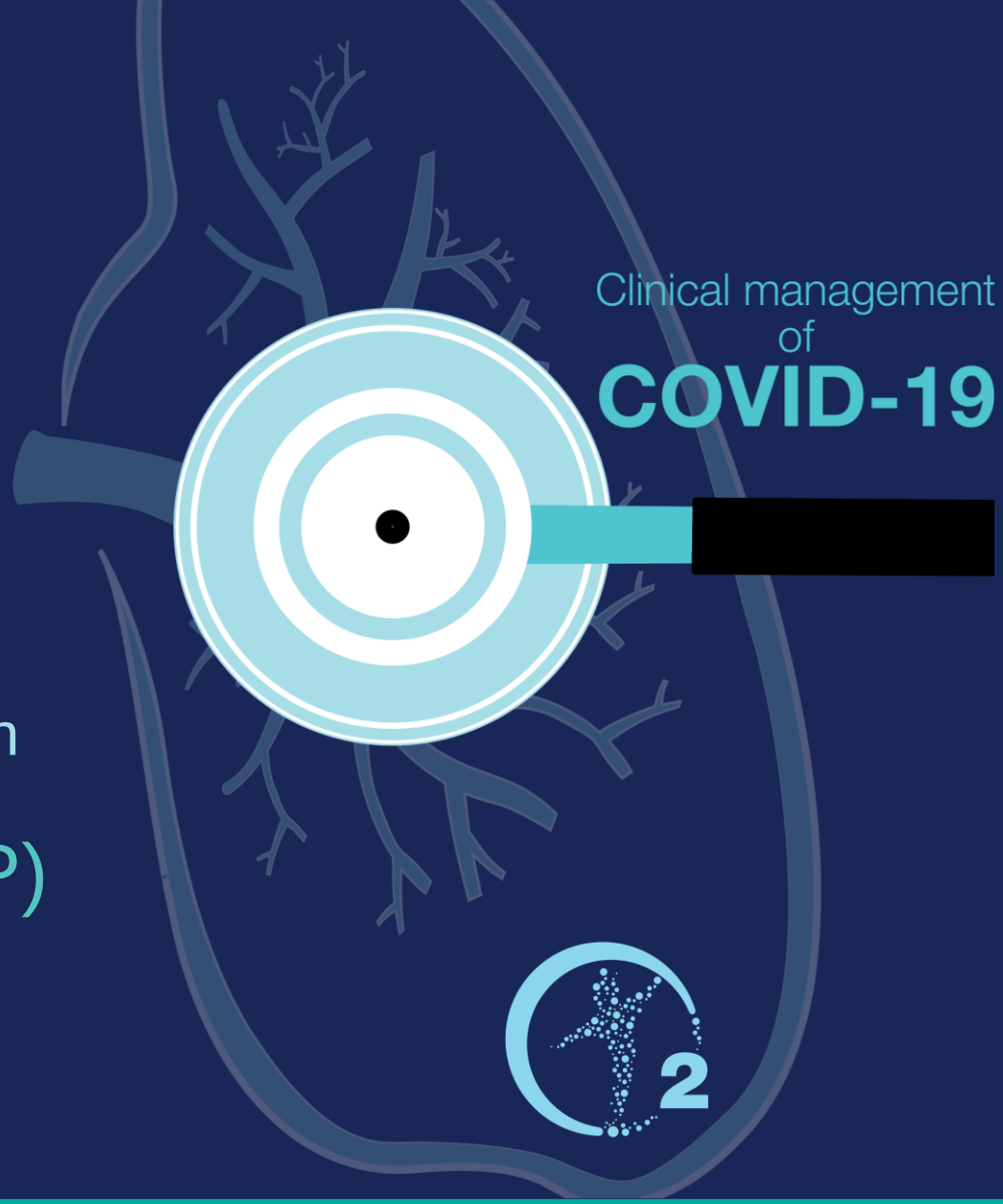
Management of critical **COVID-19**

Advanced non-invasive respiratory support:
high-flow nasal oxygen and non-invasive ventilation

Part 3: NIPPV (CPAP and BiPAP)



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Disclaimers

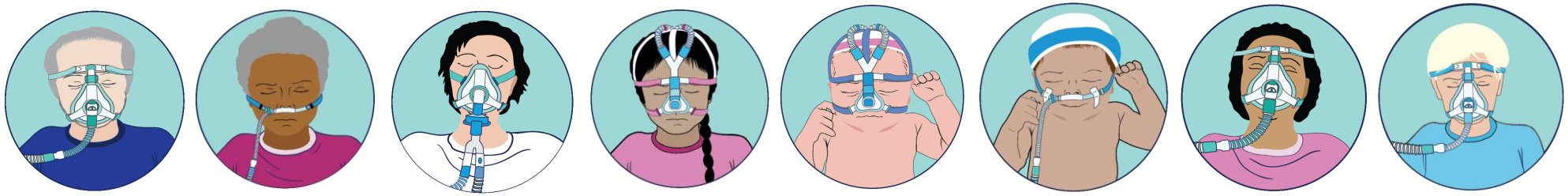
- This presentation is not intended to and cannot replace a formal critical care curriculum or training.
- Content in this presentation is for illustrative purposes only.
- Decisions regarding the use of any respiratory support modality must be made by a licensed provider and take into account each patient's specific clinical history and other circumstances; and be in accordance with relevant local guidelines and protocols, and appropriate maintenance to ensure quality and safe performance.
- Any respiratory support device should be managed with a multidisciplinary support team whenever possible, which might include doctor(s), nurse(s), respiratory therapist(s) and other technician(s), depending on jurisdictional context.
- Any respiratory device should receive appropriate maintenance to ensure quality and safe performance.

Learning objectives

- Describe how to initiate, monitor and titrate NIPPV, including continuous positive airway pressure (CPAP), bi-level positive airway pressure (BiPAP) and bubble CPAP.

