Literature Review

Indonesian Journal of Health Administration
(Jurnal Administrasi Kesehatan Indonesia)
p-ISSN 2303-3592, e-ISSN 2540-9301
10.20473/jaki.v10i1.2022.133-142

SRI LANKA OXYGEN READINESS AND STRATEGIES ADAPTED FOR COVID-19 PATIENTS' MANAGEMENT

Kesiapan Oksigen Sri Lanka dan Strategi yang Diadaptasikan untuk Penanganan Pasien Covid-19

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Abstract

Background: Shortly after the Covid-19 oxygen crisis in India, the Sri Lanka Ministry of Health started investigating and analyzing gaps in oxygen production, supplies and demands.
Aims: This study aimed to evaluate the preparedness in Covid-19 cases management and recommend strategies to prevent oxygen crisis in healthcare facilities.
Methods: This study used information on oxygen source redundancy and delivery methods to assess whether a healthcare facility is prepared to provide the necessary oxygen demand for patients in need and to estimate the number of patients that can be treated with the currently available oxygen supplies. The predicted oxygen supplies and demands were assessed with a panel of experts using qualitative and quantitative methods. Data were collected using the Health Information Update System.
Results: Sri Lanka had 39,529 designated hospital beds including Intensive Care Unit and High Dependency Unit beds for Covid-19 patients. Even though an average number of patients were reaching 30,000, the actual oxygen demands were around 1,200 which were easily manageable with the current capacity of 80 tons per day.
Conclusions: Sri Lanka has made progress to increase access to oxygen by using novel methods to procure and increase oxygen availability, storing, and carrying capacity.

Keywords: COVID-19, oxygen, Case scenario, Sri Lanka, Ministry of Health

Abstrak

Latar belakang: Setelah terjadinya krisis oksigen pada kasus Covid-19 di India, Kementrian Kesehatan Sri Lanka mulai meneliti dan menganalisis kesenjangan produksi, ketersediaan, dan kebutuhan oksigen.
Tujuan: Kajian ini bertujuan untuk mengevaluasi kesiapan dalam penanganan kasus Covid-19 dan merekomendasikan strategi dalam mencegah adanya krisis di fasilitas kesehatan.
Metode: Kajian ini menggunakan informasi seputar ketidaktersediaan sumber oksigen dan metode pengiriman oksigen untuk mengevaluasi apakah fasilitas kesehatan siap untuk memenuhi kebutuhan oksigen yang penting untuk pasien yang sedang membutuhkan dan untuk memperkirakan jumlah pasien sesuai dengan ketersediaan oksigen saat ini. Estimasi ketersediaan dan kebutuhan oksigen dinilai oleh sekelompok pakar dengan menggunakan metode kualitatif dan kuantitatif. Data dikumpulkan menggunakan "Sistem Informasi Kesehatan Terkini".
Hasil: Sri Lanka memiliki 39,529 kasur pasien Covid-19 termasuk yang di ruangan ICU dan HDU. Meskipun jumlah rata-rata pasien mencapai 30.000, kebutuhan oksigen yang sebenarnya adalah 1.200, masih mudah ditangani dengan adanya kapasitas oksigen saat ini yang mencapai 80 tons per harinya.
Kesimpulan: Sri Lanka telah berproses untuk meningkatkan akses oksigen dengan menggunakan metode yang penting untuk menyediakan dan meningkatkan kapasitas produksi, penyimpanan, dan ketersediaan oksigen.

Keywords: COVID-19, oxygen, Case scenario, Sri Lanka, Ministry of Health

Indonesian Journal of Health Administration (*Jurnal Administrasi Kesehatan Indonesia*)
p-ISSN 2303-3592, e-ISSN 2540-9301
Volume 10 No.1 2022 DOI: 10.20473/jaki.v10i1.2022.133-142
Received: (2021-07-31), Revised: (2022-01-07), Accepted: (2022-05-24), Published: (2022-06-30)
Published by Universitas Airlangga in collaboration with Perhimpunan Sarjana dan Profesional Kesehatan Masyarakat Indonesia (Persakmi).

