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Anaesthesiology

OXYGEN UPSTREAM FROM PATIENT END TO PRODUCTION

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ABSTRACT The world has been facing unprecedented times for last two years, owing to one of the deadliest medical crises- the war against corona virus. In such gleamy situation, the medical fraternity is trying hard to leave no stones unturned for ensuring proper healthcare delivery. Despite making good progress with the vaccination policy, the current situation requires effective management of healthcare services and supplies at the ground level facilities such as hospitals, primary healthcare units, nursing homes, and others. In response, the judicious use of oxygen or oxygen management in these health care facilities can save lives by ensuring proper supply to meet patient requirements. This article pinpoints the rational and viable oxygen management process for handling the load on medical professionals as well as production plants. Based on the analysis of the problems at hand, the article provides insights and suggestions to ensure unrestricted and timely oxygen supply in the healthcare units.

KEYWORDS : Oxygen, Coronavirus, Policy, Oxygen Consumption, Oxygen Wastage, Vidhya Samay T Piece

INTRODUCTION

The professional requirements of being anaesthesiologists revolves around understanding intricacies of oxygen therapy; however, the practical application of oxygen management seems missing from the medical curriculum. During the surge of coronavirus cases in India, the healthcare fraternity first-time experienced how the rational use of oxygen supplies can considerably improve the chances of a patient's survival. In simple terms, saving one litre of oxygen equivalents to one litre of oxygen produced.

The pandemic situation has forced us to ascertain how oxygen moves from the production site to the patient end, to monitor the steps of rate-limiting and the ones in which saving time and oxygen seem a feasible option. Against this background, the present article sheds light on means and ways to reduce oxygen requirement and essentially save oxygen.

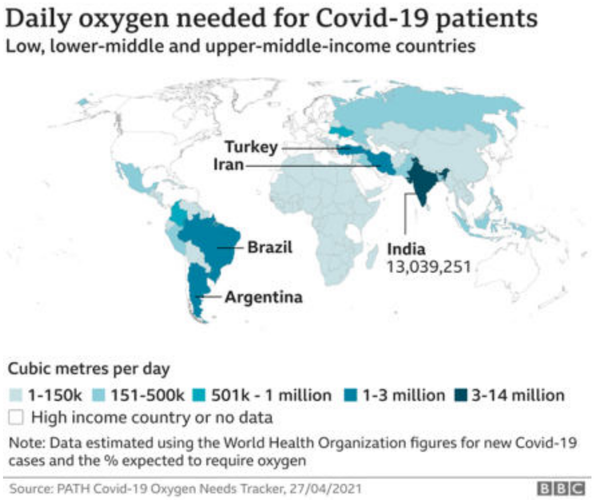
The steps involved in production to patient end are:

1. Production & storage in factories
2. Transport to the hospitals
3. Storage in hospitals
4. Distribution in wards
5. Flow at patient end

Epidemiology - A battle for breath

Ideally, healthcare facilities consume around 15% of the oxygen supply, leaving the rest for use by industries. But amidst the second wave of Corona Virus Disease-19 (COVID-19)in India, around 7,500 Metric Tons (MT) of oxygen, daily, which accounts for almost upto 90% of the oxygen supply - is being diverted for medical use. That is higher by nearly 3 times than what was consumed at the peak of the first wave, every day in mid-September 2020.At that time India was adding nearly 90,000 cases on an everyday basis. A single day spike of 144,000 was noticed in early April 2021. The daily caseload had more than doubled to well more than 300,000 in late April 2021.[1]

A community of open data professionals have estimated in India about 512 deaths took place in April -May2021as a result of either oxygen shortage or denial during second wave. The open data tracker made by Data Meet was created with an aim to "archive lost lives due to the lack of oxygen and counter the ongoing denial and erasure of these deaths in official and government narratives."The tracker estimated that the highest number of deaths related to oxygen(83deaths)happened across five medical colleges in Goa.[2] FIGURE-1