Characteristics of NIPPV

- Delivers positive pressure ventilation, either CPAP or BiPAP, to improve oxygenation, elimination of CO_2, reduce the work of breathing.
- Delivered via a tight-fitting nasal mask, face (oro-nasal) mask or helmet. **A good seal is necessary to deliver the desired positive pressure.**
- Reliably titrates FiO_2 up to 100% when connected to high pressure oxygen source. Oxygen is blended with room air inside the machine. Some CPAP machines, can work on low pressure oxygen from a concentrator but maximal FiO_2 will be lower.



Resource considerations: medicinal oxygen and air supply

1. Depending on the specifications of the non-invasive device, it may require an external source of medical oxygen and/or air. It is important to verify if the requirement is a high-pressure or low-pressure inlet to properly select the source.
   (Link: Priority medical devices list for the COVID-19 response and associated technical specifications(who.int))
2. If high-pressure **medicinal air** is required, it can be supplied by integrated air compressors or turbines, or by piped from the medicinal gas station (wall outlet is > 50 psi).
3. If high-pressure **medicinal oxygen** is required, it can be supplied by high-pressure gas cylinders or piped from the medicinal gas station (wall outlet is > 50 psi). If low pressure medicinal oxygen is required, it can be supplied by a bedside oxygen concentrator.
4. Between the gas supply and the non-invasive device there is typically a pressure and/or flow regulator (see image below).

Precautions to consider with NIPPV

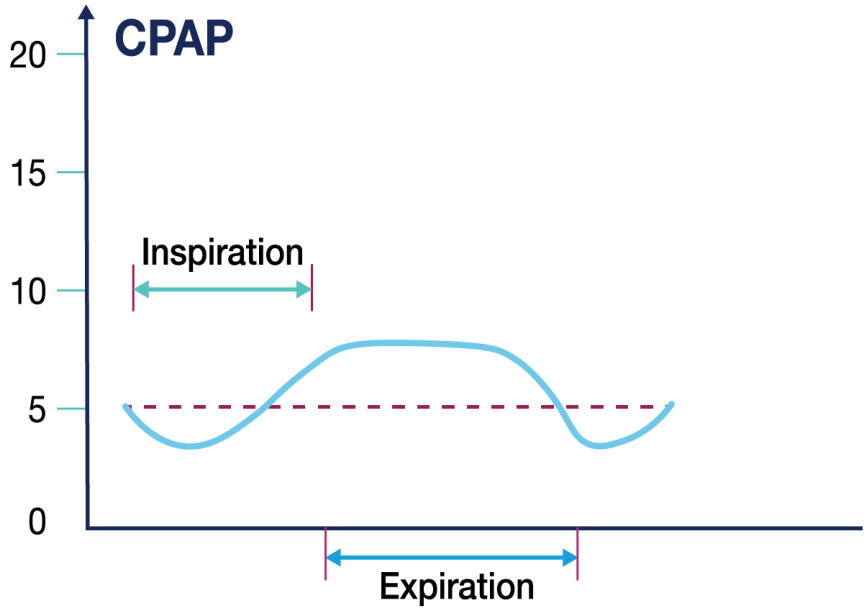
Important **considerations that may lead to harms** include:

- **Delayed intubation** due inadequate monitoring and response.
- **Uncontrolled tidal volumes** leading to injurious transpulmonary pressures.
- **Skin breakdown** from pressure of mask on face.
- **Undernutrition** due to mask reducing capacity to take oral intake. Careful assessment and consideration of feeding to achieve early enteral feeding within 24–48 hours of admission through nasogastric tube.

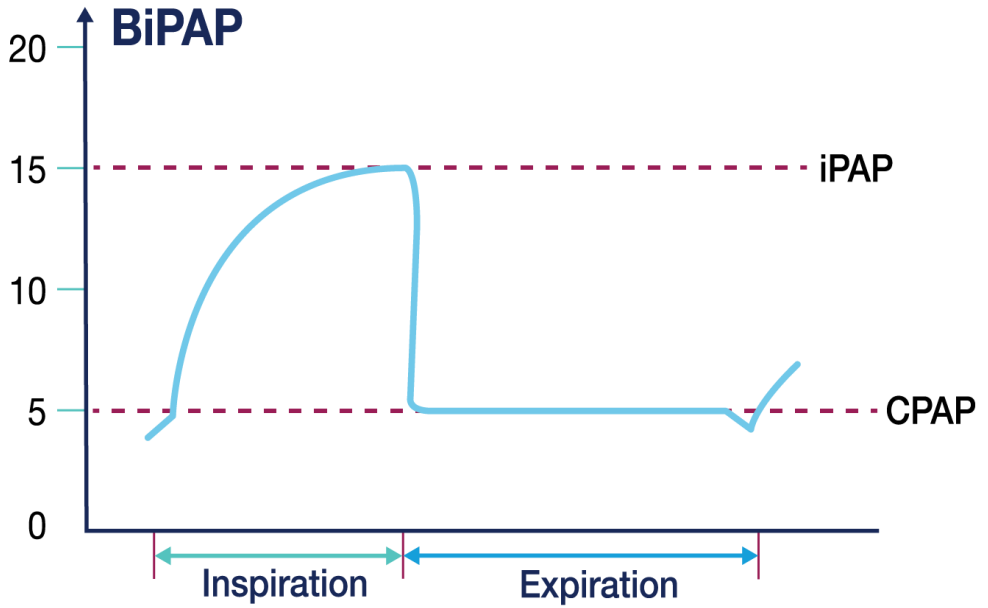
To minimize adverse effects, ensure NIPPV is used by trained staff in context of close monitoring and protocols about skin care, nutrition and adjustment of settings.

Comparing CPAP and BiPAP

CPAP provides a continuous level of positive end expiratory pressure (PEEP, cmH_2O).
End expiratory pressure is used to improve hypoxaemia by recruiting collapsed alveoli.



BiPAP provides a level of inspiratory pressure, or iPAP; and separately, an expiratory pressure support (ePAP). The addition of iPAP reduces the work of breathing. ΔP, is the difference in pressure between iPAP and ePAP.



