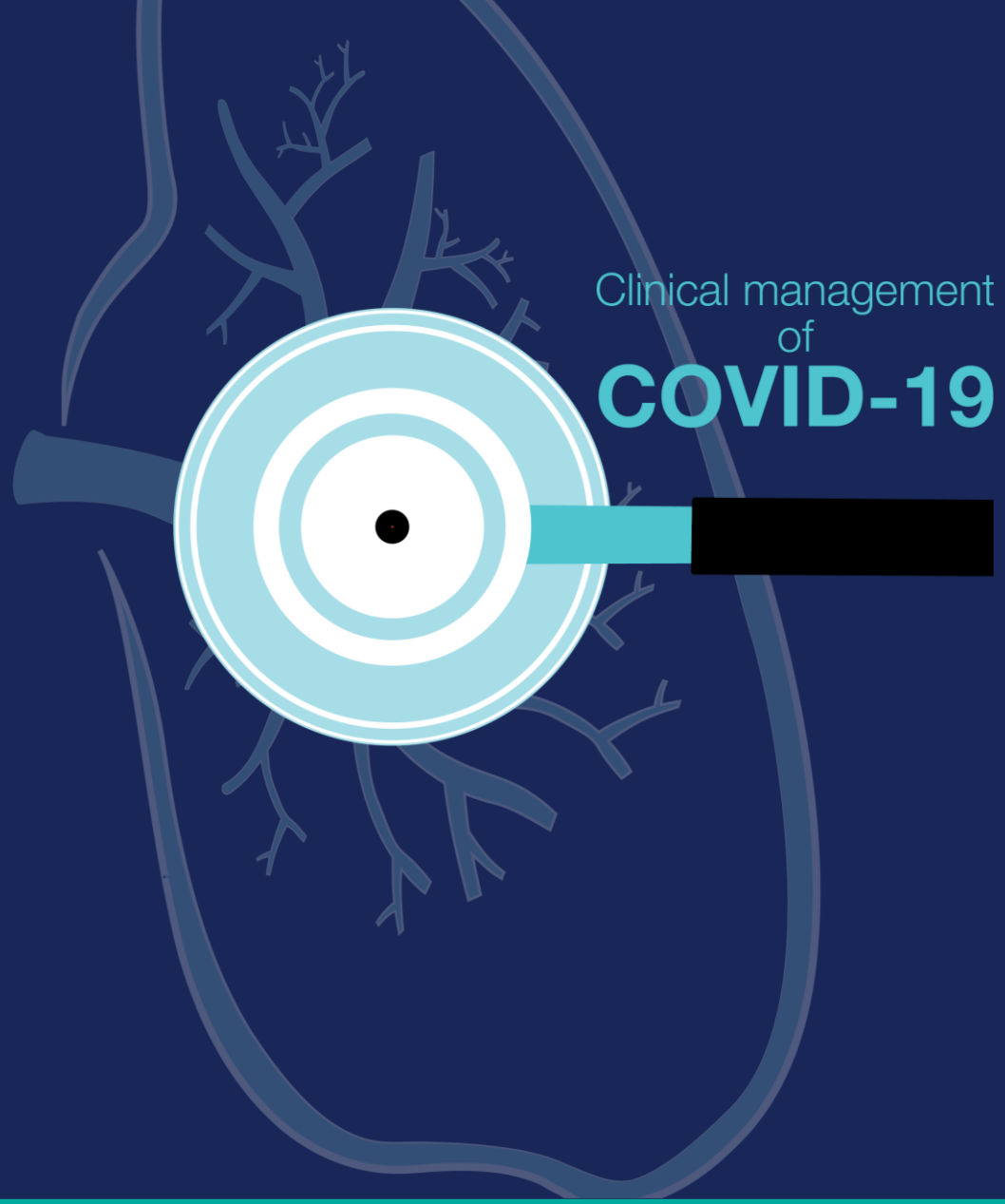
Management of critical **COVID-19**

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

Part 1: Characteristics of NIV



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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 support device should receive appropriate maintenance to ensure quality and safe performance.

Learning objectives

- Explain the rationale for high-flow (HFNO) and non-invasive positive pressure ventilation (NIPPV) approaches in patients with COVID-19.
- Describe how best to select appropriate patients to treat with HFNO and NIPPV.
- Describe how to initiate, monitor and titrate HFNO and NIPPV, including continuous positive airway pressure (CPAP), bi-level positive airway pressure (BiPAP) and bubble CPAP.

