International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 08 August 2024
DOI: 10.47191/ijcsrr/V7-i8-73, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

Overview of Strategic Supply Management of Oxygen for COVID- 19 Pandemic Patient Care in Sri Lanka

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ABSTRACT: The immensurable COVID-19 pandemic has a ceaseless destabilizing effects on health systems, economies, and societies around the world. Total number of 671,756 positive cases have been reported in the country and 654,910 of them have recovered from the disease with 16,808 number of deaths out of the population of 21.8 million up to December 2022. Immense burden to the health system and heavy death rate was reported during the 3rd wave for which mainly the delta variant of COVID virus was responsible. Total number of 491,508 patients and 14375 number of deaths as well as nearly 3500 Oxygen dependent patients were managed per day in ICU, HDU, and inward set up using Oxygen concentrator, bi-pap and c -pap machine during 3rd wave. During this period, Ministry of Health had been urged to reassess its hospital surge capacity in relation to predicted COVID patient load. Based on that, the increasing COVID-19 surge has warranted the rapid hospital facilities expansion in every aspect especially in facilities for Oxygen therapy.
Ministry of Health, Sri Lanka had to develop strategies for Medical Oxygen management to fulfill its rising demand. All those interventions were focused to improve the accessibility and availability of medical oxygen while preventing irrational use and wastage of Oxygen. The ultimate goal of spending such cost was to prevent morbidity and mortality due to poor access of oxygen. To improve the efficiency and effectiveness of medical oxygen gas utilization, it was important to monitor the capacity improvement and supply process.

KEYWORDS: COVID-19, Oxygen, Preparedness, Sri Lanka

BACKGROUND

Health system of Sri Lanka provided inward care to all patients tested positive for COVID 19 through its 234 designated in-patient care centers in three levels until introduction of Home Based Care system for management of asymptomatic or mildly symptomatic patients through distant monitoring via telephone calls by dedicated trained medical officers team. As per the opinion of the technical experts about 60% of COVID-19 patients were asymptomatic and 40% were symptomatic also 20% of them are oxygen dependent. Out of all oxygen dependent patients, 4% require critical care. Accordingly, 2,400 patients out of 30,000 average number of inward COVID19 patients required oxygen therapy.

In June 2017, WHO included oxygen in the WHO Model List of Essential Medicines (EML) beyond the use during anesthesia because of its proven life-saving properties and its indispensable therapeutic value. Oxygen therapy had shown to be effective in treating patients with COVID 19 and is recommended for all severe and critical COVID-19 symptoms.

Medical oxygen is an essential gas used in health care to prevent hypoxia as well as treating in many medical emergencies especially in Emergency Treatment Units, ETU, HDUs, ICUs and theaters. The oxygen flow rates for oxygen therapy range from low, such as 1-2 L/min for children, 5 L/min for adults, to high, such as 30-60 L/min. In Sri Lanka, different devices were used for oxygen delivery and these devices are subdivided into low-flow oxygen devices to high-flow nasal oxygen delivery (HFNO) devices.
Twenty tons were usually used for normal patient care, out of total capacity (80 tons) of two supplying companies in the country. In COVID patient care management, especially in this 3rd and 4th waves due to highly virulent delta strain, Oxygen demand was high for management of complications with Oxygen desaturation other than the demand for normal patient care. Oxygen demand

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www.ijcsrr.org

was gradually but drastically increased during these waves exceeding even the further enhanced production capacity of two companies which led to import Oxygen from other countries.

Table 1: Cumulative COVID – 19 cases and Death (Ministry of Health Sri Lanka, no date; Worldometer, 2021)

WHO Region	Cumulative Cases and %	Cumulative Deaths and %
Europe	260,908,612 (42%)	2,115,732 (32%)
Western Pacific	93,459,805 (15%)	275, 647 (4%)
Americas	180,023,346 (29%)	2,855,664 (43%)
South-East Asia	60,444,729 (10%)	798,738 (12%)
Eastern Mediterranean	23,151,287 (4%)	348,685 (5%)
Africa	9,361,319 (1%)	174,737 (3%)
Global	627,349,862 (100%)	6,569,216 (100%)

OBJECTIVE

This article on "**Overview of Strategic supply management of Oxygen for COVID- 19 Pandemic Patient Care"** is elaborating the strategies and measures taken over to overcome the challenges in delivering high quality, medical-grade oxygen efficiently and effectively for necessary oxygen demand in COVID patient care management in Sri Lanka while continuing normal patient care and also the effectiveness of strategies for preparedness to cater predicted demand for oxygen.

