The Changing Face of Oxygen Therapy: Past, Present and Future

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Goal: To provide a review of the history of oxygen therapy and relate how recent innovations are changing how oxygen therapy is delivered to patients.

Objectives: After completing the session the participant will be able to:
1) Describe the discovery of oxygen as a life sustaining gas
2) Describe the first therapeutic application of oxygen
3) Describe the scientific advancement of administration/monitoring of oxygen therapy since World War 1
4) Identify the impact of portable pulse oximetry on current oxygen therapy protocols
5) Relate how recent innovations in delivery devices continue to change the 'face' of oxygen therapy.

Disclosures
John Barnes is employed by Southmedic, Inc.

In the Past.....
Oxygen was discovered by "Hard Luck" Carl Wilhelm Scheele
He generated "Fire Air" by heating nitrate salts in 1771
Shared his findings with Antoine Lavoisier in 1774; documented in 1775 and published in 1777
He died of mercury poisoning from heating mercuric oxides to generate oxygen

Where's the Oxygen?

In the Past.....
Oxygen was "described" in 1774 by Joseph Priestly in his "Experiments and Observation on Different Kinds of Air"
Priestly described oxygen as "dephlogistigated" air.
"The feeling of it to my lungs was not sensibly different from that of common air; but I fancied that my breast felt peculiarly light and easy for some time afterwards. Who can tell but that, in time, this pure air may become a fashionable article in luxury. Hitherto only two mice and myself have had the privilege of breathing it."
Increased Understanding

- Antoine Lavoisier used the term Oxygen as he performed experiments that discredited the 'phlogiston' theory and proved atomic theory and the existence of elements.
- Both scientists proved the importance of oxygen to sustaining life and understood that plants produced the gas.

Initial Application of Oxygen Therapy

- The Lunar Society and Pneumatic Institution founded in 1798 "Lunarticks"
- Oxygen administered free of charge to outpatients for consumption, asthma, palsy, dropsy, obstinate venereal complaints among other things!
- They made no claim for cure-FiO₂ was 23-28%.
- Concern was expressed that too much could cause life to 'burn' too fast!

The Dark Ages of Oxygen Therapy

- 1869 Lancet publication advocated the use of oxygenated bread and water.
- Philadelphia physicians offered compound oxygen to home patients and in their oxygen parlour. The fee was $30 per month in advance for 30 treatments. No charge for consultation!
- Compound Oxygen was touted as a panacea treatment for many diseases; Oxygen bars became popular.

Origin of Modern Oxygen Therapy

- 1900 Dr. Blodgett was the first to use continuous delivery of oxygen at 6 lpm for a 46 year old woman with pneumonia.
- WWI-Adolph Fick and Paul Bent described oxygen tension in terms of partial pressure. Those units then described the difference between arterial and venous blood, oxygen consumption, Cardiac output, and the first to describe oxygen toxicity.
Bridging the Gap

1917-1934 Haldane used his WW1 experience and published “The therapeutic administration of oxygen”.

Haldane classified three categories of anoxaemia; lack of oxygen, lack of hemoglobin, lack of circulation.

Identified ventilation/perfusion mismatch.

1962-Paper demonstrated that intermittent oxygen therapy followed by hypoxemia worse than before treatment.

1968-First true study on long term \(O_2\) therapy.

Present Day

- Oxygen is still considered as the “cure all” drug for many disease conditions: now validated by science!
- Clinicians must know
  - Oxygen delivery concept
  - How oxygen is utilized
  - Patient’s oxygen needs and restrictions

American Association for Respiratory Care

AARC Clinical Practice Guidelines

- 1992 Pulse Oximetry
- 2002 Oxygen Therapy for Adults in the Acute Care Facility
- 2007 Oxygen Therapy in the Home or Alternate Site Facility

Hypoxia

- 4 Major types of hypoxia
  - Hypoxic
  - Anemic
  - Stagnant
  - Histotoxic

Effects of Hypoxia

- Work of breathing
  - Increase respiratory rate and depth
- Cardiovascular
  - Cardiac output increased
- Central nervous system
  - Brain is least able to tolerate hypoxia and usually the first to be affected
Clinical Signs & Symptoms of Hypoxia

