Oxygen Utilization In Critical Illness

What's the Evidence?

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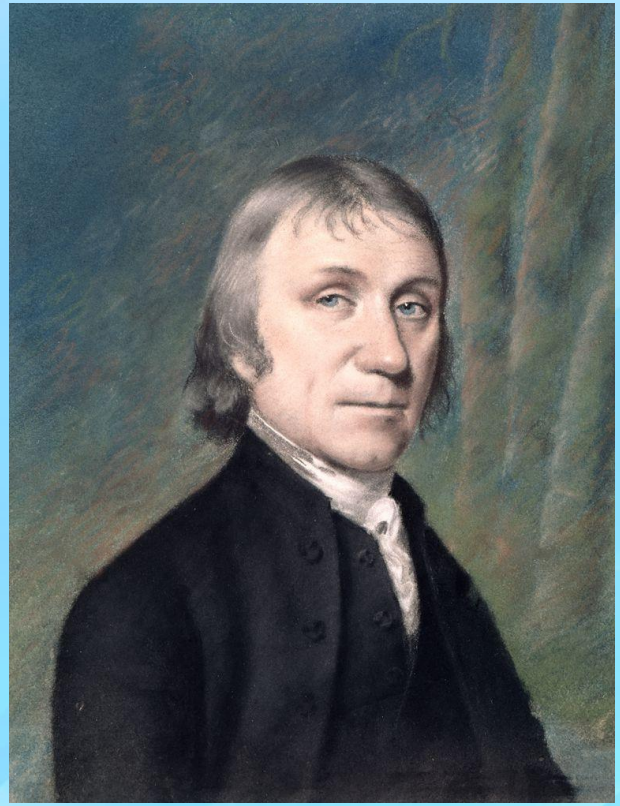
Learning Objectives

- Describe the history of oxygen utilization in medicine
- Define the clinical indications for oxygen administration
- Describe different oxygen delivery devices
- Review the current evidence regarding oxygen administration in specific patient populations
- Review the current recommendation for oxygenation goals during oxygen administration

Discovery Of Oxygen

- Discovered in the 18th Century by Joseph Priestley
  - Isolated a colorless gas by heating mercuri oxide
  - Increased the flame of a candle
  - Prolonged life of mice in a container
  - Warned that if over-used could be dangerous
- Named by Antoine Lavoisier
  - French chemist that use oxygen in human experiments

