
Disease Control Division
Directorate General of Health Services
Ministry of Health & Family Welfare
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>LMIC</td>
<td>Low and middle income countries</td>
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<tr>
<td>LMO</td>
<td>Liquid medical oxygen</td>
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<tr>
<td>PSA</td>
<td>Pressure Swing adsorption</td>
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<tr>
<td>VSA</td>
<td>Vacuum Swing adsorption</td>
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<tr>
<td>DGHS</td>
<td>Director general of health services</td>
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<tr>
<td>CPAP</td>
<td>Continuous positive airway pressure</td>
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<tr>
<td>BiPAP</td>
<td>Bilevel positive airway pressure</td>
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<tr>
<td>NIPPV</td>
<td>Nasal intermittent positive pressure ventilation</td>
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<tr>
<td>$\text{N}_2$</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>$\text{O}_2$</td>
<td>Oxygen</td>
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<tr>
<td>psig</td>
<td>Pound per square inch gauge</td>
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<td>Nm$^3$</td>
<td>Normal Cubic meter</td>
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<td>VPSA</td>
<td>Vacuum Pressure Swing adsorption</td>
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<td>ICU</td>
<td>Intensive care unit</td>
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<td>HFNOT/HFNO</td>
<td>High flow nasal oxygen therapy</td>
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<td>ESFT</td>
<td>Essential supply forecast Tool</td>
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<td>NIV</td>
<td>Noninvasive ventilation</td>
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<tr>
<td>HFNC</td>
<td>High flow nasal cannula</td>
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<td>NRM</td>
<td>Non-rebreather mask</td>
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<tr>
<td>FiO$_2$</td>
<td>Fraction of inspired oxygen</td>
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<td>SpO$_2$</td>
<td>Peripheral oxygen saturation</td>
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<tr>
<td>SOP</td>
<td>Standard operating procedure</td>
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<tr>
<td>ABG</td>
<td>Arterial blood gas analysis</td>
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<tr>
<td>CXR</td>
<td>Chest X ray</td>
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<td>LPM</td>
<td>Liters per minute</td>
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<td>VT</td>
<td>Ventricular tachycardia</td>
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<td>BVM</td>
<td>Bag-valve-mask</td>
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<td>MCH</td>
<td>Medical college hospital</td>
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<td>PEEP</td>
<td>Positive end-expiratory pressure</td>
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<td>SBT</td>
<td>Spontaneous breathing trials</td>
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<tr>
<td>CLT</td>
<td>Cuff leak test</td>
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<td>ETT</td>
<td>Exercise tolerance testing</td>
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<td>RASS</td>
<td>Richmond agitation sedation scale</td>
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<td>ECHO</td>
<td>Echocardiogram</td>
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<td>CBC</td>
<td>Complete blood count</td>
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<td>RFT</td>
<td>Renal function test</td>
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<tr>
<td>LFT</td>
<td>Lung function test</td>
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<tr>
<td>ECG</td>
<td>Electrocardiogram</td>
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<tr>
<td>CTPA</td>
<td>Computed tomography pulmonary angiogram</td>
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<td>CT</td>
<td>Computed tomography</td>
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<tr>
<td>ET</td>
<td>Endotracheal tube</td>
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<tr>
<td>CVC</td>
<td>Central venous catheter</td>
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<td>LDH</td>
<td>Lactate dehydrogenase</td>
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<tr>
<td>CNS</td>
<td>Central nervous System</td>
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<td>CDC</td>
<td>Communicable disease control</td>
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<tr>
<td>TV</td>
<td>Tricuspid valve</td>
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<tr>
<td>AC</td>
<td>Acute coronary syndrome</td>
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Introduction

Background
The second wave of COVID-19 pandemic has hit South-Asian countries hard. Bangladesh is not different from other South Asia countries, where COVID-19 cases increased at an unprecedented rate. Bangladesh has seen a surge of COVID-19 cases since the last week of May 2021 (1). As the number of cases continued to rise exponentially, scarce hospital resources ran thin, and critical care units were overburdened. As oxygen therapy is the cornerstone for management of patients with moderate and severe COVID-19, rational use of oxygen during the crisis cannot be overemphasized (2).

Oxygen therapy is essential component in COVID-19 pandemic situation which was never thought previously. Oxygen is an essential medicine that is used to treat hypoxia at all levels of the health care system. It is required for surgery and management of acute respiratory illnesses such as severe pneumonia, chronic pulmonary diseases, emergencies and cardiovascular diseases, among others. Yet in the 21st century many patients require oxygen and it is not available, especially in low-resource settings. The COVID-19 pandemic has highlighted the need for and gaps in oxygen globally. Severe pneumonia from COVID-19 has resulted in a surge in oxygen demand globally. However, even before the COVID-19 pandemic, there were reports that in the majority of LMIC, there was a struggle to access reliable medical oxygen. For example, across sub-Saharan Africa 31% of facilities have interrupted oxygen availability, and 25% have no availability at all. It was also reported that the availability of oxygen for medical use is the primary rate-limiting factor for treatment once a diagnosis has been made. Specific barriers to availability may include: high cost, lack of funding for long-term operations, lack of trained human resources, weak supply chains and non-continuous and unreliable power supply access. Medical oxygen has often been omitted in holistic planning efforts while strengthening health systems, and technical guidance related to installation and maintenance of oxygen systems is limited (3, 4).

In June-July 2020, Directorate General of Health Services (DGHS) of the Ministry of Health and Family Welfare (MOHFW) undertook a survey with support from different partners on Health Facility Preparedness and Readiness assessment for the COVID-19 response. It looked at 120 health facilities including specialized hospitals, medical college hospitals, district hospitals, upazilla health complexes, Non-government organizations (NGOs), and private health facilities across eight divisions of the country. This survey showed that in at least one hospital in the city have oxygen plant or liquid medical oxygen (LMO). It was found that there was no piped oxygen system in many district health facilities. Thus, the hospitals were not ready to receive any patients with COVID-19 who required oxygen for their better management. It was also revealed that around 70% of the facilities did not have adequate oxygen infrastructure including oxygen plant or liquified medical oxygen system, and other essential oxygen equipment such as oxygen concentrator and pulse oximeter (5).

To mitigate the impact of the pandemic on health outcomes, the DGHS of the MOHFW with support from different donors worked to strengthen the capacity of existing LMO system with extended pipeline and gas in specialized hospitals, medical college hospitals, and district
hospitals. The Government is also expanding the capacity by installing Pressure Swing adsorption (PSA) plant and Vacuum Swing Adsorption plant system which are the latest technology of oxygen production system. The principal target of the government is not only to combat COVID-19 but also to improve the oxygen structure of several hospitals for better care of maternal and child health (5).

