INDIAN MEDICAL ASSOCIATION

HOSPITAL BOARD OF INDIA

IMA HEADQUARTERS, NEW DELHI

MEDICAL OXYGEN – HOPE OF LIFE

Review Article

India is reeling under the clutches of the SARS-COV-2 virus in its second wave and struggling with determination to face the challenge .Augmentation of the infrastructure ,materials ,man power and mass vaccinations are the strategy adopted by Government with the support of all stake holders . The devastation that we see around us today caused by the second wave of COVID-19 in the country, is not just because of the rates of contagion and the virulence of the disease, but also — and perhaps, more significantly — because of the crunch in life-saving resources. Especially something we have always taken for granted — Oxygen.

One of the formidable challenge is to make the availability of oxygen for the affected patients who are in acute need of the oxygen to overcome the disease onslaught . The government had diverted all the oxygen produced ,including those used as industrial use for the disposal of medical needs . India had, a production capacity of approximately 7200 MT. However the production capacity is not spread evenly. Eight states, Maharashtra, Gujarat, Jharkhand, Odisha, Tamil Nadu, Karnataka, Kerala and West Bengal account for nearly 80% of India's total oxygen production.The production capacity is augmented to nearly 10000 MT now.

The second wave of Covid-19 in India quickly went from being a healthcare crisis to a humanitarian crisis. Thousands of patients gasped for breath in the absence of enough high-flow oxygen, which is an effective treatment for the disease. Oxygen consumption is directly proportional to the number of cases. The pre-pandemic requirement for medical oxygen in India was about 700 tons a day. In wave one, the demand went up about 3,000 tons a day and in wave two, it's now 8,000 tons a day.

Oxygen is produced as liquid oxygen at minus 183 degrees centigrade and it's stored in specialised containers. There are only 1,170 cryogenic transportation tankers available in India to move liquid oxygen. India has only 70 oxygen plants and these 1,170 containers were moving the entire production of oxygen. In the pre second wave out of 100 tankers only 15 were going to medical, and 85 were going to industry. So majority of oxygen plants are located in areas very close to industry, and not in the most densely populated areas where there are hospitals. Now the major concern is to make these liquid oxygen reach the end users in the remote corner of the country by the tankers and then make it available to them in cylinderS .Hence the focus need too be on

- Procuring more cryogenic containers to transport liquid oxygen to the liquid storage tanks. We need to import more of cryogenic tankers from outside as the production capacity in India is less.
- Asking Industries with captive oxygen manufacturing capability to manufacture oxygen for medical requirements.
- Attempting to convert Nitrogen manufacturing facilities into Oxygen manufacturing facilities — this presents its own technical challenges and additional equipment.
- Ramping up the overall oxygen production in the country to cope with this demand explosion. But this won't be easy, as the issue will be on what to do with the excess capacity once the crisis is behind us.
- Ramping up oxygen cylinder manufacturing capacity — this again does not lend itself to quick upscaling
- Enhancing the production or import of oxygen concentrators.
- Initiating steps to install more PSP units in the hospital complex.

To give an overview of the need of oxygen, sources for getting it adequately at the door steeps ,procedures to conserve oxygen judicious use and alternative method to enhance oxygenations are need of the hour to understand at this crucial moment .I am glad the Hospital Board of India is rising to the occasion and releasing this article to update the know how on the oxygen in the management of COVID-19 .On behalf of IMA HQ we congratulate the team HBI.

Dr. J. A. Jayalal
National President

High demand of medical oxygen during the covid-19 pandemic makes it necessary to address the issues of availability of good quality, affordable, safe and appropriate oxygen systems in hospitals. The purpose of this document is to provide information on specifications of range of oxygen supply equipment & rationale, safe use guidelines.

Medical Oxygen

Medical oxygen is high-purity oxygen, which is used for medical treatments and developed for use in the human body. Medical oxygen is an important supplement in the management of various conditions or procedures. Medical oxygen cylinders contain a high purity of oxygen gas. Industrial oxygen is used in industrial plants of which the purity levels are not appropriate for human use. Medical oxygen is used in hospitals, operation theatres during anesthesia, during resuscitation in medical emergencies, as support to patients either through nasal prongs or invasive/non-invasive ventilation. The normal air contains 21% of oxygen.

Oxygen has emerged as of primary importance during the current Covid Pandemic. Happy Hypoxic or desaturating covid patients need oxygen in a bigger amount. Nasal prongs, HFNO, BiPAP, Ventilation are the commonly used modalities where supplementary medical oxygen is needed. Medical oxygen used in hospitals is highly concentrated and can be obtained in several ways. Various types of oxygen cylinders can provide oxygen at bed. Bigger oxygen cylinders & liquid oxygen cylinders provide oxygen through the central oxygen system from the oxygen station through a manifold & valves. The Oxygen Generator system provides oxygen through a collection module, control valves with central oxygen pipeline. Any oxygen supply system should be designed to provide a safe, cost-effective and convenient delivery of oxygen at the point-of-use. A hospital oxygen system should have a backup facility to address the emergency arising out of failure of the primary source of supply. The oxygen production and transport mechanism should be robust for uninterrupted supply of medical oxygen.

Oxygen Production

This is an area about which we are usually unaware of. It is better that we all know the basics of it to understand the smooth supply & careful running of the oxygen system in hospitals.

One of the processes is by separating atmospheric oxygen from air. It is commonly used for commercial production of large volumes of oxygen by fractional distillation of air. It is supplied as a liquid oxygen either cryogenic liquid system or in smaller oxygen units.

Another mode for small scale oxygen generation from the air itself is by a machine called an oxygen concentrator which is a self-contained, electrically powered medical device designed to concentrate oxygen from ambient air. Oxygen Concentrators are portable devices which separate oxygen from air. It compresses oxygen & filters other gases in the air through sieve beds. Oxygen from oxygen concentrators have 95% purity. Pressures can be adjusted with valves in oxygen concentrators.

Image 1 : Air fractional distillation Plant

Concentrators supply on an average 5 liters oxygen per minute. So, patients with milder requirements can be treated with these devices.

Image 2 : oxygen concentrator

A third method of oxygen generation is through pressure swing absorption (PSA) plants. A PSA oxygen plant absorbs nitrogen from ambient air to concentrate oxygen for supply to hospitals.

The supply chain - Transport of medical oxygen

Oxygen is stored either in cylinders and tanks in a gaseous form under pressure (Cylinders) or in cryogenic tanks at very low temperatures in liquid form (Dura). All hospitals rely upon cylinders or a supply of liquid oxygen. The transport of oxygen

Image 3 : PSA oxygen plant

cylinders or liquid oxygen dura play an important role. Primary transport of oxygen from source to distribution system has various modes. Containers, trains & air transportation are being subjected to use owing to severe scarcity & high demands. Secondary distribution system to the hospitals is another challenge. Inadequate transport vehicles, refilling capable tankers lack in availability all across. This is reflecting in the form of delay in actual delivery of medical oxygen. Medical oxygen is an essential public health commodity and any impediment in the supplies of Medical Oxygen in the country may critically impact the management of patients suffering from COVID-19 disease. Distribution system needs to brace up to match the increased demands. Repetitive delivery is needed in many healthcare facilities owing to high patient numbers. This is increasing stress on the supply chain. Diverting an industrial oxygen to medical use shall prove adequate, provided the transportation backs up the system.