Joseph Priestley



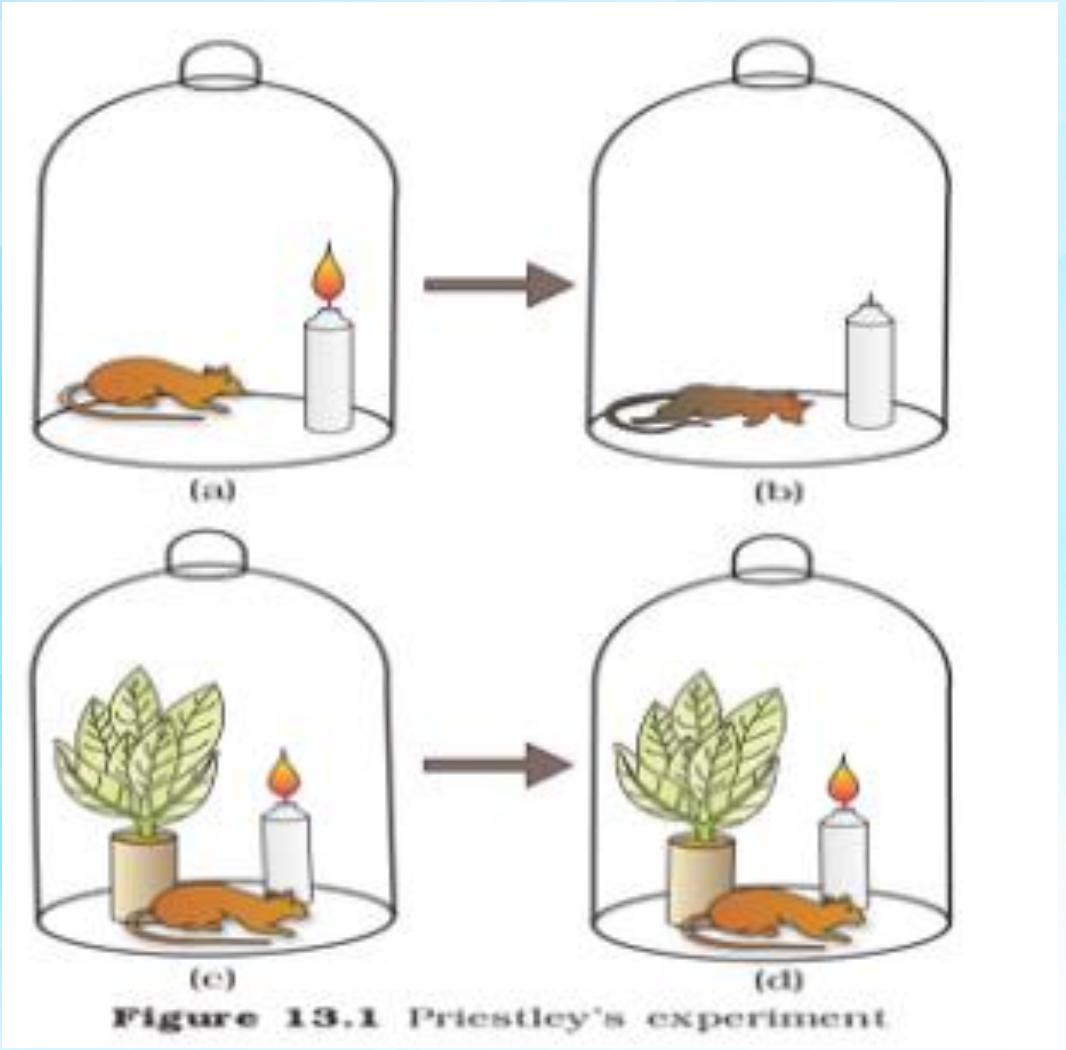
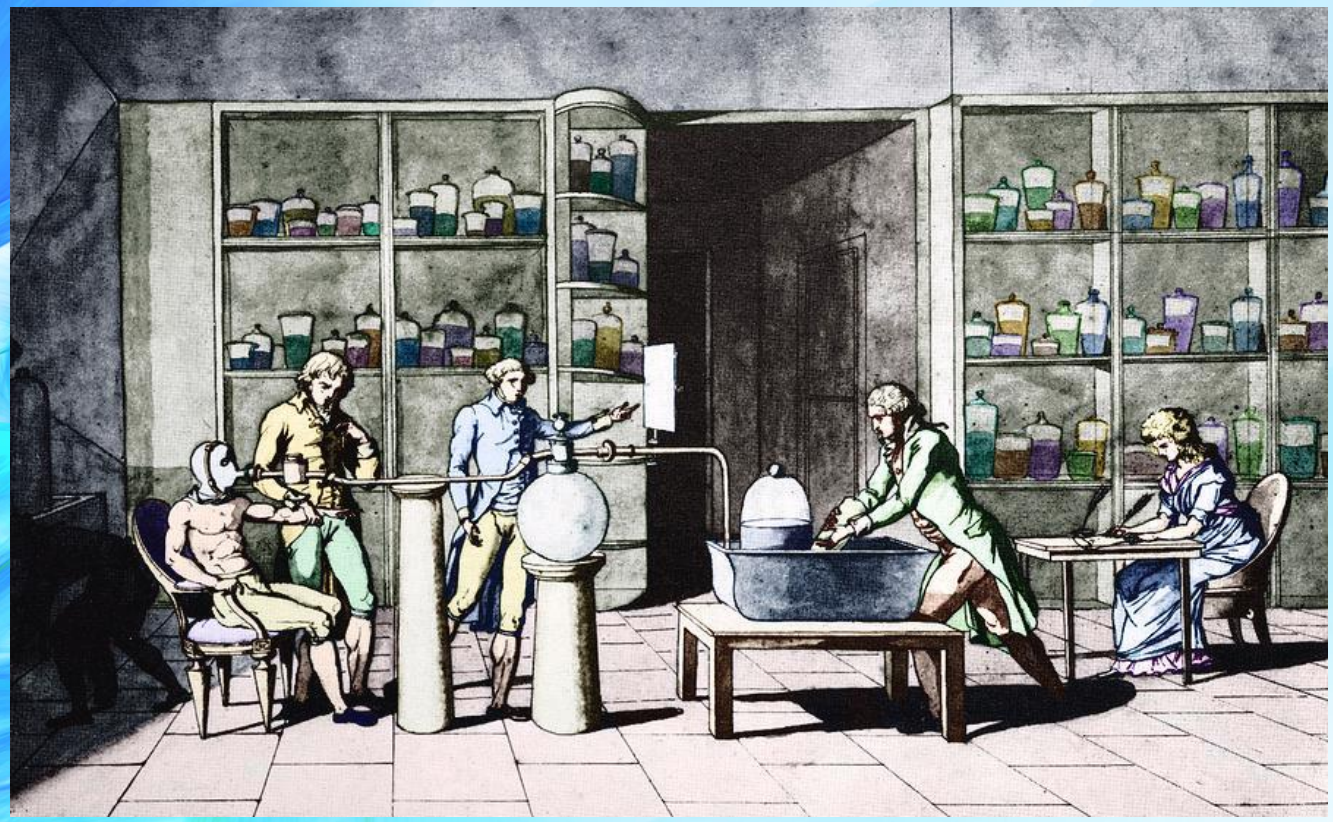
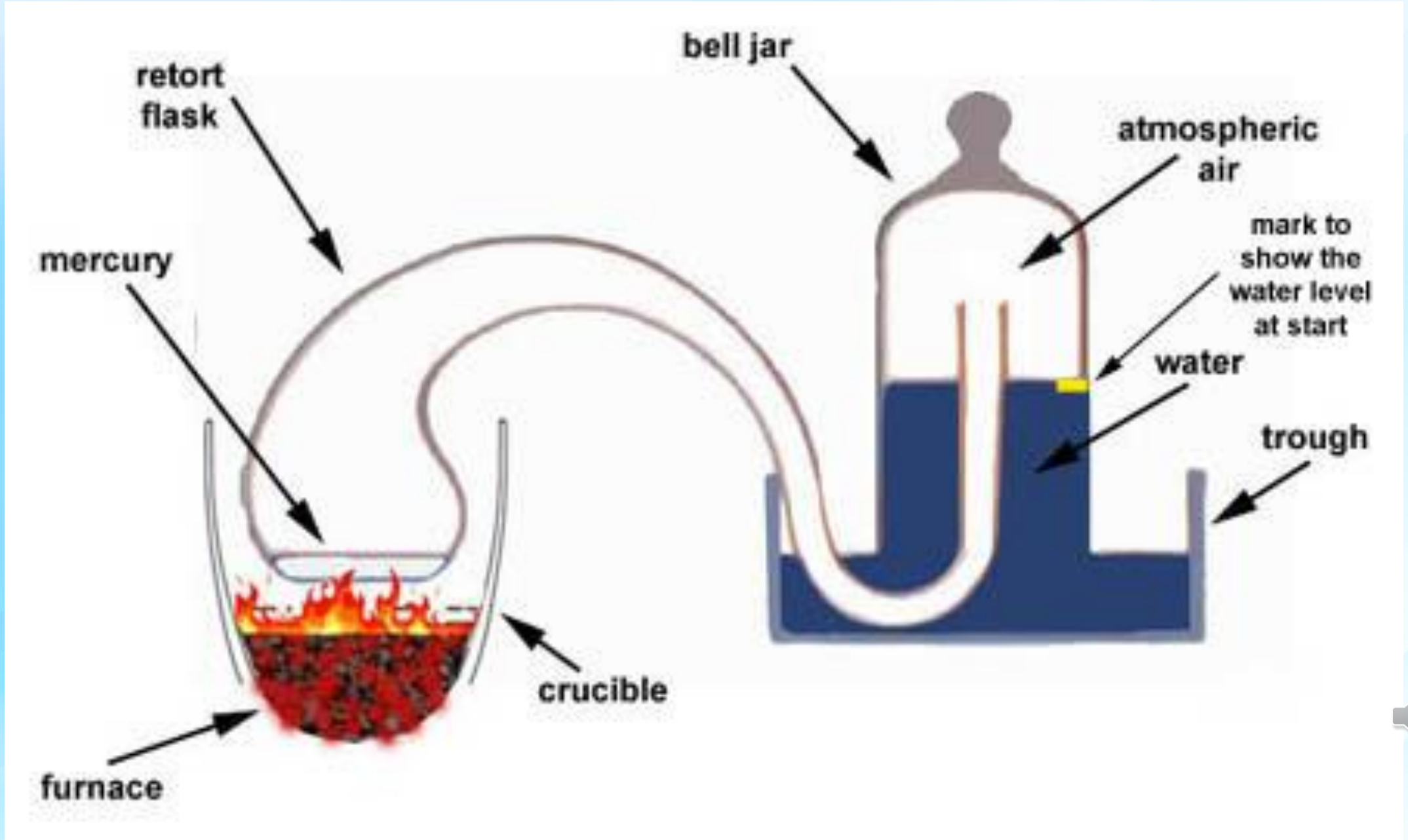


Figure 13.1 Priestley's experiment

LAVOISIER RESPIRATION EXPERIMENT




bell jar
retort flask
atmospheric air
mercury
mark to show the water level at start
water
trough
crucible
furnace

Also discovered Nitrous Oxide

Laughing gas parties:☺

Lehigh Valley Health Network

Nitrous Oxide Parties Today!!

Thomas Beddoes "Oxygen Lab"

Medical Use of Oxygen

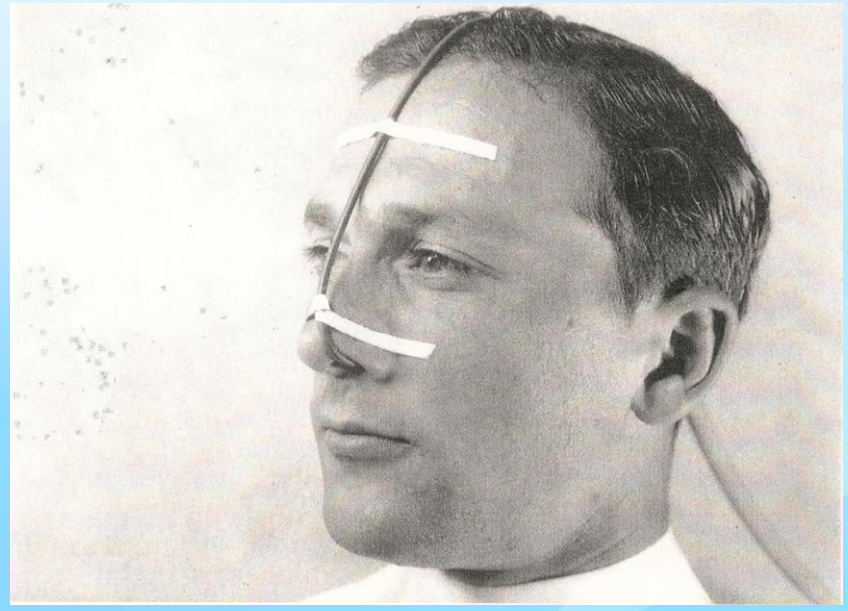
- 1798 Thomas Beddoes founded the pneumatic institution for inhalation gas therapy in Bristol England
- First common use for oxygen was for the treatment of Tuberculosis
- Oxygen supplies and delivery system were very scare and primitive

