Oxygen and Respiratory Care Equipment for COVID-19 Patient Management in Vietnam

Survey results and analysis from 993 health facilities

September 2021

PATH

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Abbreviations

BEIT	Biomedical Equipment Inventory Tool
BiPAP	bi-level positive airway pressure
BR-VT	Bà Rịa – Vũng Tàu
COVID-19	coronavirus disease 2019
CPAP	continuous positive airway pressure
ECG	electrocardiogram
ESFT	Essential Supplies Forecasting Tool
GoV	Government of Vietnam
HCMC	Ho Chi Minh City
ICU	intensive care unit
LPM	liters per minute
m^3	cubic meter
MOH	Ministry of Health
POX	pulse oximeter
PSA	pressure swing adsorption
RCE	respiratory care equipment
SpO2	blood oxygen saturation
UNICEF	United Nations Children's Fund
WHO	World Health Organization

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Executive summary

Overview

Relative to its population and other countries, Vietnam has experienced few COVID-19 cases, a testament to strategies by the Government of Vietnam (GoV) to combat the pandemic. Quick action to limit foreign travel, contain outbreaks, and treat patients has meant that, throughout most of the pandemic, the people of Vietnam have been able to live life as normal. However, since July 2021 cases rose to levels of approximately 10,000 to 14,000 per day and it is important to remain vigilant and constantly assess the strengths and weaknesses of the health system to ensure that any challenges presented by COVID-19 can be overcome. This report is an assessment on the state of medical oxygen and respiratory care equipment (RCE) needed for COVID-19 patient treatment in Vietnam. In addition, because medical oxygen and RCE are needed also for pneumonia, newborn conditions, asthma, heart failure, obstetric emergencies, and surgery, the findings from this report offer important lessons for improving the health system in general and preparing for the next pandemic.

Working together, the Ministry of Health (MOH) Cabinet Office and PATH used the World Health Organization (WHO) Biomedical Equipment Inventory Tool to survey 1,445 health facilities, quantifying the amount of medical oxygen and RCE available. Of these facilities, 993 were identified as likely to provide care to COVID-19 patients given a large-scale outbreak—mainly district general hospitals and higher-level facilities. Survey results were compared to estimated equipment amounts needed for critical and severe COVID-19 patients, as stipulated by the WHO Essential Supplies Forecasting Tool (ESFT) and MOH Decision 2626.

Key findings

Key findings on medical oxygen are as follows:

- Using assumptions from the WHO ESFT, it is estimated that **the current supply of medical oxygen in the 993 surveyed facilities identified as likely to provide care to COVID-19 patients is sufficient for a maximum outbreak of approximately 74,000 COVID-19 cases within a two-week period**, assuming these cases are distributed optimally within the health system, with 15 percent of all cases being severe and requiring 10 liters per minute (LPM) of oxygen for one week and 5 percent being critical and requiring 30 LPM for two weeks. Using these assumptions, patient demand would exceed medical oxygen supplies in hospitals if there were more than 74,000 cases over two weeks, which is about 5,300 cases per day for two weeks.
- Assuming patients are distributed optimally among facilities, at a maximum number of patients **the health system could provide oxygen for approximately 3,300 critical patients and 5,100 severe patients simultaneously**.
- However, using case data from the Vietnam MOH that put the percentage of severe and critical cases at 5.1 and 3.0 percent, respectively, there is sufficient medical oxygen for a maximum outbreak of 142,000 cases within a two-week period, or about 10,000 a day. It should also be kept in mind that **dynamic emergency response activities have likely increased the ability of the health system to respond** since the time data were recorded in the survey, and approximately 25% of hospitals were not captured by the survey.

- In reality, outbreaks will be focal, and patients will not be distributed optimally to maximize use of oxygen supplies. Identifying the most vulnerable provinces and increasing their oxygen capacity can overcome this challenge.
- Vietnam produces large amounts of liquid oxygen and **increasing the frequency of liquid oxygen deliveries would increase the maximum caseload the health system could handle**.
- **The daily production capacity of liquid oxygen in Vietnam is estimated to be 1,129 m^3, which is 69% of the total volume of liquid oxygen storage tanks in hospitals (1,628 m^3).** At least ten companies supply liquid oxygen at 66 locations around Vietnam.
- Nearly every national hospital has liquid oxygen, and 63 percent of provincial hospitals and 6 percent of district hospitals have liquid oxygen. In addition, 92 percent of provincial hospitals and 54 percent of district hospitals already have oxygen piping installed, indicating there are many facilities where liquid oxygen tanks could be installed and attached to existing pipe networks.

Key findings on intensive care unit (ICU) beds are as follows:

- **The survey recorded 16,645 ICU beds in total**. Using the WHO ESFT assumption that 40 percent of ICU beds would be needed for non-COVID-19 patients and 60 percent could be made available for critical COVID-19 patients, there are 9,900 ICU beds for COVID-19 patients recorded by the survey.
- The five provinces with the least number of ICU beds recorded in the survey (and the number of ICU beds each has) are Bà Rịa – Vũng Tàu, or BR-VT (18); Hưng Yên (51); Lai Chau (54); Hải Dương (57); and Đắk Nông (68).
- Medical oxygen availability at hospitals would be a limiting factor before ICU beds would be. The number of severe and critical patients that could be treated with available oxygen is less than the number of ICU beds, indicating that hospitals would run out of oxygen before ICU beds if oxygen deliveries were not increased.

Key findings on RCE are as follows:

- The types and amount of RCE in hospitals were compared to a list of equipment required by the MOH to treat COVID-19 patients (Decision 2626) and the list of equipment in the WHO ESFT**. Only a small percentage of hospitals had a complete set of RCE** as defined by these lists.
- 54 hospitals met the guidance from the MOH's Decision 2626 when the survey was conducted in January and February 2021. However, Decision 2626 was published on May 28, 2021, so it is likely more hospitals since have fulfilled this guidance.
- Using the WHO ESFT estimated standards, **there are enough ventilators for more than 11,000 critical COVID-19 patients**.
- District hospitals recorded many more ICU beds than patient monitors, which raises concerns about how they may be defining "ICU bed."

Recommendations

Based on these findings the project team has developed the following recommendations:

- **Equip more provincial- and district-level hospitals with liquid oxygen**. A single 6 cubic meter (m^3) liquid oxygen tank could provide oxygen for up to 11 critical COVID-19 patients and 17 severe patients simultaneously for a week before needing to be refilled, which would increase the oxygen

capacity of the health system to handle roughly 227 more cases over a two-week period, or about 16 cases per day. It would be important to focus first on BR-VT, Đắk Nông, Phú Yên, Gia Lai, Hải Dương, and Lào Cai Provinces, as these provinces have the lowest capacity as far as number of patients they can treat with sufficient oxygen in absolute and per capita terms.

- **Create an oxygen supply coordination emergency plan** by doing the following: contact liquid oxygen and oxygen cylinder suppliers to record their oxygen supply capacities; during a crisis require hospitals to track oxygen consumption and report daily to an emergency operations center that can aggregate consumption data and calculate regional demand; forecast oxygen needs weeks to months in advance based on hospital oxygen consumption data and changes in caseloads; and contact suppliers again to ensure they can supply enough oxygen to meet forecasted demand. All data collected can be used to coordinate oxygen deliveries to hospitals in need.
- **Create a real-time equipment management system**. Many facilities recorded a lack of complete sets of equipment per bed type as stipulated by the MOH in Decision 2626 and the WHO ESFT. Having a real-time monitoring system could help quickly identify which facilities need support due to missing equipment. This system would also make it possible to understand the capacity of the heath system to handle health emergencies, and new directives on medical equipment could be promulgated via this system. While it is incredibly useful to understand availability of oxygen, surveys such as the one reported here take a significant amount of time and resources to conduct and analyze. Real-time asset management systems allow for real-time understanding of equipment availability planning.

As an industrializing economy, Vietnam produces large quantities of liquid oxygen, and many facilities already have the necessary oxygen piping installed, meaning they could relatively quickly install and make use of liquid oxygen tanks. Increasing the number of facilities with liquid oxygen would greatly increase the ability of the health system to provide oxygen to patients if a worst case–scenario outbreak was to occur. Liquid oxygen systems will be a strength for Vietnam during a crisis because they can be resupplied relatively efficiently, and Vietnam already produces lots of liquid oxygen. If a real-time equipment management system were in existence, the survey that was conducted by the MOH and PATH could be conducted daily via automated systems and monitored from dashboards within the MOH, which would enhance the ability to quickly prepare for and respond to epidemic emergencies. This system also could be used to monitor data on nonfunctioning equipment and target resources for repairs, potentially resulting in fewer unnecessary procurement orders and saving money.