HFNO and NIPPV

Rationale

- HFNO and NIPPV can **provide higher levels of respiratory support** for patients with acute hypoxaemic respiratory failure despite supplemental oxygen flow (> 10–15 L/min via mask with reservoir).
- This includes the delivery of higher flow rates (up to 60 L/min), more consistent higher oxygen concentrations (FiO_2 of 100%) and provision of positive pressure.
- HFNO and NIPPV may provide more comfort, well tolerated in appropriate patients.
- However, the use of HFNO and NIPPV should not delay intubation if there are emergent indications.
- Clinicians should choose between the devices on the basis of considerations such as availability and the supply of oxygen, their personal comfort and experience, and patient-specific factors (such as claustrophobia that some patients experience with CPAP masks, and nasal discomfort that some patients experience with HFNO).
- WHO recently reviewed the evidence and recommendations (slide 6).

Link to database of clinical studies around the world in COVID-19: www.clinicaltrials.gov

Azoulay E, et al. A. High-flow nasal oxygen vs. standard oxygen therapy in immunocompromised patients with acute respiratory failure: study protocol for a randomized controlled trial. Trials. 2018;19(1):157. doi: 10.1186/s13063-018-2492-z. PMID: 29506579; PMCID: PMC5836389.

HFNO and NIPPV: background

The role of NIPPV in patients with **acute hypercapneic respiratory failure** (i.e. BiPAP in COPD exacerbations) and **pulmonary oedema** (i.e. CPAP for acute heart failure) is well established.

WHO commissioned a systematic review of direct evidence generated in COVID-19 as well as indirect evidence generated prior to the COVID-19 pandemic.
https://doi.org/10.1101/2022.05.25.22275586

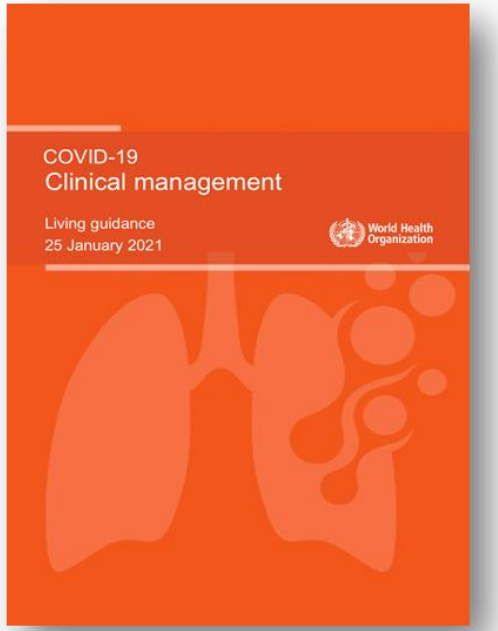
WHO recommendations for COVID-19

WHO recommends prompt recognition of progressive acute hypoxaemic respiratory failure when a patient with respiratory distress is failing to respond to standard oxygen therapy and adequate preparation to provide advanced oxygen/ventilatory support.

Hypoxaemic respiratory failure in ARDS commonly results from intrapulmonary ventilation-perfusion mismatch or shunt and usually requires mechanical ventilation.

At any time, if there are urgent or emergent indications for intubation, do not delay.

WHO suggests that hospitalized patients with severe or critical COVID-19 with acute hypoxaemic respiratory failure that do not require emergent intubation be treated with HFNO, or CPAP or NIV (BiPAP) rather than standard oxygen therapy.

