Hypoxemia in the Surgical ICU
A Pragmatic Approach

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Surgical Critical Care Specialist
Department of Surgery
Denver Health Medical Center
Overview

- **Mechanisms of Hypoxemia**
  
  Let's keep it as simple as ABC!

- **Detection of Hypoxemia**
  
  Will I know it when I see it?

- **Hypoxemia vs Hypoxia**
  
  Playing with fire or a clinical goal!

- **Hypoxic Events in the SICU**
  
  The clock is ticking!
Mechanisms of Hypoxemia

1) Low Inspired PO2
2) Hypoventilation
3) Ventilation/Perfusion mismatch
4) Right- to- Left Shunt
5) Diffusion defect
Low Inspired $\text{PiO}_2/\text{FiO}_2$ → Hypoxemia

Three variables determine Alveolar $\text{Po}_2$: $\text{FiO}_2$, $\text{Pb}$, and $\text{Paco}_2$

- **Altitude**
  - $\text{FiO}_2$ = 0.21 everywhere
  - Barometric pressure ($\text{Pb}$)
    - Seattle: 760 mm Hg
    - Denver: 630 mm Hg
    - Cheyenne: 593 mm Hg
    - Mt Everest: 225 mm Hg

- **Alveolar $\text{O}_2$** = 25 ~ mm Hg on Mt Everest
The Mount Everest of the ICU

Potential Inadequate flow delivery

Room air entrainment

Decreased FIO₂ Delivery
The Mount Everest of the ICU

Mechanical/Device Related Hypoxia

Normal Inspiratory flow
With spontaneous breathing
15 – 30 L/M

Poiseuille law
\[ \text{Raw} = 6\pi s L/r^4 \]

Inspiratory flow with
Increased Raw
60 – 100 L/M

\[ \downarrow \]

Decreased FIO\textsubscript{2} Delivery

10 – 15 L/M
Alveolar Hypoventilation in the ICU

Brainstem respiratory depression

Peripheral neuropathy

Muscle weakness

Hypoxemia with a normal A-a gradient is a result hypoventilation!

**A-a gradient: \( Pb - H_2O \text{ vapor} \times FIO_2 - PaCO_2/0.8 - PaO_2 \)**

\[
630 - 47 \times 0.21 \div 55/0.8 - 50 = 7 \text{mm Hg}
\]
Ventilation/Perfusion Relationships

V = 4 L/M
Q = 5 L/M

V/Q
Ventilation/Perfusion Ratio

Most common clinical cause for arterial hypoxemia!!

Settings:
- Atelectasis
- Bronchospasm
- Partial airway obstruction
- COPD

V/Q ratio responds to supplemental O₂
Ventilation/Perfusion Ratio

Classic Acute Dead Space Situation

$\uparrow$ PaCo$_2$

$\downarrow$ PaO$_2$
Right-to-Left Shunt

**Physiologic shunt** = ~ 3-5% of C.O.

- **Pulmonary shunt**
  - Severe pneumonia
  - ARDS
  - Lobar collapse
  - Reversal of H.P.V.

- **Extrapulmonary shunts**
  - (atrial/ventricular/PDA)

- **Hepatopulmonary syndrome**
  - Perfusion without ventilation

Left – to – Right Qs/Qt does not respond to increased FIO₂
In Sum

- Mechanical/Device related exacerbation of hypoxemia is common
- Hypoventilation associated hypoxemia results in a normal A-a gradient
- V/Q Mismatch is the most common cause for hypoxemia
- Left – right – Qs/Qt does not respond to oxygen therapy
Detection of Hypoxemia
Will I Know It When I See It?
The Unreliability of Cyanosis in the Recognition of Arterial Anoxemia

By Julius H. Comroe, Jr., M.D.
And
Stella Botelho, A.B.
Philadelphia, Pennsylvania

Table 1.—Percentages of Total Observations at Various Arterial Oxygen Saturation Levels Noted as Normal Color, Slight Cyanosis or Definite Cyanosis