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyspnea</td>
<td>Respiratory Distress</td>
</tr>
<tr>
<td>Restlessness</td>
<td>Cyanosis</td>
</tr>
<tr>
<td>Palpitations</td>
<td>Confusion</td>
</tr>
<tr>
<td>Headache</td>
<td>Hypertension</td>
</tr>
<tr>
<td>Diaphoresis</td>
<td>Coma</td>
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</tbody>
</table>

Goals of Oxygen Therapy

- Prevent and treat tissue hypoxia
- Diminish the work of breathing
- Decrease the workload of the heart

AARC – Clinical Indications

- Documented hypoxemia
  - Decreased PaO₂ in the blood below normal range.
    - PaO₂ less than 60 torr or SaO₂ less than 90% in subjects breathing room air OR
    - With PaO₂ and/or SaO₂ below desirable range for a specific clinical situation

- Acute situation in which hypoxemia is suspected
  - Severe trauma
  - Acute MI
  - Short-term therapy or surgical intervention (post-anesthesia recovery)

Three factors of Oxygen Delivery

- Concentration of Oxygen delivered
- Relationship of Oxygen Flow or Pulse Dose amount to Patient’s inspiratory flow/minute ventilation
- Flow of Oxygen with a mechanism for increasing intrapulmonary pressure (CPAP)

Complication of Oxygen Therapy

- Retrolental Fibroplasia
  - Retinal arteries hemorrhage and the scarring causes retinal detachment and blindness
  - Caused by high levels of oxygen
Oxygen Toxicity

- Potentially fatal and progressive in patients who inspire > 50% oxygen for over 24 hours
- Inflammatory response of lung tissue

Absorption Atelectasis

- Absorption of oxygen from the alveoli exceed replenishment of alveolar gas
- \( \text{FiO}_2 \) levels above 50% cause atelectasis by washing nitrogen out of poorly ventilated areas of the lungs and depleting nitrogen from the tissue

Selecting the Correct Oxygen Device

- Physical characteristics of the patient
- \( \text{FiO}_2 \) required
- Humidity or Aerosol Requirement
- Patient compliance and tolerance

Inspiratory Demands -

- Low flow devices rely on the nasopharynx and oropharynx to serve as a reservoir
- Estimated volume 50cc’s (adult)
- Low flow device only provide a part of the inspiratory needs, delivered oxygen varies
  - Flow of oxygen through device
  - Patient's respiratory rate
  - Patient's tidal volume

Monitoring Effectiveness of Oxygen Therapy

- Clinical assessment including but not limited to cardiac, pulmonary, and neurologic status
- Measurement of oxygen tensions or saturation in any patient treated with oxygen
  - Within 12 hours of initiation with \( \text{FiO}_2 \leq 0.40 \)
  - Within 8 hours \( \text{FiO}_2 > 0.40 \)
  - Within 72 hours in acute MI
  - Within 2 hours of any patient with principal diagnosis of COPD
Monitoring Oxygen Therapy

- Physical Signs- Please look at the patient!
  - Cyanosis
  - Respiratory Rate/Depth
  - Work of Breathing
- Arterial Blood Gases
  - Verify Partial Pressure of Oxygen in Arterial blood
- Pulse Oximetry
  - Saturation of Hemoglobin

Mechanism of Oxygen Therapy

- Two categories for delivery devices
  - Low flow devices
    - Variable performance systems
    - Deliver oxygen at or below the inspiratory flow rate
    - Provides variable oxygen concentration to the patient
  - High flow devices
    - Fixed performance systems
    - Deliver oxygen rates above the normal inspiratory flow rate

Low Flow Devices

- 100% oxygen at flows that are less than the patient's inspiratory flow rate (resp. rate and tidal volume), thus the oxygen concentration ($FIO_2$) is variable
- Key to higher $FIO_2$ are to meet or exceed the Patient's Inspiratory Flow!

