Conventional and High-flow Oxygen Therapy in COVID-19

Irandi Putra Pratomo, M.D., Ph.D.

Holistic Management of COVID-19 and Other Emerging Diseases

PIPKRA Workshop, 26 February, 2021
Presentation Outline

• Pulmonary Physiology at-A-Glimpse
• Oxygen Impairments in COVID-19
• Oxygen Therapy in COVID-19
• High-flow Oxygen Therapy in COVID-19
• Preparation & Unfavored Events of High-flow Oxygen Therapy
• Conclusion
Pulmonary Physiology at-A-Glimpse

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FiO₂ = 21%

PAO₂ = 100 mmHg

PACO₂ = 40 mmHg

PvCO₂ = 46 mmHg

PaO₂ = 100 mmHg

https://doi.org/10.4187/respcare.03377
Alveolar surface tension by AT2 cells

Laplace's Law:
$$\Delta P = 2\gamma/r$$

1. $r_1 < r_2$
2. $\gamma_1 = \gamma_2$
3. $\Delta P_1 > \Delta P_2$
4. $r_1 < r_2$
5. $\gamma_1 > \gamma_2$
6. $\Delta P_1 = \Delta P_2$

Collapse

Lung Surfactant

+ LS

https://doi.org/10.3389/fphys.2020.00386
Gas Diffusion by AT1 Cells

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**Oxygen Impairments in COVID-19**

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https://doi.org/10.1161/ATVBAHA.120.314515
Alveolar-arterial oxygen gradient (A-a DO₂)

Ventilation – Perfusion (V/Q) Mismatch ••

PaO₂:FiO₂ decreased/ARDS (<300)

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https://doi.org/10.1161/CIRCULATIONAHA.120.047915
Oxygen Therapy in COVID-19

• Determine an Increased Oxygen Demand in COVID-19 → Clinical signs of hypoxemia:
  • Increased work of breathing
  • Increased respiration rate
  • Decreased peripheral oxygen saturation (SpO₂)
  • Abnormal CXR (i.e. pneumonia, effusion, etc)

• Estimate Oxygen Demand & Treat:
  • Take blood gas analysis (BGA)
  • Calculate A-a DO₂
  • Calculate required FiO₂
  • Oxygen supplementation

https://dx.doi.org/10.4103%2F0970-2113.197116
https://www.ncbi.nlm.nih.gov/books/NBK482316/
### A-a DO$_2$

- **In normal young adult**, A-a DO$_2$ < 10 mmHg
- **Increases with age:**
  - Age 20: 4 to 17 mmHg
  - Age 40: 10 to 24 mmHg
  - Age 60: 17 to 31 mmHg
  - Age 80: 25 to 38 mmHg

### Table: A-a DO$_2$, Hypoxemic Condition Associated with A-a DO$_2$, Oxygen response

<table>
<thead>
<tr>
<th>A-a DO$_2$</th>
<th>Hypoxemic Condition Associated with A-a DO$_2$</th>
<th>Oxygen response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Hypoventilation Drive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Neuromuscular disorders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Central nervous system disorder</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low inspired FiO$_2$ (e.g. high altitude, <strong>inadequate oxygen</strong>)</td>
<td></td>
</tr>
<tr>
<td>Increased</td>
<td>Dead space</td>
<td>Responsive</td>
</tr>
<tr>
<td></td>
<td>• Pulmonary embolism</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• <strong>Atelectasis</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• <strong>Pneumonia</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Obstructive lung disease (e.g. Asthma, COPD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Pneumothorax</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Altered diffusion/blood-gas barrier</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• <strong>Interstitial lung disease, incl pulmonary fibrosis</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shunt</td>
<td>Unresponsive</td>
</tr>
<tr>
<td></td>
<td>• Congestive heart failure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• <strong>Lobar/diffuse pneumonia</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• <strong>Adult Respiratory Distress Syndrome (ARDS)</strong></td>
<td></td>
</tr>
</tbody>
</table>

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**PaO\(_2\):FiO\(_2\)**

- Identify **current FiO\(_2\)**
- Obtain **PaO\(_2\)** from BGA
- Calculate **PaO\(_2\):FiO\(_2\)**
  - **target >300**
- Re-adjust FiO\(_2\) → re-adjust device & flow rates
- Keep in mind: **Patient’s Comfort**