Objective

The objective of this report is to describe the state of medical oxygen and respiratory care equipment (RCE) availability in the health system of Vietnam and estimate how many COVID-19 severe and critical patients could be treated with available medical oxygen and RCE. Primary data on the supply of medical oxygen and RCE were collected using an online version of the World Health Organization's (WHO) Biomedical Equipment Inventory Tool[1] (BEIT) sent to 1,445 health facilities. Projected data on the demand for medical oxygen and RCE were calculated using parameters from the WHO Essential Supplies Forecasting Tool (ESFT)[2] that specify how much medical oxygen and RCE a severe or critical COVID-19 patient is estimated to need. The ESFT's parameters are used to estimate how many severe or critical COVID-19 patients can be treated with available medical oxygen and RCE recorded by the BEIT.

Background

Oxygen is essential

In 2017, the World Health Organization (WHO) listed medical oxygen as an essential medicine for hypoxemia, or dangerously low levels of oxygen in the blood.[3] Before 2020, increasing access to medical oxygen was widely supported as a way to decrease childhood mortality, and it is estimated that improved access to oxygen and pulse oximetry, the devices used to measure blood oxygen levels, can reduce childhood mortality from pneumonia by 35 percent.[4] However, in the early months of 2020, with the outbreak of COVID-19, the world began to realize how important oxygen is for emerging infectious respiratory diseases that can grow exponentially and quickly overwhelm health systems.[5]

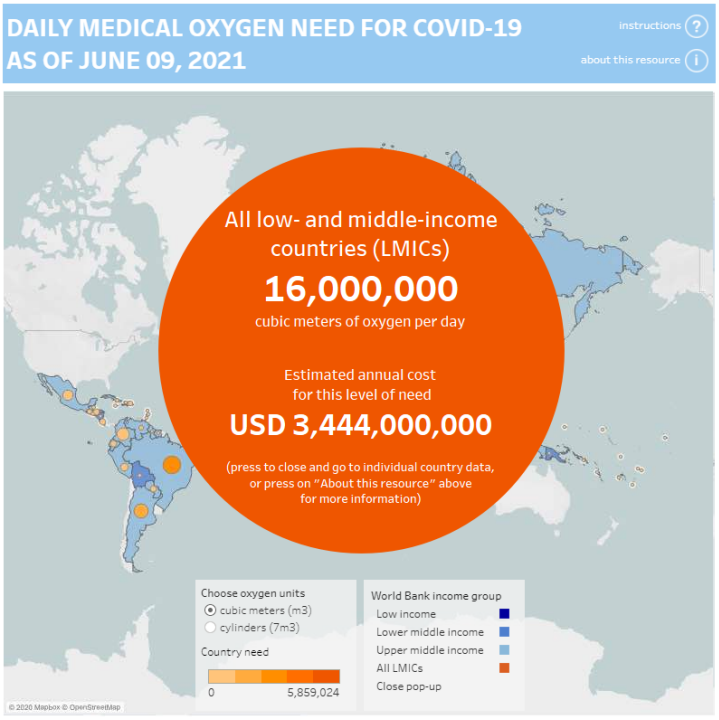
To help countries estimate their oxygen and respiratory care equipment (RCE) demands in the face of increasing numbers of COVID-19 patients, tools like the WHO Essential Supplies Forecasting Tool (ESFT) were developed rapidly, and international organizations, donors, and countries came together via initiatives like the WHO Partners Platform to help match country demands with potential supplies. Despite these efforts, over the course of 2020 and much of 2021, countries have still faced crippling and deadly shortages of RCE and medical oxygen, as seen in India in April and May of 2021. Oxygen is not only an essential medicine but also an essential utility that hospitals need, just like water and electricity. Acute shortages in a medicine that is also a utility are an exceedingly complex problem that cannot be solved quickly during an emergency. Today's emergency shortages in medical oxygen and RCE must be solved months to years in advance by proper emergency planning and robust supply networks.

Global project

PATH, together with a consortium of partners, is leading the COVID-19 Respiratory Care Response Coordination project to support country decision-makers in the development and execution of a comprehensive respiratory care plan to meet the demands of COVID-19.[6] The project is also pursuing strategies to help prioritize and improve access to oxygen therapy and other essential equipment involved in respiratory care as an integral part of health systems strengthening, beyond the pandemic response.

In total, there are 13 core project countries and approximately 14 additional countries receiving technical assistance and support, as needed. Since the start of the project, PATH has worked with ministries of health to

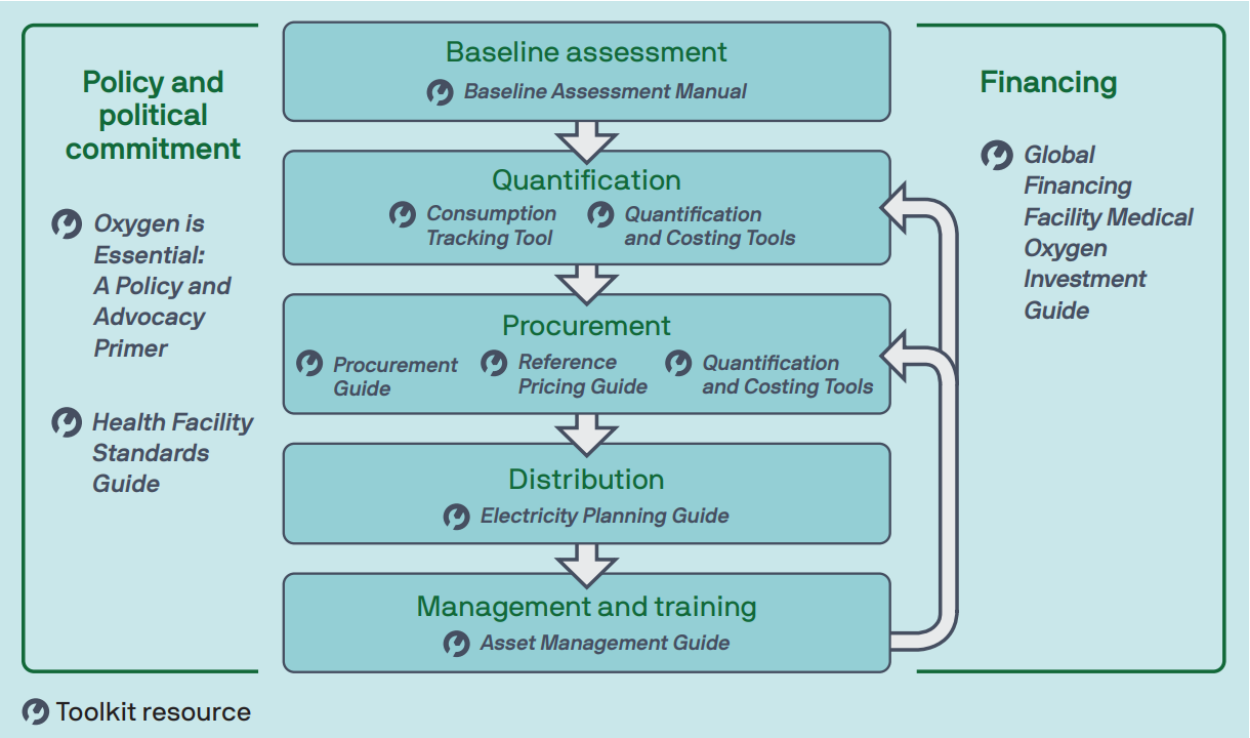
Figure 1. Global Oxygen Needs tracker.



complete BEIT surveys in Senegal, the Democratic Republic of the Congo, Malawi, and Zambia. PATH helped mobilize specific funding for India's oxygen needs and, working within the WHO's COVID-19 Oxygen Emergency Taskforce, ensured that Global Fund financing can be used to support countries' RCE and oxygen needs. PATH also has helped draw the world's and donors' attention to oxygen via the Global Oxygen Needs tracker (Figure 1), which monitors how much oxygen is needed in every country for COVID-19. However, most importantly, through local offices, PATH has partnered with Ministries of Health (MOH) to overcome medical oxygen and RCE challenges specific to each country.

PATH has been working to increase access to medical oxygen for nearly a decade and in 2020 published an Oxygen Delivery Toolkit, which provides materials to help decision-makers, implementers, and advocates plan for, manage, and communicate the value of scaling up oxygen delivery systems and access to oxygen and pulse oximetry. In total, there are 11 resources within the toolkit ranging from an advocacy primer to help advocates understand how to campaign for medical oxygen to facility-level consumption tracking tools for implementers supporting specific health systems. However, most of the resources focus on decision-makers to help them decide how best to optimally scale access to medical oxygen and increase patient health outcomes. Figure 2 displays the suite of resources within this toolkit.

Figure 2. Oxygen Delivery Toolkit resources life cycle.