METHODS

This descriptive study was done by objectively analyzing the available information on records, and key informant interviews was done as qualitative method on effectiveness of preparedness and strategies for oxygen production, storage, delivery and utilization methods with a view to assess whether healthcare service is prepared to cater the necessary oxygen demand for COVID 19 patients in need. It was also assessed how effective the evidence based prediction of oxygen demand and the strategies adopted to match the supply of Oxygen with such oxygen demand predicted with panel of experts using qualitative and quantitative methods adapting a pre-validated

WHO online tool. Data was collected using Health Information Update System (HIUS), which is an open-source, free data collection tool. Qualitative data were collected through key informant interviews (KII). Each thematic area was analyzed and transformed into information.

RESULTS

Sri Lanka had more than 50000 designated hospital beds for COVID-19 patient care management across all sectors (public, semi-government, tri-forcers and private). These beds were prepared for COVID – 19 patient care in at all levels. COVID-19 treatment centers were comprised in 3 levels; Level 1- 152 Intermediate Care Centres (ICC) including 60 private hospitals and selected hotels. Initial management for asymptomatic and mild disease patients were treated at this level. Level II – 73 Secondary Care Centres - (Base Hospitals and some Divisional Hospitals with ICU and HDU facilities). Special COVID Treatment Centres for the Initial management of asymptomatic patients or with mild disease; Level I – 152 centers with 22912 bed capacity (79 Non Medical Institutions with 20140 beds and 60 (7162 beds in private hotels affiliated to Private Hospitals). Level II hospitals for management

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of symptomatic oxygen dependent or non-oxygen dependent patients with moderate disease; 74 centers with 6033 bed capacity and also 180 ICU beds and 556 HDU beds facilities has been allocated for management of oxygen dependent patients in government Hospitals. Level III hospitals for care of patients with severe/critical progressive de-saturation patients and with other complications; surgical, maternal cases, dialysis etc. includes 10 main hospitals with 1550 bed capacity (3). Further to these, all hospitals previously dedicated for routine patient care had to be opened for COVID patient care management. Previously developed 120 COVID ICU bed number were enhanced up to 220, but with opening of all hospitals part of the beds available in normal ICUs and HDUs were utilized when necessary for COVID patients.

Table 2: Waves of COVID – 19 pandemic, Treatment Centres and Bed strength (Ministry of Health Sri Lanka, 2020)

Waves		**1st Wave - (27/01/2020 3/10/2020)**		**2nd Wave (04/10/2020 14/04/2021)**		**3rd Wave -(15/04/2021 – up to now)**	
Centers & Beds		Centres	Beds	Centres	Beds	Centres	Beds
Level III Severely symptomatic patients with complications	**High end Centres**	2	400	9	1,550	9	1,550
Level II Moderately symptomatic patients without complications also with Special needs Surgical, Obstetrics, Dialysis etc	**Base & DGH Hospitals**	8	<1000	37	2,750	73	5,963
Level I - Intermediate Care Centres Asymptomatic or mildly symptomatic patients (Non Health Institutions and Divisional Hospitals converted as treatment centres)	**Hotels + Private Hospitals**	-		37	12,441	153	29,904
Total beds			1400		16,741		37,417

Table 3: Waves of COVID – 19 pandemic, number of patients effected, Deaths and Case Fatality Rate (Ministry of Health Sri Lanka, 2022)

Waves	**1st Wave (27/01/2020 - 3/10/2020)**	**2nd Wave (04/10/2020 - 14/04/2021)**	**3rd Wave (15/04/2021 – up to now)**
Home Based Care (Asymptomatic or mildly symptomatic patients are managed			
No of Patients	3,396	92,341	195,861
No of Deaths	13	604	3,661
Case Fatality Rate *	0.38	0.64	0.97