The bird's eye view of transportation with diverting industrial sources of oxygen may appear satisfactory. But the ground level management is not reaching its requisite goal to transport adequate medical oxygen & that too in real time. Visionary & qualitative administrative management with vigilance back up is must while supplying the medical oxygen to hospitals.

Industrial & Medical Oxygen

Oxygen is used in industries for combustion, oxidation, cutting and various chemical reactions. The difference is that purity levels of industrial oxygen are not at par with medical oxygen. There can be impurities from the containers of industrial oxygen. Medical oxygen cylinders should also be free of contaminants. The industrial cylinders should be thoroughly cleaned before use. Medical oxygen cylinders strictly control the presence of water to prevent the rusting process inside the cylinder. Medical oxygen is no odor oxygen.

Medical Oxygen Cylinders

Medical Oxygen is stored as a compressed gas in cylinders. Oxygen cylinder size varies as per the capacity to hold water & amount of compressed gas or liquid oxygen, ranging from portable 1 liter to Jumbo cylinders. The cylinders are produced in various sizes designated by a capital letter code. Homecare domiciliary oxygen cylinders are smaller though. These cylinders are identified according to color. For color code identification, all oxygen cylinders have their shoulders painted with white color. Commonly used oxygen cylinder types are B, C, D, E & G. In India, commonly used oxygen cylinders in hospitals are B type, D type & Dura LMO Cylinders. A type oxygen cylinders are for anesthesia purpose.

B Type & D Type oxygen cylinders.

B Type are used as bed-side cylinders

D Type are used for Central Oxygen Supply system.

Approximate Specifications of Oxygen Cylinders

O2 Cylinder	B Type	D Type	Dura - 200	Dura - 208	Dura - 247
Type	Ward Cylinder	Jumbo	LMO	LMO	LMO
Capacity	1320 L Compressed Gas	7000 L Compressed Gas	1,67,000 Liters	1,74,000 Liters	2,10,000 Liters
Wastage – Approximate 15-20%					

Duration for which Cylinders will last as per oxygen use. (after excluding wastage)

1 L/min	17 hours	95 hours	-	-	-
2 L/min	8.5 hours	50 hours	-	-	-
5 L/min	3.5 hours	20 hours	-	-	-
8 L/min	2 hours	12 hours	350 hours	365 hours	437 hours
10 L/min	1.7 hours	9.5 hours	275 hours	290 hours	350 hours
15 L/min	1 hour	6 hours	185 hours	195 hours	233 hours
This is the approximate time that cylinder will last for 1 bed. Time may shorten due to leakage or if the cylinder is not completely filled.					

Oxygen Dura Cylinder

Dura Cylinders - LIQUID MEDICAL OXYGEN (LMO) : Site Requirements

LMO site location should be fixed in the hospital. The site should be located inside a compound wall preferably, be easily accessible. Flammable materials must be away from LMO. The compound part directly in front of the fill connection or the replacement area must be approachable. The unit should be fitted with standard accessories and should undergo routine standard inspection. The responsibility of safe and secured maintenance of the entire infrastructure should equally belong to the LMO supplier.

Safe oxygen supply

Primary supply

The oxygen supply system which supplies the central pipeline distribution system. This system is always on while patients are on oxygen. Hospitals should use this system as the first system. Dedicate Manifold should be used for the primary supply system.

Secondary supply

The oxygen supply system which supplies the pipeline distribution system in the event of failure of the primary supply system. Either part of primary manifold or a separate manifold is used for secondary system.

Reserve source of supply

The oxygen supply system which supplies the complete or part of the central pipeline distribution system in the event of failure or exhaustion of both the primary and secondary sources of supply systems. Reserve source may have additional bedside B type cylinders or rack of reserve jumbo cylinders.

Manifold & Oxygen Gas Station

Manifold is a device for connecting the outlets of one or more cylinders. An oxygen manifold system is essential in providing a constant source of oxygen. Manifold system provides a primary flow of gas to the patient through regulators, gauges and relief valves. The room where Gas Control Panels are kept is known as Manifold Room or Manifold Station. It is preferable that this gas station is located on the ground floor and should have easy access to delivery. Avoid installing liquid oxygen cylinders in an indoor environment or near drains or pits. The control equipment should be protected. Oxygen cylinder storage should be preferably separated from the central vacuum and medical air compressor plant.

The alarm system

Alarm system requirements should have important alarm signals. It should alarm for the minimum liquid oxygen or gas level in the dura or cylinders. Changeover from primary to secondary supplies or to the reserve supply should be available. Pressure changes are in-built part of the alarm system. If an audible alarm can be silenced, it should have the back up for automatically setting in a new alarm. Alarm system is the most important part of the oxygen supply system & should be tested periodically. Master alarm should be located in an area where 24 hours manpower is present.

Oxygen System Audit

The oxygen supply system has to run round the clock. Its failure can be fatal if not restored at the earliest. Awareness is must regarding the safe & continuous oxygen supply unit. The important segments of the entire central oxygen system are the manifold room or gas station, bends in copper pipes, valves and end use connectors with outlet sockets. These are the key areas where leakage occurs. Manifold, valves can have issues with actual delivery or low-pressure delivery. The installation needs to be tested and verified at timely intervals. Formulating Standard Operating Procedures in the hospitals with designated staff & documentation is must. Maintaining log books helps in avoiding loss or lack of information to be carried from one duty shift to the next. Keeping all the equipment under Annual Maintenance Contract is a must. 24 x 7 manning by trained staff & Periodic training of manifold & gas station is must. Daily checking of contingency plans will save hospitals from emergency accidents.

OXYGEN USE

Oxygen use is a flashpoint in the current scenario. Covid-19 patients need uninterrupted & adequate oxygen supply. Hypoxia refers to low blood oxygen levels. Pulse oximetry is the standard available method for detecting Hypoxia. Hypoxia or need for oxygen should be clinically diagnosed. Basic examinations of Respiratory Rate, Efforts of breathing, Respiratory drive with associated symptoms give fair idea about hypoxia & need for supplementary oxygen. Hypoxia is common in Covid-19 patients. Pulse oximeter gives us an idea of hypoxia.