First Widespread Use of Oxygen Administration

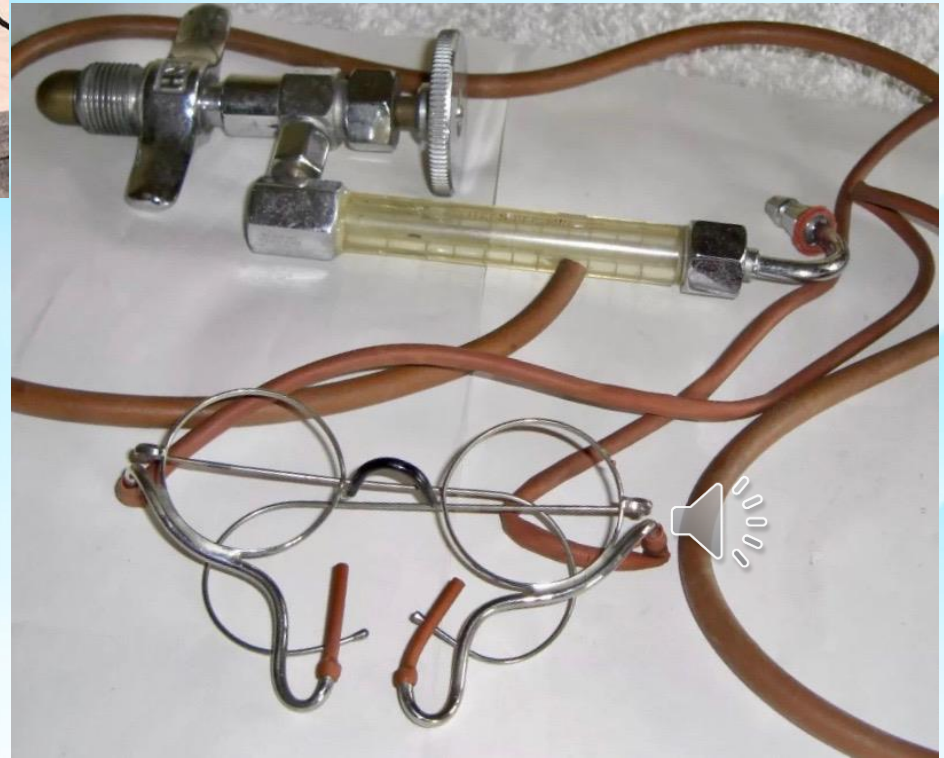
- Management of toxic gas inhalation by soldiers during World War I
- John Haldane develop the first “gas” mask
- Also warned against the excessive use of oxygen

