardiopulmonary system
B. Correct documented or suspected acute hypoxemia
C. Prevent hypoxemic induced multiple system failure
D. Decrease the symptoms associated with chronic hypoxemia
Assessing need for O$_2$ therapy

- Laboratory documentation
  - PaO$_2$ (ABG), SaO$_2$(ABG), SpO$_2$ (Pulse Oximeter)
- Specific clinical problem
  - e.g., patient suspected of carbon monoxide poisoning
- Clinical findings at bedside
  - Tachypnea, tachycardia, confusion, etc.
Oxygen Therapy (cont.)

- Precautions & hazards of supplemental O$_2$
  1. Oxygen toxicity
    - Primarily affects lungs & central nervous system
    - Determining factors include PO$_2$ & exposure time
    - Prolonged exposure to high FIO$_2$ can cause infiltrates in lung parenchyma
Oxygen Toxicity
Oxygen Therapy (cont.)

- Precautions & hazards of supplemental $O_2$ (cont.)
  2. Depression of ventilation
     - Occurs in COPD patients with chronic hypercapnia
  3. Retinopathy of prematurity
     - Excessive blood $O_2$ levels cause retinal vasoconstriction & necrosis
Oxygen Therapy (cont.)

- Precautions & hazards of supplemental O₂ (cont.)
  4. Absorption atelectasis
     - Can occur with FIO₂ above 0.50
     - Patients breathing small tidal volumes at greatest risk
Absorption Atelectasis

FiO₂ = 100%

Alveolus
O₂ = 668
CO₂ = 45
H₂O = 47
Total = 760

Pulmonary Artery
O₂ = 55
CO₂ = 45
H₂O = 47
Total = 147

FiO₂ = 21% (Room air)

Alveolus
O₂ = 100
CO₂ = 40
N₂ = 573
H₂O = 47
Total = 760

Pulmonary Artery
O₂ = 40
CO₂ = 45
N₂ = 573
H₂O = 47
Total = 705
Oxygen Therapy (cont.)

- Precautions & hazards of supplemental O₂ (cont.)
  5. Fire hazard
    - Fires in O₂-enriched environments continue to occur
    - Practitioners in surgery suites & in presence of hyperbaric O₂ therapy need to be most careful
All of the following are major precautions and hazards of supplemental oxygen therapy, except:

A. Oxygen toxicity
B. Depression of ventilation
C. Retinopathy of prematurity
D. Oxygen induced encephalopathy
Avoiding O2 toxicity:

- Limit patient exposure to 100% to less than 24 hours whenever possible.
- High FiO2 is acceptable if the concentration can be decreased to 70% within 2 days and 50% or less in 5 days.
Oxygen Therapy (cont.)

- O₂ delivery systems: design & performance
  - 3 basic designs exist
    1. Low-flow systems
    2. Reservoir systems
    3. High-flow systems
Oxygen Delivery Systems

A = Low flow device
B = High flow device
C = Reservoir device

Flow

= Patient's flow
= Device's flow

Exp

Insp

A

B

C
Oxygen Therapy (cont.)

- Low flow (variable performance): Does not meet pt.’s insp. demand
  - Delivers an $F_{1}O_{2}$ of 0.22 to 0.80
  - $F_{1}O_{2}$ is affected by
    - inspiratory flow rate
    - tidal volume
    - respiratory rate
    - flow rate of oxygen
Oxygen Therapy (Cont.)

Low-flow devices include:
- Nasal cannula
- Nasal catheter (rarely used)
- O2 Conserving Devices:
  - Transtracheal catheters
  - Reservoir Cannula
  - Pulse Demand O2 Delivery System
- Reservoir Masks
  - Simple face mask
  - Partial rebreather mask
  - Non-rebreather mask
Oxygen Therapy (Cont.)

