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Analysis of Oxygen Supply and Demand amid the Coronavirus Disease 2019 (COVID-19) Pandemic in Thailand, 2021

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Abstract

The need for medical oxygen in Thailand tends to be increasing due to rising coronavirus disease 2019 (COVID-19) cases. An analysis of oxygen supply and demand can provide a useful insight into the demand for oxygen therapy during the pandemic. To overcome the oxygen supply crisis, the government needs to address the shortage of related equipment, such as oxygen cylinders, generators and concentrators, which are mostly used for home and community isolations and also in field hospitals. We recommend that the government should dramatically increase the capacity for oxygen production as well as the production of related equipment. Furthermore, mechanisms to ensure adequate and equitable distribution of oxygen therapy should be in place. A promotion of domestic research and development to increase the capacity of oxygen production and ensure equitable oxygen distribution is urgently needed.

Keywords: oxygen supply, demand, COVID-19, Thailand

Introduction

Coronavirus disease 2019 (COVID-19) is now considered a major health crisis with more than 212 million people infected.[1] Recent research has indicated that 14% of patients face severe signs and symptoms.[2] The most common symptoms are associated with respiratory failure and 5% of patients need intensive care.[3,4] Oxygen therapy is a critical component of treatment and is included in the list of essential medicines recommended by the World Health Organization. It is used for the treatment of hypoxemic conditions, which are commonly found in COVID-19 patients. Delayed treatment with oxygen for more than 2 days after the onset of hypoxia may almost double the risk of death.[5] Therefore, hospitals and health care facilities need a robust supply of oxygen as part of the management.[6]

The COVID-19 situation in Thailand was under control and manageable since the first case was discovered in January 2020. Until December 2020, the accumulated cases were 6,900, and more than 2,500 patients were hospitalized.[7] However, the number of cases has sharply increased since March 2021, leading to more than 1 million cases with approximately 5,000 severe cases currently hospitalized.[8] Hospital beds in Bangkok and in other big cities have been occupied entirely by COVID-19 patients. In the past, the Ministry of Public Health (MOPH) stipulated that all COVID-19 patients must be hospitalized. However, due to the skyrocketing of cases in mid-2021, the MOPH has set a new treatment policy to prevent the healthcare system from being overwhelmed. The new treatment guidelines categorize patients according to the severity of their symptoms. Asymptomatic and those with mild symptoms are classified as 'green' and are encouraged to isolate at home (Home Isolation—HI) or at designated areas in the community (Community Isolation—CI). Patients with moderate symptoms or at risk of developing a severe condition are classified as 'yellow'. This group is required to stay in a field hospital or a 'hospitel' (a hotel transformed into a small hospital under the supervision of health personnel). Patients with pneumonia or any other severe complications are classified as 'red'. This group needs to be hospitalized and some require close monitoring and aggressive treatment in an intensive care unit (ICU).

The new treatment guidelines came in parallel with the supply of medicines and self-monitoring kits such as pulse oximetry provided by the National Health Security Office for green and yellow classified patients. However, there is debate among health practitioners and policymakers that there should be an adequate supply of oxygen in addition to medicines and monitoring kits, especially for the yellow patients whose conditions might turn red any time. In addition, experiences from other regions such as India and sub-Saharan Africa showed that during the peak of the pandemic, it is critical to have a clear plan on oxygen supply in response to COVID-19.[9-11]

This article thus investigated the situation of medical oxygen supply for COVID-19 patients in Thailand based on both supply and demand perspectives, and aimed to provide optimal recommendations for a better management of oxygen supply in Thailand in response to the COVID-19 pandemic.

Analysis on the Demands for Oxygen Therapy

The Department of Disease Control and the International Health Policy Program of the Ministry of Public Health estimated the prevalence of COVID-19 patients stratified by severity level. The model employed the compartmental (susceptible-exposed-infectious-recovered) model in combination with the system dynamics concept. Table 1 describes the key parameters of the model.