The government understood that installing only larger oxygen plant will not solve the problem of oxygen demand in coming future, a rational approach to use of oxygen is also imperative. During the surge of COVID-19, we have observed that people were running for oxygen cylinder, even those who did not need oxygen. On the other hand those who need oxygen could not get enough oxygen. Misconception and lack of knowledge regarding oxygen use existed across the health system during rise of COVID-19 cases in Bangladesh. Not only that, several fire outbreak occurred from mis-handling of Oxygen equipment in few government and private hospitals.

Improving the clinical outcomes of patients admitted to the hospital with COVID-19 requires a concerted effort by all stakeholders. As resources are limited and the case-load in hospitals tends to rise fast during COVID-19, this is an opportune time to focus on the basics of medical care, including oxygen therapy. It is important to do the fundamentals right as we do not have adequate resources for the widespread adoption of resource mapping protocols and expensive pharmacological agents. Considering that, DGHS, MOHFW felt the necessity to develop a guideline titled “Oxygen Sources, Distribution and Need Estimation with Rational Use of Oxygen in COVID-19 patient management”.

The present publication has two sections, one for policy makers and hospital management; another for frontliners who directly manage the patient. The first describes the need for oxygen, introduces the technologies of oxygen sources, the different oxygen delivery devices and oxygen safety guideline. The second section illustrates a simple flow chart for oxygenation of COVID-19 Patient, and it’s detail description and the concept of oxygen toxicity.

**Purpose of the guideline**

The first section will help policy makers and hospital or clinic managers to identify the types of technologies of oxygen sources available in the market, and based on need the hospital submit request or purchase the selected technologies of oxygen sources. This section will also support policy makers and health managers can calculate the oxygen demand in their hospital and save their hospital by following the oxygen safety guideline.

The second section is for the healthcare worker who treat patients at their bedside. This section will guide them to provide oxygen in COVID-19 patients by following a simple flow chart. This section will also give them an understanding of different oxygen delivery devices and oxygen toxicity which is not discussed much, but an integral component of oxygen therapy.
Definitions
Oxygen therapy: Oxygen therapy or supplemental oxygen is the provision of medical oxygen as a health-care intervention.
Composition of Medical oxygen: Medical oxygen contains at least 82% pure oxygen extent 99%, is free from any contamination and is generated by an oil-free compressor. Only high quality, medical-grade oxygen should be given to patients.
Hospital Oxygen system: Hospital oxygen system must consist of an oxygen source, or production combined with storage and supply system.

Section 1: For policy makers and hospital/clinic managers
Overview of oxygen therapy products
Common oxygen sources
1. Cylinder. Single time procurement and need to refill. The most common source of oxygen storage used in health-care settings is a cylinder.
2. Oxygen concentrators. 5 to 10 L/ minute; Single time procurement and need continuous electric supply
3. Liquid oxygen in bulk storage tanks; Need company supply channel
4. Oxygen generating plants; Need continues electrical supply

Common Oxygen delivery devices
1. Direct to patient
   a) Cylinder with flowmeter: Low Flow system: 1 to 15 l/min
   b) Oxygen concentrator: Low Flow system: 1 to 10 l/min
   c) Central Gas pipeline: Connect with Cylinder manifold or PSA or VSA and liquid oxygen tank: Uses with all devices

2. Oxygen devices in patient end:
   a) Nasal canula: Flows 1-6 l/min, used with all oxygen supply or storage system
   b) Face mask: Flows 4-10 l/min, used with all oxygen supply or storage system
   c) Partial rebreathing mask: Flows 10-15 l/min, used with all oxygen supply or storage system except oxygen concentrator
   d) Non rebreathing mask: Flows 10-15 l/min, used with all oxygen supply or storage system except oxygen concentrator
   e) Venturi mask: Flows 6-15 l/min, used with all oxygen supply or storage system except oxygen concentrator
   f) High flow nasal oxygen therapy: Flows up to 80 l/min, used with central gas line and electric supply

3. Artificial / Mechanical Ventilation
   a) Noninvasive: Continuous positive airway pressure (CPAP), Bilevel positive airway pressure (BiPAP) and Nasal intermittent positive pressure ventilation (NIPPV): Need
special mask; Flows 2-10l/min, used with all oxygen supply or storage system and electricity
b) nvasive ventilation: Endotracheal intubation: Flow 4-10 l/min, used with central gas line and electric supply

**Oxygen Sources**

The appropriate choice of oxygen source depends on many factors, including:
1. The amount of oxygen needed at the treatment center,
2. The available infrastructure,
3. Cost,
4. Capacity and supply chain for local production of medicinal gases,
5. Availability of electrical supply, and
6. Access to maintenance services and spare parts, etc.

**Oxygen cylinders**

Oxygen gas can be compressed and stored in cylinders. These cylinders are filled at a gas manufacturing plant, either via a cryogenic distillation or a process known as pressure swing adsorption (PSA), and transported to health facilities to be connected to manifold systems (groups of cylinders linked in parallel) that are piped to areas of the health facility; or to cylinders can be used directly within patient areas. The use of cylinders typically involves transport to and from the bulk supply depot for regular refilling, which could have logistical challenges and ongoing cost implications, often leading to unreliable supply in many settings. While less common, cylinders can also be filled by a PSA oxygen plant that is co-located with a health facility and that has a high-pressure compressor for cylinder filling purposes. Cylinders do not require electricity, but they do require several accessories and fittings to deliver oxygen, such as pressure gauges, regulators, flowmeters, and, in some cases, humidifiers. Cylinders also require periodic maintenance, commonly provided by gas suppliers at the point of refilling. Cylinders can be used for all oxygen needs, including high pressure supply and in facilities where power supply is intermittent or unreliable. Cylinders are also used for ambulatory service for patient transport and used as a backup for other systems (4).
**Oxygen concentrator**

An oxygen concentrator is a self-contained, electrically powered medical device designed to concentrate oxygen from ambient air. Utilizing PSA technology, an oxygen concentrator draws in air from the environment, extracts the nitrogen, and can produce a continuous source of 95.5% concentrated oxygen. Oxygen concentrators are portable and can be moved between clinical areas, but they are also often set up to be stationary fixtures in patient areas. Concentrators designed for home care or bedside use are available in models that can deliver maximum flow rates between 5 and 10 L/min. When used with a flowmeter stand for splitting flow, concentrators can provide a continuous supply of oxygen to multiple patients at the same time. Concentrators can provide a safe and cost-efficient source of oxygen, but they do require a source of continuous and reliable power and regular preventive maintenance to ensure proper functioning. It is a best practice to also have cylinders as a backup supply.

Oxygen concentrators are used to deliver oxygen at the bedside or within proximity to patient areas. A single concentrator can serve several beds with the use of a flowmeter stand to split output flow (4).

**Oxygen Manifold Systems**

A manifold is a fluid or gas distribution system or device that serves to bring many junctions into one place or a single channel into an area where many points meet. Manifold systems range from simple supply chambers with several outlets to multi-chambered flow control units including integral valves and interfaces to electronic networks. Complex pneumatic and hydraulic circuits can utilize manifolds and manifold systems with interfaces to sophisticated electronic networks.