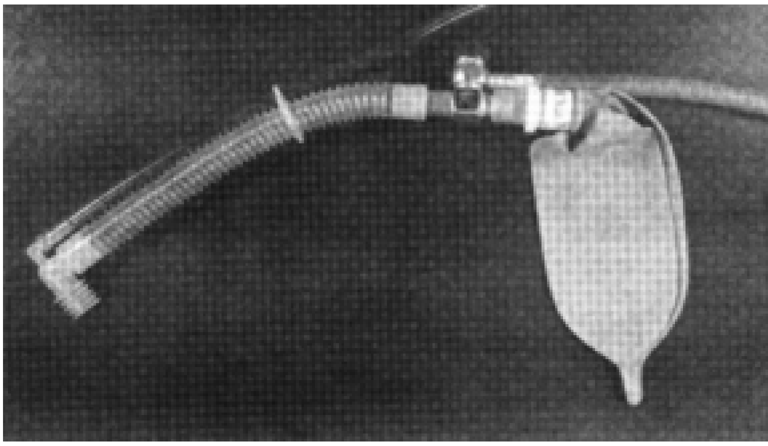
Nail polish/paint can make it difficult for the oximeter to accurately detect the light. It will usually cause the SpO2 reading to be lower than it really is. Strong overhead lights (e.g., theatre lights) shining on an oximeter can result in a higher SpO2 reading.

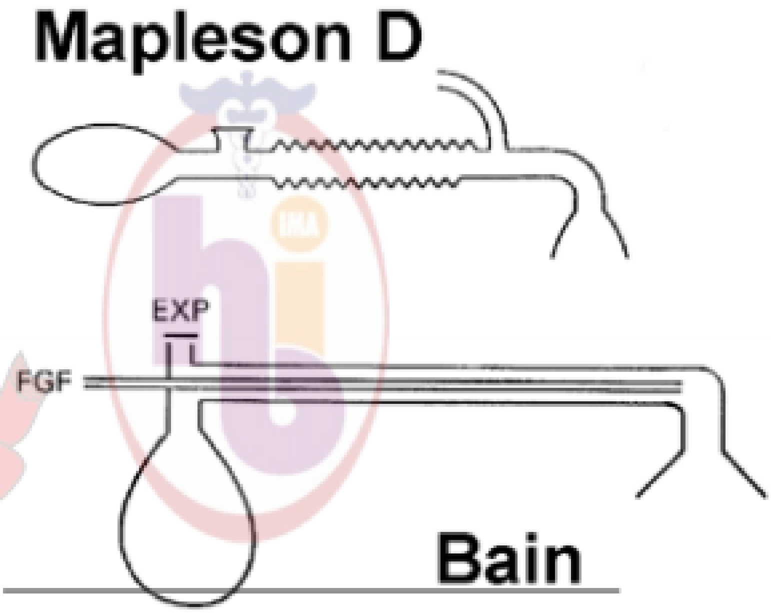
Safe and effective use of oxygen requires prompt and accurate detection of hypoxia and early administration of oxygen. Simultaneously appropriate clinical evaluation and management of the underlying condition is must. Start patient on 1-2 L/minute. Then titrate the flow rate to maintain SpO2 in the target range.

While the patient is on oxygen, monitor the oxygen saturation by pulse oximeter. If hypo saturation persists, position of nasal prongs & blockage, if any, in nasal prongs should be checked repeatedly. Leaks in the oxygen delivery system should be checked. Check for correct oxygen flow rate. Check for nasal & respiratory passages for Airway obstruction by mucus. The prongs should be removed & cleaned at least twice a day.

Oxygen should be administered via nasal prong cannulas. Where nasal prongs are not available, nasal catheters can be used. This choice is based on safety, tolerability, and effectiveness. Nasal prongs are very safe, well tolerated, and provide consistent concentrations of oxygen. Nasal or Nasopharyngeal catheters achieve higher oxygen concentration but require humidification. Special attention for insertion and monitoring is needed for nasopharyngeal catheter use as it can irritate the airway causing increased secretions. Nasal catheters are inserted into the nostrils & nasopharynx. Nasal catheters achieve similar oxygen concentration as that of nasal prongs, but similarly can irritate the nasal airway causing nasal secretions.

Oxygen Masks, NRB masks are other modalities for use. Face masks achieve only low oxygen concentration make feeding difficult, and have a risk of carbon dioxide retention. Non-rebreathing ((Mapleson) (NRB) circuits lack unidirectional valves.





The Bain circuit is a coaxial with the same components, but the fresh gas flow tubing is directed within the inspiratory limb, with fresh gas entering the circuit near the mask. Fresh gas flow requirements are similar to other NRB circuits. The Bain circuit has been shown to add more heat and humidity to inhaled gases than other Mapleson circuits. A unique hazard of the use of the Bain circuit is occult disconnection or kinking of the inner, fresh gas delivery hose. If this occurs, the entire corrugated limb becomes dead space. This results in respiratory acidosis which is unresponsive to increased minute ventilation.

The commonest problem with all delivery devices is obstruction from airway secretions. Therefore, nurses should regularly check the delivery system devices and clean or change them if necessary.

Oxygen Sources

Three main sources of oxygen are–

- Oxygen cylinders
- Oxygen concentrators
- Oxygen generator

For hospitals, the choice of oxygen system will depend on

- How much oxygen is likely to be needed?
- Reliability of current electricity supply
- Existing oxygen infrastructure (e.g., oxygen piping into hospitals)
- Commercial procurement issues.

Oxygen Generators

Oxygen generators are large oxygen concentrators to supply large hospitals and can generate the oxygen equivalent to 2 to 50 dura cylinders of oxygen per day. They use the same technology as oxygen concentrators and require reliable electricity supply. The oxygen produced can be piped into the hospital or used to fill cylinders to transport around the area to other hospitals. Oxygen generators are built to order and trained technicians are essential for running them. Hospitals can save money with oxygen generator as the cost of buying liquid oxygen or handling cylinders can be omitted

The oxygen generator systems are designed for continuous production of medical oxygen. Local oxygen generation avoids dependence on third parties for oxygen supply. The oxygen generator plants are in varying capacities to generate oxygen. It employs a technology that absorbs nitrogen from ambient air to concentrate oxygen for supply to hospitals or the industry, as the case may be. The oxygen thus generated can be supplied straight to the site of use either through a dedicated pipeline or compressed to fill cylinders. The oxygen generator plants have an initial set-up cost, which depends on the capacity of the plant. But that is more than offset by the savings in monthly oxygen bills. A plant that can supply 25 cylinders worth of gas equivalent to 1 LMO dura cylinder per day costs about Rs 30 lakhs to set up and can be completed in 3-4 weeks. Large PSA plants with capacity of 8-10 dura cylinders cost nearly 1 Cr. For initial set up.

OXYGEN GENERATION PLANT

Oxygen Concentrators

Oxygen concentrators are small machines that convert ambient air into oxygen at 5-10 L/min. The

initial main cost is for equipment which ranges from 50 thousand to 1 lac rupees. The requirement of a reliable electricity supply is an additional infrastructure cost to facilities where electricity supply is lacking or unreliable. Concentrators also have internal and external filters to remove particles and environmental pathogens and ensure the air produced is clean. These filters need regular cleaning to prevent overheating and concentrator failure.