Select appropriate interface for NIPPV

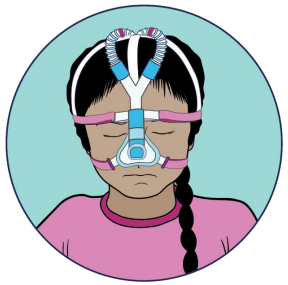
Select interface type: There are **nasal masks, oro/nasal masks, full-face masks and helmets*.**

WHO recommendation states:

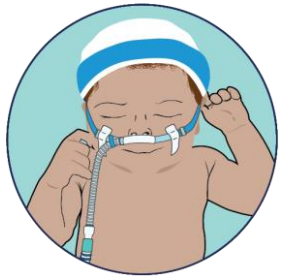
- The choice between interface should be guided by clinician experience, availability, and patient comfort.
- If the patient has claustrophobia or needs to expectorate often, choose a nasal mask.

Carefully follow the manufacturer instructions on fitting to optimize comfort and tolerability and decrease leakage.

Select the appropriate size: There are different sizes for neonates, children, adults. Choose appropriate size to ensure correct fitting prior to starting therapy.



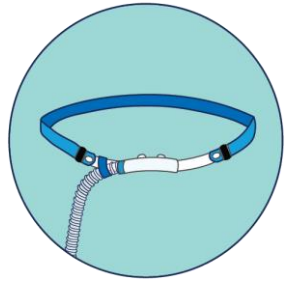
Nasal masks



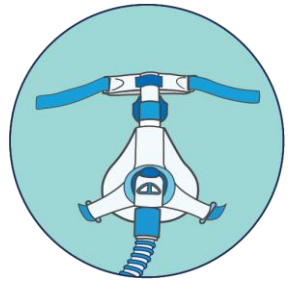
Oro/nasal masks

Full-face masks

Helmet



HFNC



CPAP/BiPAPA

Helmet interface for CPAP and NIPPV

Use of helmet interface for CPAP and Bilevel/BiPAP requires additional instruction to ensure its safe application due to physiologic properties of the helmet when compared to other interfaces:

- The helmet is a more compliant system and may compromise pressures.
- The helmet has higher physiologic dead space thus ensuring adequate CO2 clearance is important

Approaches for helmet use are described in the following resources;

1. Grieco DL, Menga LS, Cesarano M, et al. Effect of Helmet Noninvasive Ventilation vs High-Flow Nasal Oxygen on Days Free of Respiratory Support in Patients With COVID-19 and Moderate to Severe Hypoxemic Respiratory Failure: The HENIVOT Randomized Clinical Trial. JAMA. 2021;325(17):1731–1743. doi:10.1001/jama.2021.4682

2. Coppadoro, A., Zago, E., Pavan, F. et al. The use of head helmets to deliver noninvasive ventilatory support: a comprehensive review of technical aspects and clinical findings. Crit Care 25, 327 (2021). https://doi.org/10.1186/s13054-021-03746-8

The remaining slides will focus on how to use of oro/nasal and facemask

Initiating and titrating CPAP: adult using oro/nasal and facemask

Start CPAP at 5 cm H_2O and FiO_2 100%

Titrate up by 2–4 cm H_2O every 5 minutes, as needed, to achieve **good clinical response, not to exceed 12 cm H_2O.**

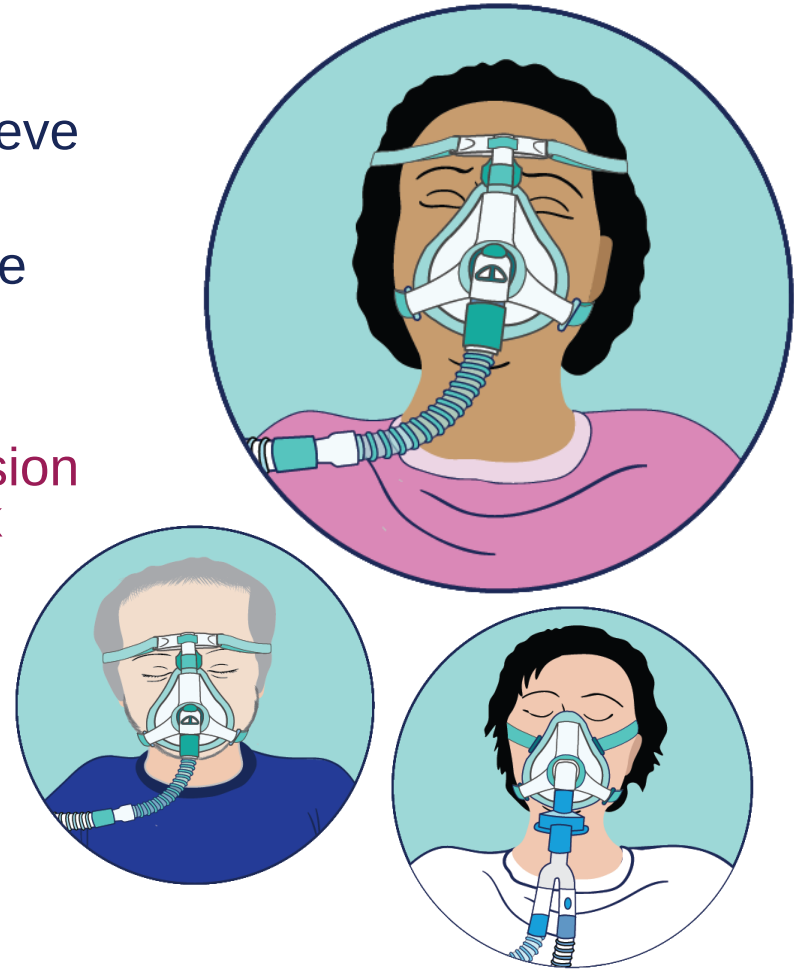
In conjunction, reduce FiO_2 to lowest setting needed to achieve target Sp_{O2} ≥ 90%.

Monitor the patient's response between all changes.