COVID-19 in Vietnam and measures taken by the MOH

Since early 2020, Vietnam has experienced 4 waves of the COVID-19 pandemic. The first wave was from 23 January 2020 to 24 July 2020 with 415 confirmed cases. The second wave was from 25 July 2020 to 27 January 2021 with 1,136 confirmed cases, most of which were detected in Da Nang and a few other provinces with epidemiological factors linked to the Da Nang outbreak. During this second wave, the disease penetrated hospital departments where severe and critical patients were being treated, like

intensive care unit (ICU), nephrology, and dialysis departments. All 35 deaths during this wave were those patients with severe existing conditions. The third wave was from 28 January 2021 to 26 April 2021 with 1,301 confirmed cases. The outbreak started in Hai Duong province around the Vietnamese Traditional New Year 2021. This was the first time a COVID-19 outbreak was detected spreading among workers in industrial zones and among those in quarantine compounds. The fourth wave begun on 27 April 2021 with community transmission occurring in many provinces with a much higher number of recorded cases and deaths than in previous waves. Southern provinces have been hit hard by the pandemic, especially Ho Chi Minh City (HCMC). The transmission of the disease during the fourth wave has been fast and widespread with multiple transmission sources, multiple clusters, and caused by multiple variants, including the Delta variant which has proven to be more contagious and dangerous than others. As of September 2021, the pandemic situation is complex in HCMC and other southern provinces; the disease has spread widely in the community in many provinces with clusters occurring in wholesale markets, industrial zones, and crowded residential areas.

Since the beginning of 2020, when the COVID-19 pandemic had not yet reached Vietnam, the Politburo, the Secretariat, the National Assembly, the Chairman, the Government, the Prime Minister, the National Steering Committee, MOH, and other ministries and relevant sectors have closely monitored the pandemic situation in order to lead and direct actions promptly, comprehensively, effectively, and appropriately. These leading organizations have been able to mobilize the power of the whole political system and support from communities and enterprises to achieve the "double goal" in which both effective epidemic prevention and control, and promoting socio-economic development simultaneously continue.

All levels, sectors and localities have been proactive and diligent in their efforts invoking the spirit of "fighting the epidemic like fighting the enemy". Effort to achieve the “double goal” utilize several strategies: early detection, identification of high risk areas, quick quarantine/isolation, aggressive and effective outbreak containment, quick stabilization of the situation; strengthening "4 localized/on-site" activities (local human resources, on-site command, local supporting vehicles, on-site logistics support), especially strengthening testing capacity; and implementing a vaccine strategy to rollout COVID-19 vaccines as early as possible. Particular focus has been placed on increasing testing capacity and vaccine adoption because these are critically important to proactively fight the pandemic. Strengthening decentralization efforts and assigning specific responsibilities to the leaders at all levels in epidemic prevention and control has also proved important.

Localities across Vietnam have activated the entire system of government for prevention and control of the pandemic, and strictly followed the direction of the central government and the guidance of MOH. Subnational authorities have also: developed different scenarios for appropriate response, implemented appropriate social distancing and quarantine/isolation based on risk level, implemented rapid contact tracing, strengthened the role of community-based outbreak response teams, applied appropriate testing methods based on outbreak contexts, and coordinated activities for sampling, testing, and implementing appropriate methods of quarantine/isolation. Provinces and cities actively set up field hospitals in a timely manner and stratified treatment facilities based on severity level for COVID-19 cases. Centers for ICUs were built to treat severe and critical COVID-19 cases. Home-based care was also applied for asymptomatic COVID-19 cases. Logistical support was provided based on the “4 on-site” strategy. Outbreak prevention and control measures in industrial zones were gradually tightened and outbreak prevention measures at workers’ residence were strengthened. Establishment of green zone (COVID-19 safe zone) appears to be a promising measure to minimize the risk of the transmission. Vietnam defines 4

risk-based zones with color indicators: red as very high risk, orange as high risk, yellow as risk, and green as safe in new normal condition.

At the current moment, the COVID-19 outbreak in some provinces/cities is still very complex, however WHO has indicated that Vietnam is on the right path with effective prevention and control measures in this fighting against COVID-19 despite Vietnam being classified as a low-middle income country with limited health care expenditure. Positive results of the pandemic prevention and control have created favorable conditions for a successful achievement of the "double goal" and ensuring the security of society.

However, there is always potential risk of having new outbreaks due to new variants of SARS-CoV-2 that might be highly virulent and pathogenic. In addition, there is currently no herd immunity to the disease and vaccines are still scarce. The health system still has limitations that cannot be ameliorated in a short time and the pandemic situation is still serious globally and in countries that share borders with Vietnam. Therefore, the implementation of the "4 on-site" strategy is necessary in order to be ready to respond to the changing pandemic situation, improve the ability to coordinate resources when breakouts occur, and especially to ensure the adequate amount of medical equipment and supplies for respiratory care, and medical oxygen for COVID-19 patients nationwide.

In order to implement the above urgent measures, the MOH Cabinet Office has collaborated with PATH and related agencies to conduct a survey at 1,445 medical facilities and hospitals nationwide to assess current situation status and propose effective solutions for prevention, control, and treatment of COVID-19 patients. The study focused on the following indicators: (1) current amount of RCE (ventilators, patient monitors, blood oxygen meters, etc.); (2) current medical oxygen availability; and (3) estimate number of COVID-19 patients that can be treated with the number of RCE and medical oxygen recorded in the survey.

Survey methods and tools

Two tools developed by WHO and adapted for Vietnam and the MOH's Decision 2626 were used to create this report: the BEIT, used to quantify the amount of RCE and medical oxygen in health facilities, and the ESFT, used to estimate how much RCE or medical oxygen is needed per severe and critical patient. Decision 2626 specifies how much medical equipment should be available for 20 beds meant to treat severe and critical COVID-19 patients.[8]

BEIT

The BEIT was created by WHO in the early months of the COVID-19 pandemic "to collect in-depth facility inventories of biomedical equipment re-allocation, procurement, and planning for COVID-19 case management."[1] The tool covers 21 different categories of equipment and consumables, and for reusable equipment, data were also collected on their functioning or nonfunctioning status. WHO made the tool available in a paper-based version and an online version via SurveyCTO, a digital survey tool commonly used by researchers. The online version of the tool was used in Vietnam.

Limited resources and time available for the project prevented the possibility of sending teams to each facility to conduct the survey; therefore, a scalable and timely solution was decided upon, whereby the MOH would email provincial health departments a link to the survey and request that each then send that link to health facilities within its province to fill out the survey online.

Before sending out the survey, PATH and the MOH Cabinet Office worked together to adapt the survey questions to Vietnam's specific context. Restrictions on data entry values were also coded into the survey to help increase data quality. For example, in certain data entry fields only numeric values could be inputted, or in other fields numeric entries could be entered only within a specified range. Additionally, some questions could only be asked based on answers to the previous questions. The tool was then piloted in several facilities to identify issues before being sent to facilities nationwide.

WHO ESFT

According to WHO, the ESFT "assists governments, partners, and other stakeholders to forecast the necessary volume of personal protective equipment, diagnostic equipment, consumable medical supplies, biomedical equipment for case management, and essential drugs for supportive care and treatment of COVID-19."[11] The ESFT is a Microsoft Excel-based tool that users can adjust to fit their specific country or subnational context. Since WHO developed the ESFT in the early months of the COVID-19 pandemic, the tool has been used in countries around the world to estimate their commodity needs, and the results of these estimates have played an important role in mobilizing international donor financing to close gaps in commodity needs.

WHO ESFT relies on three major assumptions and other important parameters:

1. *The estimated/suggested standard amount of medical equipment needed per bed or patient*. To estimate how many pieces of medical equipment are needed, the tool uses WHO estimates on the ideal amount of medical equipment needed per patient or per bed for each type of equipment (see Appendix 4). However, it should be noted that the suggested standard amounts given in the ESFT is

not an official guide by WHO, and MOHs could use other assumptions on the ideal amount of medical equipment per bed, such as those in Decision 2626.

2. *The estimated number of COVID-19 patients*. This tool relies on projected COVID-19 cases, meaning the user needs to make an estimate on the future course of the pandemic or provide scenario caseload forecasts. This assumption will not be the main focus of this analysis, and instead the analysis will focus on estimating how may COVID-19 patients could be treated with existing RCE and medical oxygen. However, RCE and oxygen demand based on hypothetical caseloads is provided in the "Demand under different scenarios" section and Appendix 2.
3. *The assumption of 60 percent of beds to be used for COVID-19 patients and the remaining 40 percent left for use by other patients*. This is the default value from the WHO ESFT and can be changed if requested by the MOH.

There are also many other assumptions within the ESFT, and below is a list of the more important ones:

- 20 percent of COVID-19 cases require hospitalization:
    - Of that 20 percent, 15 percent are "severe" cases needing oxygen therapy.
    - Of that 20 percent, 5 percent are "critical" cases needing mechanical ventilation.[12]
- Severe patients are expected to need access to treatment appropriate to their severe condition for one week and require 10 liters per minute (LPM) of oxygen.
- Critical patients are expected to need access to treatment appropriate to their critical condition for two weeks and require 30 LPM of oxygen.