Routine check list for safe oxygen system

Date / Time	Manifold	Valves	End points	Alarm	Connectors & Masks	Tubings	Monitors & Probes	Signature
xx / xx / xxxx								

Routine check list of oxygen use

Patients	Oxygen per minute	Mode	Average Saturation	Oxygen	Weaning if any	Remarks	Desaturation	Signature
1	2	Prongs						
2	5	Prongs						
3	8	NRBM						
4	2	Prongs						
5	15	HFNO						
6	10	NRBM						
Total	42 L/min	Per Hour Consumption				Per Day Consumption		
Available Oxygen in Hospital								
Next Order for Supply						Ordered by Whom		
Expected Delivery								

Hospitals should use the above charts for routine documentation. Regular use of these charts shall prevent the emergency situations & help in an uninterrupted, rationale supply of medical oxygen.

Oxygen Use & Critical Care Guidelines

COVID-19 typically shows its critical symptoms approximately 1 week after the onset of illness. Common symptoms are breathlessness which patients do not notice many times. Dyspnea is sometimes accompanied by hypoxia. Patients with severe disease & respiratory symptoms require oxygen and should be well monitored for deterioration as few patients progress to acute respiratory distress syndrome (ARDS). This is a typical surge in the inflammatory response in Covid-19. Below are the recommendations for safe & rational use of oxygen.

Delivery Devices for Oxygen Therapy

The oxygen delivery devices are grouped into two:

- Low flow oxygen delivery system
- High flow oxygen delivery system

Low flow oxygen delivery systems are those that the exact fraction of oxygen in the inspired air will be based on the patient's anatomic reservoir and minute ventilation.

Low flow oxygen delivery systems are:

- Nasal Cannula
- Simple Mask
- Partial Rebreather
- Nonrebreather

High flow oxygen delivery systems deliver oxygen at flow rates that exceed patient demand.

- Venturi Masks
- Aerosol masks
- Tracheostomy collars
- T-tube adapters
- Face tents/hoods

1. Patients with COVID-19 with mild hypoxia need conventional oxygen therapy. It is usually delivered with nasal prongs, nasal catheters.
2. Patients with acute hypoxic respiratory failure & not coping up with supportive conventional oxygen therapy need further support. As

Curved / Flared prongs
Combines the benefits of both the above designs

Straight prongs

Curved prongs :
Improved anatomical fir

Flared prongs :
Slows down the flow of oxygen

Curved prongs with ear guards
Inproved anatomical fit and patient comfort

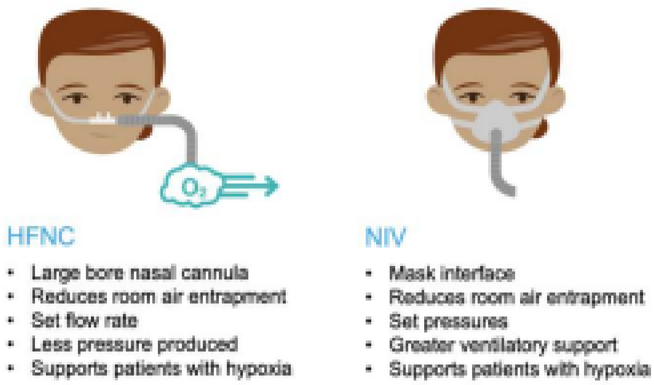
conventional oxygen therapy may be insufficient to meet the oxygen needs of the patient, further options of oxygen therapy with enhanced respiratory support include HFNC (High Flow Nasal Cannula Oxygen), NIPPV (Non-invasive Positive Pressure Ventilation), Endotracheal intubation and Invasive Mechanical Ventilation or Extracorporeal Membrane Oxygenation (ECMO) in rare cases.

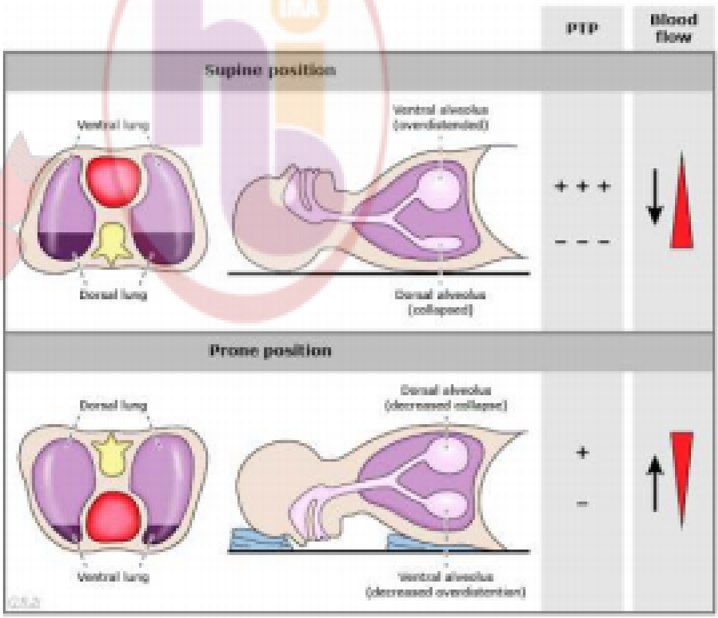
3. For COVID-19 patients with acute hypoxic respiratory failure with conventional oxygen therapy, the High Flow Nasal Cannula (HFNC) oxygen should be used.

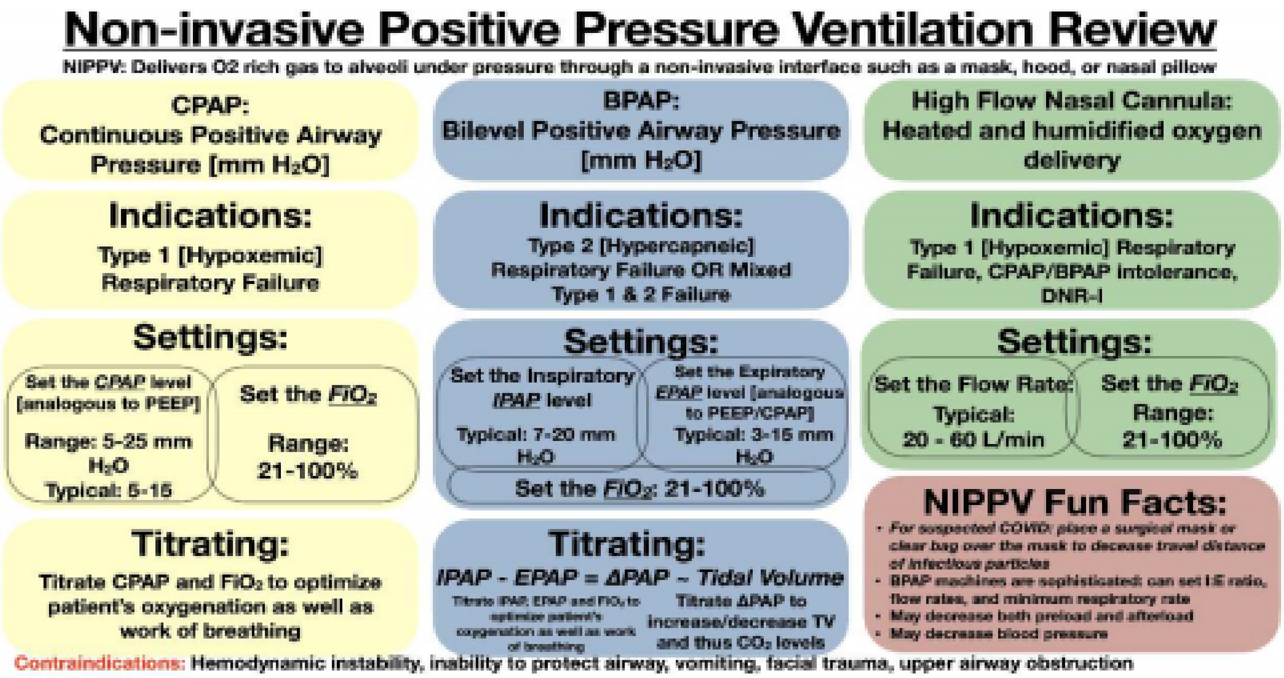
High Flow Nasal Cannula (HFNC)