Cylinders are often arranged into two groups; a primary and secondary group. In a hospital, size J cylinders are commonly used, which are capable of holding 6800 liters of oxygen each or 13,600 of nitrous oxide. Initially, the gas is used up from the primary group first, with gas being expended equally from all cylinders, as they are connected in parallel through a common outlet. Once the levels in the cylinders are sufficiently low, a pressure transducer switches to the secondary manifold; allowing the primary manifold to be replenished. Manifolds are used to supply nitrous oxide, Entonox, air or oxygen; although a vacuum insulated evaporator is more commonly used to store oxygen. Gas manifolds should be stored in an area separate from the main building. It should not be exposed to the environment and should be well ventilated (6).
**Liquid oxygen in bulk storage tanks**

Cryogenically produced liquid oxygen is always generated off-site (not at a medical facility). Medical facilities can be equipped with large bulk liquid oxygen tanks that are refilled periodically by a truck from a supplier. The liquid oxygen tank supplies a centrally piped system throughout the health facility by self-vaporization and for which a power supply is not required. Although an economical option in some settings, the use of liquid oxygen relies on external supply chain mechanisms and needs a bit more caution with respect to transport and storage due to the risks associated with higher pressures. Extra care should be taken in more extreme environments. It is best practice to also have cylinders as a backup supply.

A typical storage system consists of a cryogenic storage tank, one or more vaporizers and a pressure control system. The cryogenic tank is constructed, in principle, like a vacuum bottle. There is an inner vessel surrounded by an outer vessel. Between the vessels is an annular space that contains an insulating medium from which all the air has been removed. This space keeps heat away from the liquid oxygen held in the inner vessel. Vaporizers convert the liquid oxygen into a gaseous state. A pressure control manifold then controls the gas pressure that is fed to the process or application. These cryogenic storage tanks are equipped with pressure-relief valves and rupture disks to protect the cylinders from pressure buildup. Liquid containers operate at pressures up to 350 psig and have capacities between 80 and 450 liters of liquid.

It can be used for all oxygen needs, including high pressure supply and in facilities where power supply is intermittent or un-reliable [4).

**Oxygen generator**

An oxygen generator is a large, onsite, central source of oxygen that is piped directly to terminal units within patient areas. Generators can generate oxygen using PSA technology (similar to concentrators) or by cryogenic distillation. Generators can also be set up to refill cylinders for oxygen distribution or backup oxygen supply; these cylinders can be connected to sub-central manifold systems at the health facility or transported to neighboring health facilities. Note that oxygen plants require a reliable source of power. It is best practice to also have cylinders as a backup supply.

Pipeline systems supply oxygen at high pressure to equipment such as anaesthetic machines and ventilators. A key advantage of pipeline systems is that they obviate the need for handling and transporting heavy cylinders between hospital wards. The high cost of installing centralized oxygen sources with copper pipelines and the high level of specialized maintenance required currently make these systems of oxygen delivery unsuitable for many district-level hospitals in low resource setting. Pipeline systems can be used for all oxygen needs, including high-pressure supply [4).
**PSA generator**

Pressure swing adsorption (PSA) is the process by which ambient air passes through an internal filtration system (e.g. a molecular sieve [zeolite granules or membranes]), which has a large enough total surface area to separate nitrogen (N2) from the air, concentrating the remaining oxygen (O2) to a known purity. It typically consists of an air compressor, dryer, filters, dual separation chambers, a reservoir, and controls.

PSA oxygen generator is a unit designed to concentrate oxygen from ambient air at scale, with output capacity varying according to calculated oxygen demand, typically ranging from 2 Nm3/hr to 200 Nm3/hr. For distribution of oxygen produced from PSA plants, oxygen can either be piped directly from the oxygen tank towards, or further compressed to fill cylinders via a supplemental booster compressor and a cylinder filling ramp/manifold.

All medical PSA oxygen generator are sources of oxygen that can produce medical-grade oxygen, at scale, 24 hours a day, 7 days a week.

PSA plants themselves can be turn-key units complete with all the necessary equipment and supplies; however, the staff operating and maintaining them require specialized training. Strict maintenance schedules are needed to prevent malfunctions. Adequate supplies and spare parts are needed to allow operations for 5 years in resource-limited settings. A reliable supply chain is needed to meet any additional needs. Should repairs be required, these are often carried out by manufacturer or distributor staff (7).

**VSA generator**

Vacuum Swing Adsorption (VSA) is a non-cryogenic gas separation technology. Using special solids, or adsorbents, VSA segregates certain gases from a gaseous mixture under minimal pressure according to the species' molecular characteristics and affinity for the adsorbents. These adsorbents (e.g., zeolites) form a molecular sieve and preferentially adsorb the target gas species at near ambient pressure. The process then swings to a vacuum to regenerate the adsorbent material.

VSA differs from cryogenic distillation techniques of gas separation as well as pressure swing adsorption (PSA) techniques due to the fact that it operates at near-ambient temperatures and pressures.

**Advantages of VSA over PSA**

1. Energy efficiency is the key for VSA systems which is not found in PSA. VSA systems showed their energy efficiency when same product flow, pressure as well as purity conditions are there.
2. VSA systems are said to be much more inexpensive than PSA systems, if production rate is found to be more than 20 tons per day which can be 60 tons per day too or more (8).
## Comparison of oxygen sources