<table>
<thead>
<tr>
<th>Device</th>
<th>Flow Rates</th>
<th>Delivered O(_2)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal cannula</td>
<td>1 L/min</td>
<td>21%-24%</td>
</tr>
<tr>
<td></td>
<td>2 L/min</td>
<td>25%-28%</td>
</tr>
<tr>
<td></td>
<td>3 L/min</td>
<td>29%-32%</td>
</tr>
<tr>
<td></td>
<td>4 L/min</td>
<td>33%-36%</td>
</tr>
<tr>
<td></td>
<td>5 L/min</td>
<td>37%-40%</td>
</tr>
<tr>
<td></td>
<td>6 L/min</td>
<td>41%-44%</td>
</tr>
<tr>
<td>Simple oxygen face mask</td>
<td>6-10 L/min</td>
<td>35%-60%</td>
</tr>
<tr>
<td>Face mask with O(_2) reservoir</td>
<td>6 L/min</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>7 L/min</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>8 L/min</td>
<td>80%</td>
</tr>
<tr>
<td></td>
<td>9 L/min</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>10-15 L/min</td>
<td>95%-100%</td>
</tr>
<tr>
<td>Venturi mask</td>
<td>4-8 L/min</td>
<td>24%-40%</td>
</tr>
<tr>
<td></td>
<td>10-12 L/min</td>
<td>40%-50%</td>
</tr>
</tbody>
</table>

*Percentage is approximate.

*Room air, FiO\(_2\) = 21%*

[https://dx.doi.org/10.4103%2F0970-2113.197116](https://dx.doi.org/10.4103%2F0970-2113.197116)
NIH COVID-19 Treatment Guidelines Panel’s (the Panel’s) recommendations

• Goal of Oxygenation: SpO$_2$ 92 – 96%

• Why should SpO$_2$ >92%?

• In a trial of non-COVID-19 ARDS, target SpO$_2$ 88 – 92%:
  • Increased mortality at 90 days (between-group risk difference 14%; 95% CI, 0.7% to 27%)

• Why should SpO$_2$ <96%?

• In a meta-analysis of 25 RTs, non-COVID-19, median SpO$_2$ 96%:
  • Increased risk of in-hospital mortality vs lower SpO$_2$ (RR 1.21; 95% CI, 1.03–1.43)

High-flow Oxygen Therapy

- Advanced oxygen therapy
- Provide **heated & humidified** oxygen at flow 15-60 L/min
- Terminology:
  - High-flow nasal cannula (HFNC)
  - High-flow oxygen therapy
  - Nasal high-flow
  - Trans-nasal insufflation
  - *Kanal hidung arus cepat* (KHAC)
  - *(By respective existing brand)*

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https://doi.org/10.1164/rccm.201701-0006ED
NIH COVID-19 Treatment Guidelines Panel’s (the Panel’s) recommendations

- Adults w/ COVID-19 & acute respiratory failure after conventional oxygen therapy → high-flow nasal cannula (HFNC) vs NIV (BII)
  - Recommends a closely monitored trial of NIV for whom HFNC is not available (BIII)

- HFNC group had more ventilator-free days (24 days) vs conventional oxygen therapy group (22 days) or NIPPV group (19 days) (P = 0.02)

- 90-day mortality lower in the HFNC group vs conventional oxygen therapy group (HR 2.01; 95% CI, 1.01–3.99) vs NIV (HR 2.50; 95% CI, 1.31–4.78)

- HFNC reduced the rate of intubation (OR 0.48; 95% CI, 0.31–0.73) & ICU mortality (OR 0.36; 95% CI, 0.20–0.63) vs NIV

## High-flow Oxygen Therapy Practical Recommendations

| Flow rate          | • Start at 30-40 litres min⁻¹ and increase to meet the patient’s demand  
                  | • Increase the delivered flow until a reduction in respiratory rate and stable SaO₂ is achieved |
|--------------------|-----------------------------------------------------------------------------------|
| Temperature        | Set at 37 °C                                                                       |
| FiO₂               | • Increase the FiO₂ until satisfactory SaO₂ is achieved  
                  | • FiO₂ might set 100% in acute respiratory failure                                  |
| Monitoring         | Continuous monitoring of heart rate, respiratory rate, SaO₂                        |
| Positive response and weaning | • Gas flow rate and FiO₂ adjusted according to the clinical response  
                                | • Reduce FiO₂ by 5-10% and reassess after 1-2 h.  
                                | • Reduce the flow rate by 5 litres/min and reassess after 1-2 h.  
                                | • Consider weaning from HFNC with flow rates 25 litres/min and FiO₂ <0.4. |
| Ineffective response | • If there is no improvement, treatment escalation must be considered  
                      | • Do not delay intubation                                                          |

https://doi.org/10.1016/j.bja.2017.11.010

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Initial Assessment
Are any of the following present?
- Unconsciousness
- Cardiac arrest
- Central airway obstruction
- Hemodynamic instability