- High flow (fixed performance)
  - Provides flow rate adequate to meet patients’ inspiratory flow needs
  - Delivers a $F_{1}O_{2}$ of 0.24 to 1.0
  - Examples include:
    - Air entrainment mask
    - Incubators
    - Oxygen tents
    - Oxygen hoods
Nasal Cannula

- Used to deliver low-flow oxygen therapy through nares
- Delivers a $F_1O_2$ of 0.24 to 0.44
- Used with flow rates of $\frac{1}{4}$ to 8 L/min
- Delivered $F_1O_2$ affected by:
  - Respiratory rate
  - Tidal volume
  - Oxygen flow rate
Nasal Cannula (Cont.)

- Common problems:
  - Nasopharyngeal-mucosal irritation
  - Twisting of connective tubing
  - Skin irritation
Nasal Cannula

Keep flange against upper lip

• NC should be adjusted below chin, do not place behind head, choking risk; unless applying to neonates/small peds. On infants, tape to face
## Oxygen Therapy

### Rule of 4 = (Flow X 4) + 20

<table>
<thead>
<tr>
<th>Nasal Cannula flow rate</th>
<th>FIO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 L</td>
<td>.24</td>
</tr>
<tr>
<td>2 L</td>
<td>.28</td>
</tr>
<tr>
<td>3 L</td>
<td>.32</td>
</tr>
<tr>
<td>4 L</td>
<td>.36</td>
</tr>
<tr>
<td>5 L</td>
<td>.40</td>
</tr>
<tr>
<td>6 L</td>
<td>.44</td>
</tr>
</tbody>
</table>
Oxygen Therapy

- Nasal catheter
  - Used at flows of $\frac{1}{4}$ to 8 L/min
  - Delivers FiO$_2$ of 0.22 to 0.45
  - Rarely used in modern health care facilities today
  - Has been replaced by nasal cannula
Oxygen Conservation Devices

- Transtracheal catheter
  - Surgically placed in trachea
  - Uses 40-60% less O₂ to achieve same PaO₂ by nasal cannula
  - Used with flow rates of ¼ to 4 L/min
  - Requires careful maintenance & cleaning to prevent complications
  - Complications such as infection and obstruction are possible
Oxygen Therapy

- Reservoir cannula
  - Designed to conserve oxygen
    - Nasal reservoir
    - Pendant reservoir
  - Can reduce oxygen use as much as 50% to 75%
  - Humidification usually not needed
Oxygen Conservation Devices

- Reservoir nasal cannula
  - Available in mustache cannula or pendent cannula
  - Reservoir traps oxygen-rich gas from early portion of exhalation
  - Oxygen is inspired with next breath
  - Decreases flow rate of oxygen necessary to obtain required SpO₂
Reservoir Nasal Cannula
Oxygen Conservation Device

- Pulse demand oxygen delivery system
  - Delivers oxygen only during inspiration
  - Can be used with nasal cannulas, nasal catheters, and transtracheal oxygen catheters
  - Delivers flows equivalent to 1 to 5 L/min
Pulse Demand Oxygen Delivery System
Oxygen Therapy

Reservoir masks

- Most commonly used reservoir systems
- 3 types
  1. Simple mask
  2. Partial rebreathing mask
  3. Nonrebreathing mask
Simple Oxygen Mask

- Typically given for short term use, during deliveries, in the ER

- During inspiration, patient draws air from:
  - Tubing
  - Reservoir in the mask
  - Ports in side of the mask

- Delivers $F_{O_2}$ of 0.35 to 0.50 at flows of 5 to 10 L/min

- Flows begin at 5-6L at least to prevent rebreathing exhaled CO2

- Max flow is around 10-12L

- DO not add a bubble humidifier
Partial Rebreathing Mask

- Used for short-term therapy requiring moderate to high $F_1O_2$
- Not a commonly used mask
- Has a reservoir bag that fills with oxygen but also exhaled CO2.
- Delivers up to 60% O2 with flows of 10-15 LPM
- Delivers $F_1O_2$ of 0.40 to 0.60 at flows of 6 to 8 L/min
- Bag must be one-third to one-half full during inspiration
Non-rebreathing Mask

- Includes mask with reservoir bag
- Valve allows patient to pull oxygen from reservoir during inspiration
- Same valve prevents patient from exhaling back into reservoir
- Valve over exhalation ports on side of mask prevents air from being entrained during inspiration
Non-Rebreathing Mask