<table>
<thead>
<tr>
<th>Oximeter reading (arterial O₂ saturation)</th>
<th>No. observations at each arterial O₂ level</th>
<th>% observations reported</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Students</td>
<td>Staff</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Staff</td>
</tr>
<tr>
<td>100-95</td>
<td>2865</td>
<td>808</td>
</tr>
<tr>
<td>95-91</td>
<td>711</td>
<td>203</td>
</tr>
<tr>
<td>90-86</td>
<td>712</td>
<td>182</td>
</tr>
<tr>
<td>85-81</td>
<td>799</td>
<td>244</td>
</tr>
<tr>
<td>80-73</td>
<td>418</td>
<td>76</td>
</tr>
<tr>
<td>75-71</td>
<td>139</td>
<td>47</td>
</tr>
<tr>
<td>Total</td>
<td>5644</td>
<td>1560</td>
</tr>
</tbody>
</table>
Monitoring Oxygenation

1930’s

1939*

1941

1956

1967*

1978

1980-1990

2010
Randomized Evaluation of Pulse Oximetry in 20,802 Patients: II.

Perioperative Events and Postoperative Complications

Table 1. Respiratory and Cardiovascular Events during Anesthesia

<table>
<thead>
<tr>
<th>Event</th>
<th>Control (n = 10,490)</th>
<th>Oximetry (n = 10,312)</th>
<th>( p^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td><strong>Respiratory</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypoxia</td>
<td>143</td>
<td>0.4</td>
<td>123</td>
</tr>
<tr>
<td>Hypoventilation</td>
<td>45</td>
<td>0.4</td>
<td>106</td>
</tr>
<tr>
<td>Airway obstruction</td>
<td>29</td>
<td>0.3</td>
<td>44</td>
</tr>
<tr>
<td>Laryngospasm</td>
<td>20</td>
<td>0.2</td>
<td>24</td>
</tr>
<tr>
<td>Bronchospasm</td>
<td>66</td>
<td>0.6</td>
<td>85</td>
</tr>
<tr>
<td>Aspiration (suspected)</td>
<td>10</td>
<td>0.1</td>
<td>13</td>
</tr>
<tr>
<td>Difficulty with intubation</td>
<td>139</td>
<td>1.3</td>
<td>170</td>
</tr>
<tr>
<td>Esophageal intubation</td>
<td>31</td>
<td>0.3</td>
<td>38</td>
</tr>
<tr>
<td>Endobronchial intubation</td>
<td>5</td>
<td>0.05</td>
<td>27</td>
</tr>
<tr>
<td>Reintubation</td>
<td>20</td>
<td>0.2</td>
<td>16</td>
</tr>
<tr>
<td>Other</td>
<td>31</td>
<td>0.3</td>
<td>18</td>
</tr>
<tr>
<td><strong>Total no. of patients with 1 or more event(s)</strong></td>
<td>366</td>
<td>3.3</td>
<td>405</td>
</tr>
<tr>
<td><strong>Cardiovascular</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypotension</td>
<td>469</td>
<td>4.5</td>
<td>456</td>
</tr>
<tr>
<td>Hypertension</td>
<td>224</td>
<td>2.1</td>
<td>216</td>
</tr>
<tr>
<td>Hypovolemia</td>
<td>39</td>
<td>0.4</td>
<td>56</td>
</tr>
<tr>
<td>Arrhythmia (all)</td>
<td>197</td>
<td>1.9</td>
<td>188</td>
</tr>
<tr>
<td>Cardiac arrest with resuscitation</td>
<td>11</td>
<td>0.1</td>
<td>4</td>
</tr>
<tr>
<td>Myocardial ischemia</td>
<td>25</td>
<td>0.2</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>14</td>
<td>0.2</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total no. of patients with 1 or more event(s)</strong></td>
<td>627</td>
<td>7.7</td>
<td>330</td>
</tr>
</tbody>
</table>

*Chi-square test followed by stratification and logistic regression analyses to control for the known confounders.*
Randomized Evaluation of Pulse Oximetry in 20,802 Patients: II.