Decision 2626: List of equipment for COVID-19 treatment areas

On March 17, 2020, when Vietnam had seen fewer than 100 cases of COVID-19, the MOH promulgated Decision 941, which specifies the amount of medical equipment needed in 20-bed isolation areas in central- and provincial-level hospitals;[9] and on April 4, 2020, a brief amendment was made to this document.[10] On May 28, 2021, in the middle of a larger COVID-19 outbreak, the MOH promulgated Decision 2626, which provides a more comprehensive list of equipment, consumables, and drugs needed for 20-bed areas that treat (1) asymptomatic patients, (2) moderate patients, and (3) severe and critical patients.[8]

The list of equipment and consumables was used in this analysis to identify how many surveyed hospitals could meet the requirements for a 20-bed area meant to treat severe and critical patients. However, a few caveats should be kept in mind: (1) many facilities, especially district hospitals, may never be called upon to treat severe or critical patients; (2) some facilities are capable of treating far more than 20 severe or critical patients; and (3) the inventory of equipment and consumables surveyed in January and February 2021 may differ from the inventory currently found in facilities. A complete list of equipment and consumables for severe and critical patients required by Decision 2626 can be found in Appendix 3.

Analysis methods

Data from the survey are summarized within three categories: region, hospital level, and urban / rural split. These categories were chosen due to their relevance to the report's primary audience, the Vietnam MOH. The analysis proceeds from the macro level (e.g., number of hospitals) to the micro level (e.g., number of nasal cannula) to provide context to more detailed data as the report progresses. Most data

below are presented in sums to increase salience among decision-makers who are themselves often dealing in aggregate figures. Means, medians, and proportions are displayed when valuable for context or for decision-makers. All analysis and plots were done in R, a statistical programming language.

The analysis below relies heavily on calculating the number of patients that can be treated with available oxygen. The method to estimate hospital oxygen supply is as follows:

- Convert all oxygen source flow rates into LPM available per week:
    - Oxygen concentrators provide continuous oxygen flow rates depending on their size. For example, the analysis assumed a 5 LPM concentrator could provide 5 LPM continuously over the course of a week.
    - Oxygen cylinders were assumed to be refilled weekly. A cylinder with 1,000 liters of gas oxygen could therefore provide 0.1 LPM continuously for a week (1,000 / 7 days / 24 hours / 60 minutes).
    - Liquid oxygen tanks were assumed to be refilled weekly. A m^3 of liquid oxygen has 1,000 liters, and each liquid liter is 861 gas liters.[13] A standard 6 m^3 tank can supply 512.5 LPM continuously for a week.
    - Pressure swing adsorption (PSA) plant flow rates were directly requested in the survey so involved no calculations.
- Sum the oxygen flow rates from all oxygen sources at the facility level to arrive at individual hospital-level oxygen capacity in LPM available continuously over a weeklong period.
- At the hospital-level, divide total oxygen capacity in LPM by the oxygen rate needed by two categories of COVID-19 patient:
    - Critical patients were assumed to need 30 LPM of oxygen as estimated by the WHO ESFT. Oxygen concentrators were not used to calculate oxygen capacity for critical patients because oxygen concentrators do not provide sufficient flow rates for use with concentrators.
    - Severe patients were assumed to need 10 LPM of oxygen as estimated by the WHO ESFT.

Survey results: Supply of medical oxygen and equipment

Health facilities

In total there were 1,445 responses to the survey. Of these, 201 were excluded from the analysis due to being (a) a duplicate facility, (b) a commune health station, or (c) a private clinic or specialty hospital that does not have patient beds. Another 274 hospitals were excluded for being specialty facilities unlikely to be called upon to treat severe and critical COVID-19 patients, including traditional medicine, ophthalmology, psychiatry, dermatology, endocrinology, and other specialist facilities.

In the final count, 993 facilities were included in the analysis (Table 1). WHO states that there are 1,332 public and private hospitals in Vietnam,[14] indicating this survey represents approximately 75 percent of public and private hospitals. Since not all hospitals in Vietnam were included in the survey, the capabilities of the health system estimated by this report are likely to be conservative. The facilities that were included in the survey are (1) national-level hospitals and hospitals under medical universities (according to Decision 274/BYT-VPB1), (2) health facilities (public and private) from the district level or higher, (3) health facilities under the authority of other sectors or ministries (e.g., military hospitals), and (4) general hospitals and specialty institutions, including lung, tuberculosis, obstetric-child, and children's hospitals. The latter specialties were included because in a worst-case scenario they may be called upon to treat COVID-19 patients, and based on their specialties they have experience treating certain kinds of patients (e.g., children) and respiratory diseases.

Table 1. Categories of the 993 surveyed health facilities included in the analysis.

Division	Category	Facility count (% of total surveyed)
Region	Central	164 (16.6%)
	Central Highlands	64 (6.4%)
	North	469 (47.2%)
	South	296 (29.8%)
Facility level	National	13 (1.3%)
	Provincial	191 (19.3%)
	District	641 (64.5%)
	Private	132 (13.3%)
	Others*	16 (1.6%)
Urban / rural	Urban	477 (48.1%)
	Peri-urban	113 (11.4%)
	Rural	403 (40.5%)

* Includes military, police, and university hospitals.

Over the course of the COVID-19 pandemic, Vietnam has pursued a strategy of rapidly deploying field hospitals to areas experiencing outbreaks. RCE and medical oxygen at potential field hospitals were not taken in account during this study.

Beds

Hospital beds are a prerequisite for the use of RCE and medical oxygen, and understanding the number of hospital beds within the health system is vital information to decision-makers who plan ways to tackle

disease outbreaks. Table 2 displays the number and percentage of total hospital beds and ICU beds, by hospital division.

Table 2. Number and percentage of beds, by hospital division.

Division	Category	Population (million)	Facility count	Total beds	ICU beds
Region	Central	11.9 (12.4%)	164 (16.6%)	45,607 (17.4%)	3,278 (19.7%)
	Central Highlands	4.6 (4.7%)	64 (6.4%)	11,369 (4.3%)	560 (3.35%)
	North	43.5 (45.0%)	469 (47.2%)	126,279 (48.1%)	7,028 (42.2%)
	South	36.5 (37.8%)	296 (29.8%)	79,343 (30.2%)	5,779 (34.7%)
	Total	**96.5**	**993**	**262,598**	**16,645**
Facility level*	National		13 (1.3%)	17,531 (6.7%)	1,489 (8.9%)
	Provincial		191 (19.3%)	109,965 (41.9%)	7,361 (44.2%)
	District		641 (64.5%)	109,677 (41.8%)	6,339 (38.1%)
	Private		132 (13.3%)	20,888 (8.0%)	1,274 (7.7%)
Urban / rural	Urban		477 (48.1%)	164,231 (62.5%)	10,803 (64.9%)
	Peri-urban		113 (11.4%)	27,658 (10.5%)	1,758 (10.6%)
	Rural		403 (40.5%)	70,800 (27.0%)	4,093 (24.6%)

* There were 16 military, police, and university hospitals that are not displayed in the “facility level” category, but their beds are included in the denominators to obtain the percentage of beds.
Abbreviation: ICU, intensive care unit.

Among the 993 facilities, there are more than 263,000 total beds and 16,000 ICU beds, with 48.1 percent of the beds in the north and 30.2 percent in the south; these figures roughly match the percentage of the population in each region. In terms of level of the health system, not surprisingly, national-level hospitals represent a larger percentage of beds than they do percentage of facilities due to their large size. Provincial and district hospitals both represent about 42 percent of total hospital beds in the analysis, but there are also over three times as many district hospitals as provincial ones.

It is also important to understand what the average or typical hospital looks like in terms of the number of beds. Table 3 displays both the average and median number of total beds and ICU beds within each hospital category.

Table 3. Average and median bed count, by hospital division.

Division	Category	Facility count	Average bed count	Median bed count	Average ICU bed count	Median ICU bed count
Region	Central	164 (16.6%)	272	150	19	8
	Central Highlands	64 (6.4%)	178	120	9	7
	North	469 (47.2%)	269	191	15	9
	South	296 (29.8%)	268	150	20	10
Facility level*	National	13 (1.3%)	1,349	995	115	31
	Provincial	191 (19.3%)	570	495	38	21
	District	641 (64.5%)	171	150	10	8
	Private	132 (13.3%)	158	120	10	8
Urban / rural	Urban	477 (48.1%)	342	180	22	10
	Peri-urban	113 (11.4%)	245	190	16	10
	Rural	403 (40.5%)	176	150	10	8

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: ICU, intensive care unit.

The median bed count for national-level hospitals is just under 1,000 beds, and the same figure for provincial hospitals is just under 500. However, large hospitals at each level of the health system drag the averages above the median. Regarding ICU beds, the typical national, provincial, district, and private hospital has 31, 21, 8, and 8 ICU beds, respectively. Again, there are some large hospitals among the 993 in the survey that cause the average number of ICU beds per national and provincial hospitals to be significantly larger than the median.