Moderate-to-severe respiratory distress?
- RR >30/minute
- \( \text{SpO}_2 < 94\% \)
- \( \text{PaO}_2/\text{FiO}_2 < 300 \)

No

Yes

- Nasal Cannula 6 L/min
- Venturi mask \( \text{FiO}_2 50\% \), 2-15 L/min
- Non-rebreather mask 15 L/min

Reassess every 30 min in first one hour, then then hourly for the next few hours

Deteriorating/increasing work of breathing?

No

Yes

HFNC \( \text{FiO}_2 100\% \) or NIV

Reassess every 30 min in two hours

Intubation

Conventional supplemental oxygen therapy
Titrating oxygen up/down with target \( \text{SpO}_2 > 93\% \)
• ROX index: prediction tool to identify need for mechanical ventilation in pneumonia patients with hypoxemic acute respiratory failure treated with HFNC

\[ \text{ROX} = \frac{\text{SpO}_2}{\text{FiO}_2} \]

Respiratory Rate

• ROX index ≥4.88 at 2, 6, and 12 hrs → predict HFNC success

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HFNC: Flow 45-60 L/min, FiO₂ 100%

- Observe for 2 hrs
  - ROX ≥ 3.85 or SpO₂ ≥ 93%
    - And
    - RR < 25/min
    - Continue HFNC
  - ROX 2.85 – 3.84 or SpO₂ ≥ 93%
    - And
    - RR 25 – 30/min
    - Continue HFNC
  - ROX < 2.85 or SpO₂ < 93%
    - And
    - RR ≥ 30/min
    - Discontinue HFNC

- Observe for 6 hrs
  - ROX > 4.88 or SpO₂ ≥ 93%
    - And
    - RR < 25/min
    - Continue HFNC

- Observe for 12 hrs
  - ROX < 3.85 or SpO₂ < 93%
    - And
    - RR > 30/min
    - Discontinue HFNC

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https://doi.org/10.4103/smj.smj_64_20
## Preparation & Unfavored Events of High-flow Oxygen Therapy

### A. Related to the devise
1. Settings
   - Flow
   - FiO₂
2. PaO₂:FiO₂ interpretation
3. Start of treatment
4. Ventilation slots patency
5. Filter cleaning
6. Disinfection
7. Lack of internal battery

### B. Related to oxygenation
1. O₂ tube connection
2. FiO₂ delay
3. Internal alarms menu settings
4. Adjusting flowmeter
5. No smoking

### C. Related to humidification
1. Sterile water
2. Plastic bags
3. Cap
4. Avoid water runs out
5. Permeable circuit

### D. Related to the tubing
1. Tube electric resistance
2. Tube breaks
3. Tube position
4. Tube weight

### E. Related to nasal cannulas
1. Cannula size
2. Appropriate cannulas
3. Cannula placement
4. Adequate nasal hygiene

### F. Related to alarms
1. Internal alarm menu setting
2. Alarm identification

### G. Related to the patient
1. Nose
2. Paradoxical suffocation
3. Chest pressure
4. Understanding HFNC
5. Mobility
6. Noise
7. Claustrophobia
8. Intolerance
9. Barotrauma

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Conclusion

- Features of acute respiratory failure in COVID-19: Alveolar dead space, altered blood-gas barrier, shunt
- Signs of increased oxygen demand/hypoxemia: Increased RR, decreased SpO₂, abnormal CXR
- Oxygen therapy “dosage” $\rightarrow$ FiO₂
- Therapeutic target $\rightarrow$ PaO₂:FiO₂ >300
- HFNC in COVID-19
  $\rightarrow$ beneficial at correct timing (vs NIV)
- When giving HFNC $\rightarrow$ consider patient’s comfort & close monitoring + ROX index during first 12 hrs

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To be published soon:

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Thank You for Your Attention

https://spesialis-paru.id/