Caution with higher pressures as they may lead to overdistension of alveoli and lung injury as well as gastric insufflation and risk of aspiration.

Clinical response includes:

- patient comfortable
- improved work of breathing
- improved saturation
- stable haemodynamics and mental status.



Rational use of oxygen with FiO_2 in CPAP

- CPAPs may have fixed or variable oxygen flow rates.
- Therefore, it is necessary to use the pressure and FiO_2 necessary to achieve patient comfort and SpO_2, respectively.
- When CPAP is adjusted, check and adjust the FiO_2 needs as it may change with pressure adjustment due to the leak and minute volume.
- When using oxygen cylinder, how long the cylinder lasts depend on FiO_2, flow in L/min and the capacity of the cylinder. Amount of oxygen should therefore be monitored, and cylinder changed as needed.

Initiating and titrating CPAP in ARDS: children

Start CPAP at 5 cm H_2O and $FiO_2$10–20% above previous needs:

Titrate up by 1–2 cm H_2O every 5 minutes to **achieve clinical response**, but not to exceed a maximum of 10–12 cm H_2O.

In conjunction, titrate FiO_2 to lowest setting needed to achieve target SpO_2 ≥ 90%.

Clinical response includes:

- patient comfortable
  - improved work of breathing
  - improved saturation
- stable haemodynamics and mental status.

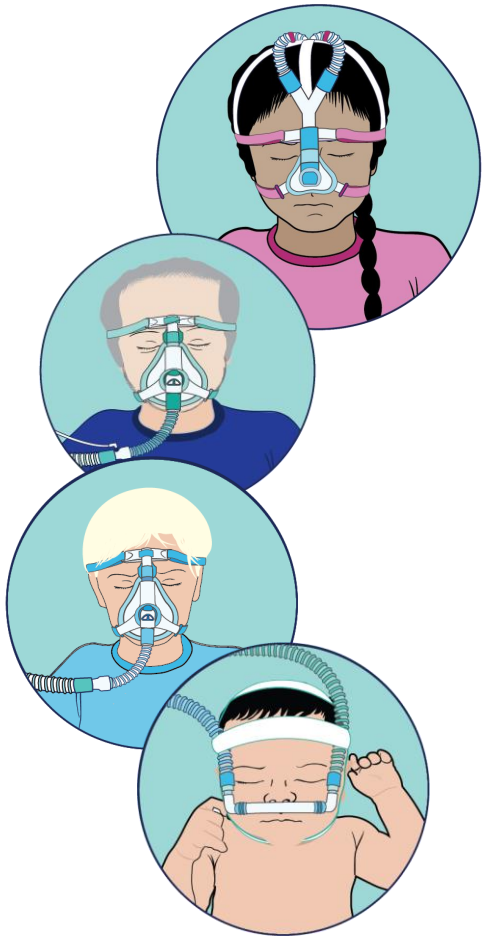
Weaning from CPAP

There is no consensus on any specific weaning process for patients on CPAP.

Three approaches have been described in practice and literature in the paediatric population: graded time off wean; sudden wean; and pressure wean.

Weaning may be initiated when the initial reason for the need has improved or resolved. Approaches include:

1. Graded time off: CPAP is reduced and allowed for a predetermined number of hours each day then gradually increase amount of time off.
2. Sudden wean: the patient is taken off CPAP all in all, with no consideration of level of airway pressure, and continuing off until indication for CPAP are met necessitating the patient to go back on CPAP.
3. Pressure wean gradually reducing the CPAP to prior determined level then come off CPAP.



Initiating BiPAP: **adult**

Common BiPAP initiation pressures are:

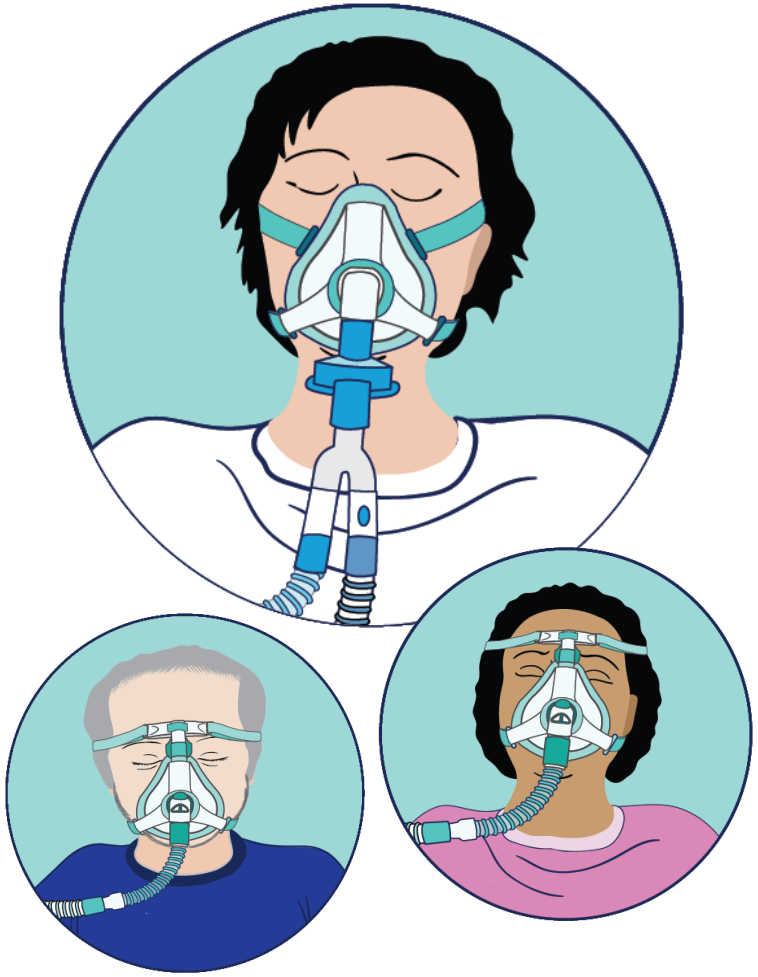
iPAP 10 cm H_2O, ePAP 5 cm H_2O, delta = 5

iPAP 15 cm H_2O, ePAP 10 cm H_2O, delta = 5

iPAP 13 cm H_2O, ePAP 5 cm H_2O, delta = 7.