Nasal Cannula

- Most common type of oxygen device
- Provides $Fio2's$ of 24%-44% oxygen at flows 1-6 L/min
- Patients with normal respiratory rate and tidal volume

Simple Mask

- Two side ports
  - Allow for room air entrainment
  - Exhalation of gases
  - 35-50% $FIO_2$
  - Minimum of 5 up to 10 L/min to ensure $CO_2$ is being flushed from mask and not rebreathed

Partial Rebreather

- Simple mask with a reservoir bag
- Provides 40-70% $FIO_2$ at flows of 6-10 L/min
- Oxygen flow should always be supplied to maintain the reservoir bag at least one third to one half full on inspiration

2002 AARC Clinical Practice Guidelines for Oxygen Therapy for Adults in the Acute Care Facility
Non-rebreather
- Provides the highest concentration of all the low flow masks
- Minimum flow of 10-15 L/min, delivered FIO₂ 60-80%
- 3 one-way valves and bag reservoir
  - Valve between the mask and bag prevents exhaled air from entering the bag
  - Valves on side port partially prevent inhalation of ambient air

Reservoir Cannula or Pendants
- Oxygen conserving devices
- Provides a 20 ml reservoir to capture initial exhalation and continued source gas
- FdO₂ from 26% to 84% at flows from .5 to 12 lpm

High Flow Oxygen Devices
- Provide flow rates that meet or exceed the inspiratory demand of the patient
- Air is mixed with oxygen to produce a defined FIO₂

Venturi Mask
- FIO₂ ranges from 24-50% when exceeding the patient’s inspiratory flow
- Higher FIO₂ will require higher input oxygen flow
- Size of entrainment port will determine the FIO₂
  - The larger the entrainment port, the more room air entrained and lower the FIO₂

Air Entrainment Nebulizers
- Utilize the same concept as the venturi mask, except allows for humidification of the airway
  - Aerosol masks, tracheostomy collars, face tents, etc
- Device can provide fixed FIO₂ 21-100%
  - Only when the total flow exceeds the patient’s minute volume

Oxygen Blenders
- Used when entrainment devices cannot provide high enough or precise FIO₂
- Need sources of oxygen and compressed air to work properly (typically 50 psi)

2002 AARC Clinical Practice Guidelines for Oxygen Therapy for Adults in the Acute Care Facility
New Oxygen Delivery Devices

- High Flow Nasal Cannula
- High Flow Heated/Humidified Nasal Cannula
- Hi-Ox-80 (no longer marketed)
- Neb-U-Mask
- OxyMask/OxyArm

High Flow Nasal Cannula's - Non-heated

Flow range 9-15 lpm
FiO2 range 44%-74%
Helps meet or exceed patient's Inspiratory Flow 'comfortably'
Must use Humidification at higher flows!
What is the level of humidification achieved?

High Flow Heated Oxygen Nasal Cannula Devices

High flow oxygen therapy
Technology to warm and saturate gas
Allows for precise control of
\[ \text{FiO2} \ (31-100\%) \text{ with a blender} \]
Temperature (33-43°C)
Humidity (up to 100%)
Flow (1-60 L/min)

HI-Ox80™ mask

- Open circuit continuous flow
- Mask (no side ports)
- Reservoir bag
- Manifold with three one way valves
- > 80% FiO2 at only 8 liters per minute and > 99% FiO2 at only 15 liters per minute

Teleflex Neb-U-Mask

- Allows for Medical Gas and Nebulizer or MDI therapy simultaneously
- Adult and Pediatric Sizes
- Approved for Oxygen and Heliox therapy

OxyArm/OxyMask

- OxyArm Flow rates 1-15 lpm or higher
- 24-50% FiO2
- OxyMask Flow rates 1 – 40 L/min or greater
- 24-90% FiO2
OxyMask/OxyArm Pin and Diffuser Technology

OxyMask
- Replaces up to seven different devices during a patient admission

OxyArm
- Unobtrusive, great for pediatrics or long term oxygen therapy at home

Oxygen Delivery Options

<table>
<thead>
<tr>
<th>FiO2 Ranges</th>
<th>24%</th>
<th>50%</th>
<th>70%</th>
<th>90%</th>
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<tbody>
<tr>
<td>Cannula</td>
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<tr>
<td>PNRB</td>
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<tr>
<td>100%NRB</td>
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<tr>
<td>Venturi</td>
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<tr>
<td>OxyMask</td>
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OxyMask Open Technology Advantages