Perioperative Events and Postoperative Complications

Multi-institutional study: Denmark

- 19 – fold increase in the incidence of diagnosed hypoxemia in oximetry group

Intraoperative:
- Incidence of myocardial ischemia: Pulse Oximetry =12  Control = 26

- Pulse Oximetry group received more interventions while in the PACU
  I. Increased use of supplemental O2
  II. Increased use of supplemental O2 at discharge
  III. Increased use of Narcan

Postoperative rate of complications:
- 10% vs 9.4%
- No difference in post-op complications of any kind
- Hospital stay 5 days both groups
- NO DIFFERENCE in MORTALITY!!
ABG’S: To Many, To Few or Just Right?
Spontaneous Blood-Gas Variability

<table>
<thead>
<tr>
<th>Variation</th>
<th>PaO2</th>
<th>PaCO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>13 mm Hg</td>
<td>2-5 mm Hg</td>
</tr>
<tr>
<td>95th Percentile</td>
<td>± 18 mm Hg</td>
<td>±4 mm Hg</td>
</tr>
<tr>
<td>Range</td>
<td>2-37 mmHg</td>
<td>0-12 mm Hg</td>
</tr>
</tbody>
</table>

Represents variation over a 1-hour period in 26 ventilator dependent trauma patients who were clinically stable.
Hypoxemia vs Hypoxia
Playing with fire or a Clinical Goal?

Definitions of Severe Hypoxemia

1967
Cyanosis refractory to oxygen therapy
*Lancet Saturday 12 August 1967*

1974
ARF is usually defined on the basis of
alterations in ABG compositions, an
arterial Po$_2$ < 50 mm Hg and/or an arterial
Pco$_2$ > 50 mm Hg  Thomas Petty

1988
PaO$_2$ /Fio$_2$ ratio < 299
Murray LIS , AM REV RESP DIS

2000
P/F ratio < 300 ALI , <200 ARDS
ARDS Net

2009
CESAR trial
Murray Score > 3.0

The nurse reminds you every 10 mins that the patients pulse-ox is 88%!!

The nurse says they need you in room 20 NOW!!
Tissue Oxygenation

Inadequate oxygen carrying capacity
- Anemic hypoxia
Inadequate oxygen transport
- Stagnant hypoxia
Inadequate peripheral Oxygen Extraction
- Cytopathic hypoxia

Inadequate oxygen saturation
- Hypoxic hypoxia,

Components | Physiologic Processes
---|---
Pulmonary | Ventilation
Gas exchange | Diffusion
Oxygen delivery | Ventilation-perfusion
Oxygen extraction | BLOOD
Oxygen consumption | Cardiac output

---

O2 | O2
Cvo2 | CaO2
O2 | O2
ATP | ATP

---

SVV | CI
ScvO2 | SVRI
Why do ARDS Patients Die??

1981-82 (n=32)
- 84% (Green)
- 16% (Yellow)

1990 (n=57)
- 86% (Red)
- 14% (Green)

1994 (n=32)
- 81% (Green)
- 19% (Red)

1998 (n=75)
- 87% (Red)
- 13% (Green)
Elements in the Management of ARDS

1. Oxygenation of arterial blood
2. Support of ventilation
3. Treatment of the inciting event
4. Monitoring patient
5. Prevention, recognition and treatment of complications

ALI/ARDS (\(P_{aO_2}/F_{iO_2}\)) Strategies 1980-2011

- Alternate modes of ventilation- HFOV, APRV, Bi-Level
- Neuromuscular blockade
- PEEP trials
- Nitric oxide
- ECLS
- Liquid ventilation
- Prone positioning
- Lung recruitment maneuvers

NO proven benefit in survival!!
What works and what are we afraid of?

LPV
- Low tidal volumes
- plateau pressures < 30
- Moderate PEEP
- A/C with volume

Oxygenation goals
- Pao₂ 55-80- SPo₂ 88-95%

ARDS Net NEJM May 4 2000

Why is there no consensus then in ordinary patient management?

FIO₂ /PEEP tolerance varies
PaO₂, Pulse oximetry/SVO₂ values that triggers an intervention differs

The “acceptable” level of arterial oxygenation varies from patient to patient and even for a given patient shift to shift!
The overall goal of permissive hypoxemia as a lung-protective strategy, is to minimize the detrimental pulmonary and systemic effects of high ventilatory support (by accepting a relatively low arterial oxygen saturation) while maintaining adequate $\text{Do}_2$ by optimizing cardiac output.
Hypoxic Events in the Surgical Intensive Care Unit