<table>
<thead>
<tr>
<th></th>
<th>Cylinders</th>
<th>Concentrators</th>
<th>Oxygen generator</th>
<th>Liquid oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distribution mechanism</strong></td>
<td>Connected to manifold of central/sub-central pipeline distribution system, or directly connected to patient with flowmeter and tubing.</td>
<td>Direct to patient with tubing or through a flowmeter stand.</td>
<td>Central/ sub-central pipeline distribution system, or can be used to refill cylinders that can be connected to manifold systems in the facility.</td>
<td>Central pipeline distribution system.</td>
</tr>
<tr>
<td><strong>Electricity requirement</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Initial costs</strong></td>
<td>Moderate; cylinder, regulator, flowmeter, installation, training.</td>
<td>Moderate; concentrator, spares, installation, training.</td>
<td>High; plant and pipeline distribution system, installation, training.</td>
<td>Can be high; tank, pipeline installation, training.</td>
</tr>
<tr>
<td><strong>Ongoing operating costs</strong></td>
<td>High; cylinder deposit and leasing fees, refill costs, transportation from refilling station to health facility.</td>
<td>Low; electricity and maintenance (spare parts and labour).</td>
<td>Low/moderate; electricity and maintenance (spare parts and labour). May require additional staff to operate/manage if not operated by third party.</td>
<td>Moderate (can be high if tank is leased); refill costs, maintenance.</td>
</tr>
<tr>
<td><strong>Maintenance requirement</strong></td>
<td>Limited maintenance required by trained technicians.</td>
<td>Moderate maintenance required by trained technicians (1), who could be in-house.</td>
<td>Significant maintenance of system and piping required by highly trained technicians and engineers, can be provided as part of contract.</td>
<td>Significant maintenance of system and piping required by highly trained technicians and engineers, can be provided as part of contract.</td>
</tr>
<tr>
<td><strong>User care</strong></td>
<td>Moderate; regular checks of fittings and connections, regular checks of oxygen levels, cleaning exterior.</td>
<td>Moderate; cleaning of filters and device exterior.</td>
<td>Minimal; at terminal unit only.</td>
<td>Minimal; at terminal unit only.</td>
</tr>
<tr>
<td>Merits</td>
<td>No power source needed.</td>
<td>Continuous oxygen supply (if power available) at low running cost.</td>
<td>Can be cost-effective for large facilities.</td>
<td>99% oxygen obtained.</td>
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<tr>
<td></td>
<td></td>
<td>• Output flow can be split among multiple patients.</td>
<td>• Continuous oxygen supply.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 99% oxygen obtained.</td>
<td>• High oxygen output.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• High pressure output, usually not suitable for CPAP or ventilators.</td>
<td>• Needs adequate infrastructure.</td>
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<td></td>
<td></td>
<td>• Requires backup cylinder supply.</td>
<td>• High maintenance for piping.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Requires maintenance.</td>
<td>• Requires backup cylinder supply.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Risk of gas leakage from piping system.</td>
<td>• Risk of gas leakage from piping system</td>
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**Pipeline Intra-Hospital Distribution**

These networks are helpful to supply oxygen at high pressure to equipment such as anesthesia machines, ICU ventilators and HFNOT. A key advantage of pipeline systems is that they obviate the need for handling and transporting heavy cylinders between hospital wards. However, the high cost and complexity of installing centralized oxygen sources with copper pipelines and the associated specialized maintenance required for this make pipeline systems less accessible for turn-key installations (9).

**Oxygen Needs Estimation**

Another aspect of selecting the most appropriate source of oxygen is taking into consideration the gross flows of oxygen that will be needed for treatment. To determine the total flow needs, the anticipated case load has to be estimated. This can be done using the WHO COVID-19 Essential Supply Forecast Tool (ESFT). From the total patients expected, the ratio of patient severity can be ascribed as outlined: mild, moderate, severe, or critical. Thus, the required flows can be estimated to meet the oxygen therapy needs for the hospitalized severe and critical patients, representing 20% of the total. Our national guideline about 85% of the COVID-19 patients requiring hospitalization will be classified as “severe”, and 15% as “critical”. Thus, the
recommended flow rates for each patient severity category using different oxygen delivery device, shown in the table below (9).

Table: Sample oxygen flow planning per 100 bed (Hypothetical) facility

<table>
<thead>
<tr>
<th>Disease Severity</th>
<th>Total Number of patient</th>
<th>Oxygen therapy device</th>
<th>Per patients Average O2 flow rate</th>
<th>Amount of O2 required</th>
<th>Preferred cost-effective source</th>
<th>Alternative source</th>
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<tbody>
<tr>
<td>Moderate to severe</td>
<td>50</td>
<td>Nasal cannula, simple facemask, NRM, Venturi mask</td>
<td>2-15 L/min</td>
<td>(50 x 10 x 60) = 30000 L/hr</td>
<td>Oxygen cylinder, manifold, concentrator</td>
<td>Oxygen generator (PSA/VSA)</td>
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<td>Severe to Critical</td>
<td>40</td>
<td>NIV / HFNC</td>
<td>15-70 L/min</td>
<td>(40 x 45 x 60) = 108000 L/hr</td>
<td>Liquid O2 tank</td>
<td>VSA / PSA, O2 generating plant</td>
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<td>Critical</td>
<td>10</td>
<td>Artificial ventilation</td>
<td>5-15 liter/min</td>
<td>(10 x 10 x 60) = 6000 L/hr</td>
<td>Liquid O2 tank</td>
<td>VSA/ PSA, O2 generating plan</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>144,000 L/Hr</td>
<td>24 Hours = 3,456,000 liter per day</td>
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Oxygen systems components
In addition to the oxygen source and oxygen delivery devices, many other oxygen system components are required to get oxygen to patients who need it. This includes mechanisms for oxygen distribution, apparatuses to control pressure, flow, humidity and concentration, and devices for delivering oxygen to patients. Pulse oximetry is also required for measuring a patient’s oxygen saturation level (SpO2) to detect hypoxia, and for monitoring their oxygen status while receiving oxygen therapy. For those devices that are electrically powered, devices are needed to protect equipment from poor-quality mains electricity or provide continuity of power during mains power interruptions. Underpinning all of this is the need for maintenance, which, in addition to available expertise, requires tools to test the functionality of the oxygen therapy equipment as well as spare parts to keep it functioning (4).
Risks and hazards from gas cylinders
Gas cylinders can be hazardous due to both their physical (size and weight) and chemical characteristics. Hazards from gases are also subject to the chemical properties of each gas. These may be one or more of the following:

• Fire or explosion from the release of flammable gases near ignition sources.
• Spontaneous combustion from oxidizing gases (e.g. oxygen or nitrous oxide)
• Exposure limits for all gases, especially toxic or corrosive gases (e.g. anhydrous ammonia);
• Asphyxiation from non-toxic, non-flammable gases by displacement of oxygen (e.g. nitrogen, carbon dioxide or argon)
• Incorrect storage
• Leaks
• Faulty equipment/connections
• Storage and Handling of Gas Cylinders Guidelines
• Physical risks
• Manual handling
• Sudden release of gas if cylinder is damaged (torpedo effect).
• Pressure – compressed gas cylinders are filled to a pressure of 200-300 atmospheres
• Gas Density (10)

Cautions with oxygen therapy
Oxygen therapy supports life and supports combustion. While there are many benefits to inhaled oxygen, there are also hazards and side effects. Anyone involved in the administration of oxygen should be aware of potential hazards and side effects of this medication.

What are oxygen use precautions?
Oxygen is a safe gas as long as it is used properly. Contrary to what most people believe, oxygen will not explode.
Oxygen does, however, support combustion. Therefore, any material that is already burning will burn much faster and hotter in an oxygen-enriched atmosphere.
It is very important to follow these precautions so that you and your family are safe when you are using your oxygen.