Other settings may be used depending on individual patient needs and clinician expertise.

Start with FiO_2 100% and titrate down to amount needed to achieve target SpO_2 > 90%. **Use lowest FiO_2 necessary to achieve target.**



Titrating BiPAP: adult

Titrate ePAP for hypoxaemia:

- Increase ePAP at increments of 2–3 cm H_2O to a maximum of 15 cm H_2O; range 5–15 cm H_2O.
- With every change in ePAP monitor patient for 3–5 minutes **for clinical response.**

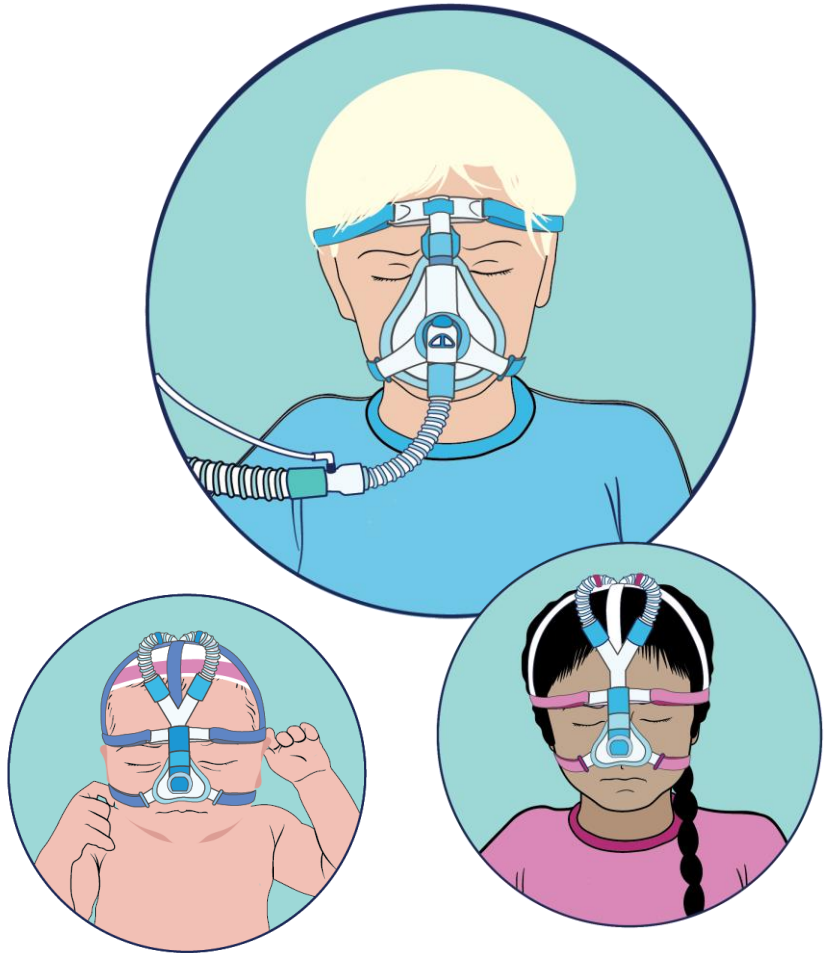
Titrate iPAP for work of breathing:

- Always increase the iPAP when increasing the ePAP, so that iPAP remains at least 5–10 cm H_2O greater than ePAP (delta = 5–10).
- Increments of 3–5 cm H_2O to a **maximum of 20 cm H_2O**; range 10–20 cm H_2O.
- with every change in ePAP monitor patient for 3–5 minutes **for clinical response.**

Initiating BiPAP in ARDS: children

Common BiPAP initiation pressures:

- iPAP 9 cm H_2O, and ePAP 5 cm H_2O, delta = 4 cm H_2O.
- Set FiO_2 10–20% above previous needs.
- If transitioning from CPAP, start ePAP at same level and add IPAP to achieve delta = 4 cm H_2O higher.
- Set respiratory back-up rate = 15 (for children use age specific lower limit).



Titrating BiPAP in ARDS: **children**

Titrate ePAP for hypoxaemia:

In increments of 1–2 cm H_2O every 5 min (max of 10 cm H_2O).

Titrate iPAP for work of breathing:

Start 10–15 cm H_2O.

In increments of 2–3 cm H_2O (max of 20 cm H_20).

Between each titration, evaluate for **clinical response:** keep delta = 4 cm H_2O to avoid self-inflicted lung injury from the machine.

Titrate FiO_2 to achieve SpO_2 ≥ 90% (aim for SpO_2/FiO_2 ratio (SF) > 200). Use lowest amount of FiO_2 necessary to achieve the goal.