Haldane's Gas Mask

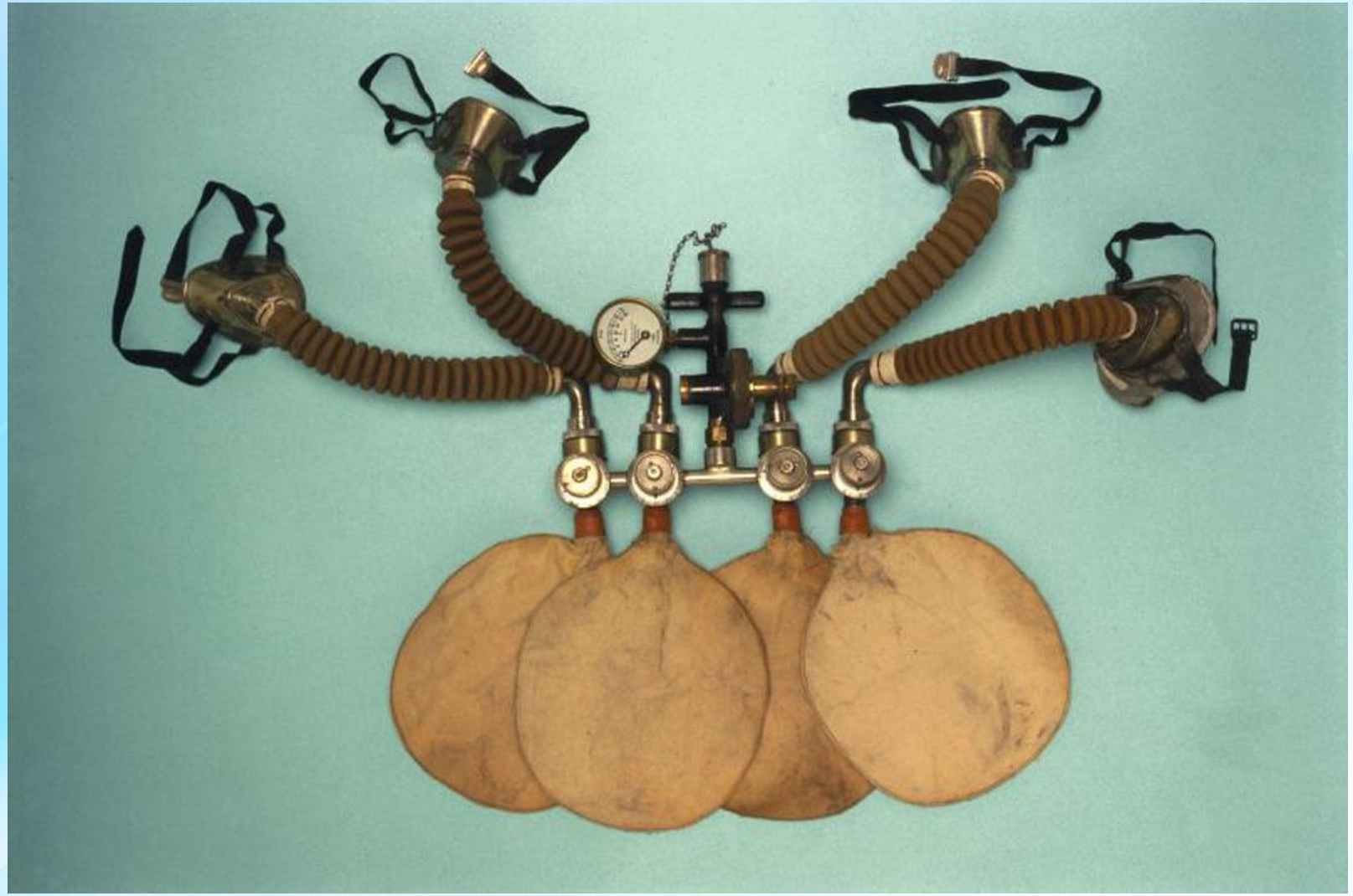
First nasal cannula



Early Oxygen Administration devices



Haldene's 4-person mask



History of Oxygen Use in The Critical Care Patient Population

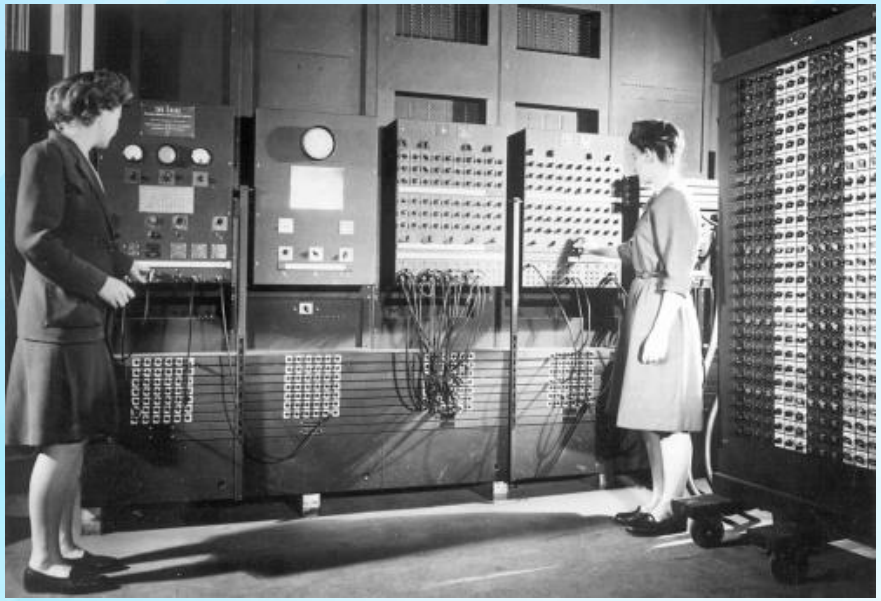
- 1950s: first ICUs and blood gas analysis was developed in Copenhagen Sweden during the polio endemic, which hospitalized hundreds of respiratory failure cases
  - Utilized Iron lungs
- 1960/1970 the advent of the mechanical ventilator which required entrained gases to be used, always involved the use of oxygen to power.

1953 Polio Epidemic

Multi-person Negative Pressure Ventilator
Boston Children's Hospital, 1950's

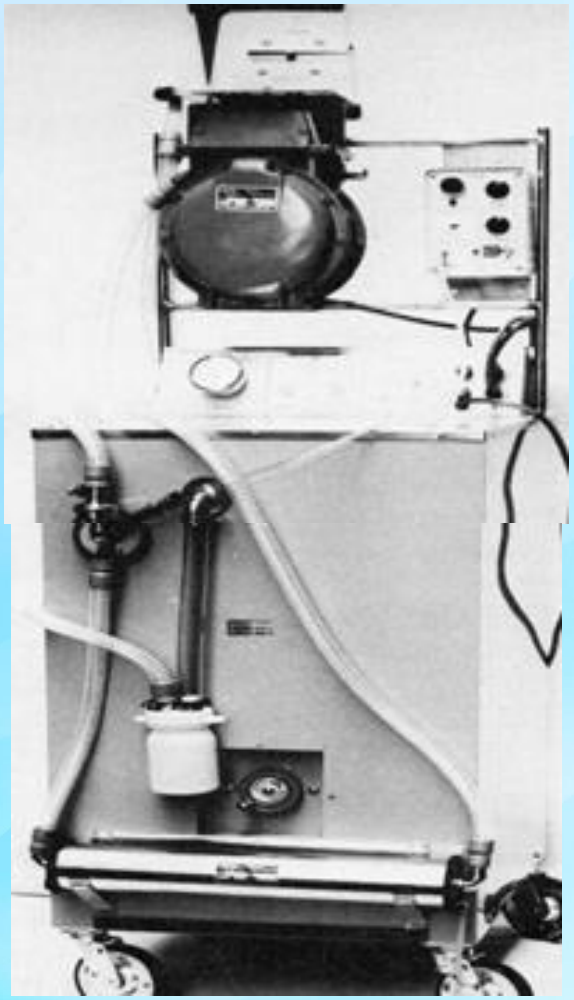
Pneumomotor chest cuirass with rocking bed

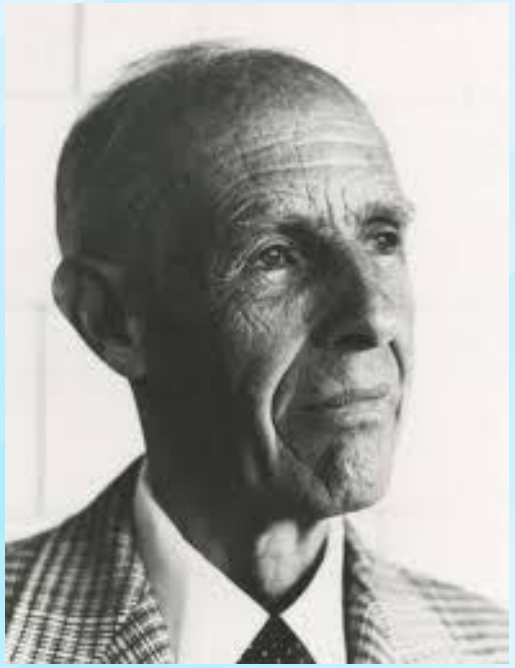
Engstrom Ventilator-Weight 500 lbs!!!