Table 1. Essential parameters of the model

Area	Reproduction number (R0)	Population (millions)	Percentage of initial infectees
Bangkok and vicinity (n=5)	1.43	12.2	50.0
Provinces with high degree of epidemics (n=7)	1.45	6.6	25.0
Other provinces (n=65)	1.35	49.3	15.0

The model also relied on the following assumptions. First, the model estimated the number of COVID-19 cases based on different scenarios: no lockdown measures, lockdown measures with 20% effectiveness in a reduction of the basic reproduction number, and lockdown measures with 25% effectiveness. Second, the model calculated the likely number of actual cases, not reported cases, based on a hypothesis that the actual (unobserved) cases were about 3-6 times greater than daily reported cases. Third, the model was based on an assumption that each type of patient (green, yellow, red) required a different amount of oxygen. For green patients, we assumed that 20% of cases required oxygen at a maximum of 5 litres per minute. The patients in the red group would need, via ventilator, 50 litres of oxygen per minute. Yellow patients would require different amounts of oxygen as follows: 30% of the patients would require, via oxygen cannula, 5 litres of oxygen per minute, 50% of patients would require, via oxygen mask, 10 litres of oxygen per minute, and the remaining 20% would require, via high-flow cannula, 20 litres of oxygen per minute.

Our analysis shows that the highest demand of oxygen would be observed if the prevalence rose to 140,842 patients (most in the yellow group). Such a situation would cause a demand for 2.15 million liters of oxygen per day. The peak of oxygen demand would occur during the end of August 2021 (Figure 1).

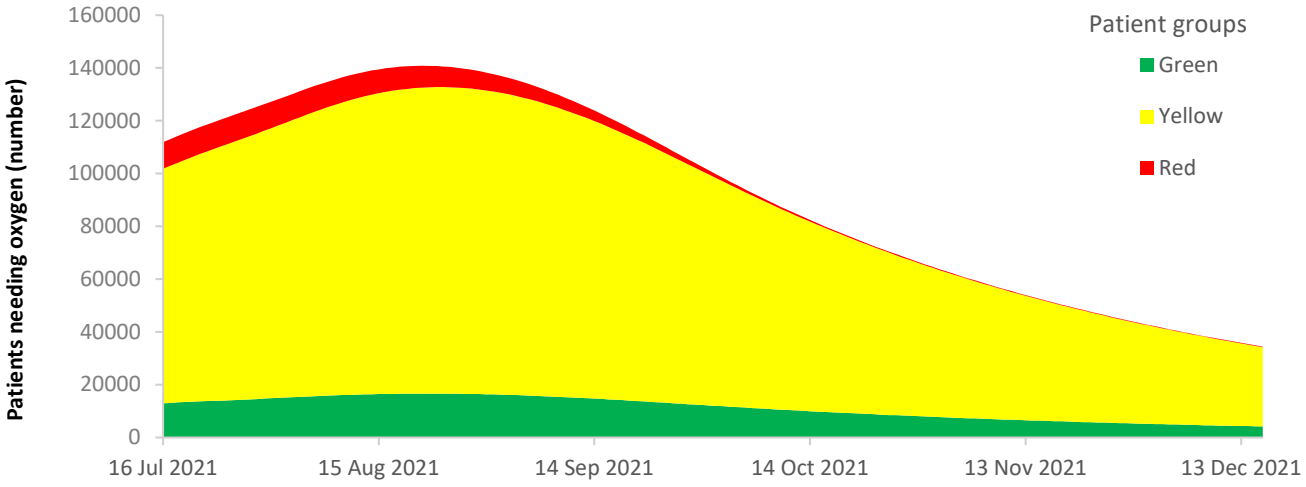

Figure 1. An estimation of the number of COVID-19 patients from July to December 2021

Figure 2 estimates the need for oxygen in each epidemic scenario. In theory, if no lockdown policy had been implemented, the demand for oxygen nationwide would have exceeded 2,000 million litres per day by mid-August 2021 then declined to below 1,500 million litres by mid-September 2021. However, a lockdown policy was a more likely scenario as Thailand had undergone lockdown measures since mid-July 2021. In the two lockdown scenarios, the peak of demand was observed between mid-July and early August 2021 then dropped to below 1,000 million litres a day by approximately the first and the second weeks of September 2021.