The following list includes at-home oxygen therapy safety DON’Ts:
• Do not go near open flames – Stay at least 10 feet away from open flames while using an oxygen concentrator or oxygen tank. Keep away from cigarettes, candles, gas stoves, etc.
• Do not use an electric razor while using oxygen therapy. They are known to put off sparks.
• Do not put on or take off clothing that is prone to static electricity while wearing supplemental oxygen.
• Do not use oil or petroleum-based products on your face while using oxygen, since they are inflammable
The following list contains at-home oxygen therapy safety DOs:
• Keep oxygen tanks and cylinders secure at all times. If they fall over, the valve can come loose, and the pressurized oxygen may turn the tank into a dangerous missile.
• Place a non-smoking sign in your home or one in each room.
• Keep the service number for your oxygen equipment nearby, in case something breaks. A good idea would be to put a sticker with the customer care number on the equipment and your first-aid box.
• Have a quick escape plan in case of a house fire, so you immediately know what to do to prevent panic and confusion.
• When not in use, store your oxygen equipment in an area of your house that is far from any sources of heat (11).

Using your cylinders safely
**While handling cylinders**
• Do no smoke or use naked flame near a cylinder usage or storage area.
• Never use oil, grease based products on the cylinder or any accessories.
• Wear appropriate personal protective equipment (glasses, boots, gloves), particular for large cylinders.
• Always have the SOPs on hand for reference and follow recommended handling instructions

**During cylinder transportation**
• Detach regulators and other accessories from the cylinder.
• Secure cylinders against movement.
• Use open or well ventilated vehicles or trailers in preference to enclosed ones. Limit the number of cylinders to be transported.

**Storing your cylinders**
• Always display a “NO SMOKING OR OPEN FLAMES” sign.
• Storage areas should be kept 3m from heat sources or combustible materials.
• Store cylinders away from oils or grease.
• Never store flammable gas near oxidising gases.
• Never store objects on top of the cylinder.
• Always rotate cylinders - first come, first used.
• Store gases in well ventilated areas.
• If something is wrong with a cylinder,
• Label as “suspect”
• Put in quarantine. (10)
Prepare a register and check the line, cylinder, and whole system daily, monthly and quarterly and write down the information in register

<table>
<thead>
<tr>
<th>Nutshell of OXYGEN SAFETY GUIDELINES FOR HOSPITAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideline</td>
</tr>
<tr>
<td>Oxygen is a medication.</td>
</tr>
<tr>
<td>Storage of oxygen cylinders</td>
</tr>
<tr>
<td>No smoking</td>
</tr>
<tr>
<td>Keep oxygen cylinders away from heat sources.</td>
</tr>
<tr>
<td>Check for electrical hazards in the home or hospital prior to use.</td>
</tr>
<tr>
<td>Check levels of oxygen in portable tanks.</td>
</tr>
<tr>
<td>Arterial blood gas analysis (ABGs) should be ordered for all critically ill patients on oxygen therapy.</td>
</tr>
</tbody>
</table>
Section 2: For healthcare workers

Important consideration
• The essence of this guideline can be summarized simply as a requirement for oxygen to be prescribed according to a target saturation range and for those who administer oxygen therapy to monitor the patient and keep within the target saturation range.
• The guideline recommends aiming to achieve normal or near-normal oxygen saturation for COVID-19 patients.

Oxygen Surge Plan
The ability to boost capacity to deliver oxygen therapy is the cornerstone of the overall approach to managing the COVID-19 outbreak and it has implications for the functioning of the entire system. The principles, set out here, of building surge capacity should be integrated into a healthcare system, either centrally or at facility level. The oxygen surge plan should be integrated into the overall COVID-19 response plan. For instance, if a new COVID-19 treatment center is planned, the location and layout of the construction site will be a key factor for the oxygen surge planning.

Protocol for oxygenation of covid 19
1. Oxygen therapy is most important for managing the covid 19 hypoxic patient.
2. When oxygen use is more than 21% then it is a drug, need proper prescription.

Oxygen delivery devices

1. Low-flow oxygen delivery systems

a) Nasal cannula
A nasal cannula is the most common oxygen delivery system, used for mild hypoxia. It delivers oxygen into the nasopharyngeal space and can be set to deliver between 1 and 6 LPM (24–40% FIO2). FIO2 increases by approximately 4% with each litre of oxygen per minute. Nasal cannulae are widely used in domiciliary oxygen devices. An oxygen flow >6 LPM should be avoided as it can dry the nasal mucosa and can disturb sleeping patterns. A nasal cannula is convenient as the patient can talk and eat while receiving oxygen, and it is easy to use. However, it can be easily dislodged and is not as effective in patients with deviated septum or polyps (13).
b) Simple face mask

A simple face mask can be set to deliver between 5 and 10 LPM (35–55% FIO2) and is indicated when a moderate amount of oxygen is needed. It fits over the patient's mouth and nose and has side exhalation ports through which the patient exhales carbon dioxide. Humidified air may be added if the oxygen concentrations are causing nasal mucosa dryness. The mask's efficiency relies on how well it fits. Eating and drinking can be difficult with the mask on, and it can be confining for some patients, who may feel claustrophobic with the mask on (13).

c) Non-rebreather mask

A non-rebreather mask is a low-flow device with high FIO2. It uses a reservoir bag (≥1000 mL) to deliver a higher concentration of oxygen. A one-way valve between the mask and the reservoir bag prevents the patient from inhaling expired air. It can be set to deliver between 10 and 15 LPM (80–95% oxygen). Oxygen flow <10 LPM can cause the bag to completely collapse during inspiration. FIO2 depends on the patient's pattern of breathing. This mask is useful in severely hypoxic patients who are ventilating well, but it carries the risk of carbon dioxide retention and aspiration in case of vomiting (13).

2. High-flow oxygen delivery systems

a) Partial rebreather mask

Unlike the non-rebreather mask, there is no one-way valve between the rebreather mask and the reservoir bag and the inspired oxygen and expired air are collected in the reservoir bag (13).
b) Venturi mask

A Venturi mask is a high-flow device that allows precise measurement of FIO2 delivered. It consists of a bottle of sterile water, corrugated tubing, air/oxygen ratio nebuliser system, a drainage bag, and a mask (e.g. aerosol face mask, tracheostomy mask, T-piece, a face tent). The oxygen flow exceeds the patient’s peak expiratory flow. Therefore, it is unlikely for the patient to breathe in air from the room. A Venturi mask utilises different sized ports to change the FIO2 delivered (24–50%). The FIO2 and oxygen flow are clearly stated on the bottom of each port. It does not dry mucous membranes, but it is confining for some patients, and it interferes with talking and eating. It is particularly useful in COPD patients, where precise oxygen delivery is crucial (13).

c) High-flow nasal cannula

A high-flow nasal cannula consists of a flow generator, an air-oxygen blender, a humidifier and a nasal cannula. The flow generator can provide gas flow up to 70 LPM, and the blender escalates FIO2 up to 100% while the humidifier saturates the gas mixture (at 31–37°C). The heated humidified oxygen is delivered to a wide-bore nasal prong. The flow rate and FIO2 can be independently titrated based on the patient’s flow and FIO2 requirements. Overall, high flows and humidification improve functional residual capacity and mucociliary clearance of secretions, and thereby they reduce the work of breathing (13).