Human resources for equipment

Biomedical equipment requires biomedical engineers and maintenance staff to ensure the equipment stays in working order and is repaired or replaced, as needed. Without these staff, the equipment and infrastructure doctors and patients rely on will quickly deteriorate, costing health systems money and negatively impacting patient health. Table 4 displays the number of maintenance staff recorded by the survey, by hospital category.

Table 4. Number/percentage of maintenance staff, by hospital division.

Division	Category	Facility count (% of all facilities surveyed)	# of maintenance staff (% of all maintenance staff surveyed)	# of maintenance staff per facility
Region	Central	164 (16.6%)	364 (21.2%)	2.2
	Central Highlands	64 (6.4%)	69 (4.0%)	1.1
	North	469 (47.2%)	711 (41.5%)	1.5
	South	296 (29.8%)	569 (33.2%)	1.9
	Total	**993**	**1,713**	**NA**
Facility level*	National	13 (1.3%)	120 (7.0%)	9.2
	Provincial	191 (19.3%)	705 (41.2%)	3.7
	District	641 (64.5%)	529 (30.9%)	0.8
	Private	132 (13.3%)	320 (18.7%)	2.4
Urban / rural	Urban	477 (48.1%)	1,204 (70.3%)	2.5
	Peri-urban	113 (11.4%)	167 (9.8%)	1.5
	Rural	403 (40.5%)	342 (20.0%)	0.8

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.

Provincial-level hospitals recorded 3.7 maintenance staff per facility, while district hospitals recorded 0.8, as did rural facilities. According to the data, higher-level hospitals have more maintenance staff per facility, as would be expected since these facilities are also generally larger (e.g., national-level facilities have 9.2 maintenance staff per facility).

Specially trained staff are required to perform intubation needed for mechanical ventilation, and the survey also recorded how many staff were capable of intubation in each health facility. Table 5 displays these data.

Table 5. Staff capable of intubation, by hospital division.

Division	Category	Facility count (% of all facilities surveyed)	# of staff capable of intubation (% of all staff capable of intubation surveyed)	# of staff capable of intubation per facility	# of staff capable of intubation per ICU bed
Region	Central	164 (16.6%)	2,209 (17.1%)	13.40	0.7
	Central Highlands	64 (6.4%)	370 (2.9%)	5.78	0.7
	North	469 (47.2%)	4,502 (34.8%)	9.60	0.6
	South	296 (29.8%)	5,872 (45.3%)	19.80	1.0
	Total	**993**	**12,953**		
Facility level*	National	13 (1.3%)	1,233 (9.5%)	94.80	0.8
	Provincial	191 (19.3%)	7,199 (55.6%)	37.50	1.0
	District	641 (64.5%)	2,735 (21.1%)	4.30	0.4
	Private	132 (13.3%)	1,647 (12.7%)	12.50	1.3
Urban / rural	Urban	477 (48.1%)	10,287 (79.4%)	21.50	1.0
	Peri-urban	113 (11.4%)	762 (5.9%)	6.70	0.4
	Rural	403 (40.5%)	1,904 (14.75%)	4.70	0.5

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: ICU, intensive care unit.

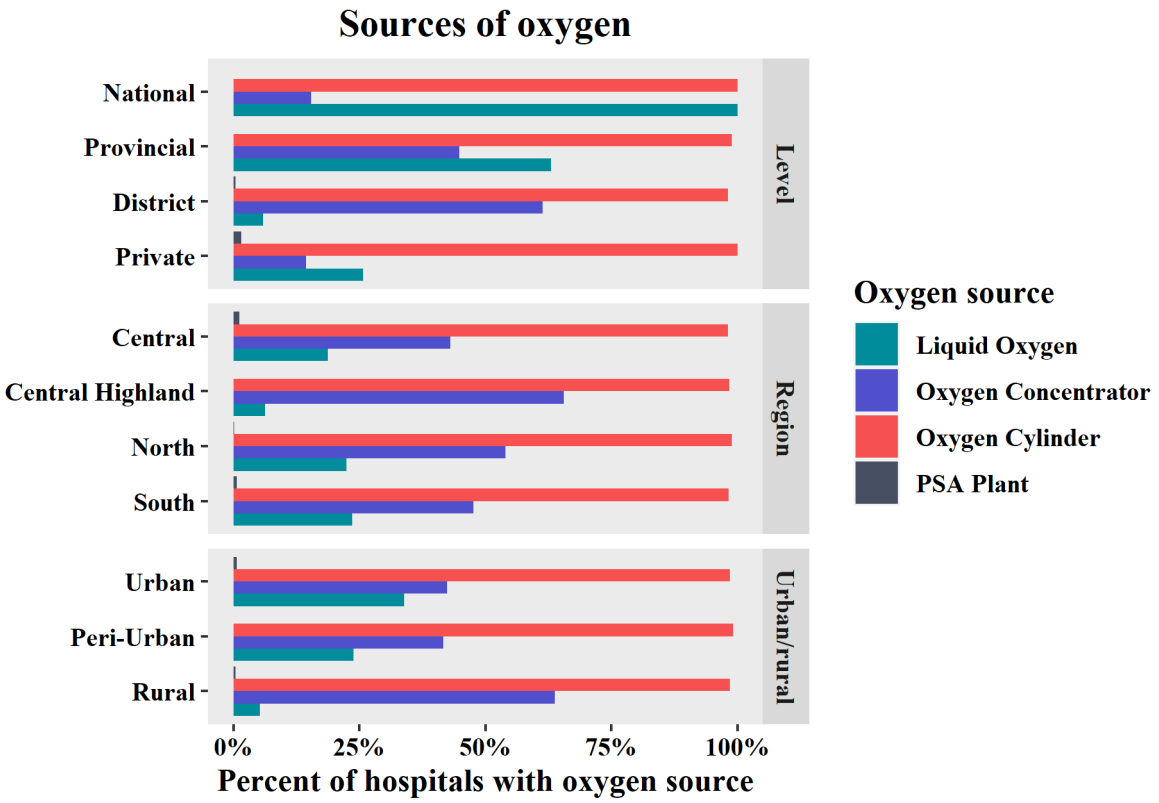
In total, the survey recorded 12,953 staff that were capable of intubation, or approximately 13 per health facility. These staff are skewed toward higher-level facilities, as would be expected, with national hospitals having 94.8 staff capable of intubation on average and district hospitals having 4.3. It is also notable that, per ICU bed, facilities in the south had nearly twice as many staff capable of performing intubation than facilities in the north, which may indicate a greater capacity of facilities in the south to manage critical patients that require intubation relative to health facilities in the north.

Medical oxygen

Overview

The BEIT records data on four sources of medical oxygen: (1) liquid oxygen, (2) oxygen concentrators, (3) oxygen cylinders, and (4) PSA plants. Simply having a source of oxygen does not mean that a hospital has sufficient quantities. For example, oxygen concentrators can only supply one or two patients at a time and generally only at flow rates of up to 5 to 10 LPM. Many large hospitals in Vietnam have liquid oxygen tanks, which can supply oxygen at flow rates needed for ventilators, and often these are the standard source of oxygen in hospitals in high-income countries. Liquid oxygen is delivered to hospitals and stored in tanks. The survey data indicate these tanks typically range from 6 to 10 m^3 in volume. Liquid oxygen's density is a major advantage over oxygen cylinders because more oxygen can be stored in a smaller space and large volumes can be delivered at one time, which generally makes it easier to resupply in a period of high demand. Figure 3 displays the oxygen sources for different divisions of hospitals.

Figure 3. Oxygen sources for different divisions of hospitals.



Abbreviation: PSA, pressure swing adsorption.