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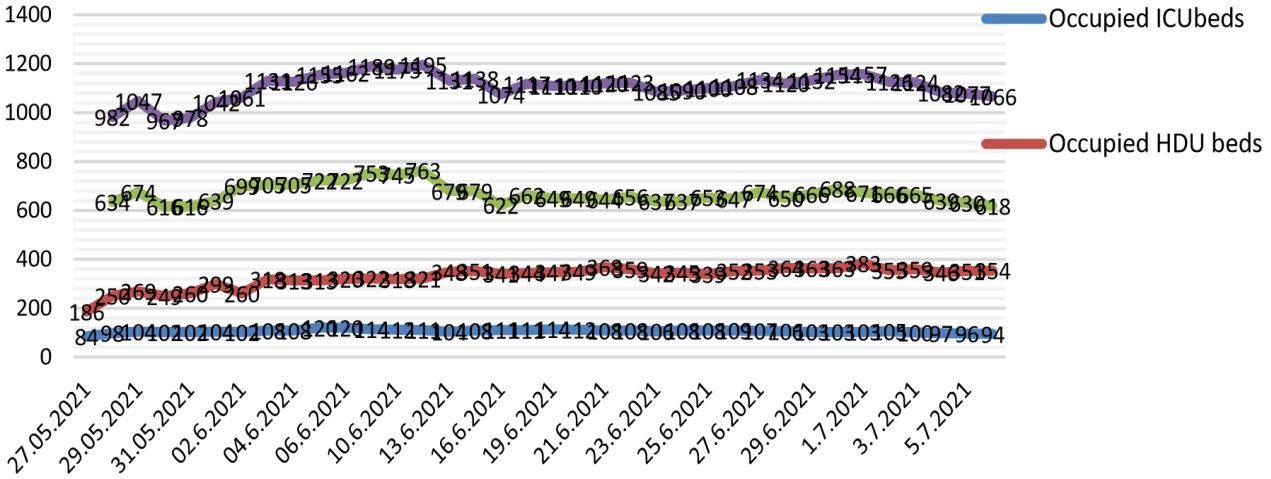