STEP 1- PRODUCTION AND STORAGE IN FACTORIES-

Cryogenic Distillation Plants (CDP) use liquid oxygen and can get above 99.5 percent oxygen in its purest form, while the Oxygen Generation Plant uses air, compresses it, and purifies it to extract 93 percent oxygen.[3]

CDP hold more oxygen in small volume but require special vessels i.e., cryogenic vessels to transport while Oxygen Generation Plant i.e., Pressure Swing Adsorption (PSA) provide oxygen in compressed gas form and transport in cylinders. India's Daily Production Capacity (7287 MT) and Stock (~50,000 MT) was comfortably more than Daily Consumption (3842 MT) during the first peak.[4]

The federal health ministry had invited bids for new oxygen plants in October 2020 - more than eight months after the beginning of pandemic in India. Of the 162 that were sanctioned, only 33 have been installed so far - 59 were to be installed by the end of April and another 80 by the end of May, the ministry had said. This implies that we are running short of time in preparation of the upcoming 3rd wave.

STEP 2 – TRANSPORT

The Petroleum and Explosives Safety Organisation (PESO) running under the Department of Promotion of Industry and Internal Trade of the Ministry of Commerce & Industries of the Indian Government is the body that deals with stockpiling, transportation, handling, and use of dangerous substances and safety in manufacturing/refining. During the pandemic peak, the Central Government and PESO had constant negotiations with the State Government units (such as the Drug Control Administration (DCA), the District Collectorates, and others). These local bodies, in-turn, have set up a communion system at the District Level. Owing to increased reports of malpractices, PESO issued orders insisting on maintaining the day-to-day record of filling, storage, and dispatch of cylinders and submitting reports.[3]

The District Collectors at the District level are empowered to make individual decisions such as preparing supply schedules, thereby rationalising the supply of cylinders to various locations and hospitals according to priority and urgency. While the authorities prepared the supply schedules, the end customer (such as hospitals) would be paying the bill. Oxygen data availability status reports from various oxygen suppliers are updated daily to the district authority, who synchronises at the state-level.

Help of oxygen expresses were also rendered during shortage. According to the department of railways, nearly 30,182 MT of Liquid Medical Oxygen (LMO) in almost 1,734 tankers have been delivered by oxygen expresses to numerous states.

As on date, Oxygen Expresses transported 8025 MT LMO from Jharkhand, 488 MT from Maharashtra, 7102 MT from Odisha, 1360 MT from West Bengal, 6384 MT from Gujarat, 218 MT from Chhattisgarh and 164 MT from Andhra Pradesh for delivery in almost 39 districts in 15 states all over country namely Nashik, Pune, Nagpur, Solapur and Mumbai in Maharashtra, Lucknow, Kanpur, Bareilly, Varanasi, Gorakhpur & Agra in Uttar Pradesh, Katni, Jabalpur, Sagar & Bhopal in Madhya Pradesh, Hyderabad in Telangana, Tuglakabad, Delhi Cantt & Okhla in Delhi, Faridabad & Gurugram in Haryana, Kota & Kanakpara in Rajasthan, Dehradun in Uttarakhand, Bengaluru in Karnataka, Nellore, Guntur, Tadipatri & Visakhapatnam in Andhra Pradesh, Tiruvallur, Chennai, Tuticorin, Coimbatore & Madurai in Tamil Nadu, Ernakulam in Kerala, Bhatinda & Phillaur in Punjab, Kamrup in Assam and Ranchi in Jharkhand.[5]

STEP 3 – STORAGE IN HOSPITAL

Depending upon the supplies, oxygen storage will be in cryogenic vessel/tank or compressed gas in cylinders. Large amount of liquid oxygen is stored in a vacuum insulated evaporator (VIE) as bulk oxygen is more economical and convenient in comparison with cylinder manifolds. Liquid oxygen is derived from liquid air by fractional distillation. One volume of liquid oxygen manufactures 842 times of its volume of oxygen as gas at 15 degrees Celsius and one atmospheric pressure.