First computers

Emerson
Post-op
Ventilator

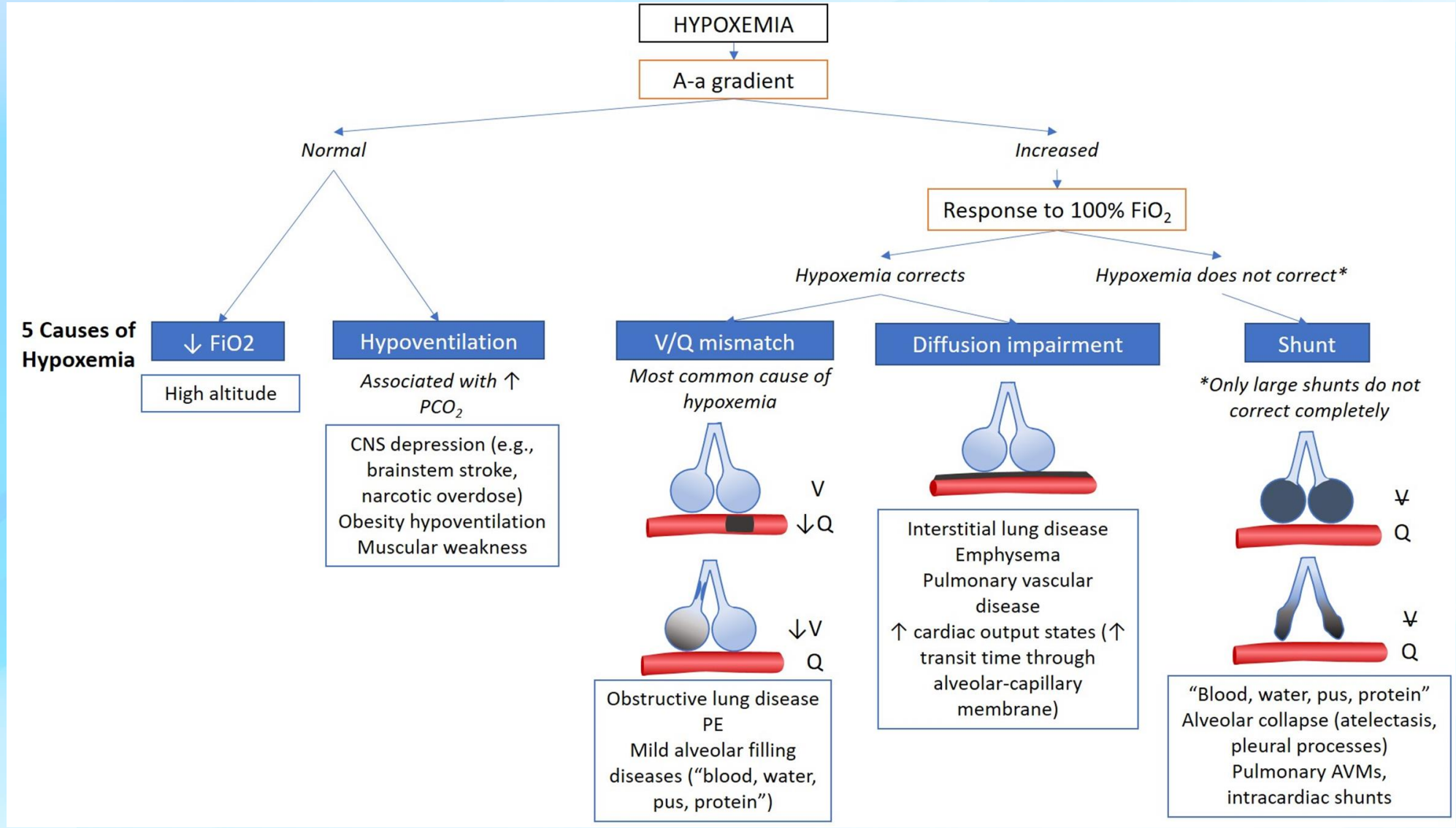




Jack Emerson

Puritan Bennett MA-1

Clinical Indications For Oxygen Administration



Clinical Management of Oxygen

- Was focused on normalization of physiological parameters
- More oxygen was better always started on 100%
  - Majority of PaO2s were>100 torr in the ICU in 1970-1980
  - 1990-2015 PaO2>85 torr
- Deadly in COPD patients
  - Induced apnea
- Injurious to newborns
  - Retrolental Fibroplasia

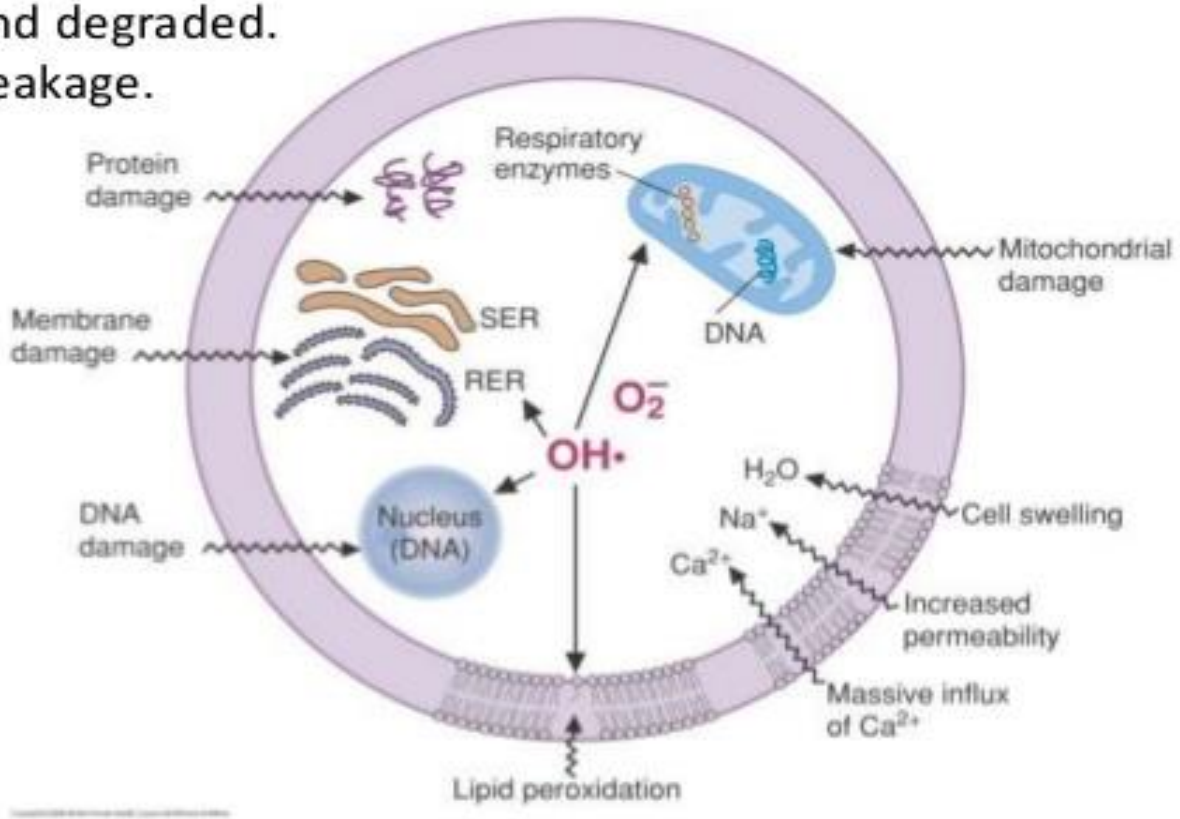
Evidence of Harm From Excessive Use of Oxygen Administration in the ICU

- High levels of PaO2 still exist in most ICUs today despite an increasing body of evidence that demonstrates harm
- High oxygen concentrations have always been known to cause lung injury
  - FIO2>70% for 4 days cause fatal pneumonitis in rats
  - FIO2>50% for>7 days cause alveolar edema in humans
  - Causes vasoconstriction and absorption atelectasis
  - VILI to increase PaO2
- Currently there has been several retrospective studies showing the harmful effects of hyperoxemia