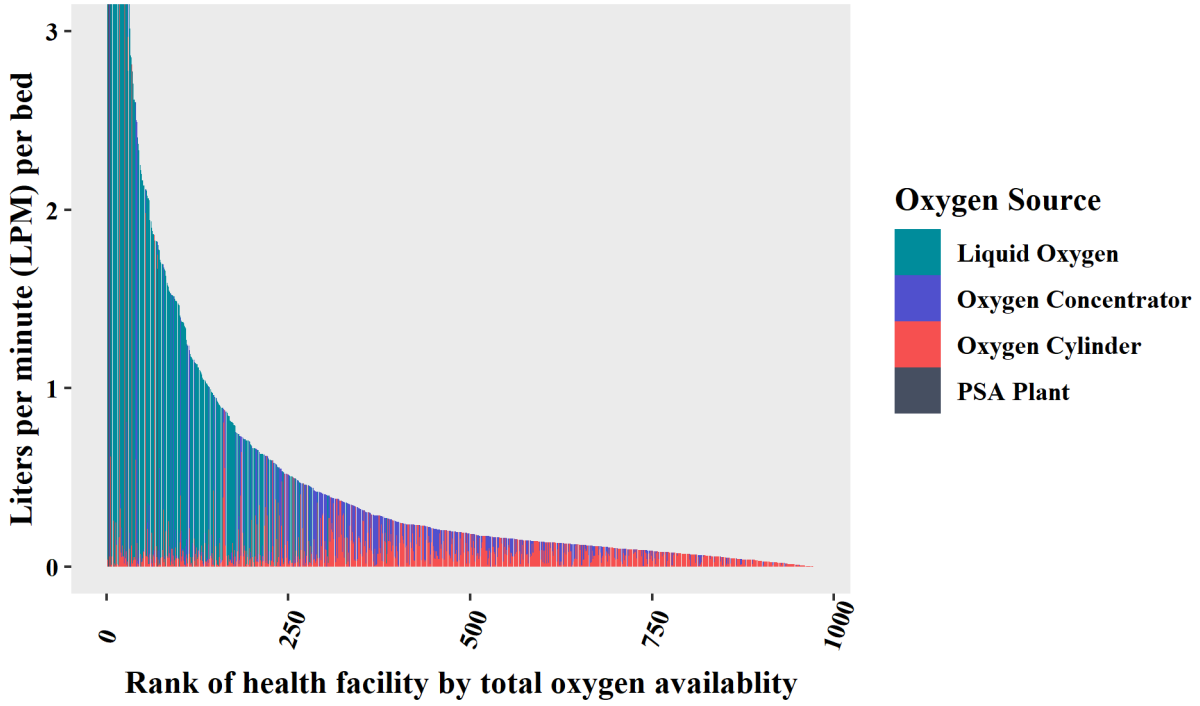
As the figure shows, **63 percent of provincial-level hospitals and 6 percent of district-level hospitals have liquid oxygen.** Nearly all hospitals in Vietnam have supplies of oxygen from at least one source, with almost every facility reporting on-site oxygen cylinders. Liquid oxygen is more prevalent at higher-level facilities and in urban areas and less used in the Central Highland provinces. Oxygen concentrators are a more common source of oxygen at lower levels of the health system, with 61 percent of district hospitals having oxygen concentrators and 45 percent of provincial hospitals. PSA plants are not a common source of oxygen in Vietnam, with only seven being recorded in the survey, three of which are on islands.

Having a source of oxygen present is a necessary but insufficient condition to measure access to oxygen. It is also critically important to measure how much oxygen is available from these sources. The BEIT recorded the number of oxygen cylinders of different sizes, the size of liquid oxygen tanks, the output of PSA plants, and the output of oxygen concentrators, making it possible to estimate how much oxygen hospitals could have available on a weekly basis. However, a couple of assumptions are needed to make these estimates:

- **Oxygen cylinders**: It is assumed that oxygen cylinders are refilled once per week. It is possible they are refilled more or less frequently in reality, but a standard refill frequency is necessary for comparison.
- **Liquid oxygen**: It is assumed that liquid oxygen tanks are refilled once per week. Like cylinders, it is possible they are refilled more or less frequently in reality, but a standard refill frequency is necessary for comparison.

Figure 4 ranks each surveyed facility by oxygen availability in LPM per bed, assuming liquid oxygen and oxygen cylinders can be refilled on a weekly basis. In other words, the figure shows the continuous flow of oxygen a hospital could *hypothetically* offer each bed over one week.[i] The "per bed" comparison is made to account for the fact that hospitals are of different sizes. The numbers on the x-axis represent the rank of individual facilities which are each depicted by a single stacked bar made up of that facilities' oxygen sources, and facilities with more oxygen available are toward the left-hand side of the figure.

Figure 4. Ranking of health facilities' oxygen availability, by source (LPM per bed).



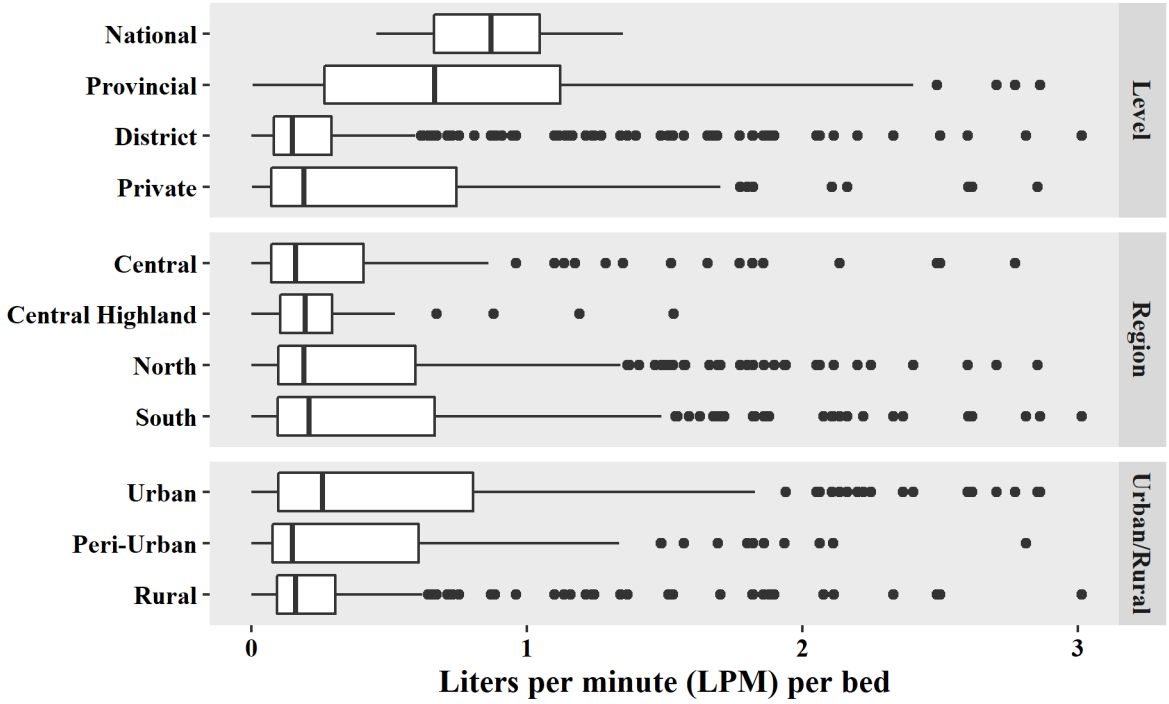
Abbreviation: PSA, pressure swing adsorption.

Simply having any liquid oxygen is strongly associated with having higher overall oxygen availability. The display of colors for each oxygen source draws out interesting characteristics of oxygen availability in Vietnam's health system. Nearly all hospitals have oxygen cylinders, as represented by the pink color running along the bottom of the plot, and oxygen cylinders play a larger role in facilities that have lower oxygen availability. For the middle-ranked hospitals, a mix of oxygen cylinders and oxygen concentrators, indicated by the purple color, contribute to oxygen availability; however, in hospitals where the only sources of oxygen are cylinders and/or concentrators, very few facilities can offer more than 0.5 LPM per bed per week. Hospitals with higher oxygen availability typically rely on liquid oxygen, as indicated by the teal color, demonstrating the importance of liquid oxygen in ensuring adequate volumes of medical oxygen within the health system. The range in oxygen availability between the highest ranked facilities and the lowest is large, which signals a high degree of variability in per-bed oxygen availability among health facilities.

[i] These data are hypothetical because there would also need to be sufficient oxygen delivery equipment (e.g., flowmeters, oxygen masks, flow splitters, etc.) for each bed, and oxygen concentrators can only service one bed at a time, potentially more with the use of a flow splitter.

The variability in oxygen availability per bed is shown by the box plot in Figure 5, which displays health facility data by division. The center box contains the second and third quartile of data from left to right, and the whiskers contain data up to 1.5 times the interquartile range.

Figure 5. Oxygen availability by division (LPM per bed).



Oxygen availability in provincial hospitals is relatively high, but so is the variability among them, while in district hospitals both oxygen availability and variability are relatively low. As expected, national-level hospitals generally have more oxygen than provincial- or district-level hospitals; however, high variability in provincial hospitals means that some of these facilities have more oxygen available than national-level hospitals, which is true for some positive district hospital outliers, as well. The variability in oxygen availability is larger in provincial hospitals than in national-level hospitals, with more than half of provincial hospitals having less than 1 LPM of oxygen available per bed. There are a large number of outliers within the set of district hospitals that have relatively higher oxygen availability; however, as indicated by the white boxes, more than 75 percent of these facilities have less than 0.5 LPM of oxygen available per bed. Urban areas generally have hospitals with higher oxygen availability than rural or peri-urban areas, which likely reflects the fact that more national- and provincial-level facilities are in urban areas.