- Delivers an $F_{1}O_{2}$ of 0.60 to 0.80
- Flow rates must be adequate to prevent excessive deflation during inspiration
Partial Vs Non-rebreather Mask
Oxygen Therapy

- High-flow systems
  - Supply given O$_2$ concentration at flow equaling or exceeding patient’s peak inspiratory flow
  - Can ensure fixed FIO$_2$
  - Most suitable for patients requiring precise FIO$_2$, with high or variable minute ventilation
  - Include air-entrainment or blending systems
    - Venturi masks
    - Air-entrainment nebulizers
Air Entrainment Mask

- Oxygen delivered through an orifice; this increases flow rate of gas
- A decrease in pressure on other side of orifice
- Causes air from atmosphere to be entrained
- Oxygen and air mixes to obtain precise concentration
- Primary application: to provide oxygen therapy for patients with COPD
Air Entrainment Mask
Air Entrainment Mask (Cont.)

- Total flow from mask is determined by multiplying oxygen flow rates by number of parts.
- Cannot be used with humidifier due to back pressure; humidity can be added by attaching collar at air entrainment ports.
Set up magic box with given % O2 in the middle of box

Place 100 and 20 and subtract from 60. This gives you the ratio

FIGURE 4-21 Method of calculating air-to-oxygen entrainment ratios.
\[ O_2 \text{ flow} = \frac{\text{Total flow} \times (\text{FiO}_2 - 0.2)}{0.8} \]

**EXAMPLE:**
Known: Total flow = 10 L/min
\[ \text{FiO}_2 = 0.4 \]
\[ O_2 \text{ flow} = \frac{10 \times (0.4 - 0.2)}{0.8} \]
\[ O_2 \text{ flow} = \frac{10 \times 0.2}{0.8} \]
\[ O_2 \text{ flow} = \frac{2}{0.8} \]
\[ O_2 \text{ flow} = 2.5 \text{ L/min} \]
(Air flow = Total flow – O₂ flow)

\[ \text{FiO}_2 \text{ flow} = \frac{O_2 \text{ flow} + (0.2 \times \text{Air flow})}{\text{Total flow}} \]

**EXAMPLE:**
Known: O₂ flow = 2.5 L/min
\[ \text{Air flow} = 7.5 \text{ L/min} \]
\[ \text{Total flow} = 10 \text{ L/min} \]
\[ \text{FiO}_2 = \frac{2.5 + (0.2 \times 7.5)}{10} \]
\[ \text{FiO}_2 = \frac{2.5 + 1.5}{10} \]
\[ \text{FiO}_2 = \frac{4}{10} \]
\[ \text{FiO}_2 = 0.4 \]

\[ \text{Total flow} = \frac{O_2 \text{ flow} \times 0.8}{\text{FiO}_2 - 0.2} \]

**EXAMPLE:**
Known: O₂ flow = 2.5 L/min
\[ \text{FiO}_2 = 0.4 \]
\[ \text{Total flow} = \frac{2.5 \times 0.8}{0.4 - 0.2} \]
\[ \text{Total flow} = \frac{2}{0.2} \]
\[ \text{Total flow} = 10 \text{ L/min} \]
### TABLE 16-5  \( \text{FiO}_2 \), Minimum Flow Requirements, Outputs, and Entrainment Ratios for an Air-Entrainment Mask

<table>
<thead>
<tr>
<th>( \text{FiO}_2 ) Setting</th>
<th>Minimum ( \text{O}_2 ) Flow (L/min)</th>
<th>Entrainment Ratio (Air:( \text{O}_2 ))</th>
<th>Total Flow (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.24</td>
<td>4</td>
<td>25:1</td>
<td>104</td>
</tr>
<tr>
<td>0.28</td>
<td>4</td>
<td>10:1</td>
<td>44</td>
</tr>
<tr>
<td>0.31</td>
<td>6</td>
<td>7:1</td>
<td>48</td>
</tr>
<tr>
<td>0.35</td>
<td>8</td>
<td>5:1</td>
<td>48</td>
</tr>
<tr>
<td>0.40</td>
<td>8</td>
<td>3:1</td>
<td>32</td>
</tr>
<tr>
<td>0.50</td>
<td>12</td>
<td>1.7:1</td>
<td>32</td>
</tr>
<tr>
<td>0.60</td>
<td>12</td>
<td>1:1</td>
<td>24</td>
</tr>
<tr>
<td>0.70</td>
<td>12</td>
<td>0.6:1</td>
<td>19</td>
</tr>
</tbody>
</table>