According to BS EN 737-3:2000, there should be three independent supply sources.[6]

Primary, secondary, and a reserve source to meet the need in case of primary and secondary supply failure. The manifold room should have 2 banks of D-type cylinders, each containing 2 days of consumption, attached to a fully-automated changeover panel. Three day consumption should be kept in reserve, as a contingency plan.[7]

STEP 4 - DISTRIBUTION IN WARDS

Control panel controls the pressure and flow of gas to the pipeline. The turbine is designed to pass a flow of 3000 L/min from the main VIE supply and 1500 L/min through the emergency cylinder. It has duplicate regulators for safety. These are designed to control the pressure at 4.1 bar for the main supply and 3.7 bar for the emergency cylinder supply.[8]

STEP 5 - FLOW AT PATIENTS ENDS

Depending upon patient requirement, type of oxygen device and interface mask, flow may vary from 2 litre to 60 litre per minute (LPM).

As the 2nd wave of COVID-19 strikes in India, the scarcity of oxygen remains a tough challenge. In the capacity of being anaesthesiologists, our team was assigned the charge of oxygen management in our hospital, i.e. Bundelkhand Medical College, Sagar, M.P., a tertiary care center draining a population of around 90 lakhs from 5 neighboring districts.

To the best of our knowledge, managing any drug shortage requires working at 3 levels:

1. increase the production
2. decrease the consumption
3. minimize wastage

As an Oxygen Manager, we can only manage to minimize wastage because production and consumption are beyond control. The situation in ICUs and wards become tricky to handle due to the lack of hospital staff, low awareness among patients, and uninformed patient's family members. Therefore, the option of decreasing oxygen consumption doesn't happen in real-time.

Anaesthesiologists can contribute by careful planning and evolving casual techniques without risking lives of patients.

Oxygen needs estimation

In selecting the most appropriate source for oxygen, one needs to take into account the volume and flow of oxygen requirements. To determine the total flow needs, the anticipated case load has to be estimated. This can be done using the World Health Organisation (WHO) COVID-19 Essential Supply Forecast Tool (ESFT).[9] From the total patients expected, the ratio of patient severity can be ascribed as: mild, moderate, severe or critical. Thus, the required flows can be estimated to meet the oxygen therapy needs for the hospitalised severe and critical patients, representing 20% of the total.

Approximately 75% of the COVID-19 patients requiring hospitalisation are people classified as "severe", and 25% as "critical". Thus, the total supply of medical oxygen required can be estimated based on the recommended flow rates for each patient severity category.[10] (Table 1)

Few things to remember:

1. Estimated oxygen consumption by ventilator will depend upon its type, Fraction of inspired oxygen (FiO_2),minute ventilation etc. O_2 (L/min)= total flow × (FiO_2 -0.21)/ 0.79 (average between 30-40 LPM)
2. 1 liter of liquid oxygen will give 860 liter of oxygen gas at 1STP (Standard Temperature and Pressure)
3. 1 MT of liquid oxygen = 720 m3 of compressed oxygen
4. 1 Kiloliter (KL) of liquid = 1.219 MT of liquid

These are few suggestions to follow for ensuring a reduction of oxygen consumption. The recommended steps are advisory and shouldn't be treated as official guidelines. Depending upon the situation and need, the hospital authorities can refer and implement these suggestions.

A-Step of transportation –

1. Make a route for the tanker that follows a fully functional broad road with no repairs and less traffic.
2. The large tanker should be filled first, followed by the smaller tanker that effectively ensures pressure handling.
3. Fill the tanker through the lower valve, so that pressure will not rise exponentially in the tank, hence more filling can occur.

B-Step of storage –

1. Regularly watch on how ice is depositing nearby VIE because increased icing can decrease the rate of vaporization thereby decreasing the rate of outflow.
2. Regularly check pipelines & storage.
3. Different type of flanges are specified to different manufacturers of oxygen, so it is advisable to stick to the same manufacturer for the tanker and your storage tank. This would result in less time consumption to fill the storage tanks and eliminate the possibilities of oxygen leakage

C- Distribution in ward -

Triaging of ward as per oxygen requirement.