Indonesian Journal of Health Administration
(Jurnal Administrasi Kesehatan Indonesia)
p-ISSN 2303-3592, e-ISSN 2540-9301
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Introduction

The immeasurable Covid-19 pandemic effect has globally been in place of health systems, economies, and societies. On January 27, 2020, Sri Lanka found its first imported Covid-19 patient, a 44-year-old Chinese woman from Hubei province, China (Colombo Page, 2020). As of July 15, 2021, a total of 288,202 positive cases were reported in the country, and 254,871 of them recovered from the disease. The Covid-19 related death toll has reached 3,661 (Epidemiology Unit Ministry of Health, 2021). The increasing Covid - 19 surge has warranted the rapid hospital expansion and has urged the Ministry of Health to reassess its hospital surge capacity in relation to predicted Covid-19 patient loads. The World Health Organization (WHO) mentioned in the Covid-19 preparedness guidelines that the health preparedness assessments must be conducted regardless of current transmission levels, and it is necessary to ensure that all facilities, including first point-of-care access points, are ready to provide basic acute care to critical Covid-19 patients (WHO, 2020b).

Sri Lanka, earlier known as Ceylon and officially the Democratic Socialist Republic of Sri Lanka, is an island nation in South Asia with a population of 21.8 million (Department of Census and Statistics of Sri Lanka, 2021). It is situated in the Indian Ocean and separated from the Indian subcontinent by the Strait of Polk. Sri Jayawardenepura Kotte is its legislative headquarters, and Colombo is its financial epicenter. Administratively, Sri Lanka is divided into nine provinces and twenty-five districts (University of Birmingham, 2021).

The health system of Sri Lanka provides inward care to all patients tested positive for Covid-19 through its 234 designated in-patient care centers. According to technical experts, about 40% of Covid-19 patients were symptomatic, and 20% of them were oxygen dependent. Out of all oxygen dependent patients, 4% required critical care (Secretary College of Anaesthesiologists and Intensivists of Sri Lanka, 2021). Furthermore, 2,400 patients out of 30,000 current inward Covid-19 patients required an oxygen therapy. Viewing these issues as national concerns, this study aimed to predict the total oxygen demands of the country in the worst context of Covid-19 pandemic where the number of oxygen-dependent patients will reach up to 4,000 to 5,000 (University of Birmingham, 2021).

Covid-19 and oxygen usage

In June 2017, the WHO included oxygen in its model list of essential medicine (EML) during anesthesia because of its proven life-saving properties (WHO, 2021c). In addition to that, oxygen therapy has shown to be effective in treating Covid-19 patients and it is recommended for all severe and critical Covid-19 symptoms (Long *et al*., 2021).

Flow rates for oxygen therapy range from low 1-2 L/min to 5 L/min to high 30-60 L/min. In Sri Lanka, different devices have been used for oxygen delivery and subdivided into low-flow oxygen devices to high-flow nasal oxygen delivery (HFNO) devices (Pinto *et al*., 2020).

Method

This study used information on oxygen source redundancy and delivery methods to assess whether a healthcare facility is prepared to provide the necessary oxygen demands for patients in need and to estimate the number of patients that can be treated with the current oxygen production capacity and future demands in healthcare facilities of Sri Lanka.

The predicted oxygen supply and demand were assessed by the principal investigator with a panel of experts using qualitative and quantitative methods, adapting a pre-validated WHO's online tool (WHO, 2020b). The questionnaire was modified by the experts to collect data by using HIUS (Health Information Update System), which is an open-source, free data-collection tool. Timely data collection was done in contact with hospital coordinators from May 15 to July 15, 2021. Reminders to complete the HIUS were sent out twice a week during this period.

The current oxygen supply gaps for designated Covid-19 treatment centers were assessed by the medical supplies division (MSD) through the direct contact of

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(Jurnal Administrasi Kesehatan Indonesia)
p-ISSN 2303-3592, e-ISSN 2540-9301
10.20473/jaki.v10i1.2022.133-142

each healthcare center. DDG MS1 (Deputy Director General Medical Services I) and DDG BMES (Biomedical Engineering Services) provided the information on other oxygen supply gaps in other healthcare institutions. The first-hand experience of managing oxygen-dependent Covid-19 patients and perceived need for equipment were assessed through interviews held with clinicians as key informants. Further, selected on-site visits were made to verify the assessments.