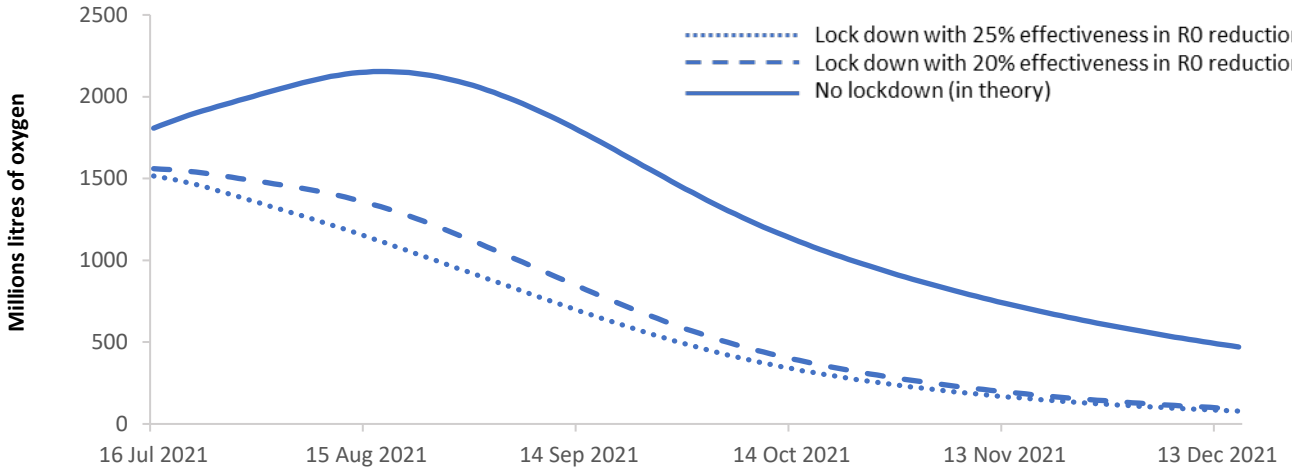

Figure 2. Estimated demand for oxygen (all patient codes combined) in different scenarios

Analysis of Supply for Oxygen Therapy

National Production Capacity

The national production capacity of oxygen in Thailand currently amounts to 1,750 million liters per day. Production capacity could be increased by approximately 20%, leading to a total of 2,100 million liters per day. Until now, only one-fifth to one-third of the national oxygen production has been dedicated to medical use, whereas the rest was effectively destined for industrial use.[12] However, an internal consultation with representatives in the industrial sector found that, in practice, the property of oxygen produced for industrial use was indistinguishable from the property of oxygen for medical use; meaning that the oxygen from both strands of production could be used interchangeably. Regarding this situation, the supply of medical oxygen was not in serious shortage.

Modalities of Oxygen Supply

Oxygen supplies used for the care for COVID-19 patients can be delivered through various means as follows.

Liquid Oxygen Tank

A liquid oxygen tank contains about 3,000 liters of oxygen, which can treat about 30 patients requiring 5 litres per minute of oxygen for at least 11 consecutive days (Figure 3). The establishment of a liquid oxygen tank needs about a week and requires an operating area of approximately 4 m^2. Then oxygen is transferred from the tank to the patients via a pipeline. Such liquid oxygen tanks are commonly used in well-established health facilities. The cost of establishment is about 200,000 baht (US$ 6,100) per unit. The tank can be rented at a cost of 20,000 baht (US$ 610) per month.

(a) (b)

Figure 3. Example of (a) oxygen tanks and (b) oxygen cylinders

Oxygen Cylinders

An oxygen cylinder is a metal tank filled with liquid oxygen under high pressure (Figure 3).[13] Normally, Thailand imports the cylinders from China as there are no domestic manufacturers. Currently, the number of cylinders is estimated to be about 100,000. During April 2021, before Thailand faced the big wave of COVID-19 cases, there was a high demand of oxygen cylinders from neighbouring countries such as Myanmar, India and Indonesia.[14-16] Numerous cylinders in Thailand were exported to those countries. Thailand is now planning to produce its own cylinders to meet the surge in demand during the COVID-19 pandemic. The cylinders can produce a flow of oxygen, via oxygen cannula or oxygen mask, of up to 15 litres per minute.

Oxygen Generator and Oxygen Concentrator

An oxygen generator is an alternative source of oxygen therapy (Figure 4). However, they are generally set up in healthcare facilities as they require the on-site establishment of oxygen cylinders and, in parallel, a central oxygen supply. Within this process, one to two months are needed for a standard test of setting up the system.