Figure 1: ICU/HDU/ Inward - Bed utilization pattern as of 5pm 15.07.2021

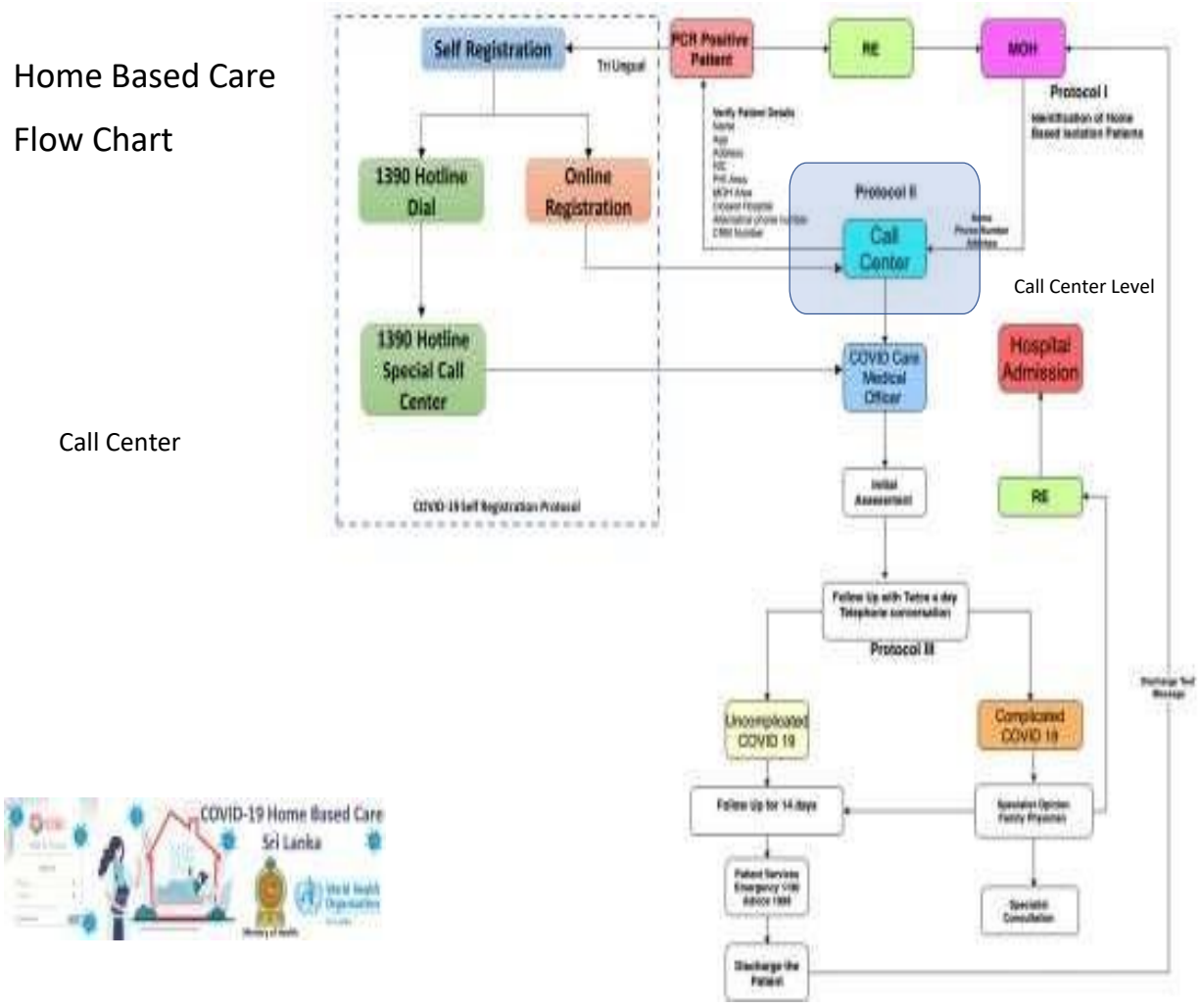

Figure 2: Home based care Flow Chart (World Health Organization. Regional Office for SouthEast Asia., 2021)

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Figure 3: Home based care statistics on 15.07.2021 (Ministry of Health Sri Lanka, 2022) Effectiveness on projections of Oxygen demand with caseload scenarios

Table 4: Oxygen production and requirement (Ministry of Health Sri Lanka, 2021c)

	Current capacity/Day	Maximum capacity/Day
Total oxygen production	**25 tons**	**80 tons**
Total oxygen production in Kg	**25,000 kg**	**80,000 kg**
Total liquid oxygen (kg/1.141 L)	**21,910L**	**70,114 L**
Total gaseous Oxygen (n L x 861)	**18,864,510 L**	**60,367,293 L**
Oxygen flow rate	**Total number of patients can receive oxygen with current capacity**	**Total number of patients can receive oxygen with increase capacity**
10 L/min	**1310**	**4192**
30 L/min	**436**	**1397**
60 L/min	**218**	**698**

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Table 5: Oxygen Demand in Various Scenarios and total Oxygen demanding patients (Ministry of Health Sri Lanka, 2021b)

Oxygen Demand in Various Scenarios Total Oxygen demanding patients	3000		6000		10000	
Oxygen flow rate	10L /min	30 L/min	10L /min	30 L/min	10L /min	30 L/min
Number of patients	2250 (75%)	750 (25%)	4500 (75%)	1500 (25%)	7500 (75%)	2500 (25%)
Daily gaseous oxygen need (L)	32,400,000 L/day	32,400,000 L/day	64,800,000 L/day	64,800,000 L/day	108,000,000 L/day	108,000,000 L/day
Daily liquid oxygen need (L) (n/861)	37,630 L	37,630 L	75,261 L	75,261 L	125,435 L	125,435 L
Daily liquid oxygen need (kg) (n x 1.141)	42,935 kg	42,935 kg	85,873 kg	85,873 kg	143,121 kg	143,121 kg
Daily liquid oxygen need (tons)	42.9 tons	42.9 tons	85.8 tons	85.8 tons	143 tons	143 tons
Total oxygen demand required to manage 3000 dependent patients	85.8 tons		171.6 tons (171.6-84=87.6 tons)		1286 tons (286-84=202 tons)	