Data were exported from the HIUS platform into an excel spreadsheet and subsequently imported into statistical software SPSS for data analysis. Qualitative data collected from the key informant interviews (KII) and focused group discussions (FGD) were recorded and transcribed with the consent of the participants. The data and testimonials were synthetized to confer to common statements and coded into thematic areas. Each thematic area was analyzed and transformed into information.

In this study, surge capacity was defined as the existing capacity designated to meet public health needs due to the Covid-19 pandemic (Cavallo *et al*., 2020). This study was granted administrative clearance from the Sri Lanka Ministry of Health.

Result and Discussion

All Covid-19 management centers, including Level I to III, may need oxygen to treat Covid-19 patients (Sri Lanka Ministry of Health, 2021). There were 152 level I Intermediate Care Centers (ICCs) including 60 private hospitals and selected hotels. Initial management for asymptomatic and lower symptomatic patients especially with mild diseases had been done at this level, and 73 level II secondary care centers at base hospitals and some divisional hospitals with ICU and HDU facilities had become places for treating symptomatic oxygen-dependent or non-oxygen-dependent patients with moderate diseases. Besides, nine level 1 centers with specialized HDU and ICU were in place to treat severe or critical progressive oxygen-desaturation patients.

Surge capacity of hospital Covid-19 beds

Sri Lanka had 39,529 designated hospital Covid-19 beds across all sectors (public, semi-government, tri-forcers, and private sectors); further, it is expected to expand the number of total beds up to 49,527.

Table 1. Distribution of resources, mortality, and morbidity across Covid-19 three 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			
Level I	-	37	153
Level II	8	37	73
Level III	2	9	9
Beds			
Level I	-	12,441	29,904
Level II	<1,000	2,750	5,963
Level III	400	1,550	1,550
Number of Patients	3,396	92,341	195,861
Number of Deaths	13	604	3,661
Case Fatality Rate *	0.38	0.64	0.97

**Case is defined as a laboratory confirmed patients*

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Table 2. Calculation of the number of patients treated with the current oxygen production (25 tons/day) and maximum oxygen production capacity (80 tons/day)

Oxygen	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 (n kg/1.141)	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 who can be treated with the current oxygen production capacity**	**Total number of patients who can be treated with the maximum oxygen production capacity**
10 L/min	1,310	4,192
30 L/min	436	1,397
60 L/min	218	698

Distribution of resources, mortality, and morbidity across all three Covid-19 waves

Understanding the resource distribution, mortality, and morbidity patterns locally across all three waves is important to take rational decisions and formulate recommendations on oxygen demand during the Covid-19 pandemic. Table 1 outlines the distribution of resources, mortality, and morbidity across the waves.

Current oxygen production capacity and demand

The current total oxygen consumption of the country was 25 tons per day, and current maximum oxygen production capacity was 80 tons per day (Manager oxygen world limited, 2021) . The oxygen required for a Covid-19 patient with moderate to severe symptoms varies from 2 L/min to 60 L/min, respectively.

The daily requirement of oxygen is dramatically increasing with higher oxygen flow rates. At the flow rate of 10 L/min and 30 L/min liters, 14,400 L/day and 86,400 L/day of oxygen are respectively required to manage an oxygen-dependent patient. Table 2 demonstrates the current and maximum oxygen production capacity in Sri Lanka and the maximum number of patients that can be treated with different oxygen production capacities at different flow rates. However, to produce the

Maximum capacity of oxygen, the suppliers (Ceylon Oxygen Limited and Gas world Limited) have to limit issuing of oxygen to industrial usage and reduce other industrial gas production.

The information in Table 2 shows that at the flow rate of 10 L/min, 1,310 and 4,192 patients can be treated with the oxygen production rate of 25 tons/day and 80 tons/day, respectively. However, with higher flow rates, the number of patients that can be treated rapidly declines. Table 6 assumes that the total production of oxygen is solemnly used for the management of Covid-19 patients. However, 20% of total hospital oxygen production must be spared for the routine medical care at hospitals, while the industrial need for oxygen must be entirely disregarded.