High Flow Nasal Cannula (HFNC)

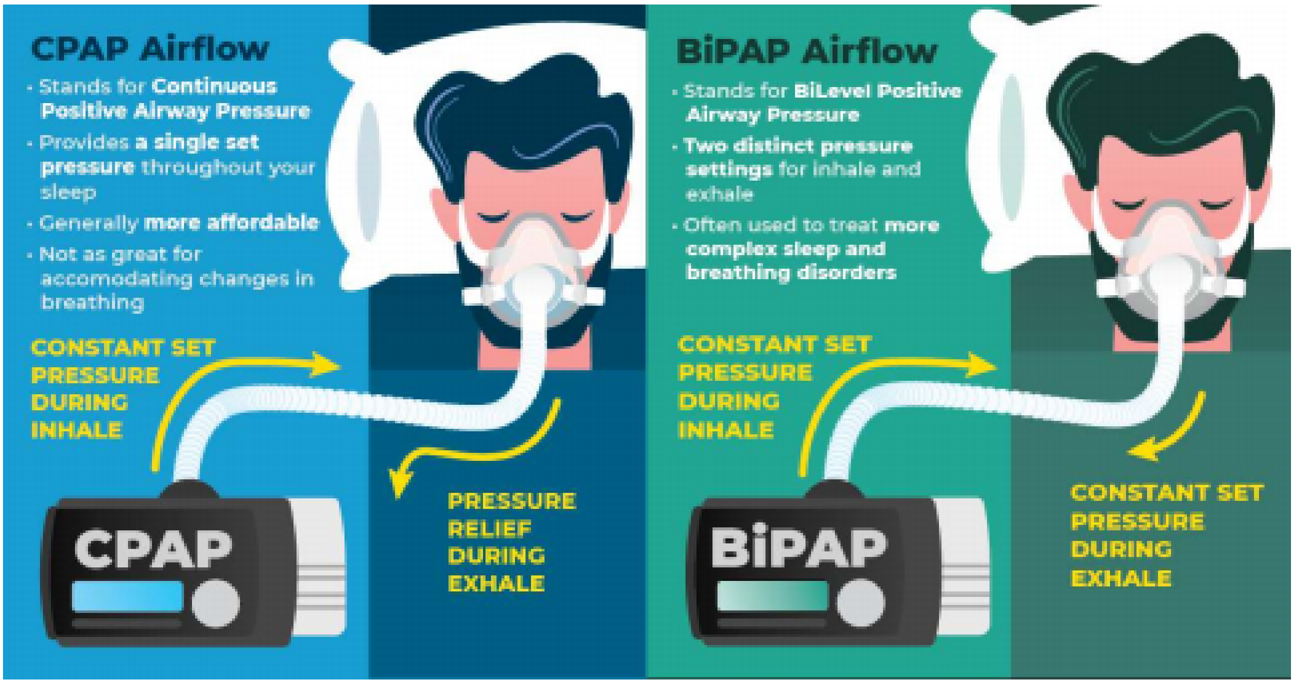
4. Well monitored Noninvasive Positive Pressure Ventilation should be used for patients with COVID-19 in acute hypoxemic respiratory failure if HFNC is not available.







Non-invasive Positive Pressure Ventilation Review
NIPPV: Delivers O2 rich gas to alveoli under pressure through a non-invasive interface such as a mask, hood, or nasal pillow
CPAP: Continuous Positive Airway Pressure [mm H_2O]
BPAP: Bilevel Positive Airway Pressure [mm H_2O]
High Flow Nasal Cannula: Heated and humidified oxygen delivery
Indications:
Type 1 [Hypoxemic] Respiratory Failure
Indications:
Type 2 [Hypercapneic] Respiratory Failure OR Mixed Type 1 & 2 Failure
Indications:
Type 1 [Hypoxemic] Respiratory Failure, CPAP/BPAP intolerance, DNR-I
Settings:
Set the CPAP level [analogous to PEEP]
Range: 5-25 mm H_2O
Typical: 5-15
Set the FiO_2
Range: 21-100%
Settings:
Set the Inspiratory IPAP level
Typical: 7-20 mm H_2O
Set the Expiratory EPAP level [analogous to PEEP/CPAP]
Typical: 3-15 mm H_2O
Set the FiO_2: 21-100%
Settings:
Set the Flow Rate:
Typical: 20 - 60 L/min
Set the FiO_2
Range: 21-100%
NIPPV Fun Facts:
For suspected COVID: place a surgical mask or clear bag over the mask to decease travel distance of infectious particles
BPAP machines are sophisticated: can set I:E ratio, flow rates, and minimum respiratory rate
May decrease both preload and afterload
May decrease blood pressure
Titrating:
Titrate CPAP and FiO_2 to optimize patient's oxygenation as well as work of breathing
Titrating:
IPAP - EPAP = ΔPAP ~ Tidal Volume
Titrate IPAP, EPAP and FiO_2 to optimize patient's oxygenation as well as work of breathing
Titrate ΔPAP to increase/decrease TV and thus CO_2 levels
Contraindications: Hemodynamic instability, inability to protect airway, vomiting, facial trauma, upper airway obstruction



CPAP Airflow
Stands for Continuous Positive Airway Pressure
Provides a single set pressure throughout your sleep
Generally more affordable
Not as great for accomodating changes in breathing
CONSTANT SET PRESSURE DURING INHALE
PRESSURE RELIEF DURING EXHALE
CPAP
BiPAP Airflow
Stands for BiLevel Positive Airway Pressure
Two distinct pressure settings for inhale and exhale
Often used to treat more complex sleep and breathing disorders
CONSTANT SET PRESSURE DURING INHALE
CONSTANT SET PRESSURE DURING EXHALE
BiPAP

BiPAP - NIPPV

of SpO2.