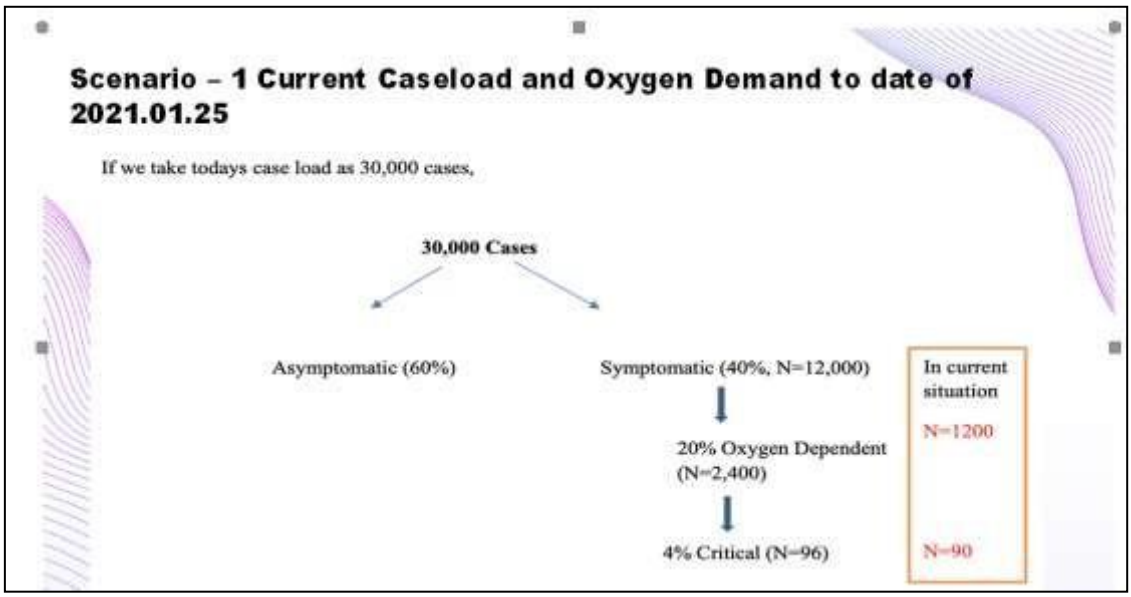

Figure 4: Caseload and Oxygen demand to date of 2021.01.25 (Ministry of Health Sri Lanka, 2021a)

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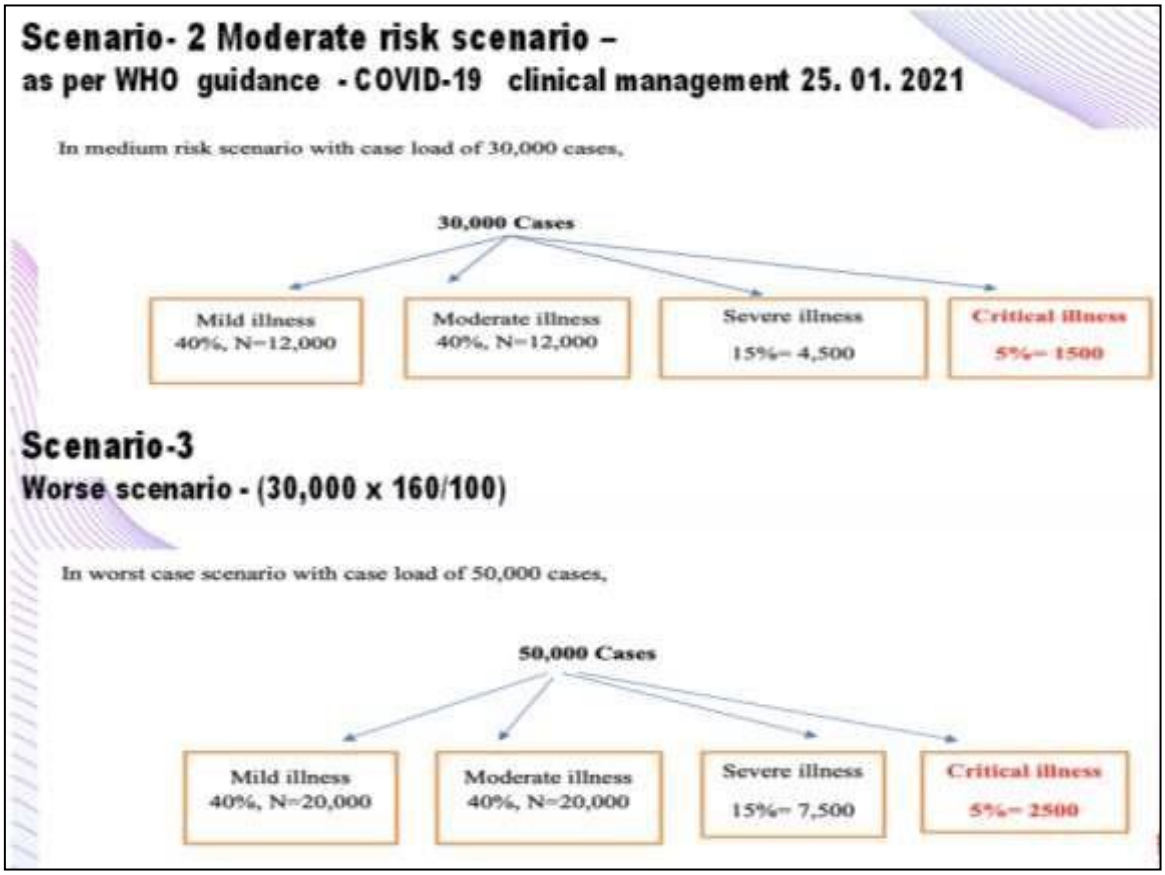