Hypoxic events in the surgical intensive care unit.
Moore FA, Haenel JB, Moore EE, Abernathy CM.
PMID: 2252129 [PubMed - indexed for MEDLINE]
New Pulmonary Process
Progression Underlying Dz
Unknown
Mechanical Ventilation
Artificial Airway
Recent Intervention
DHMC Hypoxic Events Surgical Intensive Care Unit
Etiology of 100 Consecutive Hypoxic Events in the Surgical Intensive Care Unit

1. Mechanical ventilator/airway (n = 42)
   A. Primary survey
      1. Supplemental oxygen disruption 9
      2. Proximal airway obstruction 6
      3. Distal mucous plugging 5
      4. Ventilator asynchrony 3
      5. Fluctuating FIO₂ 3
      6. Ventilator disconnect 2
      7. Tension pneumothorax 2
   B. Secondary survey
      1. Ventilator adjustments 5
      2. Weaning 7

II. Recent interventions (n = 21)
   A. Procedures 7
   B. Medications 6
   C. Positional changes 5
   D. Post-transportation 3

III. New pulmonary process (n = 19)
   A. Pulmonary edema 6
   B. Atelectasis/collapse 5
   C. Simple pneumothorax 4
   D. Pneumonia 3
   E. Aspiration (primary survey) 1

IV. Progressive underlying disease (n = 11)
   A. Sepsis 4
   B. CHF 3
   C. ARDS 2
   D. Pneumonia 2

V. Unknown causes 7
Algorithm for Initial Management of Acute Hypoxic Events

Acute Hypoxic Event → Hand Ventilating FIO₂ → ET Tube Cuff Leak → Repair/Replace ET Tube

Difficult Bagging? → Pas Suction Catheter

Obstruction → √ Tube Position Deflate Cuff R/O Plug → Obstruction Persist → Replace Airway

No Obstruction → Check: O₂ Source Ventilator Circuit → Correct Mechanical Problems

Physical Exam → Tension Pneumothorax → Chest Tube

Recent Events: ABG, CXR, U.S., EKG → New Complication → Progression Underlying Disease

Intervention Or Procedure → Secondary Survey
Algorithm for Initial Management of Acute Hypoxic Events

Acute Hypoxic Event → Hand Ventilate ↑FIO₂ → Obstruction → √ Tube position Deflate cuff R/O plug
Algorithm for Initial Management of Acute Hypoxic Events

Acute Hypoxic Event

↑
Hand Ventilate FIO₂

↓
ET Tube Cuff Leak

Leak
Algorithm for Initial Management of Acute Hypoxic Events

1. Acute Hypoxic Event
2. Hand Ventilate $\uparrow$ FIO$_2$
3. Check: O$_2$ Source Ventilator Circuit
4. Correct Mechanical Problems
Algorithm for Initial Management of Acute Hypoxic Events

1. Acute Hypoxic Event
2. Pass Suction Catheter
3. Hand Ventilate FIO₂
4. ET Tube Cuff Leak
5. Repair/Replace ET Tube
6. Obstruction
7. Difficult Bagging?
8. No Obstruction
9. Check: O₂ Source Ventilator Circuit
10. Correct Mechanical Problems
11. Physical Exam
12. Tube Position Deflate Cuff R/O Plug
13. Obstruction Persist
14. Replace Airway
15. Recent Events ABG CXR U.S. EKG
16. New Complication
17. Progression Underlying Disease
18. Secondary Survey
Recent Events
ABG
CXR
U.S.
EKG

Intervention Or Procedure

New Complication

1. Repositioning patient
2. Bathing
3. Post-CPT
4. Post-transport
5. Suctioning
6. NG placement
7. Medication: Vasoactive/sedation
8. “They” just got a CXR
9. New central line/procedure
10. Weaning patient
Selective Intrabronchial Air Insufflation for Acute Lobar Collapse in the Surgical Intensive Care Unit