Data from Branson RD. The nuts and bolts of increasing arterial oxygenation: devices and techniques. *Respir Care*, 1993;38:672–686.
The most suitable oxygen delivery device for a patient with an unstable minute ventilation, needing a precise, moderate FIO$_2$ is:

A. Nasal cannula
B. Simple mask
C. Air-entrainment (venturi)
D. Non-rebreather mask
The most suitable oxygen delivery device for a patient who requires a low FIO$_2$, desires to conserve oxygen and objects to appearance of a nasal cannula, is:

A. Pendant cannula
B. Transtracheal oxygen system
C. Simple mask
D. Nasal catheter
Oxygen Hoods

- Used to deliver supplemental oxygen to infants
- The $F_1O_2$ should be monitored at same level as infant’s nose
- Noise levels inside hood can be problematic
Oxygen Hoods (Cont.)
Incubators

- Regulate temperature, humidity, and $F_1O_2$ of infants’ environment

- Include port to regulate $F_1O_2$:
  - If port is open, $F_1O_2$ is 0.40 or less
  - If port is closed, $F_1O_2$ is 0.40 or higher

- $F_1O_2$ inside incubator can vary significantly due to opening chamber for nursing care

- Hood inside incubator may be necessary to maintain consistent $F_1O_2$
Incubators (Cont.)
Regulation of $F_{1}O_{2}$

- Oxygen adder
  - Uses two flowmeters (one oxygen and one air) that blend two gases to obtain desired $F_{1}O_{2}$
  - $F_{1}O_{2}$ is determined using same ratios as air entrainment systems
Hyperbaric Oxygen Therapy

- Increases atmospheric pressure patient is exposed to with either continuous or intermediate use of 100% oxygen

- Clinical applications:
  - Carbon monoxide poisoning
  - Smoke inhalation
  - Poor wound healing
  - Anaerobic infections
  - Thermal injuries
  - Skin grafts
  - Refractory osteomyelitis
Hyperbaric Oxygen Therapy (Cont.)

Physiologic effects

- Lung volumes: lung volumes decrease as pressure is increased (Boyl’s law)
- Alveolar and arterial partial pressure of oxygen: alveolar pressure will be increased as atmospheric pressure is increased; partial pressure of inspired gas will increase (Dalton’s law). Arterial partial pressure will increase as more oxygen is dissolved in the plasma (Henry’s law).
Partial Pressure of Alveolar O₂ (PₐO₂)

- \( P_{A\,O₂} = (P_{\text{bar}} - P_{H₂O}) \times FIO₂ - (P_{\text{CO₂}} / 0.8) \)

- \( P_{A\,O₂} \) under normal \( P_{\text{bar}} \): 1 atm:
  \( = (760 - 47) \times 0.21 - (40 / 0.8) = 100 \text{ mmHg} \)

- \( P_{A\,O₂} \) under hyperbaric pressure e.g 2 atm:
  \( = (1520 - 47) \times 0.21 - (40 / 0.8) = 259 \)
Physiologic effects (Cont.)

- *Gas temperature*: kinetic activity of gases increases as gas pressure is increased; effects are minimized by regulating the rate at which pressure increases or decreases.

- *Work of breathing*: as barometric pressure is increased, density of a gas will increase. This will increase work of breathing. This will not affect most patients. Some patients will require ventilatory support when in a hyperbaric chamber.
Hyperbaric Oxygen Therapy (Cont.)

Physiologic effects (Cont.)

- **Vascular function:** enhances growth of new blood vessels; this effect is useful in treatment of patients with skin grafts and poor wound healing

- **Immunologic function:** improved function of leukocytes during hyperbaric oxygen therapy; the therapy also inhibits growth of some types of bacteria
Hyperbaric Oxygen Therapy (Cont.)