- Eliminates re-breathing of CO2
- Wide FiO₂ range meets patient need with one device
- Reduces the need for multiple mask interfaces that provide different flows/FiO₂ ranges
- Reduced risk for aspiration
- Lightweight mask reduces skin breakdown
- Oxygenates the patient whether they are nasally or mouth breathing (or going back and forth)

Clinical Applications
Oxygen in Disaster Preparedness

- Mass casualty and pandemic events pose a substantial challenge to resources available
- Staffing shortage
  - Non-critical care professionals or volunteers may take care of patients
  - Absenteeism may range from 10-60% during a disaster
- 

Oxygen Therapy in Disaster

- Utilize oxygen devices that are simple to use
- Easy to set up
- Can deliver wide range of FIO₂
- Consume less oxygen

Oxygen in EMS

- The need to administer oxygen is based on the patient’s chief complaint
- Deliver the highest concentration possible until arrival at a medical center
- Device of choice – nasal cannula or Non-rebreather

Oxygen in EMS

- Nonrebreather-NC’s
- Medicated aerosols
- Modes of Transportation
- Multimask-Fio₂’s 24-80%, 1-15lpm
- Swivel adapter
- Medicated Aerosols

How to Provide Adequate Care – Oxygen Therapy

- Supplemental oxygen system that has the ability to adjust flows and maintain desired oxygen levels = COPD patients
- Easy to use
  - Multiple levels of ENT’s
- Consumes less oxygen
  - Transports from rural areas

Oxygen During Inter-hospital Transports

- AARC
  - Special care should be taken to avoid interruption of oxygen therapy during patient transport
  - Patient Safety Checklist for Adult/Ped/Infant Nov.2011
- Effects multiple departments
  - Radiology, physical therapy, surgery
- Standardize
  - Reduce the risk of error
Oxygen Therapy - Transports

- Oxygen therapy during a transport requires numerous steps and should be kept as simple as possible.
- Standardized procedures
  - Using standard equipment can reduce the risk of error.
  - Standardization of oxygen equipment and utilizing devices that reduce oxygen consumption may decrease reliance on memory by providing a structured process.

Oxygen - Long Term Oxygen Therapy (LTOT)

- Benefits
  - Increase duration of survival
  - Improve symptoms associated with LTOT
  - Decrease pulmonary vasoconstriction and vascular resistance
  - Decreases red cell mass and hematocrit levels

Long Term Oxygen Therapy

- Patient Quality of life
  - As a patient condition worsens, they live progressively more restricted
  - Communication and activities of daily living
- Payers
  - Non-payment for readmissions
  - Weigh the benefits and costs

LTOT - Adequate Care with Oxygen Therapy

- Patients
  - Simplistic, comfortable and appealing
- Payers
  - Meet the patient needs
- Homecare companies
  - Cost of acquiring a "system", reimbursement and lifestyle of the patient
- Manufacturers
  - Provide options including materials used, types of devices and comfort

Future

- Baby Boomers
  - Specific healthcare needs and demands!
  - Oxygen equipment being developed with patients in mind - Lightweight, easy to be mobile, small in design and footprint.
  - Appreciate costs, impact on the environment, and who monitoring the therapy

Future

- Healthcare Law: Medicare Reimbursement is dependent on these factors:
  - Patient Safety
  - Length of Stay
  - Patient Satisfaction
  - Hospital Readmission Rate
- On Staffing
- On Hospitals staying open
Summary

- Past is Present
  - Continuous Oxygen: “To give intermittent oxygen is like bringing a drowning man to the surface of the water-occasionally!”
  - Oxygen toxicity: Will the candle burn too quickly?
  - Open cannula system developed because the closed mask system filled with edema fluid

Summary (cont)

- New Challenges
  - Mass Casualty/Disaster Response
  - Titration of Oxygen to achieve the ‘Goldilocks’ level
- New/Future Developments
  - Heated Humidified High Flow Oxygen systems
  - Open Oxygen Masks
  - Closed loop flow controllers

Conclusion

- Oxygen is as important as any single word that might be applied to respiratory care.
- How much of what we have and what we know about oxygen today is really new, and how much has been there all along but imperfectly understood or appreciated
- The most dangerous phrase in RT is “We have always done it that way!”

Accreditation/Disclosure

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