Theoretically they should be divided into four levels of oxygen flow:

a) less than 5 LPM
b) between 5 to 10 LPM
c) between 10 to 15 LPM
d) more than 15 LPM

but practically, there were numerous hindrances:

1) The oxygen requirement of patients was not constant, it was dynamically changing every few hours, e.g., in the morning, patients'

demand was less, which increased drastically during the evening.

2) patients panicked when their flowmeter oxygen levels were reduced and they themselves increased the flow to maximum.
3) shifting of patients was a tedious process, so it was decided to divide it into only two zones of less than 15 LPM and more than 15 LPM so that neither the patient nor the doctor panicked about limited supply of oxygen in the ward and if patient required more than 15 LPM they were shifted to ICU, where advance oxygen therapy devices were present.

Pressure in wards was managed such that flowmeter could not deliver more than 15 LPM by applying low pressure reducing valve or using ward valve. **The advantages of this approach are:**

1. When a flowmeter is opened completely, the bobbin is stuck at the top end, but the oxygen output will depend upon pressure in pipeline and hence, even more than 15 LPM oxygen delivery is possible. By applying low pressure reducing valves, even if a patient opens flowmeter completely not more than 15 LPM oxygen can be delivered, hence oxygen wastage is minimised.
2. If the demand of patient increased from low to high flow of oxygen, it could be managed in the same ward.

E- FLOW AT PATIENTS' END

1. Properly checking that compatible probe is attached to the central oxygen outlet because even if all probes follow the British Standards, there is a slight difference in the angle which causes minute leak in the outlet.
2. Don't remove flowmeter frequently.
3. During filling of distilled water, always be attentive that the washer which is present in the bottle should not dropout and that bottle should be tightly closed before use.
4. Don't hang anything on the flowmeter.
5. Proper fixing of mask to the patients.
6. Adequate hydration of patients can help in increasing SpO_2.
7. Use of proper oxygen device as indicated by patients' demand.
   I. Nasal cannula /prongs – 1-4 LPM flow
   II. Simple face mask/polymask – 5-10 LPM flow
   III. High mask/Mask with bag – 11-15 LPM flow
8. Two suggestions to increase oxygen bed without increasing pipeline flow:

A. Splitter/ Twin adopter (FIGURE-2)

ADVANTAGES -

a. Upgrade hospital ward as ICU
b. Can provide even 30 LPM to step down from High Flow Nasal Oxygenation (HFNO).
c. Can provide even 75 LPM with HFNO (especially helpful in avoiding improper fixing of HFNO)
d. Cost effective
e. Easy upgradation

DISADVANTAGES -

a. Bulky, may affect your outlet
b. Everyone starts demanding these in hospitals

B. "Vidhya Samay" T piece(FIGURE-3)

With the help of this device, oxygen can be given to two patients simultaneously. Since 15LPM of O_2 is divided into two patients, so only the patients requiring oxygen flow < 7 LPM can be benefitted, as two patients can be administered oxygen from a single port.

This T piece is available at a common gas repairing shop in 30 - 40 rupees as it is used to give 2 connections of gas from a single cylinder. From flowmeter to the T piece, a suction pipe can be used which comes with a suction drain and two new masks can be used at two different ends.

ADVANTAGES –

a. Cheaper
b. Easily available
c. User friendly
d. Decreased wastage
e. Indirect assessment of patient severity

DISADVANTAGES -

a. Cross infection is a matter of concern.
b. Only suitable for flows less than 7 LPM.

SUMMARY:

Based on the above discussion, it becomes clear that judicious use of oxygen can do wonders for saving lives.The current pandemic situation is far from over, and effectively managing the oxygen supplies in various healthcare units plays a vital role in dealing with the crisis. Consequently, the options of minimizing oxygen wastage and rational consumption are viable and practically relevant.

To conclude, multidisciplinary coordination is needed to make a concerted effort for oxygen conservation and rationalization. Clinicians and hospitals can utilise these key strategies to conserve and extend oxygen, both for general use and during public health emergencies such as COVID-19.

The suggestions mentioned in this article can prove worthful for effective oxygen management without compromising on the patients' needs and requirements. Despite all possible efforts, the medical professionals and staff should keep looking for continuous improvements in both the healthcare process and delivery.

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