Figure 5: Caseload and Oxygen demand on moderate and service to date of 2021.01.25 (Ministry of Health Sri Lanka, 2021a)

Strategies taken for the effectiveness and to overcome above challenges to deliver high quality, medical-grade oxygen as follows;

1. Enhance oxygen production

The oxygen production capacity was up to 84 tons/day, and further increase is planned to increase within the next few months by two registered oxygen suppliers as per agreement with Ministry. Hence it was decided to establish 14 Pressure Swing Adsorption (PSA) plants which will enhance the oxygen production capacity by around 9,015,000 L/day in addition to currently available 11 PSA plants established mainly in the North-East region of the country, which the capacity was 392,400 L/day (272L/min). At the same time portable Bedside Oxygen Concentrators provided in order to mitigate the risk of cylinder-based oxygen scarcity in hospitals and to safeguard an uninterrupted supply of oxygen to both COVID-19 and non-COVID patients. **Further decided to import of liquid Oxygen 120,000 liters (six 22-Ton cryogenic ISO tanks)** as a contingency measure to secure continuous oxygen supply in order to mitigate unforeseen sudden issues related to oxygen production.

2. Rational use of Oxygen at all levels to mitigate the inappropriate usage and waste of oxygen

While reviewing of treatment guidelines and protocols in the process of changing with new evidences (*e. g. Revised guidelines for the use of non-invasive ventilation (NIV), and particularly continuous positive airway pressure ventilation - CPAP),* training of all healthcare workers (HCW) in the front line managing COVID-19 patients using online facilities in order to increase the clinical vigilance on waste reduction and appropriate delivery of Oxygen and use of proper equipment depending on clinical situation

3. Rational Patient Care Management

With the technical guidance of specialists, management protocols were changed for early detection of capillary oxygen saturation levels, and management of asymptomatic and mildly symptomatic patients in Level I COVID Treatment Centres (Intermediate Care

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Centres) or at centrally monitored Home Based Care system, with advise on strict bed rest and strict monitoring at least twice a day including Oxygen saturation using simple technology - digital pulse oximeters etc..

Even in other hospitals, establishing a triage for COVID patients on admissions in order to identify more critical patients to be admitted immediately to wards / HDUs / ICUs with facilities of highend equipment for Oxygen management; CPAP, Bi PAP and High flow machines as well as ventilators in ICUs. Moderately symptomatic patients with mild desaturation were admitted to step down Divisional Hospitals to be managed with low flow Oxygen with normal cylinders or Oxygen Concentrators sparing beds in main hospitals for patients that are more critical. Asymptomatic and mildly symptomatic patients were sent to homes enrolling them to Integrated Home Based Care Management System with active monitoring of patients by trained medical offices through mobile platform. Hence, complicated cases were minimal to higher centres as well as deaths during this period. Most of patients admitted with high complications especially with high desaturation status beyond the reversible stage and they ended up with deaths and causative factors were the patients stayed at home without medical advice and attended for heavy exertions and they were not able to measure the Blood Oxygen Saturation.

4. **Enhancement of oxygen bearing/storage capacity and oxygen carrying capacity together with improvement of efficient delivery process (inter and Intra hospital)**

Strengthening the **capacity of oxygen tanks in hospitals** (VIE (What?) / Liquid oxygen plants by establishing 25 more VIE tanks covering all districts in addition to currently **existing** 42 VIE tanks ranging of volume from 1K to 30 K. Also to arrange efficient transportation system through a proper supply chain management together with providing adequate number of suitable oxygen cylinders specially with adequate number of reserve cylinders.

5. **Improvement of efficiency of oxygen delivery at site**

Usage of proper technology; C-pap, Bi-pap, nasal cannulas, appropriate ventilators – together with training on rational usage of these apparatus will reduce the wastage and maximize the utilization of available oxygen. Also training of health staff to reduce wastage by using correct techniques in handling of cylinders. Further, establishment of high dependency units (HDU) and medical wards with wall oxygen outlets and establishment of medical oxygen cylinder manifolds in hospitals where wall oxygen supply systems do not available.