Titrating BiPAP to clinical response and tidal volume

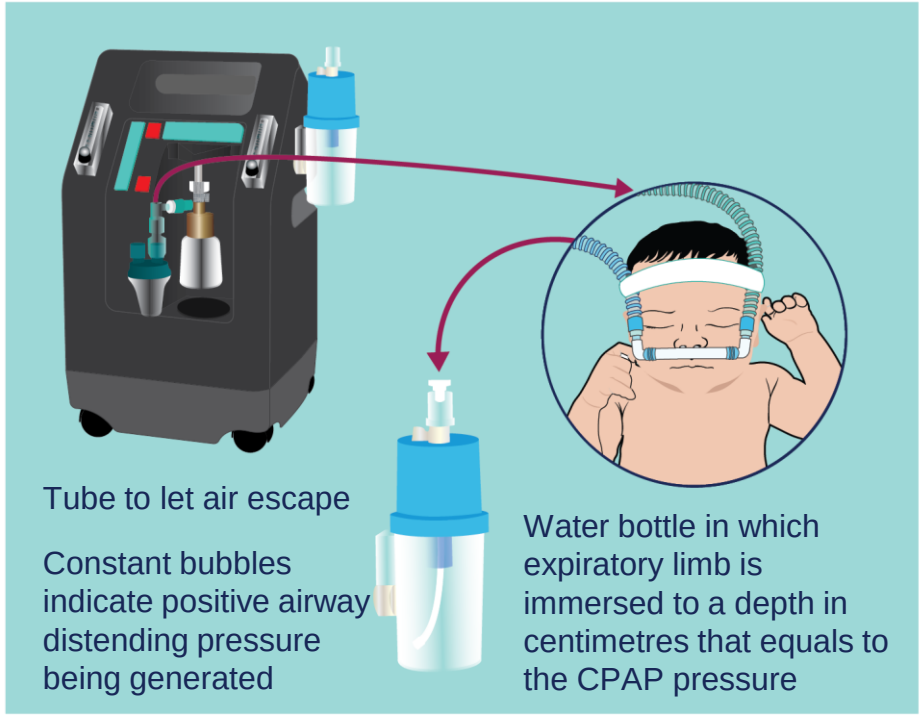
Remember, a good clinical response includes:

- patient comfortable
- improved work of breathing
- reduced RR
- improved saturation
- stable haemodynamics and mental status.

When using NIPPV, also monitor the **tidal volume (TV). A safe tidal volume target is 6–8 mL/kg ideal body weight** (see Clinical care of severe acute respiratory infections – Tool kit). This is important to avoid injurious large tidal volumes.

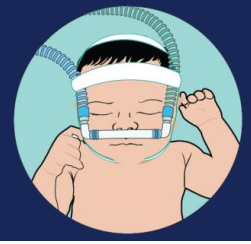
Advanced NIPPV for infants: bubble CPAP

- Where mechanical ventilation might not be available, bubble nasal CPAP may be used for newborns and children with severe acute respiratory failure (more common in resource-limited settings).
- Bubble CPAP characteristics:
  - warmed and humidified air
  - flows from a wall or oxygen cylinder
  - provides a continuous level of PEEP
  - oscillation from the bubbling improves gas exchange.
- Because of uncertainty around potential for aerosolization, bubble CPAP should be used with airborne precautions.



Oxygen therapy for children: a manual for health workers. WHO; 2016.

Settings: bubble CPAP



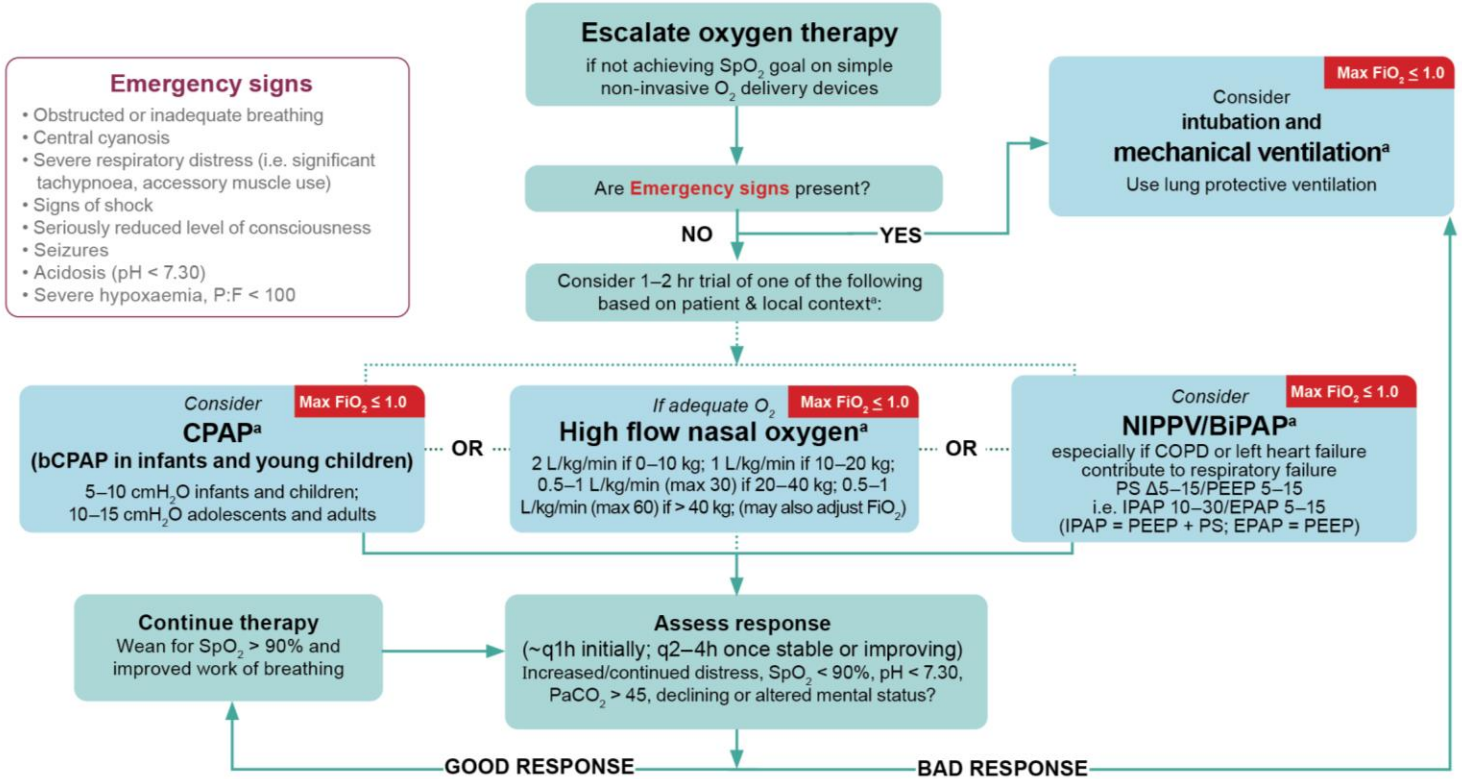
- Ensure an appropriate fit of the face mask or nasal prongs.
- Submerge the expiratory limb into sterile water chamber.
- The number of cm submerged is the amount of PEEP.
- Initiate oxygen flow rate at 2 L/kg/min. *See Clinical care of severe acute respiratory infections – Tool kit* for details about flows for kids.
- Adjust oxygen flow and PEEP to target SpO_2 > 90%.