Max V. Wohlauer, MD, Ernest E. Moore, MD, James B. Haenel, RRT, Clay C. Burlew, MD, and Carlton C. Barnett Jr, MD
Denver Health Medical Center and University of Colorado Denver, Denver, Colorado
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<table>
<thead>
<tr>
<th>Pt</th>
<th>Indication</th>
<th>Age</th>
<th>(\text{PaO}_2:\text{FiO}_2) Before SII</th>
<th>(\text{PaO}_2:\text{FiO}_2) After SII</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Non-compliant</td>
<td>3</td>
<td>225</td>
<td>285</td>
</tr>
<tr>
<td>2</td>
<td>Acute hypoxemia</td>
<td>21</td>
<td>87</td>
<td>180</td>
</tr>
<tr>
<td>3</td>
<td>Failed Conventional</td>
<td>56</td>
<td>130</td>
<td>130</td>
</tr>
<tr>
<td>4</td>
<td>Failed Conventional</td>
<td>19</td>
<td>340</td>
<td>425</td>
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<tr>
<td>5</td>
<td>Acute hypoxemia</td>
<td>28</td>
<td>90</td>
<td>240</td>
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<td>6</td>
<td>Failed Conventional</td>
<td>62</td>
<td>165</td>
<td>180</td>
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<td>7</td>
<td>Failed Conventional</td>
<td>26</td>
<td>123</td>
<td>123</td>
</tr>
<tr>
<td>8</td>
<td>Failed Conventional</td>
<td>44</td>
<td>192</td>
<td>188</td>
</tr>
<tr>
<td>9</td>
<td>Failed Conventional</td>
<td>69</td>
<td>124</td>
<td>130</td>
</tr>
<tr>
<td>10</td>
<td>Acute hypoxemia</td>
<td>86</td>
<td>61</td>
<td>188</td>
</tr>
<tr>
<td>11</td>
<td>Acute hypoxemia</td>
<td>44</td>
<td>77</td>
<td>97</td>
</tr>
<tr>
<td>12</td>
<td>Acute hypoxemia</td>
<td>21</td>
<td>60</td>
<td>338</td>
</tr>
<tr>
<td>13</td>
<td>Failed Conventional</td>
<td>12</td>
<td>160</td>
<td>195</td>
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<td>14</td>
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<td>18</td>
<td>74</td>
<td>218</td>
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<tr>
<td>15</td>
<td>Failed Conventional</td>
<td>60</td>
<td>146</td>
<td>172</td>
</tr>
<tr>
<td>16</td>
<td>Acute hypoxemia</td>
<td>23</td>
<td>100</td>
<td>200</td>
</tr>
</tbody>
</table>

**Mean**

<table>
<thead>
<tr>
<th>(\text{PaO}_2:\text{FiO}_2) Ratio</th>
<th>Before SII</th>
<th>After SII</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>188</td>
<td></td>
</tr>
</tbody>
</table>

\(\text{*}\) indicates statistical significance (p < 0.05).
Selective Intrabronchial Air Insufflation for Acute Lobar Collapse in the Surgical Intensive Care Unit

Max V. Wohlauer, MD, Ernest E. Moore, MD, James B. Haenel, RRT, Clay C. Burlew, MD, and Carlton C. Barnett Jr, MD
Denver Health Medical Center and University of Colorado Denver, Denver, Colorado
Incidence of Pulmonary Embolism

May 2010 – May 2011: 957 Admits to the SICU

30 Patients (3%) evaluated by CTPE study

# of positive CTPE studies: 3 (total incidence per 957 patients: 0.003)

Percent total positive CTPE studies: 10%

Heparin is one of the most common prescribed drugs in the ICU

- Prophylaxis
- DVT’s
- A Fib
- H.I.T.

- Cavernous sinus venous thrombosis
- Post-op vascular graft
- Carotid/ vertebral vascular injury
- Peri-op MI
In Conclusion

- V/Q mismatch is the most common mechanism for hypoxemia
- Environmental (mechanical) causes of hypoxemia are common
- There is no role for routine ABG’s
- Performance of a primary & secondary survey during an acute hypoxic event is 90% successful in identifying the cause of hypoxemia
### Physiologic mechanisms of hypoxemia