6. Limitation of usage of oxygen for other routine medical needs and non-medical needs Postponing of routine surgeries and only emergency surgeries continued. Public were educated that their careless activities like RTA will affect this country requirement though unnecessary surgeries and ICU care. Hospital staff was requested to prevent and minimize the wastage of Oxygen if any as well as to limit issuing Oxygen for industrial purposes.

Further, highlighted the importance of **reducing the oxygen demand** through minimizing the COVID case load and complications through the strategies and measures that taken were prevention of spreading the disease through strong public health awareness, legal and administrative measures, and movement restrictions, strengthening Health promotion for good practices through media, rational and well-planned vaccination programme, and public inquiry system through hotlines, FAQ platform to increase public awareness, monitoring of curative sector services, active interactions, HIUS system and Bed Management System, SMS / WhatsApp as well as Mobile App for institutional oxygen supply monitoring.

DISCUSSION

The COVID – 19 is respiratory disease that affect the airway system with oxygen dependency. In managing a COVID – 19 pandemic a country should be geared to face the challenges of oxygen demand for the patients. Health sector in Sri Lanka had prepared adequate number of centres and beds in order to manage all patients with provided bed at a treatment centre managed by medical staff even at Level intermediate care centres free of charge. Development of separate levels / centres for management of patients in each COVID disease severity levels was helpful to provide proper care to all patients based on their need. However, considering the demand of some social classes, it was opened to private sector even with affiliated hotel facilities. When the rising case load, all hospitals had to be opened COVID patient care compromising routine patient care to a certain extent. Triaging, identifying, allocating and managing of patients to suitable care level / suitable centres based on severity were strategic especially establishing a Home Based Care System with monitoring through a mobile platform with a call centre.

Level III, which is the Tertiary Care Centres with specialized HDU and ICU care facilities served for patients with severe /critical progressive de-saturated patients, while Level II hospitals managed symptomatic oxygen dependent or non-oxygen dependent

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patients with moderate disease stages, and COVID patients with other complications such as Obstetric, Surgical, and dialysis care. Though Level I Intermediate Care Centres managed asymptomatic or mildly symptomatic patients in 1st and 2nd waves, COVID patients with mild Oxygen desaturation stage, were managed at these Intermediate Care Centres with low flow rate of Oxygen and bed rest rather than moving patients during the 3rd wave mainly by delta variant.

All patient management centers needed oxygen to treat COVID-19 patients in various stages Understanding the resource distribution, mortality and morbidity pattern, case fatality rate locally across all three waves along with WHO information were analyzed to achieve predicted values for patient number and Oxygen requirement accordingly. As per oxygen manufactures, the current total oxygen consumption of the country was 25 tons per day and current maximum oxygen production capacity was 80 tons per day at that time. The oxygen requirement of a COVID patient with moderate to severe symptoms was varying from 2 L/min to 60 L/min respectively based on the methods and devises used in Oxygen therapy.

Daily requirement of oxygen was dramatically increasing with the increasing patient number especially with increasing number of Oxygen dependent patients. To achieve the flow rate of 10 L/min and 30 L/min liters, 14,400 L/day and 86,400 L/day of oxygen were respectively required to manage an oxygen dependent patient. Recent information of WHO (2020) reports that out of all oxygen dependent patients 75% require an oxygen flow of 10L/min and 25% require 30L/min. It was assessed that the maximum number of patients, which could be treated with different oxygen production capacities of the country; current and maximum and at different flow rates. At the flow rate of 10 L/min, 1310 and 4192 patients could be treated with the oxygen production rate of 25 tons/day and 80 tons/day respectively. Projections based on assessment considering above facts and the current actual case load and projected maximum caseload showed that maximum oxygen production capacity is barely enough to manage approximately 3000 oxygen dependent COVID 19 patients, but with the advancement of the flow rate, the number of patients that could be treated with oxygen was rapidly declining. However, it was assumed that the total production of oxygen is solemnly used for the management of COVID patients but 20% of total oxygen production should be kept spared for the routine medical care of hospitals and the industrial need of the country was entirely disregarded. However, to achieve this, the Oxygen suppliers had to limit issuing of oxygen to industrial usage and reduce other industrial gas production. Further, it had to restrict the Oxygen usage in hospitals only for life saving and essential patient care.