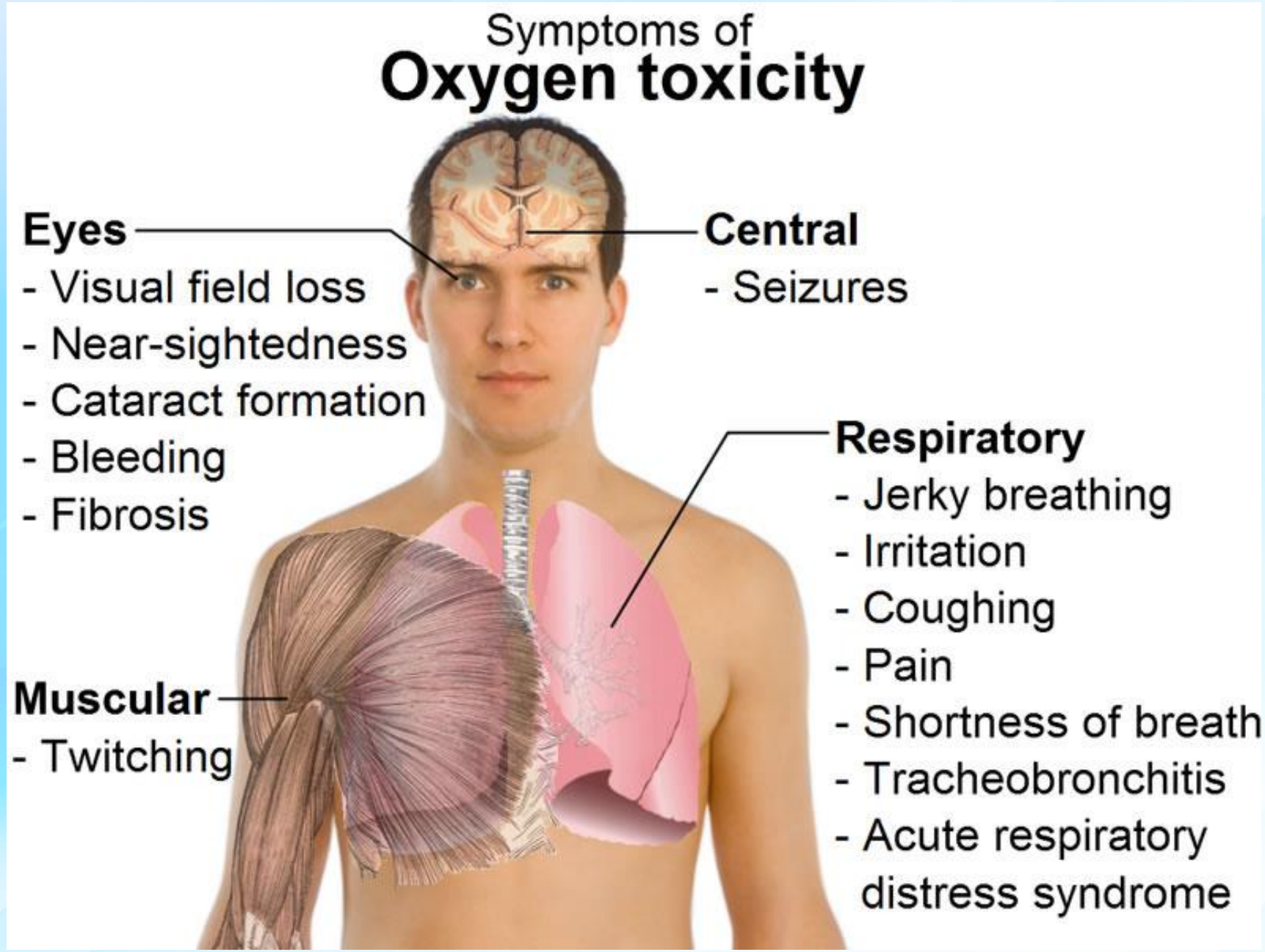
Harmful effects of these radicals…

Oxygen radicals react with cell components:

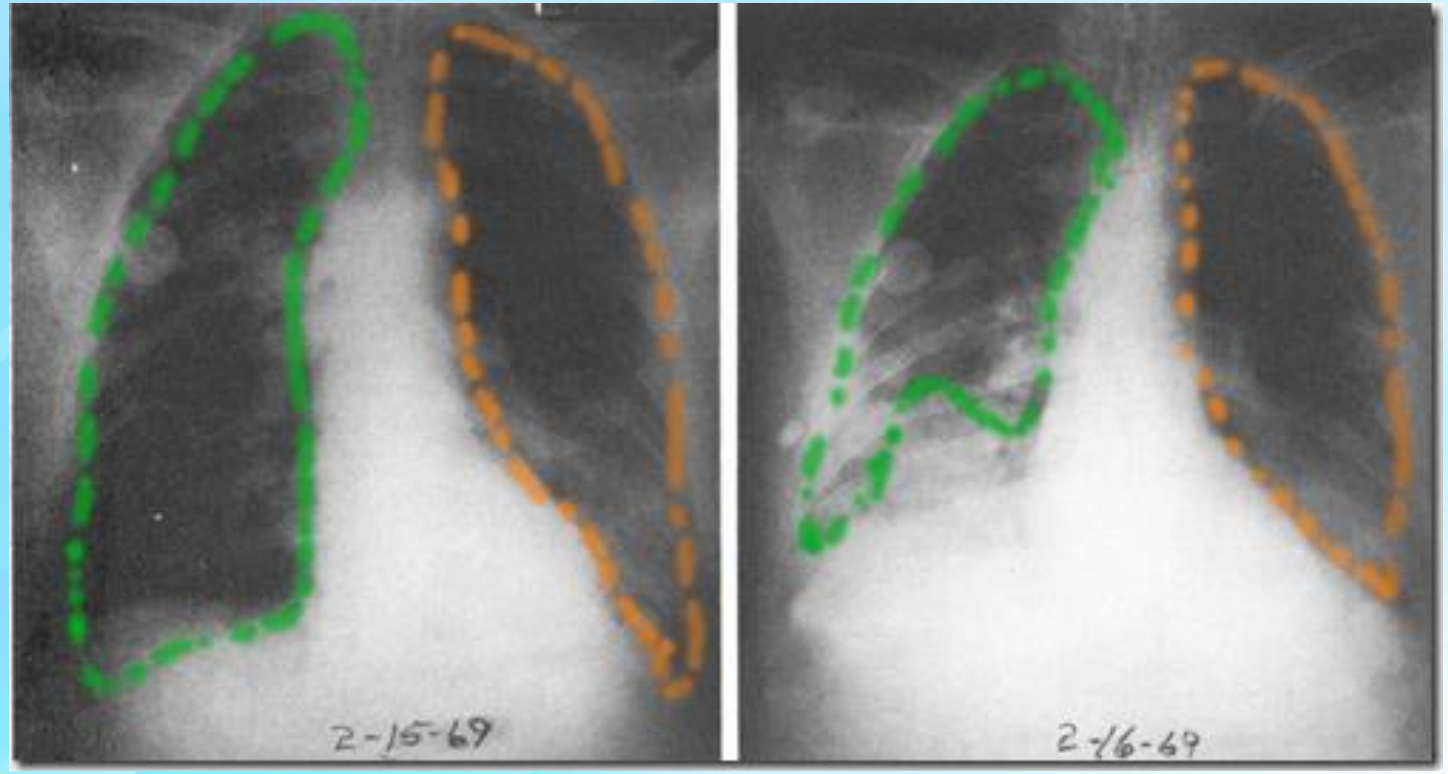
- Lipid peroxidation of membranes.
- Increased permeability → influx Ca^{2+} → mitochondrial damage.
- Proteins oxidized and degraded.
- DNA oxidized → breakage.



Hemoptysis After Prolonged Periods of High FIO2


Symptoms of
Oxygen toxicity
Eyes
- Visual field loss
- Near-sightedness
- Cataract formation
- Bleeding
- Fibrosis
Central
- Seizures
Respiratory
- Jerky breathing
- Irritation
- Coughing
- Pain
- Shortness of breath
- Tracheobronchitis
- Acute respiratory distress syndrome
Muscular
- Twitching

Absorption Atelectasis 100% O2 for 24 hrs.