WHO (2020a) recently reported that out of all oxygen-dependent patients, 75% required an oxygen flow of 10L/min, and 25% required 30 L/min (WHO, 2020). Considering the facts and the current actual caseload in Sri Lanka (Figure 1), 2,400 oxygen-dependent patients should be manageable at Covid-19 treatment centers.

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10.20473/jaki.v10i1.2022.133-142

Table 3. Calculation of total oxygen capacity for 2,400 oxygen-dependent patients

Oxygen Flow Rates	10 L /min	30 L/min
Number of patients (2400)	1800 (75%)	600 (25%)
Daily gaseous oxygen need (L)	25,920,000 L/day	25,920,000 L/day
Daily liquid oxygen need (L) (n/861)	30,104 L	30,104 L
Daily liquid oxygen need (kg)(n) x 1.141)	34,349 kg	34,349 kg
Daily liquid oxygen need (tons)	34.4 tons	34.4 tons
Total oxygen capacity required to manage 2,400 oxygen-dependent patients	**68.8 Tons**	

Table 3 shows the amount of oxygen required to manage 2,400 patients with different oxygen flow rates. From Tables 2 and 3, the maximum oxygen production capacity in Sri Lanka is barely enough to manage approximately 3,000 oxygen-dependent Covid-19 patients. The results are supported by the statement made by clinicians during the interviews. They said, "The current maximum oxygen production is closer to bare the minimum patient requirements" (Secretary, College of Anaesthesiologists & Intensivists of Sri Lanka, 2021).

The global oxygen scenario during Covid-19 surges also shows the same high-level oxygen demand in Covid-19 patient management. The Centre for Global Development (2020) reported that the hospital oxygen consumption during the Covid - 19 pandemic increased by 158% in the US and 98% in Europe (Smith *et al*., 2020). Data estimated by BBC using WHO figures demonstrated more than a three-fold daily oxygen demand increase for Covid-19 patient management in the third wave compared to the second wave in India (BBC, 2021).

To maintain an adequate oxygen supply for the upcoming challenges of Covid-19 variants, an expert committee was established to find best appropriate strategies to supply high quality, medical-grade oxygen efficiently and effectively to the government hospitals of Sri Lanka.

Are we ready to cater the oxygen demand amidst Delta or future variants?

Considering the ongoing mutations of Covid-19 virus and WHO predictions (Hafeez *et al*., 2021), this study analyzed the oxygen surge capacity, hospital readiness to develop new strategies, and recommendations to deliver high quality medical-grade oxygen adequately to healthcare facilities. The oxygen surge capacity was analyzed using three possible case scenarios that have been adapted from WHO Living Guidance of Covid-19 management (WHO, 2021b) and interim guidance on oxygen sources and distribution for Covid-19 treatment centres (WHO, 2020a). Therefore, predicted oxygen requirement was calculated based on assumptions. For example, all the designated Covid-19 centers may need to treat oxygen-dependent patients with symptoms, and one-third of the bed capacity of level II and all level III institutes need to be supplied with wall oxygen ports to ensure the smooth delivery of oxygen.

Scenario 1: Current actual caseload and oxygen demand

Scenario 1 (Figure 1) analyzes the current actual inward patient load in Sri Lanka; it is equivalent to 30,000 patients. As per literature published up to July 15th 2021, out of all patients, 60% (n = 18,000) should be asymptomatic and 40% (n = 12,000) are symptomatic. Of total symptomatic patients, 20% (n = 2,400) would be oxygen-dependent, and 4% (n = 96) of oxygen-dependent patients looked for critical care.