Liquid oxygen and oxygen cylinders

Both liquid oxygen and oxygen cylinders are delivered to hospitals and stored on-site. Either oxygen cylinders are used at the patient's bedside or oxygen from a cylinder is delivered via piping to a patient using a manifold system. Liquid oxygen is always delivered via piping to patients, after being vaporized. Table 6 displays the volume of liquid oxygen tanks and oxygen cylinders within surveyed facilities. Liquid oxygen tank sizes are generally described in m^3, with tank sizes of 6 and 10 m^3 being the most common in Vietnam. Oxygen cylinder sizes are described in different ways by different countries and

organizations; in Vietnam, they are typically described in water capacity (liters of water). Both liquid oxygen and oxygen cylinder volumes are converted into gas volumes for comparison.

Table 6. Number of liquid oxygen and oxygen cylinders in surveyed hospitals.

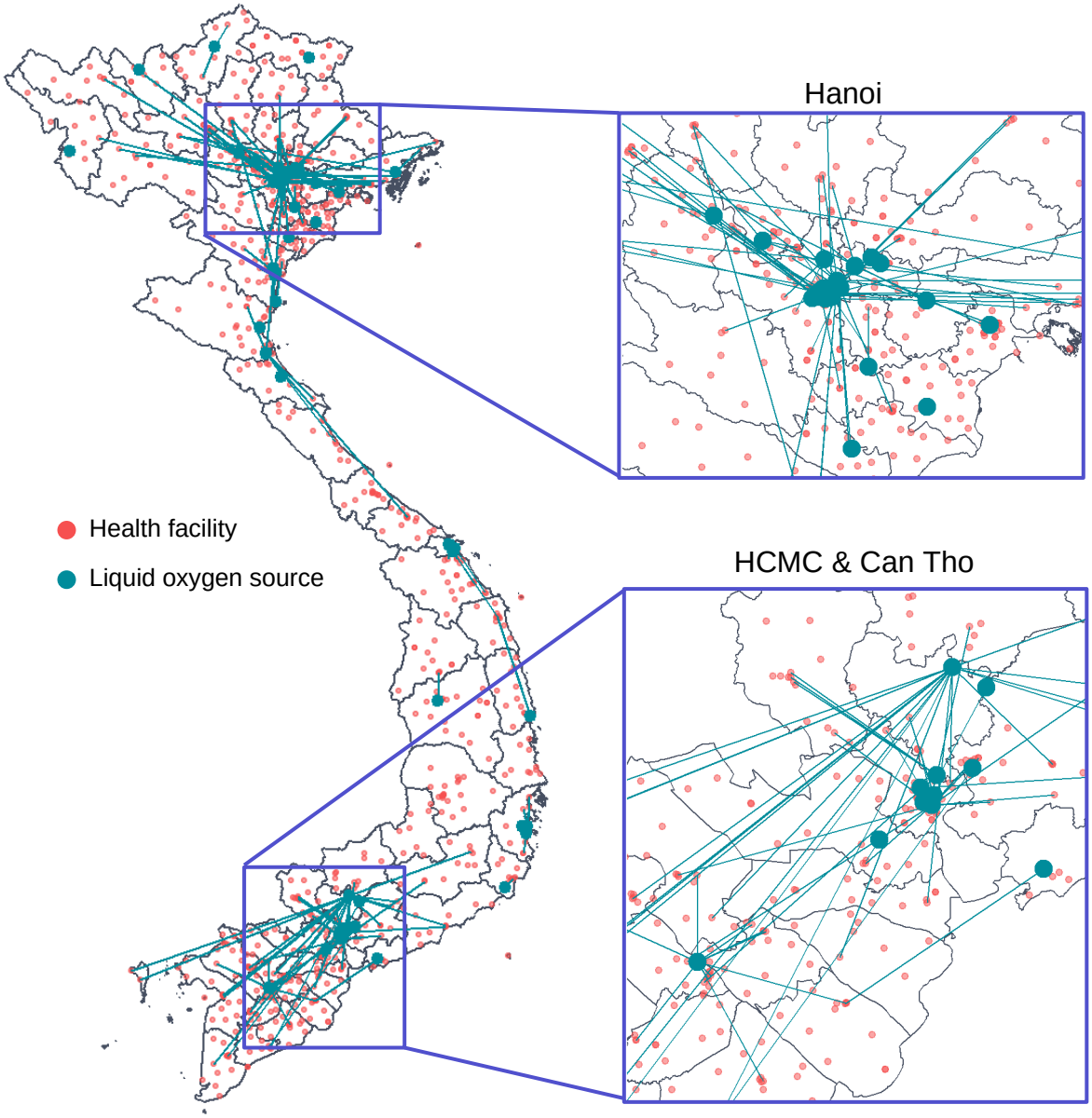
Division	Category	Liquid oxygen		Oxygen cylinders	
		Liquid volume (m^3)	Gas volume (liters)	Pressurized volume (liters)	Gas volume (liters)
Region	Central	257	221,277,000	169,926	24,480,877
	Central Highlands	30	25,830,000	52,014	7,493,510
	North	719	619,059,000	587,349	84,618,020
	South	623	536,403,000	421,192	60,680,253
	Total	**1,629**	**1,402,569,000**	**1,230,481**	**177,272,660**
Facility level*	National	162	139,482,000	34,082	4,910,178
	Provincial	1,031	887,691,000	433,239	62,415,846
	District	184	158,424,000	607,513	87,523,101
	Private	226	194,586,000	123,755	17,829,113
Urban / rural	Urban	1,332	1,146,852,000	685,137	98,706,217
	Peri-urban	191	164,451,000	118,802	17,115,546
	Rural	106	91,266,000	426,542	61,450,897

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: m^3, cubic meter.

Liquid oxygen can supply nearly eight times more oxygen on a weekly basis to the health system than oxygen from cylinders. The total volume of liquid oxygen (1,629 m^3) is approximately 30 percent more than all oxygen cylinders; however, the volume of gas provided by liquid oxygen is nearly eight times more than the gas volume provided by oxygen cylinders. Liquid oxygen is very space efficient, which has benefits in terms of delivery logistics. Only around 20 percent of the hospitals in the analysis (210 of 993) have liquid oxygen, but as indicated by Figure 4, these are the facilities with the highest oxygen availability. Eighty-two percent of liquid oxygen is in urban areas, and 63 percent, in provincial hospitals. The five Central Highland provinces have relatively low amounts of liquid oxygen, and rural facilities are more likely to rely on oxygen cylinders.

One of the biggest challenges with liquid oxygen and oxygen cylinders is the fact that these oxygen sources must be delivered to hospitals on a regular basis, or more frequently in times of high need, from suppliers that are often very far away. The map in Figure 6 displays the oxygen delivery network for liquid oxygen in Vietnam, as recorded by the survey.

Figure 6. Liquid medical oxygen network in Vietnam.



Liquid oxygen suppliers are mainly located in Vietnam's industrial hubs, with the two main network hubs being in Hanoi and HCMC, although there are smaller hubs in Nha Trang and Da Nang. Liquid oxygen is mainly used for industrial purposes, like steel manufacturing, and only a small fraction of Vietnam's total liquid oxygen production is used for medical liquid oxygen. Table 7 includes liquid oxygen suppliers with the largest production capacity in Vietnam.

Table 7. Liquid oxygen manufacturers in Vietnam.

Company	Production sites	Maximum liquid oxygen production capacity			
		North	Central	South	Total
Messer Hai Phong	Hai Duong, Quang Ngai	244	86		330
Nippon Sanso	BR-VT (2), Dong Nai, Hanoi	61		181	242
Air Liquide	Bac Ninh (2), HCM	130		38	168
Sovigaz	Binh Duong			126	126
Bac Ha	Bac Giang	26			26
Linde Gas	BR-VT			105	105
Industrial Gas Air Water	BR-VT			84	84
Sing Industrial Gas	Binh Duong			48	48
Maximum daily production capacity		**461**	**86**	**582**	**1,129**