Endotracheal Intubation – Precautions

1. For clinicians treating COVID-19 the personal protection should be the priority. Use all the barrier precautions before the intubation procedure. Use proper donning and doffing. Use proper respiratory protection with a scientific N-95 mask, gloves, face shield, and PPE. Pay close attention to avoid self-contamination.
2. Practice appropriate hand hygiene before and after the procedure.
3. Limit the number of health care providers in the room where the patient is to be intubated.
4. Standard monitoring equipment, intubation instruments, drugs, ventilator, and suction apparatus should be ready & checked.
5. Try to use a visual guiding device if possible.
6. Intubate and confirm correct position of the tracheal tube.
7. All airway equipment must be decontaminated and disinfected according to guidelines before further use.
8. After removing protective gear, avoid touching hair or face before washing hands.

How to Save Medical Oxygen

In view of scarcity of medical oxygen, saving the available oxygen is the most important. Following few suggestions will help in saving the life savior gas.

1. Preventing leakages is the primary basic measure.
2. All regulators and knobs should be closed & be ensured so by staff.
3. Never allow patients, attendants to handle oxygen flow meters.
4. Strictly abide by indications for conventional oxygen therapy to avoid unnecessary use of oxygen.
5. Monitor improvement in clinical conditions & try for weaning in time.
6. Maintaining threshold oxygenation levels play important role in saving the oxygen.
7. Appoint a dedicated 'Oxygen Nurse' in charge to continuously monitor if any open valves or knobs are there and to close them. The dedicated staff also monitors any leakage & the oxygen station issues. Hospitals should designate an Oxygen Monitoring Nurse for each shift duty.
8. An optimal use of oxygen should be ensured both for better healthcare of the patient as well as to avoid the wastage of oxygen.
9. Any hospital falling short of oxygen should be helped by nearby institutes.
10. Identify capacity of hospital beds in proportion with the oxygen capacity of hospital. Over occupancy will create serious issue of oxygen scarcity in your hospital.
11. Patients with minimal requirements may be shifted to oxygen concentrators to save the medical oxygen from central supply to be used for moderate or severe cases.

Risks of Oxygen Therapy

It is prudent to understand the negative aspects as risks of oxygen therapy.

1. **Depression of ventilation/respiration**

   It is seen in COPD patients with chronic CO2 retention, who have hypoxic respiratory drive to breath. Increased oxygenation to normal can lose the hypercapnoeic stimulus to maintain ventilation, resulting in hypoventilation in these patients.

2. **Hyperbaric oxygen toxicity**

   Long term hyperbaric O2 therapy can lead to pulmonary, optic and central nervous system toxicity.

3. **Fire hazard**

   Oxygen enhances combustion. Least level of supplemental oxygen should be used during laser bronchoscopy to avoid intratracheal ignition.

4. **Absorption atelectasis**

   Given only pure oxygen results in the collapse of the dependent part of the lungs as it quickly taken up from the alveoli.

5. **Retinopathy of prematurity (ROP)**

   It usually occurs in low birth weight (LBW/VLBW) or very premature neonates. Optimal use & successive examination should be conducted to assess the ROP.

6. **Infection**

   Bacterial contamination associated with oxygen and humidification systems is a possible hazard & it should be prevented at every cot & dealt with fiercely.

7. **Pulmonary toxicity**

   Patients exposed to high oxygen levels for a prolonged period of time can develop lung damage. The extent of lung damage is dependent on FiO2 and duration of exposure. It starts with increased permeability of the capillaries with resultant edema, thickened membranes and finally to pulmonary fibrosis.

How to Prevent Infections Due to 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.

Oxygen should be administered cautiously. Some modalities of oxygen therapy have been shown to generate aerosols, which can increase severe acute respiratory infection transmission.

The lowest flow of oxygen should be used to maintain an adequate oxygen saturation for patients with severe acute respiratory infection, and manipulation of oxygen delivery equipment should be minimized.

Change the saline in the flow meter so that chances of fungal infections can be minimized. The whole system should be sterilized before it is used for a new patient.

Useful Terms in Oxygen Therapy

FiO2 : Fraction of inspired oxygen (%).

PaCO2: The partial pressure of CO2 in arterial blood. It is used to assess the adequacy of ventilation.

PaO2: The partial pressure of oxygen in arterial blood. It is used to assess the adequacy of oxygenation.

SaO2: Arterial oxygen saturation measured from blood specimen.

SpO2: Arterial oxygen saturation measured via pulse oximetry.

Heat Moisture Exchange (HME) product: are devices that retain heat and moisture minimizing moisture loss to the patient airway.

High flow: High flow systems are specific devices that deliver the patient's entire ventilatory demand, meeting, or exceeding the patients Peak Inspiratory Flow Rate (PIFR), thereby providing an accurate FiO2. Where the total flow delivered to the patient meets or exceeds their Peak Inspiratory Flow Rate the FiO2 delivered to the patient will be accurate. High flow in approved areas only. Consult your NUM if unsure.

Humidification is the addition of heat and moisture to a gas. The amount of water vapour that a gas can carry increases with temperature.

Hypercapnea: Increased amounts of carbon dioxide in the blood.

Hypoxaemia: Low arterial oxygen tension (in the blood.)

Hypoxia: Low oxygen level at the tissues.

Low flow: Low flow systems are specific devices that do not provide the patient's entire ventilatory requirements, room air is entrained with the oxygen, diluting the FiO2.

Minute ventilation: The total amount of gas moving into and out of the lungs per minute. The minute ventilation (volume) is calculated by multiplying the tidal volume by the respiration rate, measured in litres per minute.

Peak Inspiratory Flow Rate (PIFR): The fastest flow rate of air during inspiration, measured in litres per second.

Tidal Volume: The amount of gas that moves in, and out, of the lungs with each breath, measured in millilitres (6-10 ml/kg).

Ventilation-Perfusion (VQ) mismatch: An imbalance between alveolar ventilation and pulmonary capillary blood flow.