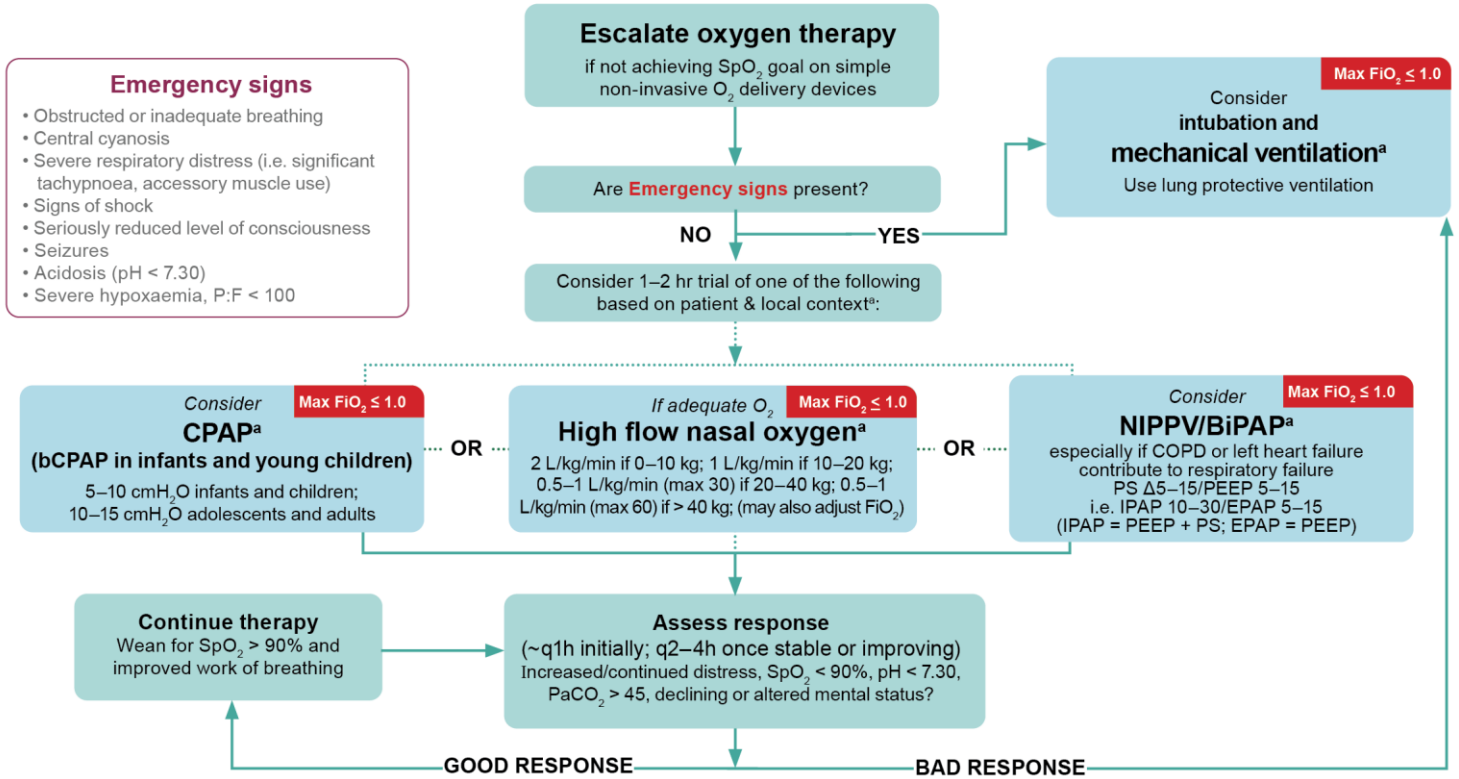


Summary of findings for HFNO vs SOT comparison

Outcome	Study results and measurements	Absolute effect estimates		Certainty of the evidence (quality of evidence)	Plain language summary
		SOT	HFNO		
Mortality	Relative risk: 0.87 (CI 95% 0.66–1.13) Based on data from 1006 patients in 3 studies	188 per 1000	164 per 1000 Difference: 24 fewer per 1000 (CI 95% 64 fewer – 24 more)	Low Due to very serious imprecision[1]	HFNO may decrease mortality
IMV	Relative risk: 0.89 (CI 95% 0.77–1.03) Based on data from 1053 patients in 3 studies	417 per 1000	371 per 1000 Difference: 46 fewer per 1000 (CI 95% 96 fewer – 13 more)	Low Due to very serious imprecision[1]	HFNO may decrease IMV
Hospital LOS	Measured by: Scale: Lower better Based on data from 1003 patients in 3 studies	16.85 days mean	14.92 days mean Difference: 1.08 fewer (CI 95% 2.48 fewer – 0.35 more)	Low Due to very serious imprecision[2]	HFNO may decrease hospital LOS
ICU LOS	Measured by: Scale: Lower better Based on data from 1003 patients in 3 studies	5.83 days mean	4.65 days mean Difference: 0.77 fewer (CI 95% 1.45 fewer – 0.08 fewer)	Moderate Due to serious imprecision[3]	HFNO probably has little or no difference in ICU LOS

LOS – length of stay; SOT – standard oxygen therapy.