WHO Living Guidance on managing COVID 19 cases updated on 25th January 2021 reports that of all symptomatic patients 40% shows mild symptoms and another 40% shows moderate symptoms and rest of all shows severe (15%) and critical (5%) symptoms. However, the analysis of actual data obtained from hospitals showed out of current actual inward patient load, a lesser number of total oxygen dependent patients is still way below the hypothetical number in calculation arrived with assumption of all ICU and HDU patients those who were oxygen dependent in addition to inward oxygen dependent patients.

The Centre for Global Development (2020) report that the global hospital oxygen consumption during the COVID pandemic was increased by 158% in the US and 98% in Europe. Data estimated by BBC using WHO figures shows more than a three-fold increase in daily oxygen demand in managing COVID-19 patients in the third wave than the second wave in India. Considering the above facts and expert opinions, it had to predict worse case Oxygen consumption and best appropriate strategies to deliver high quality, medical-grade oxygen efficiently and effectively to the government hospitals of the country in order to maintain an adequate oxygen supply to face the challenges of possible future COVID variants.

Considering the ongoing mutations of COVID 19 virus with possible Delta or future variants with the possibility of increased case load than the more common alpha variant (21), Oxygen surge capacity, hospital readiness were analyzed and the number of projected COVID-19 oxygen dependent cases needing hospitalization along with demand of Oxygen were projected, under different possible case transmission curve scenarios adapting from WHO Living Guidance (25 January 2021) of COVID-19 management and interim guidance on oxygen sources and distribution for COVID-19 treatment centres. Considering the above facts to mitigate the risk and overcome above challenges in maintaining an adequate oxygen supply for both COVID and nonCOVID patient care in hospitals, some measures and strategies were recommended and proposed to be implemented. All treatment centers should manage COVID patient in bed rest and regular screening for Oxygen saturation for early identification of oxygen dependent patients.

Enhance oxygen production capacity through manufacturers and establish Pressure Swing Adsorption (PSA) plants in identified and further, provision of bedside Oxygen Concentrators, measures for promoting rational use of Oxygen at all levels such as revision of treatment guidelines and protocols, clinical vigilance and training of health care workers, using of simple technology such as pulse

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oximeters etc. Enhancement of oxygen bearing / storage capacity through increasing the capacity of existing oxygen tanks in hospitals establishment of liquid Oxygen tanks in identified hospitals, while enhancing oxygen carrying capacity through and mechanism for efficiency oxygen delivery at point of care through supply and use of new technology, reduction of wastage, training of health staff to identify and use stable methods, establishment of wall oxygen outlets in hospital settings and establishment of high dependency units (HDU), improvement of delivery process efficiency (inter and Intra hospital); increment of number of reserve cylinders (efficient supply and delivery mechanism), maintenance of adequate number of transport, reduction of delays in filling, and transport of oxygen were the successful strategies adopted. Activities suggested by the above strategies would enable to secure the continuous oxygen supply to hospitals and meet the daily excess oxygen demand.

CONCLUSIONS

Ensuring a reliable oxygen supply could be achieved only through implementation of multifaceted strategies to reduce oxygen wastage, enhance oxygen delivery, and improve the oxygen-bearing, improving oxygen production and storing capacity of hospitals and rational use. Emergency breakdowns are not often rare. Hence, the availability of an adequate number of backup oxygen cylinders in place is of utmost importance to consider along with the liquid oxygen capacity expansion. Availability of oxygen in hospitals does not ensure adequate delivery to those who need it most. Hence, the improvement and expansion of oxygen delivery systems and making necessary equipment available at the site are imperative together with adequate training for management in each section. Home Based Care system as well as regular frequent monitoring through mobiles and IT solutions was very successful.

RECOMMENDATIONS

Increment of oxygen production capacity of the suppliers, increment of oxygen production at hospital sites, reduction of wastage and increment of oxygen bearing capacity of hospitals, supplementation of equipment to hospitals as per the identification of oxygen demand. Increase the access to oxygen by using novel methods in production and to enhance oxygen baring, storing, carrying capacity and rational use in a sustainable way and also to implement measures to assess and monitor real oxygen need and consumption of each institutions and whole country is paramount important.

Capacity expansions have their own ceiling limits. Hence, reducing the oxygen demand through reduction of the caseload is an essential measure to match the hospital bed capacity with the patient surge. Therefore, endeavoring to control the disease spread through strong public health, legal, administrative measures and movement restrictions, Health promotion for good practices, strengthening public awareness and inquiry system through media, FAQ platforms and hotlines, Rational and well-planned vaccination programme etc., is much more important than any other measure.

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