Key Oxygen Plant Manufacturers in India

S. No.	Company Name & Details	Website	Address	Contact Details	Remarks
1.	**Universal ING.LA. Boschi Plants Pvt. Ltd.**	www.universal-boschi.com	A-104/2, Okhla Industrial Area, Phase Two New Delhi	Mr. Shiv Kumar (+91 80100 88130)	Only deals in cylinder filling plant i.e. liquid oxygen plants Installation time – 2 to 4 months, based on capacity 200 cylinder/ day plant – 2 months installation time – Rs 1.35 Cr cost 500 cylinder/ day plant – 3 months installation time – Rs 1.85 Cr cost 600 cylinder/ day plant – 4 months installation time – Rs 1.95 Cr cost
2.	Trimech Engineers Pvt. Ltd.	www.trimechindia.com	7, Giriraj Industrial Area, Opp Screenotex Engineering Pvt. Ltd., Paldi-Kankaj, Old Ahmedabad-Bhavnagar Highway, Daskroi, Ahmedabad – 382425	Not able to contact	
3	Inox Air Products Pvt	http://www.inoxairproducts.com/	7th Floor, Ceejay House, Dr. A.B. Road, Worli, Mumbai - 400 018	Mr. Mr. Vinod Singh, business Head (North), Inox Air Products Pvt. Ltd (9999162672)	Currently, he is not picking up the call. we will reconnect with him tomorrow.
3.	MOS Techno Engineers	www.mosengg.com	Registered Office: 117/O/408, Geeta Nagar, Kanpur, 208025, Uttar Pradesh Factory: F22, Surajpur Industrial Area, Site C, Surajpur, Greater Noida, Uttar Pradesh, India	Mr. Shikhar Singh +91 95606 78443 / 87567 21304	Deals in PSA (Pressure Swing Adsorption) as well as cylinder filling plants PSA plants (plants custom-made for hospitals) can be installed within 2 months' time while cylinder filling plant may take 6 to 8 months' time
4.	Trident	www.tridentpneumatics.com	5/232, KNG Pudur Road, Somayampalayam P.O. Coimbatore - 641 108. India. Ph : +91 - 422 - 2400492 Extn: 223 Fax : +91 - 422- 2401376 e-mail : sales@tridentpneumatics.com	Mr. Shyam Pratap: +91 7397719565	► Deals in Air Separation plant on PSA based technology for hospitals. They can setup one plants in 8 weeks' time per location. ► Government of UP has given order to setup 5 plants in

S. No.	Company Name & Details	Website	Address	Contact Details	Remarks
					Government hospitals ► Cost of 50 Lt/min plant is 20 lakhs (Installation time 8 weeks0) ► Cost of 200 cylinder capacity plant is 1 crore
5.	Sam Gas Projects Pvt. Ltd.	www.samgasprojects.com	E - 30, Udyog Kunj, U. P. S. I. D. C., Industrial Area, Near Mehrauli Rly. Station NH-24 Ghaziabad - 201015, Uttar Pradesh, India	Mr. Mridul Gupta (Director) +91 98101 13798	Deals in PSA (Pressure Swing Adsorption) oxygen plants for hospitals; can supply 4 plants per month

Note:

GoI recently sanctioned 162 PSA (Pressure Swing Adsorption) oxygen plants to states. These will augment medical oxygen capacity of states by 154.19 MT (metric tonne). The entire cost of 162 PSA oxygen plants amounting to Rs 201.58 Crs.

Source:

1. https://www.business-standard.com/article/current-affairs/covid-19-162-psa-oxygen-plants-sanctioned-by-centre-33-installed-121041800252_1.html
2. https://www.thehindubusinessline.com/news/covid-19-in-india-central-government-sanctions-162-psa-oxygen-plants/article34349256.ece

Accordioning to the above-mentioned article, **the cost discovered by GoI for PSA oxygen plants, through tender process is Rs 1.31 Crs/ metric tonne.**

Suggested Strategy

1. Every hospital of over 100 beds should be mandated (by executive order/ law) to have PSA oxygen plant. Additionally, to encourage these hospitals to install PSA oxygen plant, the state government should incentivise them;
2. To expedite installation of PSA oxygen plants in the state government's hospitals, GoI vendors should be engaged at the rate discovered by GoI. Additionally, we can engage other vendors at the same rate;
3. PSA oxygen plants at large hospitals will free oxygen cylinders for small hospitals/ home use;
4. Additionally, to further promote the expansion of existing medical oxygen plants and installation of new medical oxygen plants, the State Government may come up with a dedicated policy with the following incentives:
    1. 25% to 60% Capital Subsidy, based on early commercial production – 60% capital subsidy if plant is operationalised by 31st July 2021; 50% capital subsidy if plant is operationalised by 31st October 2021; 40% capital subsidy if plant is operationalised by 31st January 2022; 25% capital subsidy if plant is operationalised after 31st January 2022; subsidy is capped at Rs 1 Cr/ unit
    2. Electricity duty subsidy for 5 years form the date of commercial operation; subsidy is capped at Rs 10 lakh/ unit/ annum
    3. Rs 2/ unit electricity subsidy for 5 years form the date of commercial operation; subsidy is capped at Rs 10 lakh/ unit/ annum
    4. 100% stamp duty reimbursement
    5. All related approvals shall be provided with one week
    6. 50% subsidy on land purchased from UP government agencies; subsidy is capped at Rs 1 Cr/ unit
    7. Customize package for setting up "Tonnage Oxygen Plant of minimum 100 TPD" in Uttar Pradesh within 3 months of Government approvals. Tonnage Oxygen Plant will be able to supply liquid oxygen to liquid oxygen plants manufacturers.

Tackeling Shortage of oxygen

Hospitals are facing severe shortage of oxygen at most of the places. While treating Covid patient the shortage of oxygen stands as the most serious issue & can prove a serious lifethreatening hazard. Medical oxygen is a critical component in the treatment of COVID-19. It is the most essential tool in our fight against COVID-19. Even if 10-15% of covid patients need active management including oxygen, this small percentage of patient load is itself enough for oxygen scarcity. If the numbers rise now or in future it shall prove extremely dangerous for patient management.

Shortage of oxygen is due to demand-supply mismatch. The demand for medical oxygen has increased exponentially during the pandemic. As per the reports, medical oxygen demand was about 700 MT/day before covid started. It increased to 2,800 MT/day after the outbreak. AT present it is above 5,500 MT/day. Supply chain is facing difficulties on this account to match the demands. At this juncture the country will have to face two important tasks; the first being to meet the demands immediately & to raise the reserve portion considering the future. Geographical constraints in the oxygen transportation across the country is the biggest practical issue. Oxygen is an inflammable gas. To prevent accidents, it is stored and transported in cryogenic cylinders. But India does not have enough cryogenic cylinders. The increased transport cost has increased the cost for the end users. Hospitals are getting oxygen at rates 3-4 times higher than the normal rates.

In such scenario, oxygen generation plants stand as savior. Hospitals will have to stand on their own for the requirement to good extent. Industries manufacturing oxygen needs to be augmented towards medical oxygen & robust transport mechanism needs to be in place immediately. Government red tapes need to be wrapped up to create hassle free mechanism.

Portable Oxygen Cylinders

Portable Oxygen Cylinders can provide oxygen to the patient while traveling, shifting from one place to another, also this can be used as a small backup oxygen system for several purposes like for emergency situations. Portable oxygen cylinders are commonly used at home when patients need oxygen support. Ready back up support is must & most important while using portable oxygen cylinders actively for patients.

Oxygen Concentrators

Oxygen Concentrators are very safe and helpful to provide oxygen to patients. They are useful in hospitals as well as in domestic surroundings. Flow rate must be checked before buying oxygen concentrator. Not all concentrators provide same flow rate. Few provide minimum oxygen per minute. Others provide up to 10 Liters/ min as well. So, selection of flow rate as per requirement is must. Concentrators need continuous electrical supply. So, the one with in built battery backup facility or those which sustain on minimum electrical supply like inverters should be preferred. Oxygen concentrators should be easily portable. Purity of oxygen delivered should be an important point. Lower noise levels & warranty products should be preferred. Price range of the oxygen concentrators is between Rs. 30,00/- & 90,000/-. Average life span of oxygen concentrator is between 1500 to 2000 hours.