Comparison of different oxygen delivery devices

<table>
<thead>
<tr>
<th>Name of devices</th>
<th>Amount of oxygen can be delivered</th>
<th>Achievable FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal Canula</td>
<td>1 – 6 LPM</td>
<td>24 – 40%</td>
</tr>
<tr>
<td>Simple Face mask</td>
<td>5 – 10 LPM</td>
<td>35 – 55%</td>
</tr>
<tr>
<td>Non-rebreather mask</td>
<td>10 – 15 LPM</td>
<td>95 – 100%</td>
</tr>
<tr>
<td>Partial rebreather mask</td>
<td>10 – 15 LPM</td>
<td>80%</td>
</tr>
<tr>
<td>Venturi mask</td>
<td>5 – 15 LPM</td>
<td>28 – 100%</td>
</tr>
<tr>
<td>High-flow nasal cannula</td>
<td>5 – 15 LPM</td>
<td>100%</td>
</tr>
<tr>
<td>Non-invasive Ventilation</td>
<td>5 – 15 LPM</td>
<td>90%</td>
</tr>
<tr>
<td>Artificial ventilation</td>
<td>5-15 LPM</td>
<td>90 – 100%</td>
</tr>
</tbody>
</table>
Demand and Supply

All assisted ventilation implies a mix of medical air and oxygen. Flows for critical patients indicated here represent only the oxygen portion of the total gas flow required to achieve target therapeutic fraction of inspired oxygen (FiO2), which is the total % oxygen in the lungs available for gas exchange. FiO2 will change over the course of a treatment and vary from one patient to the next. The oxygen flow rate indicated here represents an average of the proportion of oxygen flows over the course of a patient's time on assisted ventilation. A simple equation to determine flow proportion at any time is as follows (9):

$$\text{Target FiO}_2 = \frac{\text{O}_2 \text{ L/min} + (\text{air L/min} \times 21\%)}{\text{Total flow, L/min}}$$
Flow chart for oxygenation of COVID 19 Patient

Suspected or confirmed COVID-19 patient

Initial quick assessment
• Rapidly Increasing Oxygen demand
• Unconsciousness: Hypotension/Tachycardia/Bradycardia
• Increased alarm marker: CRP, D-dimer, Serum ferritin, N-L Ratio

No

Yes

Respiratory Distress (Moderate)
• RR<= 30/ min
• SpO2 94%

Yes

No

Venturi mask FiO2 50%; 2-15L/min
Nonrebreather mask 15L/min

Respiratory Distress (Severe)
• RR>/= 30/ min
• SpO2 90%
• PaO2/FiO2 300

No

Yes

Critical Case

Yes

Yes

Venturi mask FiO2 50%; 2-15L/min
Nonrebreather mask 15L/min

Reassessment at least every 30 mins in first one hour and then hourly for the next few hours.
• Is the patient deteriorated; no improvement and increasing work of breathing?

No

Yes

Nasal Cannula 2-5 L/min
Venturi mask FiO2 50%; 2-15L/min
Face mask 5-8 L/min

Improved

Yes

Conventional supplement oxygen therapy
• Titrating oxygen up/down with target of SpO2> 90%

No

Yes

CPAP/BiPAP

Reassessment at least every 30 mins in two hours.
• Is the patient deteriorated; no improvement and increasing work of breathing?

No

Continue NIV Titrating Oxygen up/down with target of SpO2>90%

Yes

Intubation

RR: Respiratory Rate;
SpO2: Oxygen Saturation;
PaO2: Partial Pressure of Oxygen; FiO2: Friction of inspired oxygen; L: Liter;
HFNC: High flow nasal canula; NIV: Non-invasive ventilation.
Details of Oxygenation of COVID-19 patients with examples

Step 1: Quick clinical assessment

- Disorientation
- Hemodynamic stability
- Any sign of airway obstruction
- And Check SpO₂
- Optional ABG and CXR

Step 2: Resuscitation based on A B C

- ‘A’ stands for airway – look for airway patency
- ‘B’ stands for breathing – look for breathing pattern
- ‘C’ stands for circulation – look for pulse and blood pressure

Step 3: Start Oxygen

It is assumed that patient with

mild disease (SPO₂ ≥ 94) may be treated at home;
moderate disease (SPO₂ 90 to 92) may require non-ICU oxygen supported bed; and severe disease (SPO₂ < 90) may need ICU for noninvasive/invasive ventilation.

<table>
<thead>
<tr>
<th>Condition of patient</th>
<th>Oxygenation procedure</th>
<th>Target</th>
<th>Preferred source</th>
<th>Preferred device</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpO₂ is persistently lower than 94%</td>
<td>Start supplemental oxygen up to 1-6 LPM and provide up to 40% FiO₂ <strong>Consider awake proning</strong> Monitor SpO₂, Consciousness, Respiratory rate, Pulse and Blood pressure</td>
<td>SpO₂ 92% to 96% with the minimum FiO₂</td>
<td>Oxygen cylinder or oxygen concentrator</td>
<td>Nasal cannula or face mask</td>
</tr>
</tbody>
</table>
Step 4: If no improvement in oxygenation

<table>
<thead>
<tr>
<th>Condition of patient</th>
<th>Oxygenation procedure</th>
<th>Target</th>
<th>Preferred source</th>
<th>Preferred device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild to moderate SPO2 ≤ 90% to 92%</td>
<td>Give higher oxygen 5-10 LPM which provide up to 60% FiO2. <strong>Consider awake proning</strong> Monitor SpO2, Consciousness, Respiratory rate, Pulse and Blood pressure</td>
<td>SpO2 92% to 96% with the minimum FiO2.</td>
<td>Oxygen cylinder or oxygen concentrator</td>
<td>Nasal cannula or face mask</td>
</tr>
</tbody>
</table>

Step 5: If no improvement in oxygenation, plan to transfer to any appropriate health facility where higher oxygen storage system is available

1. Calculate oxygen requirement during transfer and keep extra cylinder and pulse oximeter in the ambulance.
2. It is recommended that the following delivery devices should be available in ambulance settings where oxygen is administered.
   - High concentration reservoir mask (non-rebreath mask) for high-dose oxygen therapy.
   - Nasal cannulae (preferably) or simple face mask for medium dose oxygen therapy.
3. This Guideline suggests aiming to achieve a normal or near-normal oxygen saturation for all acutely ill patients apart from those at risk of hypercapnic respiratory failure. The suggested target saturation range for most patients is 94-98%. Patients at risk of hypercapnic respiratory failure have a lower target saturation range, usually 88-92%.
4. In ambulance, if SpO2 is 85 – 91%, Titrate O₂ flow to SpO₂ of 92 – 96%
   - Initial dose of 2 – 6 L/min via nasal cannulae
   - Consider simple face mask 5 – 10 L/min
5. In ambulance, if SpO₂ < 85%
   - Initial dose nonrebreather mask 10-15 L/min
   - If inadequate VT, consider BVM ventilation with 100% Oxygen
6. Once Patient haemodynamically stable and has reliable oximetry reading
   - Titrate O₂ flow to SpO₂ of 92 – 96%
Calculation of oxygen requirement with transport time (considering Type D Oxygen Cylinder-1500 Liter)