Oxygen / Air Mixing Chart

Air Flowmeter (lt/min)		0	1	2	3	4	5	6	7	8	
Oxygen Flowmeter	1	95.0	57.5	45.0	38.8	35.0	32,5	29.4	28.3	30,7	% Oxygen
	2	95.0	70.0	57.5	50.0	45.0	41.4	38.8	36.7	35.0	
	3	95.0	76.3	65.0	57.5	52.1	48.1	45.0	42.5	40.5	
	4	95.0	80,0	70.0	62.9	57.5	53.3	50.0	47.3	45.0	
	5	95.0	82.5	73.6	66.9	61.7	57.5	54.1	51.3	48.8	
	6	95.0	84.6	76.3	70.0	65.0	60.9	57.5	54.6	52.1	
	7	95.0	85.6	78.3	72.5	67.6	63.8	60.4	57.5	55.0	
	8	95.0	86.7	80.0	74.5	70.0	66.2	62.9	60.0	57.5	

Assuming an oxygen concentrator output of 95% Oxygen

Evaluating success of advanced non-invasive respiratory support



[a] Selection of optimal delivery device should be based on local clinician's judgment and risk-benefit assessment tailored to the individual patient, global and local outcomes data, as well as local resources including O_2 supply, skill of personnel, availability of consumables, monitoring and therapeutic adjuncts, among other factors.

[b] Venturi/entrainment face masks deliver FiO_2 24–60%, depending on flow rate and device setup

LPM (litres per minute), **EPAP** (expiratory positive airway pressure), **PS** (pressure support), **COPD** (chronic obstructive pulmonary disease), **SpO_2** (oxygen saturation), **$PaCO_2$** (arterial partial pressure of carbon monoxide), **P:F** (ratio between arterial partial pressure of oxygen and the fraction of inspired oxygen - **FiO_2**), **CPAP** (continuous positive airway pressure), **bCPAP** (bubble CPAP), **NIPPV** (non-invasive positive pressure ventilation), **BiPAP** (bi-level positive airway pressure); Δ - change.

- Patients with ARDS on HFNO, CPAP, BiPAP should be placed on a **time-limited trial (1 hour).**
- Patients wi**th good clinical response** can be continued on therapy, but should be monitored frequently (see monitoring modules) and cared for by trained staff.

If patient does not have a good response, such as persistent hypoxaemia and/or progressive respiratory distress despite adjustment of NIPPV or HFNO, the patient should be intubated without delay.

Special precautions: patients that are **not appropriate** for advanced non-invasive respiratory support

Abnormal mental status: patient may not tolerate tightfitting mask (i.e. **agitation**) or patient may not be able to protect airway
(i.e. **coma)**.

Patients with multi-organ failure, including haemodynamic instability, for when coupled with acute respiratory failure raise concern of imminent arrest.

Anatomic barriers that do not permit adequate face mask seal (i.e. NIPPV).

Copious respiratory secretions when using face mask (i.e. NIPPV).

Active vomiting when using face mask (i.e. NIPPV) increases risk of aspiration.

The primary risk NIPPV is a delay to intubation that may increase mortality. Thus, patients need to be managed by trained staff, close monitoring and short trial period.

Indications to prepare for intubation and invasive mechanical ventilation (IMV)

Despite appropriate titration of HFNO if patient shows any urgent indication for intubation or fails to show improvement, then proceed to airway management, intubation and invasive mechanical ventilation.

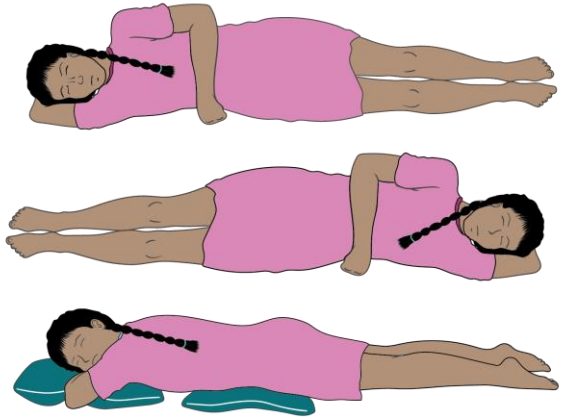
RED FLAGS:

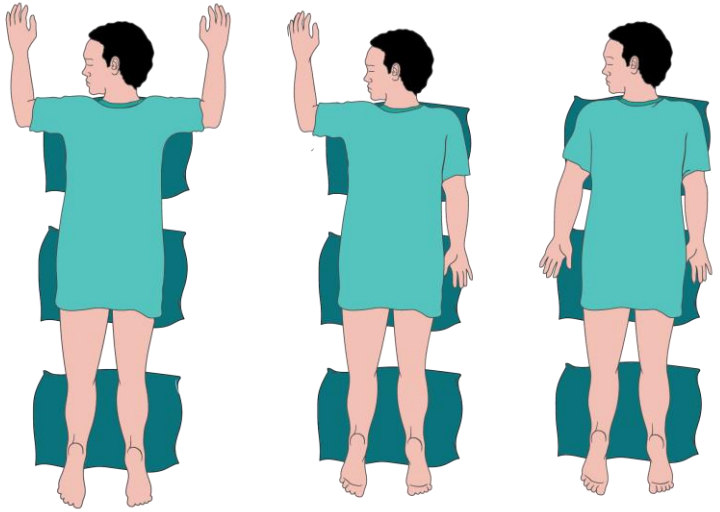
- Severe signs of respiratory distress, such as consistently elevated respiratory rate for > 60 min **≥ 60 bpm** if < 2 months; **≥ 50 bpm** in 2–11 months; **≥ 40 bpm** if 1–5 years; **≥ 30 bpm** in adults and children > 5 years.
- Severe hypoxaemia, such as P/F < 100.
- Apnoea or periodic breathing (unstable drive).
- Hypoventilation:
  - increase in $PaCO_2$ ≥ 10 mmHg or 1.3 kPa
  - respiratory rate < 8/min.
- Severe agitation, acute change in mental status, diaphoresis, patient discomfort.
- Haemodynamic instability (signs of shock).