Another option is an oxygen concentrator. This is a device that uses nitrogen to remove oxygen from a gas supply. It is commonly used to provide enriched air in a household area. The cost varies from about 10,000 to 40,000 baht (US$ 308-1230). It is easily movable and can be operated in a household context. However, the flow of oxygen is limited (normally about 1-10 litres per minute) compared with that of oxygen cylinders. Therefore, the use of oxygen concentrators is likely to be limited to green and yellow patients. The majority of oxygen generators and oxygen concentrators were imported from China. Other necessary equipment includes oxygen valves and pipes, of which existing stock is now able to meet the national demand.

(a) (b)

Figure 4. Example of (a) oxygen generators and (b) oxygen concentrators

Which Choice is Suitable and in Which Setting?

Overall, the supply of medical oxygen is considered adequate to meet the demand of the lockdown policy. However, the demand may be far greater than at present if the lockdown policy is relaxed and the pandemic worsens. In such circumstances, current oxygen supplies are likely to be insufficient. Thus, an increase in production capacity is still needed.

A more challenging situation involves the supply of related equipment needed for oxygen therapy. Under current market conditions, there is still a shortage of oxygen cylinders, generators, and concentrators as this equipment is mostly produced abroad. In this scenario, green and yellow patients, who are supposed to be treated at home, may suffer most from the shortage.

Oxygen generators may be a suitable option for a small field hospital or a hospitel. A central bank of oxygen cylinders should be created in communities with a high number of cases in order to ensure adequate delivery for patients undergoing home and community isolation.[9] However, any community oxygen bank must be implemented in parallel with strong safety measures of setting up the system. Table 2 summaries the advantages and limitations of each oxygen modality based on the capacity of oxygen equipment and its use in diverse health care settings.

Table 2. Summary of oxygen modalities

Option	Advantages	Limitations	Suitable setting
Liquid oxygen tank system	• Suitable for high demand for care • Needs a well-established engineering system	• Needs a pipeline system in tandem	• Well-established health facilities (such as hospitals or large field hospitals)
Oxygen cylinder	• Easy to use • Have surge capacity from using nitrogen cylinders	• Needs intensive exchange for a new cylinder, therefore it is a risk for disease transmission • Shortage of cylinders • Needs high levels of precaution for setting up the system	• Suitable for home and community isolation, and field hospital or hospitel (if necessary) • Option for supplementing oxygen supplies
Oxygen generator	• Closed system • Low cost • Relatively mobile	• May take a long time to set up • Shortage of domestic supply • Oxygen needs to be filled on site.	• Field hospital • Hospitel • Community isolation
Oxygen concentrator	• Easy to use and relatively safe • Low cost compared to other modalities • Very mobile	• Shortage of domestic supply • Need to be imported from abroad • Low productivity of oxygen • Suitable for only patients with mild conditions	• Home isolation • Community isolation

Conclusion and Policy Recommendations

Our analysis shows that oxygen production is likely to catch up with demand for oxygen under the status quo. The crucial point is related to the supply of related equipment. To address this, the following recommendations are proposed.

1. The Ministry of Public Health should work closely with the Ministry of Industry to carefully monitor the oxygen supply situation in parallel with the monitoring of COVID-19 cases.
2. Additional authorization from the Ministry of Commerce regarding, for example, the export of oxygen cylinders, should be authorized under the Central Committee on the Price of Goods and Services under the Act on Goods and Services Prices B.E. 2542 (1999), since this will support the effectiveness of existing legislation.
3. Oxygen supplies in large hospitals should be kept in reserve. A model of a hospital-chain system to provide oxygen supplies from a large hospital to smaller hospitals under its network is recommended.
4. The industrial sector should rapidly increase oxygen production capacity before the lockdown policy is relaxed and before the COVID-19 cases begin to rise again.
5. Liquid oxygen tanks should be set up in large hospitals and field hospitals with authorized standards and quality checks.
6. Procurement of oxygen generators and concentrators should be negotiated between the government and providers. Rapid response for products at affordable prices is urgently needed. Additionally, domestic production should be increased in order to alleviate the reliance on imported products.
7. Domestic research and development on the production and distribution of oxygen in response to the public health crisis should be promoted. This needs mutual collaboration among all parties, including government authorities, academics, and the private sector.

Suggested Citation

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