Algorithm to escalate 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.

If patient is getting worse or the same, be systematic in your response:

- Is measurement correct?
- Is there a technical difficulty in delivering treatment?
- Is the patient getting appropriate therapy?
- Is there an alternate diagnosis?
- Is the treatment causing harm?

Choose best next intervention systematically:

- Does patient need urgent intubation and invasive ventilation?
- Is patient a good candidate for non-invasive modalities?
- What advanced device is available to use?
- Initiate treatment on selected device.

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).

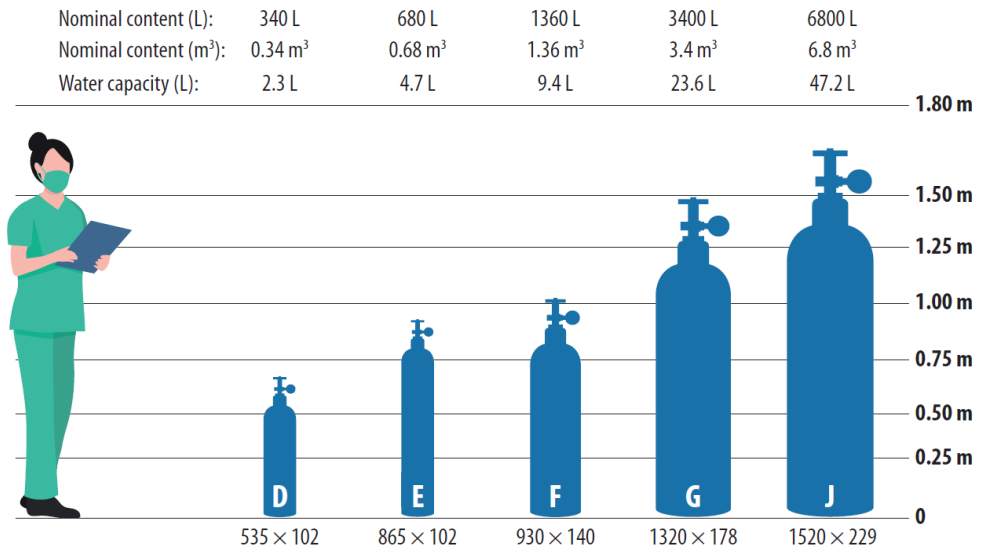
Resource considerations: medicinal oxygen and air supply

5. HFNO devices are able to generate flow rates as high as 60 L/min that could be only air, or a mix of air and oxygen.
6. FiO_2 will be adjusted with a **combination of medicinal air and oxygen**. FiO_2 depends on the following:
   - the oxygen and air flow rate
   - the relation between the patient's face and the delivery interface
   - the entrainment of ambient gas by the patient during each spontaneous inspiration (when applicable).
7. FiO_2 in room air is 0.21 (21% of oxygen).

Resource considerations: medicinal oxygen and air supply

Note: When using high-pressure gas cylinders, consider:

- The size of the cylinder to prevent activation of alarms and lack of supply.
- The compatibility of the accessories (valves, pressure and flow regulators, as applicable).
- Safety management to prevent accidents and fire (from sparks and short cuts).



Note: dimensions: height × diameter mm

Source: Adapted from WHO-UNICEF technical specifications and guidance for oxygen therapy devices.

Cylinder size

	D	E	F	G	J
Nominal content/oxygen capacity (L)	340	680	1360	3400	6800
Water capacity (L)	2.3	4.7	9.4	23.6	47.2
Dimensions (height × diameter) (mm)	535 × 102	865 × 102	930 × 140	1320 × 178	1520 × 229
Approximate full weight (kg)	3.9	6.5	17	39	78
Valve outlet connection (and specification)	Pin index (ISO 407)	Pin index (ISO 407)	Bullnose (BS 341)	Bullnose (BS 341)	Pin index side spindle (ISO 407)
Nominal service pressure (kPa/bar/psi)	13 700 kPa (137 bar/1987 psi)	13 700 kPa (137 bar/1987 psi)	13 700 kPa (137 bar/1987 psi)	13 700 kPa (137 bar/1987 psi)	13 700 kPa (137 bar/1987 psi)
Health facility use	Emergency and ambulance transport	Emergency and ambulance transport	Stand-alone	Stand-alone	Manifold connection and stand-alone

Notes: BS – British Standard; ISO – International Organization for Standardization; psi – pounds per square inch absolute.