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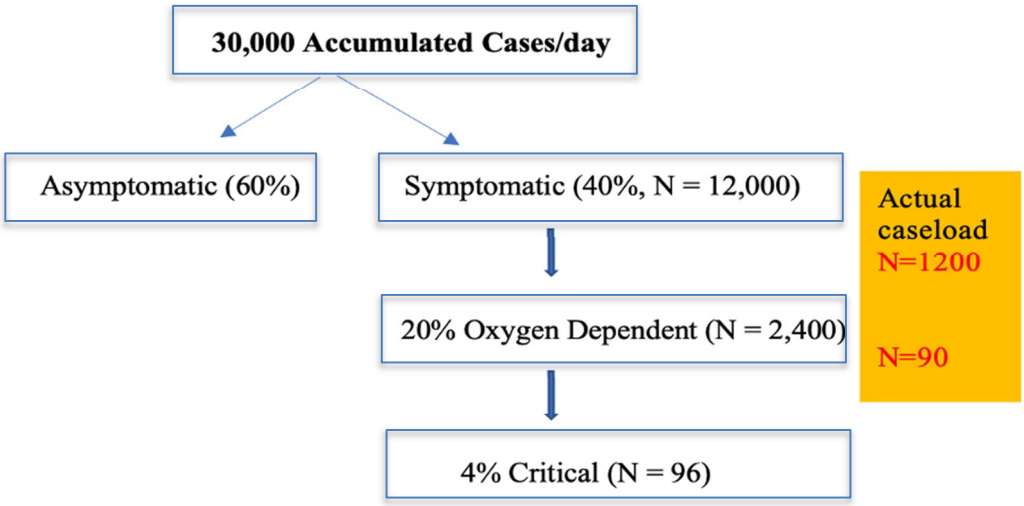

Figure 1. Current Covid-19 case load

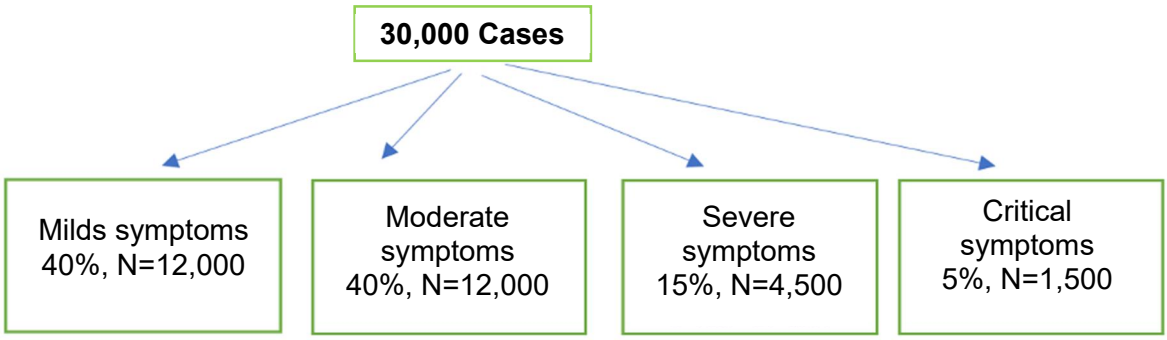

Figure 2. Calculation predicted cases per patient categories as per WHO data in 2021

However, the analysis of actual data obtained from hospitals showed a lesser number of total oxygen-dependent patients (n =1,200) which were still way below the hypothetical number (n = 2,400) calculated. Further, all ICU and HDU patients were presumably oxygen-dependent in addition to inward oxygen-dependent patients. Hence at this point, the Ministry of Health did not face challenges in supplying oxygen requirements to inward patients.

Case scenario 2: Moderate level of oxygen dependency

The WHO Living Guidance on Covid-19 cases management updated on January 25, 2021 reported that of all symptomatic patients, 40% showed mild symptoms, and another 40% showed moderate symptoms; the rest of all showed severe (15%) and critical (5%) symptoms (WHO, 2021b). Considering the total number of cases (n= 30,000), the calculation in Figure 2 can work out.

Under different transmission curve scenarios with possible Delta or future variants, the possibility of cases increased by 50 % than the more common alpha variant (Bhutta *et al*., 2021); case load might increase up to around 50,000. In such situation, the number of projected Covid-19 oxygen-dependent patients in need for hospitalization may increase up to 10,000 cases, and oxygen requirement will increase by 3 times which will account for 286 tons (Figure 3).