<table>
<thead>
<tr>
<th>Type of device</th>
<th>Oxygen delivered by device (per minute)</th>
<th>Oxygen delivered by device (per hour)</th>
<th>Support time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal cannulae</td>
<td>5 Litre</td>
<td>300 Litre</td>
<td>Five hours</td>
</tr>
<tr>
<td>Face mask</td>
<td>10 Litre</td>
<td>600 Litre</td>
<td>Two and half hours</td>
</tr>
<tr>
<td>NRB mask</td>
<td>15 Litre</td>
<td>900 Litre</td>
<td>Around One and half hours</td>
</tr>
</tbody>
</table>

Step 6: Referred to in any appropriate health facility where higher oxygen storage system is available

<table>
<thead>
<tr>
<th>Condition of patient</th>
<th>Oxygenation procedure</th>
<th>Target</th>
<th>Preferred source</th>
<th>Preferred device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Referred to District Hospital/ MCH and condition is deteriorating</td>
<td>Venturi Mask: up to 15 LPM and provide up to 60% FiO₂ or Partial rebreather mask: up to 15 LPM and provide up to 70% FiO₂ or Nonrebreather mask: up to 15 LPM and provide up to 95% FiO₂</td>
<td>SpO₂ 92% to 96% with the minimum FiO₂.</td>
<td>Central gas line or Large cylinder at District Hospital/ MCH/ in any appropriate health facility</td>
<td>Venturi Mask or Partial rebreather mask or Nonrebreather mask</td>
</tr>
</tbody>
</table>
### Step 7: If no improvement in oxygenation

<table>
<thead>
<tr>
<th>Condition of patient</th>
<th>Oxygenation procedure</th>
<th>Target</th>
<th>Preferred source</th>
<th>Preferred device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe disease SPO₂ &lt; 90</td>
<td>1. HFNC should be preferable in ICU settings and should only be used in the presence of trained person. HFNC can provide up to 100% FiO₂ with 60L/min flow. Increased risk of aerosolization. Need frequent adjustment. Can not be used for prolonged time and improve filtration must be followed. Indicated for hypoxic respiratory failure, COPD exacerbation and acute cardiogenic pulmonary edema. Or CPAP/BiPAP via oronasal mask. CPAP can reduce work of breathing and improve oxygenation, while bilevel positive airway pressure (BiPAP) generally improves ventilation and can improve tidal volumes. CPAP/BiPAP should be considered in patients who have failed by high-flow nasal cannula or if high-flow nasal cannula is not available and those who don’t prefer to intubate. 2. Patients who remain hypoxemic despite use of oxygen, HFNO, or NIV, and who do not exhibit clear signs of respiratory distress; this however requires close monitoring and clear failure and escalation criteria. Prone positioning for 12–16 hours in case of refractory hypoxemia (PaO₂/FiO₂ &lt; 150 mmHg, FiO₂ ≥ 0.6, PEEP ≥ 10 cmH₂O). 3. Monitor SpO₂, Consciousness, Respiratory rate, Pulse and Blood pressure.</td>
<td>SpO₂ 92% to 96% with the minimum FiO₂.</td>
<td>1. For HFNC need central oxygen line with 4 bar pressures 2. PSA or VSA Oxygen Plant Noninvasive ventilation (BiPAP and CPAP) can be used with any oxygen source with backup battery</td>
<td>High flow nasal cannula/non invasive ventilation</td>
</tr>
</tbody>
</table>

27
## Step 8: If no improvement in oxygenation

<table>
<thead>
<tr>
<th>Condition of patient</th>
<th>Oxygenation procedure</th>
<th>Target</th>
<th>Preferred source</th>
<th>Preferred device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indications of tracheal intubation and mechanical ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>➢ Signs of impending respiratory failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>➢ Rapid progression of disease over hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>➢ Lack of improvement on &gt;40L/min of high flow oxygen and FiO₂ &gt;0.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>➢ Increasing work of breathing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>➢ Worsening mental status</td>
<td></td>
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</tr>
<tr>
<td>➢ Arterial pH &lt; 7.3 with PaCO₂ &gt;50</td>
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<td></td>
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</tr>
<tr>
<td>➢ Hemodynamic instability</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>➢ Multiorgan organ failure</td>
<td></td>
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<tr>
<td>Ventilator setup for COVID 19 patients with ARDS</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Low tidal volume ventilation strategy:</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>➢ AC with TV target 6 ml/kg BW (range 4 to 8 ml/kg BW)</td>
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</tr>
<tr>
<td>➢ RR 12 to 25 breaths/min</td>
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</tr>
<tr>
<td>➢ PEEP: PEEP 5 to 20 cm H₂O.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>➢ FiO₂: titrate oxygen to target PaO₂ 55 to 80 mmHg, SpO₂ 90 to 96 for most patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>➢ Plateau pressure &lt; 30 cmH₂O</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitor SpO₂, Consciousness, Respiratory rate, Pulse and Blood pressure</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SpO₂ 92% to 96% with the minimum FiO₂.</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. For HFNC need central oxygen line with 4 bar pressures</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. PSA or VSA Oxygen Plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Non invasive ventilation (BiPAP and CPAP) can be used with any oxygen source with backup battery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High flow nasal cannula/Noninvasive ventilation</td>
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</tbody>
</table>
**Step 6:** Referred to in any appropriate health facility where higher oxygen storage system is available.

**Extubation and weaning**

- Patients are often ready for extubation while they remain infectious. As extubation is frequently associated with some coughing, it is considered an aerosol-generating procedure.

- For weaning use closed systems rather using a T-piece trial for spontaneous breathing trials (SBT).

- To reduce the risk of reintubation following extubation due to respiratory failure, cuff leak test (CLT) should be performed if clinical suspicion for upper airway edema is high (eg, fluid overload) or the presence of risk factors for post extubation stridor (eg, prolonged intubation ≥6 days, age >80 years, large endotracheal tube, traumatic intubation).

- As there is potential risk of aerosolization during cuff leak test, it should be preferentially done in an airborne isolation room. Administer glucocorticoids (eg, methylprednisolone 20 mg intravenously every four hours for a total of four doses) to most patients with COVID-19 before extubation and only extubate those in whom the CLT is positive after glucocorticoids.

- Perform extubation in an airborne isolation room.

- Respiratory therapists and others in the room during extubation should adhere to airborne precautions including N95 masks with eye protection or equivalent. Some experts use medications to decrease coughing (eg, lidocaine via ETT, low-dose opioid bolus, dexmedetomidine, remifentanil if available), although data to support the routine use of anti-tussive are limited.