Source: BOC Healthcare (https://www.bochealthcare.co.uk/en/images/cylinder_data_med309965_2011_tcm409-54065.pdf, accessed 12 June 2019).

High-pressure medicinal air source: Piped oxygen

Type 1. Air Oxygen
Type 2: Oxygen

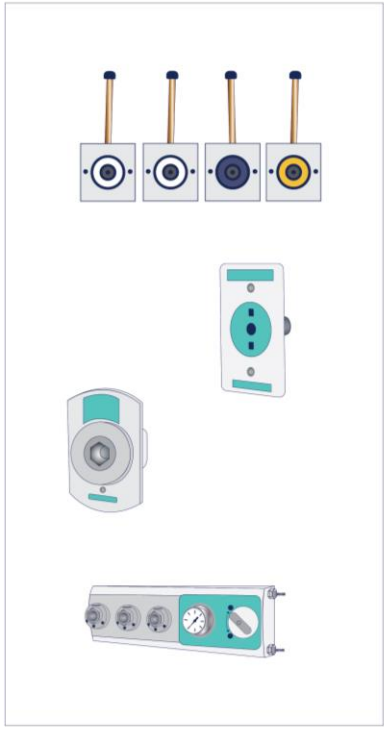
It might vary by country

Connector

1. DISS-Oxygen
2. Ohmeda-Oxygen
3. Puritan-Oxygen
4. Chemetron
5. French (NF S 90-116)
6. German (DIN 13260-2)
7. British (BS5682-1998)
8. Japanese Style
9. Australian (AS2896)
10. AGA-Oxygen

...

Piped Oxygen Source (Wall Outlet)



High-pressure medicinal air source: Cylinder

+

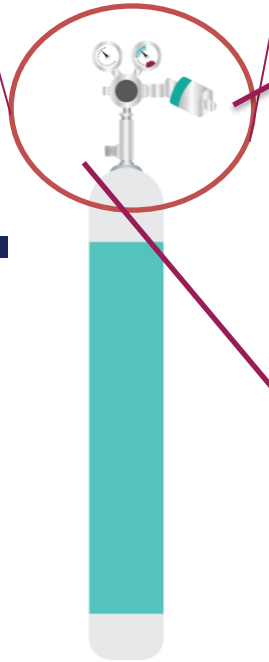
+

Conector
Conectors Mentioned in the previous slide

No Conector
When Brarbed Fitting terminal unit regulator

+

Regulator



Regulator Type

Barbed Fitting
Diss
Ohmeda
DIN 13260
FRENCH AFNOR
SS
Many More

Terminal Unit Type

Inlet Connections

UNI 111 44
EN 850
NF-E-29-650
BS 341-3
DIN 477-1
ISO 5154

Warnign: Cylinder size

Resource considerations: infection prevention and control

Use airborne precautions when treating patients with HFNO or NIV:

- A respirator should always be worn (very low certainty evidence) along with other PPE (including gown, gloves, eye protection) by health workers performing aerosol-generating procedures (AGP) and by health workers on duty in settings where AGP are regularly performed on patients with suspected or confirmed COVID-19, such as intensive care units, semi-intensive care units or emergency departments.

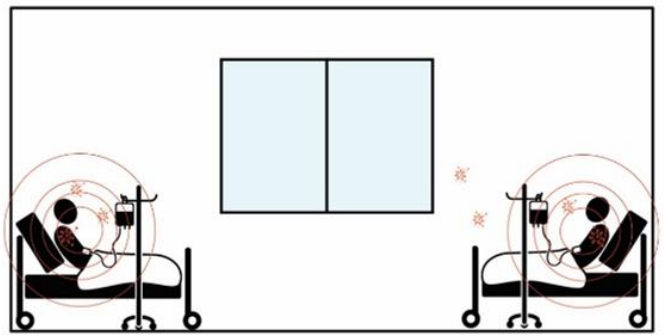
Where possible, designate a team of health workers to care for patients with suspected or confirmed COVID-19 and restrict their contact with COVID-19 patients:

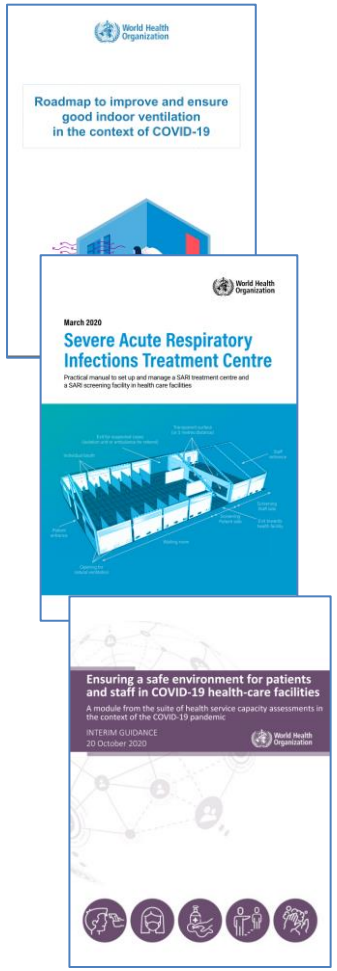
- Place all cases in well ventilated single rooms if feasible.
- When single rooms are not available or bed occupancy rate is anticipated to be 100% or more, suspected, probable or confirmed COVID-19 patients should be grouped together (cohorted) in adequately ventilated areas with bed space at least 1 m apart.
- Limit patient movement within the institution and ensure that patients wear medical masks when outside of their care area (e.g. when being transported).

Ventilation systems and minimum requirements

Specific indoor ventilation requirements should be met: (see documents shown for further information).

Area	Natural ventilation	Mechanical ventilation
AGPs are NOT performed	Average 60 L/s/patient	At least 6 air changes per hour (ACH)
AGPs are performed	Average 160 L/s/patient	Old building: at least 6 air changes per hour (ACH)





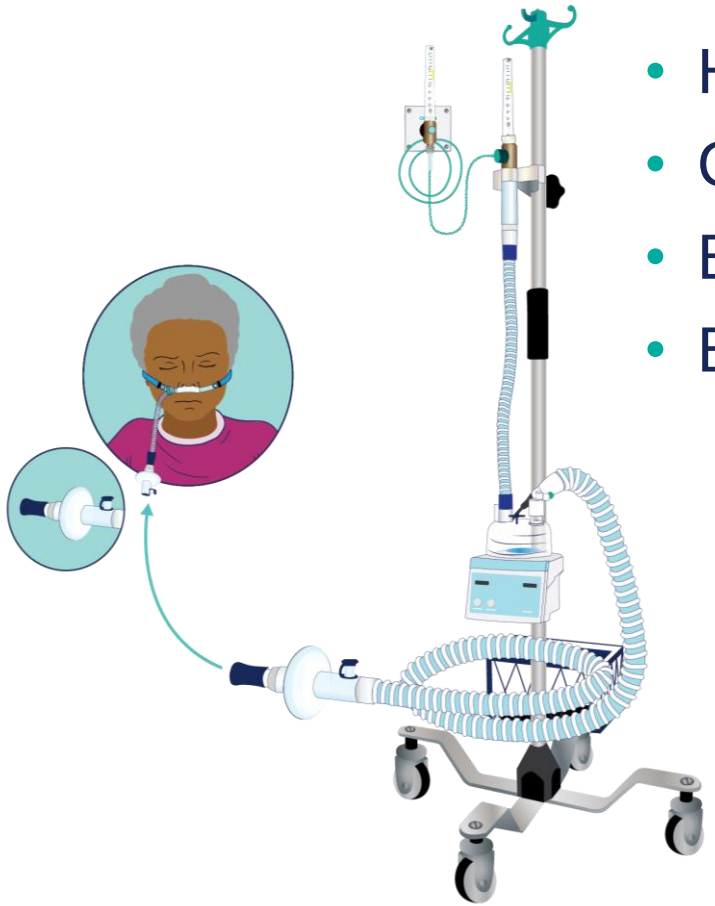
Building ventilation has three basic elements:

1) **Ventilation rate:** the amount of outdoor air that is provided into the space, and the quality of the outdoor air.
2) **Airflow direction:** the overall airflow direction in a building, which should be from clean zones to less-clean zones.
3) **Air distribution or airflow pattern:** the air should be delivered to each part of the space in an efficient manner and the airborne pollutants generated in each part of the space should also be removed in an efficient manner.