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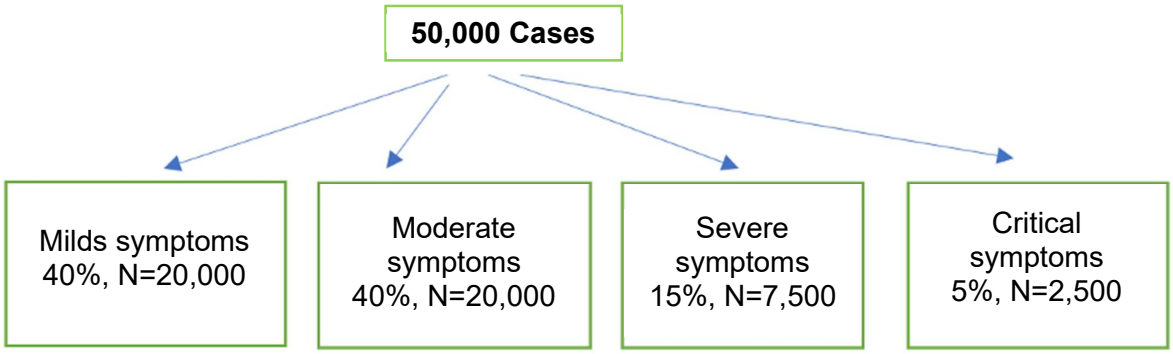

Figure 3: Calculation of predicted cases per patient categories for delta variant

Case scenario 3: High number of patients and oxygen dependence

This scenario was built up for new Covid-19 variants such as delta variant which has a more impact over 50% (30,000 x 150/100 = 45,000).

Considering the above factors, adequate oxygen supplies should be available in government hospitals of Sri Lanka to mitigate the risk and overcome the challenges with measures and strategies that have reached the consensus of all expert committee members.

Strategies and measures to overcome challenges in high quality, medical-grade oxygen supplies

Enhancing oxygen production

The supply of oxygen to the healthcare institutions in Sri Lanka mainly depends on Ceylon Oxygen Ltd and Gas World Private Ltd. Most level II and III hospitals supplied oxygen through oxygen cylinders; level I hospitals are through both the cylinders and installed Vacuum Insulated Evaporators (VIEs) or liquid oxygen tanks. The oxygen suppliers and the Secretary of Health agreed to increase the oxygen production capacity up to 84 tons/day within the next few months.

Further, planned to establish Pressure Swing Adsorption (PSA) plants in identified hospitals. Currently, Sri Lanka has 11 PSA plants established mainly in the North-East region of the country with a capacity of 392,400 L/day (272L/min). Furthermore, the Ministry of Health has sought cabinet approval of establishment of 14 PSA plants which will enhance the oxygen production capacity by around 9,015,000 L/day. The PSA plants in peripheries will increase oxygen production and reduce the transportation time and cost. Besides, it was decided to import bedside oxygen concentrators to mitigate the risk of cylinder-based oxygen scarcity at hospitals and to safeguard an uninterrupted supply of oxygen to both Covid-19 and non-Covid-19 patients. The cabinet approval was granted to procure 2,500 portable oxygen concentrators (100 units per district) based on the population density (Secretary to the State Ministry of Pharmaceutical Production, Supply and Regulation, 2021).

Rational use of oxygen at all levels

The standard use of oxygen was achieved through the revised treatment guidelines and protocols, clinical vigilance, and training of health care workers. Furthermore, it could be reduced by using a simple technology such as pulse oximeters and promoting the rational use of oxygen among health staff to reduce and mitigate the inappropriate usage of oxygen.

Improvement in oxygen storage capacity

An increase in the existing oxygen tanks at hospitals could happen as the current VIE or Liquid oxygen plants were strengthened efficiently and effectively through proper maintenance, phantomatic systems, supply chain management and so on. For example, there must be regular monitoring on the pressure adjustment of the regulators as required, and ensuring that the evaporators do not ice up excessively.