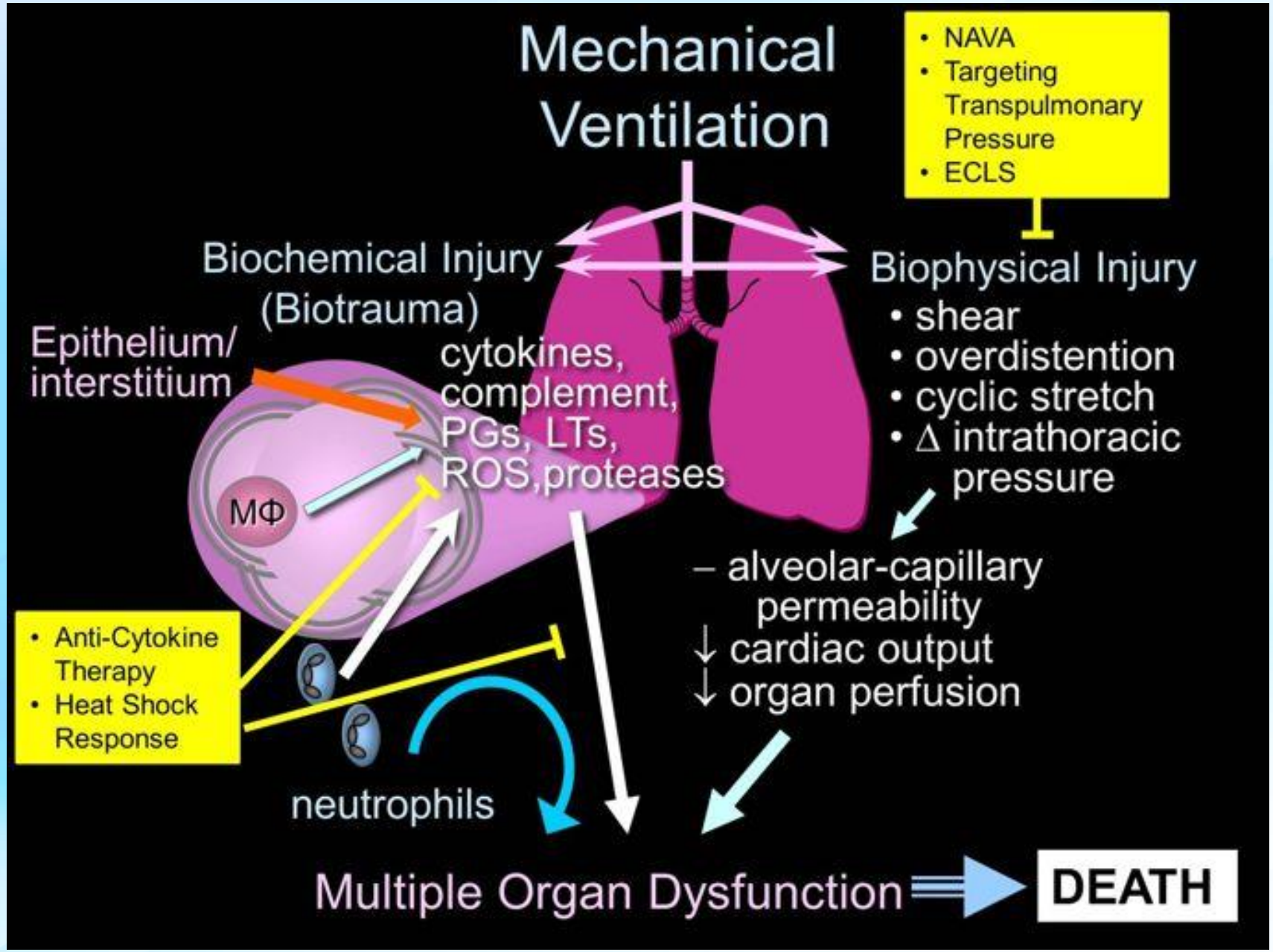
Evidence of Harm In Specific Patient Populations

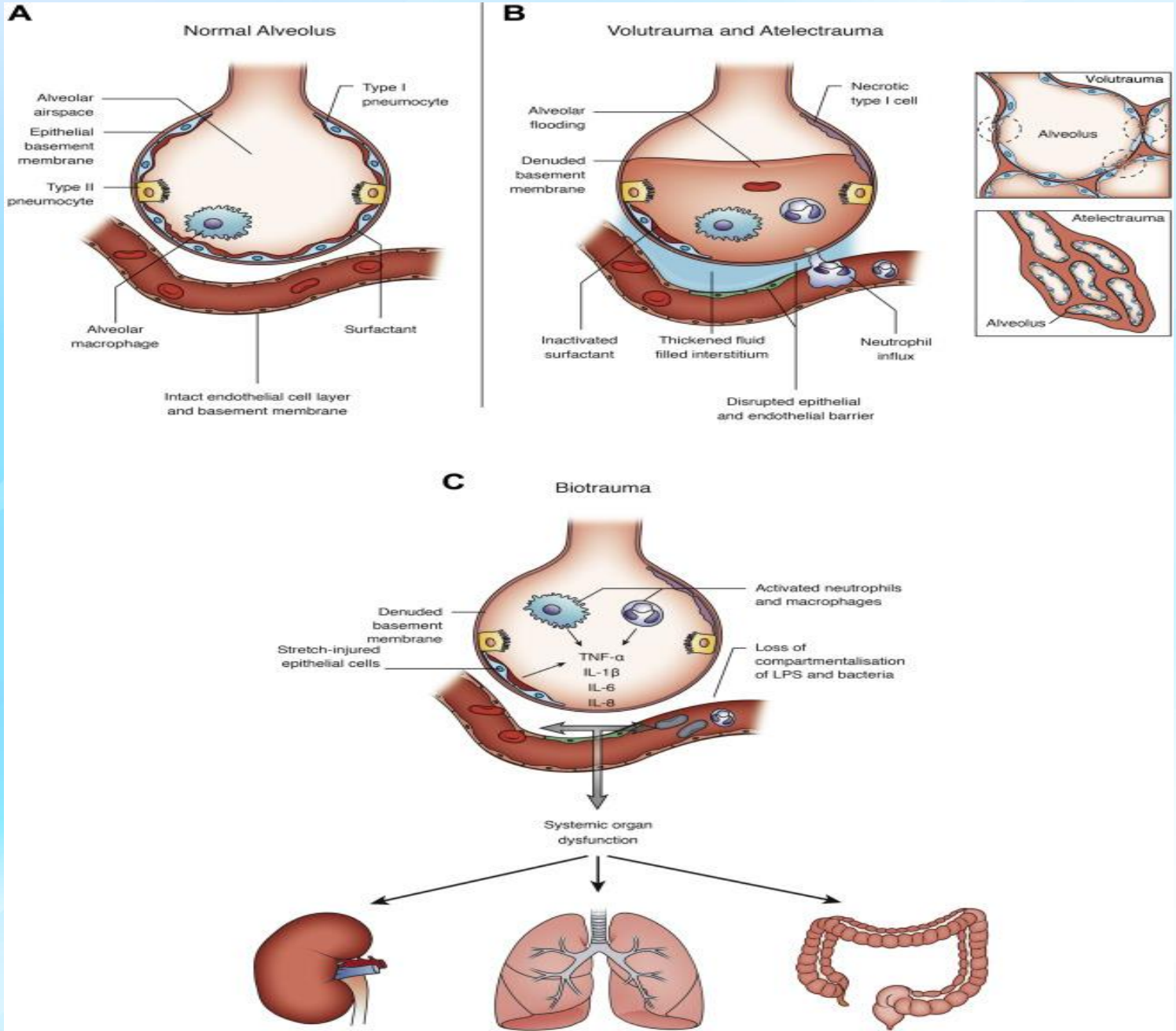
Survivors of CPR

- 1.8 times increase risk of hospital mortality for patients who has a PaO2>300 torr post resuscitation thirty minutes
- In the first 24 hrs. those patients with PaO2>300 torr were 57% more likely to die that those patients with PaO2<300 torr
- Clinical rational: oxygen radials may be release during re-perfusion of distal organs

Mechanical Ventilated Patients

- Patients with PaO2>100 torr had twice the mortality than patients with PaO2 60-80 torr 24 hours post intubation
- In almost every ARDS study patients with the lower PaO2 had higher survival rates than those patients a with higher PaO2
- Clinical rationale: VILI maybe be more evident in patients with higher a PaO2. The cost of higher PaO2 may lead to more VILI


Mechanical Ventilation
• NAVA
• Targeting Transpulmonary Pressure
• ECLS
Biochemical Injury (Biotrauma)
Epithelium/ interstitium
cytokines, complement, PGs, LTs, ROS,proteases
MΦ
Biophysical Injury
• shear
• overdistention
• cyclic stretch
• Δ intrathoracic pressure
– alveolar-capillary permeability
↓ cardiac output
↓ organ perfusion
• Anti-Cytokine Therapy
• Heat Shock Response
neutrophils
Multiple Organ Dysfunction
DEATH