<table>
<thead>
<tr>
<th>Decreased alveolar partial pressure of oxygen ((PAO_2)); normal alveolar minus arterial difference ((PAO_2 - PaO_2))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decreased (PiO_2):</strong></td>
</tr>
<tr>
<td>Lower atmospheric pressure ((PATM)) with normal fraction of inspired oxygen ((FiO_2))(e.g., high altitude)</td>
</tr>
<tr>
<td>Lower (FiO_2) with normal (PATM) (e.g., iatrogenic)</td>
</tr>
<tr>
<td><strong>Alveolar hypoventilation:</strong></td>
</tr>
<tr>
<td>(PAO_2 = PiO_2 - PaCO_2/R) (e.g., depressed respiratory drive)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Increased (PAO_2 - PaO_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diffusion limitation</strong> — blood leaving an alveolus fails to reach equilibration with alveolar gas; rarely significant as a cause of clinical hypoxemia</td>
</tr>
<tr>
<td><strong>Ventilation-perfusion ((V/Q)) mismatching</strong> — specifically, the low (VA/Q) areas cause hypoxemia by contributing blood with reduced content to the arterial mixture</td>
</tr>
<tr>
<td><strong>Shunt</strong> — the extreme of low (V/Q); shunt flow of deoxygenated blood has no contact with alveolar gas</td>
</tr>
</tbody>
</table>

On 100% oxygen (\(FiO_2 = 1.0\)) only the shunt mechanism contributes to the \(PAO_2 - PaO_2\) difference. Breathing air or on any \(FiO_2 < 1.0\), both shunt and low \(V/Q\) areas (plus any diffusion limitation) contribute to the \(PAO_2 - PaO_2\) difference. This combined effect is termed *venous admixture* and has also
Algorithm for Initial Management of Acute Hypoxic Events

Acute Hypoxic Event → Hand Ventilate $\uparrow$ FIO$_2$ → Check: O$_2$ Source Ventilator Circuit → Correct Mechanical Problems
IAH and the lung

High IAP:
- Diaphragm elevation
- ↑ ITP, ↑ Pleural Press
- ↓ FRC
- ↑ PIP (on volume control MV)
- ↑ Atelectasis
- ↓ Compliance
- ↓ PaO2:FiO2 ratios
- ↑ Inflammatory response

Correlation IAP - Ppleura

\[ y = 0.7815x + 1.55 \]
\[ R^2 = 0.8127 \]

Chatham and Malbrain, Acta Clin Belg 2007
IAH and the lung
Elevated IAP effect on lung

- Marked reduction in chest wall compliance
- Increased atelectasis / reduced recruitment

Ventilation optimization and IAH

Ppleural \approx\ Peso \approx IAP

Useful for establishing PEEP settings to enhance alveolar recruitment.

- Pelosi suggests setting PEEP = IAP
- Quintel suggests incremental ↑PEEP, observe PaCO₂ effect, repeat
- Talmor suggests setting PEEP = TPP of 0-10 (TPP=Pplat-Ppleural where Ppleural \approx Peso or \approx IAP)
Hypoxic events in the surgical intensive care unit.
Moore FA, Haenel JB, Moore EE, Abernathy CM.
PMID: 2252129 [PubMed - indexed for MEDLINE]
A mural of William Green Morton performing surgery on a patient anesthetized with ether in the Ether Dome at Massachusetts General Hospital on Oct. 16, 1846.

Photo of mural taken by Adam Leventritt at the Ether Dome at Massachusetts General Hospital, Boston.
The diagram represents the Krebs cycle, also known as the citric acid cycle or the tricarboxylic acid (TCA) cycle. It involves the oxidation of acetyl-CoA (H₂C-C-COO⁻) and the production of carbon dioxide (CO₂), hydrogen ions (H⁺), and reduced nicotinamide adenine dinucleotide (NADH). The cycle includes several key reactions such as the condensation of acetyl-CoA with oxaloacetate (HOOC-C-COO⁻) to form citrate (H₃C-C-C-COO⁻), the oxidation of citrate to form isocitrate (H₂C-C-C-COO⁻), the conversion of isocitrate to α-ketoglutarate (H₂C-C-C-COO⁻), and the production of succinyl-CoA (H₂C-C-C-COO⁻). The cycle also involves the generation of ATP (GTP), GTP, and the participation of coenzyme A (CoASH) and NAD⁺. The figure illustrates the complex interplay of these biochemical processes, which are crucial for cellular respiration and energy production.
Getting Back to the Basics!
Table 2
Patients, indications for therapy, their age, and average PaO₂ to FiO₂ ratios before and after selective intrabronchial air insufflation.

<table>
<thead>
<tr>
<th>Pt</th>
<th>Indication</th>
<th>Age</th>
<th>PaO₂/FiO₂ Before SII</th>
<th>PaO₂/FiO₂ After SII</th>
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ACUTE HYPOXIC EVENTS DURING MECHANICAL VENTILATION