Adjunctive interventions: awake proning

The WHO COVID-19 clinical Guideline Development Group conditionally recommends:

Awake prone positioning of patients severely ill and hospitalized with COVID-19 requiring supplemental oxygen (including high-flow nasal oxygen) or non-invasive ventilation.





Benefits: observational studies of awake prone patients with severe COVID-19 suggest decreased mortality and need for intubation (*very low certainty evidence*).

Harms: include possible patient discomfort and pain (*very low certainty evidence*).

Awake proning indications and contraindications

Characteristics of patients appropriate for prone position	Contraindications to prone positioning
• Awake and alert • Capable of communicating and moving independently • Patient must be able get help if they have discomfort or pain • Patient must be able to supinate independently, if needed • Hemodynamically stable • Able to protect their airway • Able to be closely monitored by workers with experience with prone positioning	• Need for immediate intubation • Haemodynamically unstable (tachycardia, hypotension) • Spinal instability • Altered mental status or reduced ability to protect the airway • Unable to readily call for help if needed • Caution if nausea or vomiting • Not enough human resources in the unit to monitor

Awake proning tips

Patients should be able to follow instructions to self-prone without assistance from health care workers

- Patients should attempt to prone on a regular basis (e.g. every 4 hours) and maintain the prone position for as long as possible. (Many patients are unable to maintain the prone position for more than 1–2 hours.)
- Patients should be able to stop proning at any time and return to the supine position as needed.

Rotation and timed position changes

- Regimens vary, and target being in awake prone position 8–12 hours/day, broken into shorter periods over the day.
  For example, some institutional protocols describe rotational protocols, with patients changing position on a regular schedule (e.g. every 1 hour changing position, with positions rotating from prone, to lying on right side, to sitting straight upright, to lying on left side, to prone again, etc.).

Patient comfort: frequent limitations for patients are low back pain, nausea and vomiting

- For nausea or vomiting, immediately assist the patient to an upright position or recovery position. Gently suction or wipe the airway, if the patient cannot clear spontaneously.
- For low back pain, patients may find comfort using padding (i.e. pillows, blankets) under the pelvis.
- If possible, tilt the bed slightly in reverse Trendelenburg position to reduce pressure on the eyes and face.

Troubleshooting

For patients on NIPPV or HFNO with persistent hypoxaemia or respiratory distress:

- Check the **equipment:** inspect the exterior of the machine, the tubing (circuit), the mask for any sign of mechanical damage, confirm it fits securely without leak (if CPAP/BiPAP) and the filters are in place. Ensure the settings are appropriate and flow is maximized.
- Check the **oxygen source:** there is sufficient oxygen available and flowing through the device. If FiO_2 > 50% of oxygen is needed, the ventilator must have a blender.
- Check there is no **obstruction with secretion**s**:** patients with COVID-19 may have very thick secretions which may block small and large airways and cause sudden respiratory deterioration.

Avoid strategies which may dry secretions (e.g. high flow dry O_2/air).

Ensure adequate **secretion clearance** and consider failure to clear secretions as a trigger to abandon advanced non-invasive respiratory support and proceed to intubation and invasive mechanical ventilation.

Do not delay intubation if the patient is worsening on a short trial (1 hour) of advanced non-invasive respiratory support or has any urgent indication for intubation.

Summary

- Advanced non-invasive respiratory support (BiPAP and CPAP) probably reduce the need for intubation in COVID-19 patients with acute hypoxaemic respiratory failure not requiring emergent intubation.
- Good candidates are **awake, alert** and **cooperative**.
- Advanced non-invasive respiratory support (BiPAP and CPAP) is a risk for aerosol generation and use with **airborne precautions.**
- Keys to success with these modalities include **early initiation**, **close monitoring** by **experienced health workers,** and **frequent adjustment** of oxygen flow and/or pressures as needed for beneficial clinical response.

Do not delay intubation if the patient is worsening on a short trial (1 hour) of advanced non-invasive respiratory support or has any urgent indication for intubation.

Resources

COVID-19 clinical management: living guidance. https://www.who.int/publications/i/item/clinical-management-of-covid-19

IMAI district clinician manual: hospital care for adolescents and adults: guidelines for the management of illnesses with limited resources. https://www.who.int/publications/i/item/imai-district-clinician-manual-hospital-care-adolescents-and-adults

Oxygen therapy for children: a manual for health workers. https://www.who.int/maternal_child_adolescent/documents/child-oxygen-therapy/en/

WHO-UNICEF technical specifications and guidance for oxygen therapy devices. 2019. https://www.who.int/publications/i/item/9789241516914

Technical specifications for invasive and non-invasive ventilators for COVID-19 https://www.who.int/publications/i/item/technical-specifications-for-invasive-and-non-invasive-ventilaotrs-for-covid-19

WHO COVID-19 technical guidance: essential resource planning. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/covid-19-critical-items

WHO: Oxygen sources and distribution for COVID-19 treatment centres. 4 April 2020. https://www.who.int/publications/i/item/oxygen-sources-and-distribution-for-covid-19-treatment-centres

Transmission of SARS-CoV-2: implications for infection prevention precautions (who.int) https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions

Oxygen sources and distribution for COVID-19 treatment centres https://www.who.int/publications/i/item/oxygen-sources-and-distribution-for-covid-19-treatment-centres

Clinical care of severe acute respiratory infections – Tool kit https://www.who.int/publications/i/item/clinical-care-of-severe-acute-respiratory-infections-tool-kit

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