A
Normal Alveolus
Alveolar airspace
Epithelial basement membrane
Type II pneumocyte
Type I pneumocyte
Alveolar macrophage
Surfactant
Intact endothelial cell layer and basement membrane
B
Volutrauma and Atelectrauma
Alveolar flooding
Denuded basement membrane
Necrotic type I cell
Inactivated surfactant
Thickened fluid filled interstitium
Neutrophil influx
Disrupted epithelial and endothelial barrier
Volutrauma
Alveolus
Atelectrauma
Alveolus
C
Biotrauma
Denuded basement membrane
Stretch-injured epithelial cells
Activated neutrophils and macrophages
TNF-α
IL-1β
IL-6
IL-8
Loss of compartmentalisation of LPS and bacteria
Systemic organ dysfunction

CVA/TBI Patients

- Low flow oxygen administration @ 2-4 lpms demonstrated improved outcomes compared to patients on oxygen mask
- Optimal SpO2 range for CVA patients 90-94%
- Optimal SpO2 range for TBI 90-92%
- Clinical rationale: high PaO2 may cause vasoconstriction and lead to increased intracranial pressures

MI=NRB Mask?

Myocardial Infarction Patients

- Higher SpO2 was associated with increased levels of cardiac enzymes and infraction size
- No evidence that oxygen administration via a NRB mask is beneficial in MI patients and should not be considered a standard of care
- Clinical rationale: oxygen may cause re-perfusion injury to occur

Randomized Trials of Oxygen Therapy in the ICU

- Italian study:
  - 94-97% had 11.6% mortality rate
  - >97% had 20.1 % mortality rate
- ICU-ROX Study
  - 24% risk reduction in patients with SpO2 90-94%
- NICU study with Sepsis
  - Terminated secondary to increased atelectasis and muscle weakness in the hyperoxia group (PaO2>100 torr)

So Why Have We Used too Much Oxygen for Decades???

- Old habits die hard
- Dyspnea is associated with hypoxemia
- High oxygen administration demonstrated success in:
  - WWI victims to gas attacks
  - Tuberculosis
  - Pneumonia
- Aggressive use of oxygen historically was used without reliable oxygen measuring tools
  - No ABGs/SpO2 probes
  - Became the standard of care of ALL critical ill patients

Increase Oxygen Carrying Capacity In The Blood

- Maintain a patent airway
- Increased blood volume
- Correct anemia
- Enhance cardiac output
- Give supplemental O2 only if the patient is hypoxemic
- Treat the reason for the hypoxia (heart failure, pneumonia)

Different Oxygen Delivery Devices

- Nasal cannula
- Simple/NRB mask
- Venti-mask
- High Flow Oxygen
- CPAP/BIPAP
- Ventilators
- ECMO

Low Flow Oxygen

- Nasal cannula
  - 1-8 lpm
  - 22-44%
- Simple mask
  - 6-12 lpm
  - 30-60%
- Non-rebreathing mask
  - 10-15 lpm
  - 50-95%

Variable oxygen delivery when respiratory pattern is outside normal parameters

Mid Flow Oxygen Devices

- Cannula-15 lpm
- Oxygen Pendant
- Oximes

High Flow Oxygen

- Optiflow
- Vapotherm
- Telflex

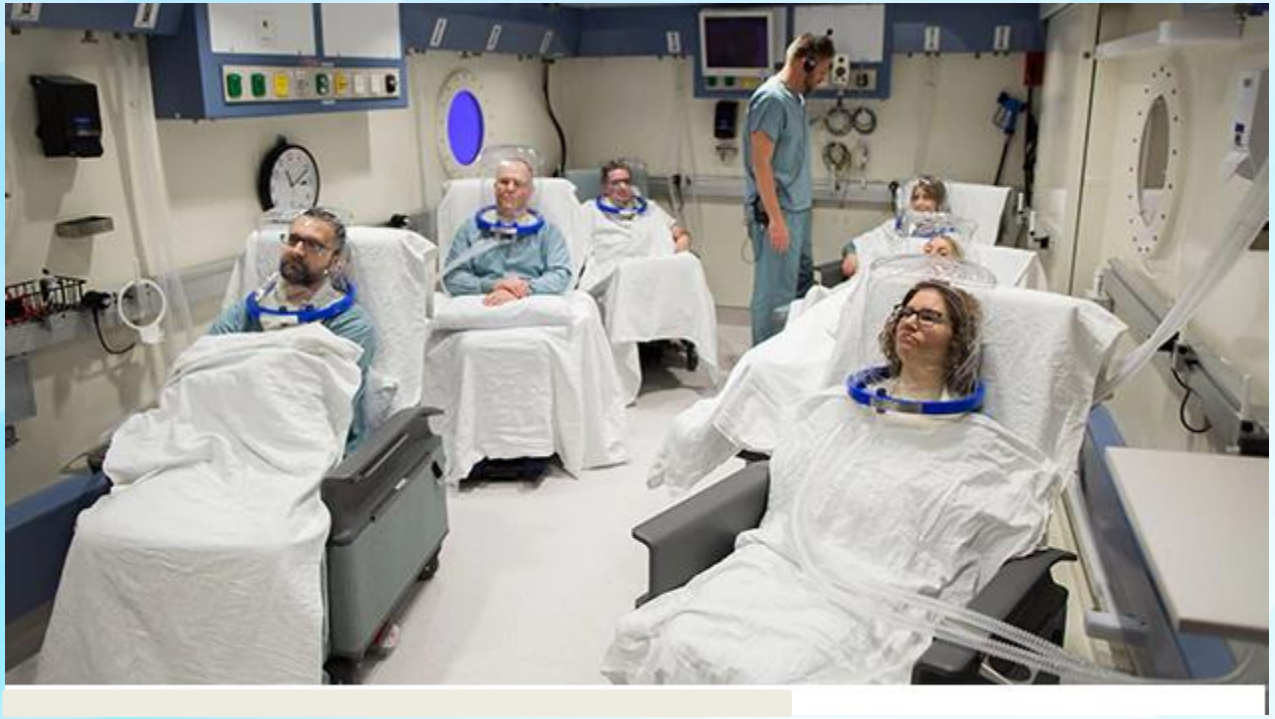
- Delivery of exact FIO2
- Delivers molecular humidity
- Provides “pseudo CPAP” ?

Venti-Mask/Oxi mask

Ventilators

- Conventional
- Oscillators/VDR/HFJV
- Non-invasive

Hyperbaric Chambers



Wound healing
CO poisoning
Deep sea decompression
Brain abscess

Lebron James

Future Directions of Oxygen Administration

- Oxygen is now recognized as a dangerous drug if over-used
- Should only prescribed in documented hypoxemic patients not as a panacea for all serious ill patients
- We must be careful that oxygen administration does not suffer the see saw pendulum effect
- High oxygen concerations are indicated for specific emergent situations

Current Best Practice For Oxygen Utilization In Critical Illness

- Target SpO2 90-94% for most patients
- Target SPO2 88-92% in ARDS
- Target Spo2 88% in COPD, IPF
- 100% Oxygen administration in CO poisoning
- Target SpO2 90-92% for CVA/TBI/MI patient populations
- Use high FIO2 until patient is stabilized or resuscitated
  - Reduce FIO2/SPO2 target with assessment

Summary

- Untreated hypoxemia and hyperoxemia are both harmful
- The former is much feared but not uncommon, but the latter is common and under recognized
- Utilization of oxygen therapy should be administered with specific clinical end-point targets
- RRTs play a pivotal role in determining best oxygen administration practice

Questions?

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