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
Severe Acute Respiratory Infections Treatment Centre (who.int) https://www.who.int/publications/i/item/10665-331603
Roadmap to improve and ensure good indoor ventilation in the context of COVID-19 (who.int) https://www.who.int/publications/i/item/9789240021280
Ensuring a safe environment for patients and staff in COVID-19 health care facilities https://www.who.int/publications/i/item/WHO-2019-nCoV-HCF_assessment-Safe_environment-2020.1

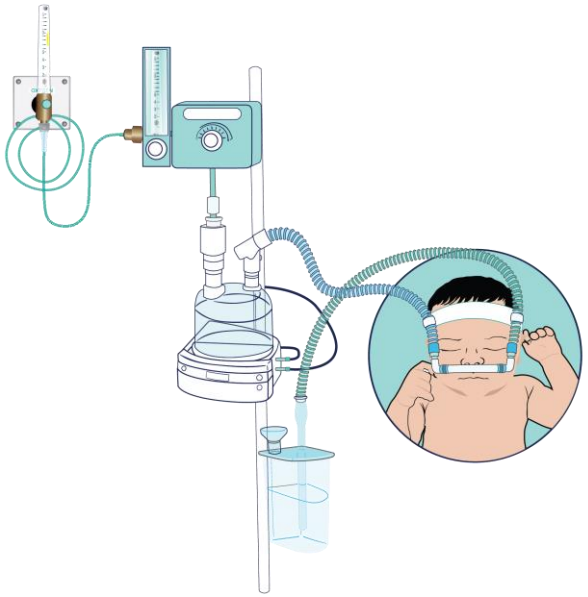
Types of advanced non-invasive respiratory support devices

- High-flow nasal oxygen (HFNO)
- Continuous positive airway pressure (CPAP)
- Bi-level positive airway pressure
- Bubble CPAP



HFNO

NIPPV: CPAP, bi-level



Bubble CPAP

Sources: Biomedical equipment for COVID-19 case management-inventory tool. WHO; 2020.
Oxygen therapy for children: a manual for health workers. WHO; 2016.

Example of non-invasive respiratory support

HFNC

	Resmed/ **Lumis 150 VPAP ST-A**	**YUWELL/** **YH-830**	**F&P/** **AIRVO2**	**MASIMO/** **TN1 softFlow 50**
Intended use	Adult, Paediatric (patients weighing more than 13 kg)	Adult, Paediatric (patients weighing more than 30 kg)	Adult, Paediatric	Adult, Paediatric
Modes	S, ST, T, PAC, iVAPS, CPAP	S, ST, T, VGPS, CPAP	Target temperature settings: 37, 34, 31 ˚C	Target temperature settings: 30 – 37 ˚C
Supplemental Oxygen	Up to 15 L/min	Up to 15 L/min	Up to 60 L/min (Low pressure inlet)	Up to 50 L/min (Low pressure inlet)

Indications for advanced respiratory support: COVID-19

WHO suggests the use of HFNO, bi-level or CPAP for patients with acute hypoxaemic respiratory failure that do not require emergent intubation over the use of standard oxygen therapy.

Criteria for ARDS:

- Signs of severe or worsening **respiratory distress.**
- **Hypoxaemia** (SpO_2 < 90%) despite escalating oxygen therapy.
- **SpO_2/FiO_2 < 315.**
- **Pulmonary oedema**, **cardiac failure or fluid overload** not the primary cause.
- **New bilateral opacities** on chest imaging.

ARDS Definition Task Force, et al. Acute respiratory distress syndrome: the Berlin definition. JAMA. 2012;307(23):2526-33.
Riviello ED, et al. Hospital incidence and outcomes of ARDS using the Kigali modification of the Berlin definition. Am J Respir Crit Care Med. 2016;193(10):52-9.

Patient selection: appropriate patients for advanced non-invasive respiratory support

Patients with acute hypoxaemic respiratory failure, not in need of emergent intubation AND:

- **awake**
- **cooperative**
- **haemodynamically stable.**

Do not delay intubation and invasive mechanical ventilation (IMV) if patient has urgent indications for airway management and invasive ventilation.

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

Abnormal mental status: patients 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 of HFNO and NIPPV is a delay to intubation that may increase mortality. Thus, patients need to be managed by trained staff and a short trial of non-invasive support with close monitoring for signs of deterioration or non-improvement.

Monitoring patients on HFNO and NIPPV

Patients on HFNO and NIPPV can decompensate quickly and should be cared for in a closely monitored setting (i.e. high dependency unit or in an ICU, see Module 1.1).

For example:

- Continuous pulse oximetry is preferred with vital signs checked at least every hour.
- By personnel experienced with advanced non-invasive respiratory support and with skills for advance airway management (i.e. intubation and invasive mechanical ventilation (IMV).