- Drape the patient’s chest and face with a plastic cover to provide barrier protection between the patient and the operator.

- After balloon deflation, extra care should be taken during extubation to keep the inline suction catheter engaged during cuff deletion and to have another handheld suction catheter available for the removal of pharyngeal and oral sections.

- The endotracheal tube should be removed as smoothly as is feasible during inspiration and disposed of into a biohazard plastic bag bundled together with the ventilator tubing, the plastic drape, and tape/ETT holders, and inline suction catheter. The bag is sealed and disposed of immediately.

**Discontinuation of oxygen therapy**

1. Oxygen should be reduced in stable patients with satisfactory oxygen saturation.
2. Plan of reducing FIO2 to at least 40%.
3. Gradually change the device.
Awake prone positioning

Awake prone positioning in non-intubated patients with COVID-19 pneumonia:
- Improves oxygenation
- Lowers intubation rate.

Appropriate candidates for awake prone positioning: Those who are able to adjust their position independently and tolerate lying prone.

Contraindications
- Who are in respiratory distress
- Who require immediate intubation
- Hemodynamically unstable patients
- Patients who recently had abdominal surgery
- Who have an unstable spine

Steps of Awake prone positioning:
Patient will maintain each step for 30 minutes to 2 hours and this cycle will continue. Monitor pulse oximeter 15 minutes after each step to make sure that oxygen saturation.

---

**Awake Repositioning/Proning**

1. Prone
2. Right lateral recumbent
3. Sitting up 60-90 degrees
4. Left lateral recumbent

---
Other

General Management

Sedation and analgesia

• Requirements for sedation and analgesia appear high in mechanically ventilated patients with COVID-19 and that heavy use of sedatives and analgesic medication is required for ventilator synchrony.
• Target a Richmond Agitation-Sedation Scale (RASS) of -1 to -2 and in patients with ventilator desynchrony, a RASS of -2 to -3.
• RASS of -4 to -5 are targeted in those with severe desynchrony and those requiring neuromuscular blockade.

Monitoring in ICU (Daily management of COVID-19 patient)

• Check vital signs and SpO2 regularly
• Do routine investigations like CBC, CXR, RFT, LFT, ECG regularly
• ECHO if cardiac involvement is suspected
• CT chest and CTPA if needed
• Ensure adequate sedation if patient is on mechanical ventilator: use Fentanyl / propofol /midazolam for sedation
• Use neuromuscular blocking agents if needed if patient is on mechanical ventilator
• Monitor ET displacement or ETCO2 monitoring & CVC in place during prone ventilation
• Check special laboratory markers like D-dimer, LDH, Ferritin, Procalcitonin, Lactate, Troponin I & Pro-BNP regularly

Oxygen toxicity or oxygen poisoning

Oxygen is vital to sustain life. However, breathing oxygen at higher-than-normal partial pressure leads to hyperoxia and can cause oxygen toxicity or oxygen poisoning. The clinical settings in which oxygen toxicity occurs is predominantly divided into two groups; one in which the patient is exposed to very high concentrations of oxygen for a short duration, and the second where the patient is exposed to lower concentrations of oxygen but for a longer duration. These two cases can result in acute and chronic oxygen toxicity, respectively. The acute toxicity manifests generally with central nervous system (CNS) effects, while chronic toxicity has mainly pulmonary effects. Severe cases of oxygen toxicity can lead to cell damage and death. Those at particular risk for oxygen toxicity include hyperbaric oxygen therapy patients, patients exposed to prolonged high levels of oxygen, premature infants, and underwater divers (14).
**Oxygen therapy for children**

Fewer children than adults have been affected by the COVID-19 pandemic, and the clinical manifestations are distinct from those of adults. Some children particularly those with acute or chronic co-morbidities are likely to develop critical illness.

**Indications**

Any child with a SPO₂ < 90% should receive oxygen (15)

### Oxygen delivery methods in children and infants

<table>
<thead>
<tr>
<th>Method</th>
<th>Maximum O₂ flow (LPM)</th>
<th>Actual inspired fraction (%) from 1LPM by a 5 kg infant</th>
<th>PEEP</th>
<th>Humidification</th>
<th>Risk for hypercapnoea</th>
<th>Risk for airway obstruction</th>
<th>Equipment required</th>
<th>Nursing demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal prongs</td>
<td>Neonates: 0.5 - 1</td>
<td></td>
<td></td>
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<td>Infants: 2</td>
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<td>Preschool: 4</td>
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<td>School: 6</td>
<td>45</td>
<td>Minimal</td>
<td>Not required</td>
<td>No</td>
<td>Minimal</td>
<td>Nasal prongs</td>
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<tr>
<td>Nasal catheter</td>
<td>Neonates: 0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Infants: 1</td>
<td>50</td>
<td>+</td>
<td>Not required</td>
<td>No</td>
<td>+</td>
<td>8-F catheter</td>
<td>++</td>
</tr>
<tr>
<td>Nasopharyngeal catheter</td>
<td>Neonates: 0.5</td>
<td></td>
<td></td>
<td></td>
<td>++</td>
<td></td>
<td></td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>Infants: 1</td>
<td>55</td>
<td>++</td>
<td>Required</td>
<td>No</td>
<td></td>
<td>8-F catheter, humidifier</td>
<td>+++</td>
</tr>
<tr>
<td>Head box, facemask, incubator, tent</td>
<td>Head box: 2–3 LPM</td>
<td>Nil</td>
<td>Not required</td>
<td>Yes</td>
<td>No</td>
<td>Head box, facemask</td>
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</tbody>
</table>

F, French; PEEP, positive end expiratory pressure

Higher flow rates without effective humidification may cause drying of nasal mucosa, with associated bleeding and airway obstruction (16).
Monitoring oxygen therapy
Pulse oximetry should be available to all healthcare staff managing patients receiving oxygen therapy and they should be trained in their use. Clinicians should be aware that pulse oximetry gives no information about the PCO2 or pH and most pulse oximeters are unreliable when a patient’s SpO2 falls below about 85%. Pulse oximetry is dependent on pulsatile flow, and it may not be possible to achieve a satisfactory oximeter reading in patients with cold hands, especially those with severe Raynaud’s phenomenon due to collagen vascular diseases (which may also cause hypoxic lung disease). The readings may also be affected by shock, skin pigmentation, nail varnish, etc. It is essential to record the oxygen delivery system alongside the oximetry result. All measurements of oxygen saturation should be recorded in the observation chart along with the code for the oxygen delivery system that is being used.

Retrieved from British Thoracic Society guideline for emergency oxygen use in adult patients (17)
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Step 6: Referred to in any appropriate health facility where higher oxygen storage system is available.

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Reference
সহযোগিতায়: ইউএসএআইডির 'মামলী' মাহুত ও নবজাতক রক্ষণ উন্নয়ন প্রকল্প: ইমাজিং রেপল্ড টু কোভিড-১৯ প্যাডমিক, ২০২২