- Monoplace chambers:
  - large enough to hold one person
  - entire chamber is filled with pressurized oxygen

- Multiplace chamber:
  - large enough to hold two or more patients; there is usually an attendant.
  - Chamber is filled with compressed air, and patient wears hood filled with oxygen
Hyperbaric Oxygen Therapy (Cont.)
Hyperbaric Oxygen Therapy (Cont.)

- Monitoring devices
  - Transcutaneous oxygen monitoring provides evaluation of perfusion
  - Arterial blood gas analysis can be done in chamber
Indications for Hyperbaric Oxygen Therapy

- Air embolism
- Carbon monoxide positioning
- Cyanide poisoning
- Decompression sickness: dissolved gases coming out of solution into bubbles inside the body on depressurisation
- Gas gangrene
- Refractory anaerobic infection
- Refractory osteomyelitis
- Skin grafts
- Thermal burns
- Wound healing
Contraindications for Hyperbaric Oxygen Therapy

- Congenital spherocytosis: familial hemolytic disorder with defects in red blood cell
- High fevers
- Hypercapnia (>60 torr)
- Obstructive airway disease
- Optic neuritis
- Pneumothorax (Absolute)
- Seizure disorders
- Sinusitis
- Upper respiratory tract infection
- Viral infection
The most common indications for hyperbaric oxygen therapy (HBO) administered by RTs are:

A. Air emboli and CO poisoning
B. Wound healing and gas gangrene
C. Neovascularization and wound healing
D. Cardiac anomalies and lung transplantation
Nitric Oxide Therapy

- Used as a pulmonary vasodilator to treat persistent pulmonary hypertension on the newborn
- Initial therapeutic dose is 5 to 80 parts per million
- Commonly administered with INOmax
INOmax
Helium-Oxygen Therapy

- Low density of gas improves ability of gas to move around obstruction

- Clinical application:
  - Exacerbation of asthma
  - Treatment of postextubation stridor
  - Treatment of refractory croup
  - Treatment of severe airway obstruction in chronic bronchitis and emphysema
Available concentrations:
- 80% Helium and 20% oxygen
- 70% Helium and 30% oxygen
Helium-Oxygen Therapy (Cont.)

- Can be administered through an endotracheal tube or well-fitted nonrebreather

- Actual flow: due to low density of gas oxygen flowmeters are not accurate

- Correction factors used to determine actual flow rate of gas:
  - 80:20 – 1.8 \times \text{liter flow}
  - 70:30 – 1.6 \times \text{liter flow}
The main indication for heliox therapy is:

A. Upper airway obstruction
B. Pulmonary hypertension
C. Pulmonary embolism
D. Refractory hypoxemia
Carbon Dioxide (Carbogen) Therapy

- Used to treat hiccups and carbon monoxide poisoning and in prevention of washout of CO$_2$ during cardiopulmonary bypass
- Supplied as 5% carbon dioxide and 95% oxygen or 7% carbon dioxide and 93% oxygen
Monitoring Carbon Dioxide Therapy

- Blood pressure
- Patient pulse
- Respiration
- Mental status

If decreases are observed, therapy should be stopped immediately.
A confused 8-year-old patient presents to the emergency department with a high fever, tachycardia, tachypnea, and blue lips. The physician would like for you to set up oxygen. Which of the following devices will you place the patient on?

A. Simple mask at 5 L/min
B. Nasal cannula at 5 L/min
C. Air entrainment mask at 40% oxygen
D. Nonrebreathing mask at 15 L/min
A patient is receiving O2 through an air-entrainment device set to deliver 50% O2. The input O2 flow is set to 15 L/min. What is the total output flow of this system?

- **Step 1:** Compute the air-to-O2 ratio by substituting 50 for the %O2
- **Step 2:** Add the air-to-O2 ratio parts
- **Step 3:** Multiply the sum of the ratio parts times the O2 input flow

An air-entrainment device set to deliver 50% O2 that has an input flow of 15 L/min provides a total output flow of approximately 41 L/min.