See modules on monitoring for more details.

Brower RG, et al. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. N Engl J Med. 2000;342(18):1301-8. doi: 10.1056/NEJM200005043421801. PMID: 10793162.
Amato MBP, et al. Driving pressure and survival in the acute respiratory distress syndrome. N Engl J Med. 2015;372(8):747-55. doi: 10.1056/NEJMsa1410639. PMID: 25693014.

Monitoring patients on HFNO and NIPPV

When initiating HFNO or NIPPV, use a **time-limited trial (i.e. 1 hour)**, to assess for clinical response:

A good response includes:

- patient comfort
- reduced work of breathing
- reduced respiratory rate (RR)
- improved oxygen saturation
- stable haemodynamics
- stable mental status.

Note: Patients with severe air hunger and very large spontaneous tidal volumes may need consideration for earlier intubation and lung protective ventilation.

Brower RG, et al. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. N Engl J Med. 2000;342(18):1301-8. doi: 10.1056/NEJM200005043421801. PMID: 10793162.
Amato MBP, et al. Driving pressure and survival in the acute respiratory distress syndrome. N Engl J Med. 2015;372(8):747-55. doi: 10.1056/NEJMsa1410639. PMID: 25693014.

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

Kelly, S. E., & Wells, G. A. (2022). Noninvasive ventilation strategies for patients with severe or critical COVID-19: A rapid review of clinical outcomes. MedRxiv, 2022.05.25.22275586.

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

Agarwal A, Basmaji J, Muttalib F, Granton D, Chaudhuri D, et al. [High-flow nasal cannula for acute hypoxemic respiratory failure in patients with COVID-19: systematic reviews of effectiveness and its risks of aerosolization, dispersion, and infection transmission.] Can J Anaesthesia. 2020;67(9):1217-1248. https://doi.org/10.1007/s12630-020-01740-2

Christi MJ, Salam MA, Smith JH, Ahmed T, Pietroni MA, et al. Bubble continuous positive airway pressure for children with severe pneumonia and hypoxaemia in Bangladesh: an open, randomized controlled trial. Lancet. 2020;386(9998):1057-65. https://doi.org/10.1016/S0140-6736(15)60249-5

Lissauer T, Duke T, Mellor K, Molyneux L. Nasal CPAP for neonatal respiratory support in low and middle-income countries. Arch Dis Child Fetal Neonatal Ed. 2017;102(3):F194-F196. https://doi.org/10.1136/archdischild-2016-311653

Myers S, Dinga P, Anderson M, Schubert C, Mlotha R, et al. Use of bubble continuous positive airway pressure (bCPAP) in the management of critically ill children in a Malawian paediatric unit: an observational study. BMJ Open Respiratory Research. 2019;6:e000280. https://doi.org/10.1136/bmjresp-2018-000280

Navas-Blanc JR, Dudaryk R. Management of respiratory distress syndrome due to COVID-19 infection. BMC Anesthesiol. 2020;20(1):177. https://doi.org/10.1186/s12871-020-01095-7

Sun Q, Qiu H, Huang M, Yang Y. Lower mortality of COVID-19 by early recognition and intervention: experience from Jiangsu Province. Ann Intensive Care. 2020;10(1):33. https://doi.org/10.1186/s13613-020-00650-2.

Jardine L, Davies MW. Withdrawal of neonatal continuous positive airway pressure: current practice in Australia. Pediatr Int. 2008;50(4):572-575. doi:10.1111/j.1442-200X.2008.02617.x

Acknowledgements

Contributors

Dr Paula Lister, Great Ormond Street Hospital, London, UK

Dr Neill Adhikari, Sunnybrook Health Sciences Centre, Toronto, Canada

Dr Janet Diaz, WHO, Geneva, Switzerland

Dr Wilson Were, WHO, Geneva, Switzerland

Dr Pryanka Relan, WHO, Geneva, Switzerland

Dr Jacobus Preller, WHO, Geneva, Switzerland

Dr Angela Aramburu, Royal Brompton Hospital NHS Foundation Trust, London, UK

Dr Marta Lado, WHO, Geneva, Switzerland

Dr Bharath Kumar Tirupakuzhi Vijayaraghavan, Consultant, WHO

Dr John Adabie Appiah, WHO Consultant, Kumasi, Ghana