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Besides, the Ministry of Health has already been establishing more than 25 VIE tanks covering all districts and importing liquid oxygen up to 120,000 liters (22-ton cryogenic ISO tanks). In the first stage, the Ministry of Health planned to establish 14 units and in the second stage other 11 units. Currently, the public health sector had 42 VIE tanks established at hospitals. The volume ranged from 1K to 30 K. During that period, to anticipate unforeseen sudden issues related to oxygen production, these ISO tanks may help as a contingency measure to secure continuous oxygen supply to state sectors.

Increasing oxygen production capacity

The importation of 15,000 oxygen jumbo cylinders in addition to available 6,962 jumbo cylinders would be made to secure the supply. Further, the Ministry of Health also planned to set medical oxygen cylinder manifolds at hospitals where wall oxygen supply systems are available. Manifolds are safe, convenient, and cost-effective systems at the point of use, and they can be used as backup systems for VIE tanks.

Improvement in oxygen delivery efficiency

This plan could be successful through the use of technology, C-pap, Bi-pap, nasal cannula, appropriate ventilators training on rational usage of these apparatus, reduction of wastage by using correct techniques in handling of cylinders, and training of health staff to identify and use stable methods. Besides, other ways to achieve this goal are through the establishment of wall oxygen outlets in hospital settings (establishment of high dependency units (HDU) with wall oxygen outlets on provincial basis (100 in each province) for the treatment of 900 critical Covid-19 patients in addition to available 6442 oxygen outlets in the country), development of norms for each Covid-19 treatment center for the distribution of equipment, and supply of necessary equipment for essential care.

Improvement in delivery process efficiency (Inter and intra hospitals)

Oxygen manufactures agreed to increase the number of reserve cylinders (efficient supply and delivery mechanism), maintain an adequate number of transport vehicles to increase the oxygen distribution capacity in the country, and reduce delays in filling and transport of oxygen to improve the delivery process.

In addition to the strategies and measures, expert groups suggested the strategies should be adapted only in the worst scenarios such as reduced usage of oxygen for other routine medical needs and non-medical needs.

The strategies will enable us to secure the continuous oxygen supply to state health sectors, especially hospitals, and meet the daily excess oxygen demand of 51 tons required for Covid - 19 patients management amidst rapidly spreading variants (Secretary of Production, Supply and Regulation of Pharmaceuticals state Ministry of Sri Lanka, 2021).

Conclusions

The continuous supply of oxygen to hospitals cannot be guaranteed during this unpredictable pandemic. Even though the capacity to produce an additional oxygen volume by the local factories is available, the production process is dependent on interlinked multifaceted factors. A breakdown of one linkage may end the health system up in a disastrous situation. Therefore, ensuring a reliable oxygen supply cannot be achieved only through establishing EIA/PSA plants. Hence, the implementation of multifaceted strategies to reduce oxygen wastage, enhance oxygen delivery and oxygen production capacity of hospitals is essential.

Emergency breakdowns are not often rare due to the fact that an adequate number of backup oxygen cylinders in place are of utmost importance to consider along with the liquid oxygen capacity expansion.

The availability of oxygen at hospitals does not ensure adequate delivery to those who need it most. Therefore, the improvement and expansion of oxygen delivery systems and making necessary equipment available at the sites are imperative.

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Since capacity expansions have their own ceiling limits, reduction of the caseload is an essential measure to match the hospital bed capacity with the patient surge. In short, efforts to control the disease spread are much more important than any other measures.

Abbreviations

WHO: World Health Organization; EML: List of Essential Medicine; HFNO: High-Flow Nasal Oxygen; DDG: Deputy Director General; HIUS: Health Information Update System; ICC: Intermediate Care Centers; BBC: British Broadcasting Corporation; VIE: Vacuum Insulated Evaporators; PSA: Pressure Swing Adsorption;

Declarations

Ethics Approval and Consent Participant
Not applicable.

Conflict of Interest
The authors declare no conflict of interest in this article.

Availability of Data and Materials
Not applicable.

Authors' Contribution
DHL, MDAK, PNW, AKSBDA, PWCP, UAASP, and ISY conceptualized the study; created the methodology; wrote, reviewed, and edited the manuscript.

Acknowledgment
Not applicable.

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Indonesian Journal of Health Administration
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p-ISSN 2303-3592, e-ISSN 2540-9301
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