Oxygen Generation Plants

Medical Oxygen Generation Plants serve as reliable source for the generation of continuous medical-grade Oxygen for all hospital needs. A plant that can supply 30-40 cylinders of oxygen per day (One/Two Dura approximately) costs about Rs 30-40 lakhs to set up and can be completed in a 2-3 weeks. Plant with 4-6 Dura capacity costa approximately Rs. 90 lakhs.

Few Oxygen Generation Plant Manufacturers

1. **Universal Boschi**
   UNIVERSAL BOSCHI
   B-524, RIICO Industrial Area, Bhiwadi, Rajasthan, 301019
   INDIA: +919818255334,
   info@universalboschi.com
   Contact: +919818255334

2. **Agastya Aero works Pvt. Ltd.**
   84 Mehta House,
   203, No. 85, opposite Natraj Theatre,
   Vasco da Gama, Goa 403802
   +91-8322513921, admin@agastyaaeroworks.in

3. **Agastya OxtechT6, SIDCO Women's Industrial Estate**
Kattur Village, Vellanur, Chennai,
Tamil Nadu 600062,
Contact - +91-8322513921,
admin@agastyaaeroworks.in

4. **Gaztron Industrial Oxygen Gas Generator**
179 , Udhog Kendra - Ist , Ecotech
3rd, Greater Noida, Gautam Budh Nagar, Uttar Pradesh
Contact - +91 9667849547, +91-9667849547

5. **Air- N- Gas Process Technologies**
CONTACT PERSON - Shailesh Verma
B 1, 801, Westgate Business Bay, Makarba,
Ahmedabad - 380051, Gujarat, India
Contact - 8048764272

6. **Oxyplants India Pvt Ltd.**
No. 101, Kempanna Garden 4th Phase,
Peenya Industrial Area, Peenya,
Peenya, Bengaluru - 560058, Karnataka
Contact - 8048600087

7. **Sam Gas Projects Pvt. Ltd.**
H.O. & Works : E - 30, Udyog Kunj,
U. P. S. I. D. C., Industrial Area,
Near Mehrauli Rly. Station NH-24,
Industrial Area, Ghaziabad - 201015, Dist. Ghaziabad, Uttar Pradesh
Contact - 8048418436

8. **Nitrox Engineering Pvt. Ltd.**
Plot No. 20/6A, New DLF Industrial Area,
Faridabad - 121003, Dist. Faridabad, Haryana
Contact - 8048587012

9. **Patel Gas Plants**
B - 201/202, M Cube - The Business Hub,
District Valsad, NH - 48, Balitha,
Vapi - 396195, Dist. Valsad, Gujarat
Contact - 8048749743

10. **Gastek Engineering**
710, Modicorp Tower, 98, Nehru Place,
Nehru Place, New Delhi - 110019, Delhi

11. **MVS**
'MVS HOUSE' E-24, East of Kailash,
New Delhi - 110065 (INDIA).
+91 (11) 4999 7000, marketing@mvsengg.com

12. **Hi-Tech Engineering Solutions**
262 KM Stone, National Highway-1,
Mandi Gobindgarh-147301, Punjab
+91-1765-500999,
sales@hitechgas.com, www.hitechgas.com

13. Dharmarajan R
DBS Engineering Services
47/26, Burmah Colony, Pavali Road,
Virudhunagar - 626001, Tamil Nadu, India
Contact - 8048082732

14. B.R. Singh (Director)
Atmos Power Private Limited
Plot No. C-1-39/3, Phase 3, Near Mazda Limited,
Nana Chiloda Circle, G. I. D. C., Naroda
Ahmedabad - 382330, Gujarat, India
Contact - 08046027774

15. **Delhi Cryogenic Products Private Limited**
Kunal Kumar (General Manager)
Delhi Cryogenic Products Private Limited
Okhla Industrial Area, Phase-2,
New Delhi - 110020, Delhi, India

16. Rajmohan Sathyadev (Director)
Summits Hygronics Private Limited
SF. No. 192, Eari Thottam
Kannampalayam, Coimbatore - 641402,
Tamil Nadu, India
www.summitshygronics.com17.

17. **In Age Industries**
E/ 2, Model Indl. Colony, Off Aarey Road,
Goregaon East, Mumbai - 400063, Maharashtra
www.inageindustries.com

18. **Swastik Synergy**
302, Business Suites, 9, S. V. Road,
Opposite Shop In, Santacruz West,
Mumbai - 400054, Maharashtra
www.swastiksynergy.in

19. New India Works
A- 2, Dronagiri, Modern Usha Colony,
Evershine Nagar, Link Road, Malad West,
Mumbai - 400064, Maharashtra

20. Rajendra Singh (Manager)
Pooja Industries
Kanika Atrium 2, 10th Floor, Unit 1003
Mariout Hotel, Andheri Kurla Road,
Andheri East, Mumbai - 400093 , Maharashtra.
www.poojagroupmumbai.com

21. Toyam technologies
Off. No. 18-19, 1st Floor, Parmar Pavan,
Lulla Nagar Kondhwa Road, Pune,
Maharashtra, 411048, India

Approximate Specifications of Oxygen Cylinders

O2 Cylinder	B Type	D Type	Dura - 200	Dura - 208	Dura - 247
Type	Ward Cylinder	Jumbo	LMO	LMO	LMO
Capacity	1320 L Compressed Gas	7000 L Compressed Gas	1,67,000 Liters	1,74,000 Liters	2,10,000 Liters
Wastage – Approximate 15-20%					

Duration for which Cylinders will last as per oxygen use. (after excluding wastage)

1 L/min	17 hours	95 hours	-	-	-
2 L/min	8.5 hours	50 hours	-	-	-
5 L/min	3.5 hours	20 hours	-	-	-
8 L/min	2 hours	12 hours	350 hours	365 hours	437 hours
10 L/min	1.7 hours	9.5 hours	275 hours	290 hours	350 hours
15 L/min	1 hour	6 hours	185 hours	195 hours	233 hours
This is the approximate time that cylinder will last for 1 bed. Time may shorten due to leakage or if the cylinder is not completely filled.					

SAVE OXYGEN ....

- ✓ Appoint Dedicated Staff.
- ✓ Oxygen Nurse is effective strategy.
- ✓ Do not allow relatives, attendants to handle the oxygen units.
- ✓ Prescribe Oxygen carefully.
- ✓ Identify & Rectify leakages.
- ✓ Train the staff for regular checking the system.
- ✓ Target optimal SpO2 levels.
- ✓ Use proper facemasks to avoid leakage.
- ✓ Oxygen is a Drug.
- ✓ Use it Judiciously.

Summary

Oxygen is a lifesaving treatment. It should be dealt with very meticulously. Selection of appropriate system, monitoring, prompt action, timely weaning & administrative management of system are the keys to successful use of the medical oxygen.

• • •