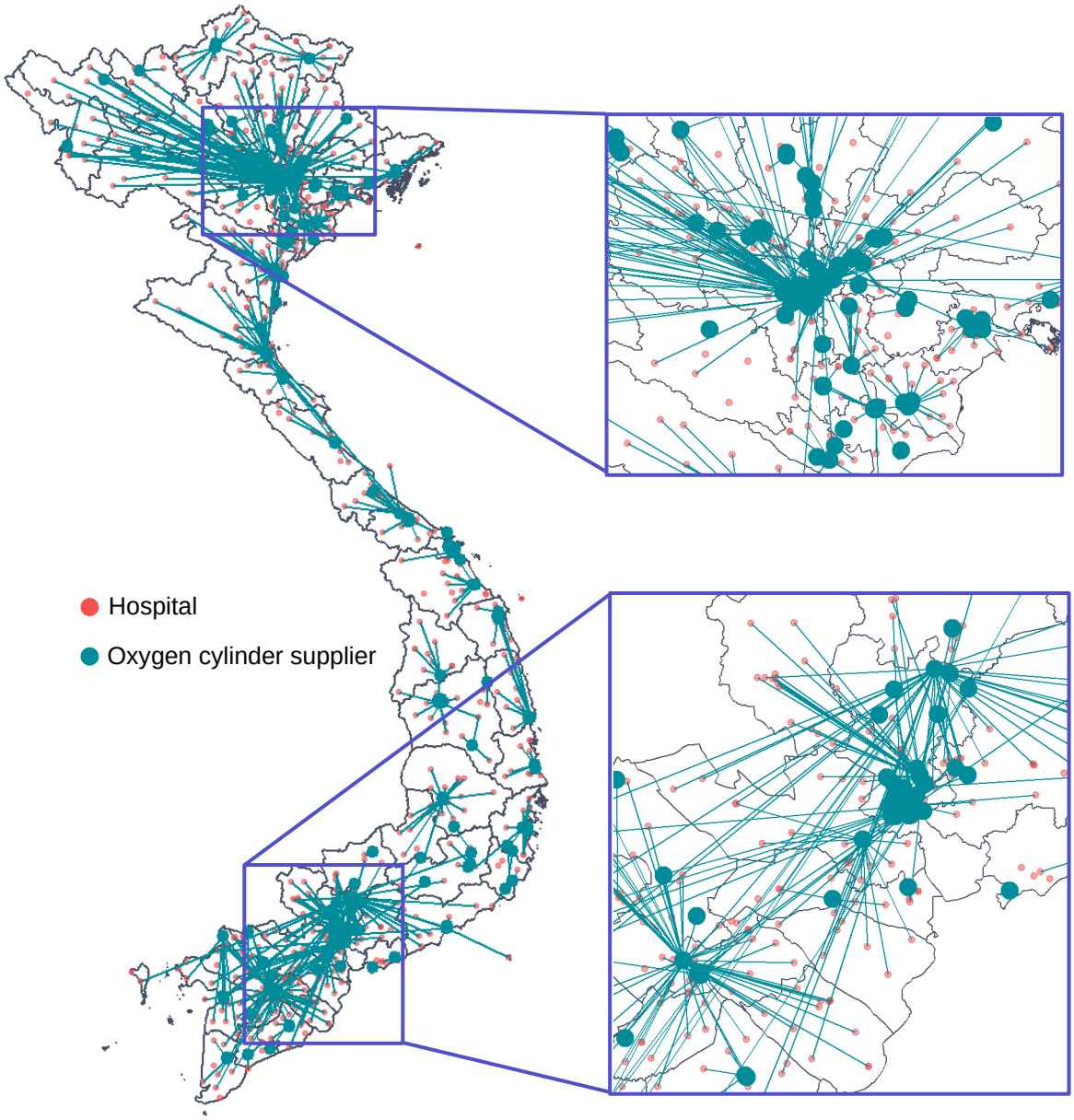
The daily production capacity of liquid oxygen in Vietnam is estimated at 1,129 m^3 according to the table above provided by MOH as part of their efforts to help ensure oxygen supplies during the outbreak. In total, there are 8 manufacturers of liquid oxygen in Vietnam. Among them, 6 are foreign companies and 2 are domestic. The three biggest companies, Messer, Air Liquide, and Nippon Sanso, account for approximately 66 percent of the total daily production. Regionally, 92.4 percent of the production capacity is in Northern and Southern Vietnam, 40.8 percent and 51.6 percent, respectively. In addition, while plants are located throughout the country, most production sites are concentrated in provinces near Hanoi and HCMC, such as Binh Duong and BR - VT in the south and Hai Duong and Bac Ninh in the north. Liquid oxygen manufacturers sell either directly to health facilities or via distributors. In addition, they can supply liquid oxygen to distributors and/or gas suppliers to fill in oxygen cylinders. Besides the above companies, there are steel manufacturing companies in Vietnam that possess liquid oxygen production capacity. According to data from the Asia Industrial Gas Association presented at the Vietnam in MOH's *Enhancing Medical Oxygen Supply and Usage Conference*, Formosa Steel could produce approximately 26 cubic meters of liquid oxygen per day. However, there is no data regarding the total liquid oxygen production capacity of all steel companies in Vietnam.

Prior to the outbreak starting in June 2021, average production capacity is about estimated to be 915 m^3 per day and approximately only 10 percent of liquid oxygen produced was used for medical purposes. However, according to the Vietnam MOH, the demand for medical oxygen has increased approximately 16 times compared to before the pandemic[26]. During the fourth COVID outbreak, there were approximately 12,000 new COVID-19 cases per day between August 28th and September 10th, and the number of total active cases was consistently over 200,000. **It is estimated that 1,040 m^3 of liquid oxygen would be needed per day to treat a two-week caseload of 200,000, which is approaching the daily production capacity estimation of 1,129 m^3.** Nevertheless, as stated by MOH in an interview in July 2021, liquid oxygen supply could still meet demand as production capacity could potentially be increased 50 percent to 100 percent from the current capacity of over 1,300 tons per day (equivalent to 1159 m^3 liquid), if necessary.[27] In addition, oxygen manufacturers and distributors in Vietnam could store a reservoir of 12,500 m^3 of liquid oxygen in total [28], enough to meet demand for 12

days. Despite these possibilities, it is still apparent that this outbreak put stress on the liquid oxygen supply system and careful coordination to increase supplies of this essential medicine is necessary to maintain proper patient care. Fortunately, the MOH too action to coordinate supplies.

The map in Figure 7 displays the oxygen delivery network for oxygen cylinders in Vietnam, as recorded by the survey.

Figure 7. Medical oxygen cylinder network in Vietnam.



Nearly every hospital in Vietnam uses oxygen cylinders, which results in a much denser delivery network than for liquid oxygen. However, like liquid oxygen, the two main hubs are in Hanoi and HCMC, but there many smaller networks across the country. The map above clearly displays networks at

the provincial level, with the provincial capital acting as the hub. Smaller delivery distances are an advantage during times of increased oxygen demand, which require more frequent deliveries.

Oxygen concentrators

Oxygen concentrators are a mobile and relatively inexpensive way to provide point-of-care medical oxygen to patients. They are especially useful in settings where piping from cylinders, liquid oxygen, or PSA plants is not available or in health facilities that experience irregular deliveries of oxygen cylinders. However, without proper, regular maintenance, a significant proportion of oxygen concentrators will stop working properly.[15] They typically are produced in models that output 5 or 10 LPM of oxygen, although concentrators with different output capacities are also manufactured. Global organizations like WHO, United Nations Children's Fund (UNICEF), and PATH have been working for years to increase access to oxygen concentrators by convening experts, creating technical guidance, and developing overviews of the concentrator market.[16–19] The COVID-19 pandemic has highlighted their use for providing life-saving oxygen in times of need, with experts rapidly creating guides to install oxygen systems based on concentrators[20] and UNICEF delivering more than 20,000 concentrators since the start of the pandemic.[21]

Table 8 displays the number functioning and nonfunctioning oxygen concentrators in the 993 facilities within the analysis by output capacity and division of the health system.

Table 8. Number of functioning and nonfunctioning oxygen concentrators.

Division	Category	Total number of oxygen concentrators by size (functional/nonfunctional)				
		3 LPM	5 LPM	8 LPM	10 LPM	10+ LPM
Region	Central	21 / 08	193 / 044	10 / 03	38 / 03	3 / 2
	Central Highlands	12 / 05	90 / 054	8 / 00	33 / 07	0 / 0
	North	83 / 39	675 / 227	69 / 18	162 / 45	28 / 1
	South	54 / 07	391 / 088	68 / 05	44 / 11	13 / 0
	Total	**170 / 59**	**1,349 / 413**	**155 / 26**	**277 / 66**	**44 / 3**
Facility level*	National	0 / 00	5 / 002	11 / 00	0 / 00	0 / 0
	Provincial	27 / 02	251 / 120	38 / 02	96 / 12	7 / 2
	District	128 / 56	1,054 / 284	97 / 24	166 / 53	34 / 1
	Private	5 / 00	27 / 003	4 / 00	13 / 00	3 / 0
Urban / rural	Urban	119 / 48	545 / 197	74 / 02	128 / 08	15 / 2
	Peri-urban	9 / 04	143 / 055	23 / 04	9 / 04	0 / 0
	Rural	42 / 07	661 / 161	58 / 20	140 / 54	29 / 1

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: LPM, liter per minute.

Nearly 22 percent of all oxygen concentrators are nonfunctioning, indicating better maintenance may be required. Within specific divisions, the highest percentage of nonfunctioning oxygen concentrators is found in the Central Highland provinces (32 percent), while the lowest percentage of nonfunctioning concentrators is found in private facilities (5 percent). The data indicate that district hospitals rely most on oxygen concentrators, with 75 percent of oxygen concentrators found in district hospitals even though they make up less than 65 percent of the analyzed facilities. This is what would be expected, as concentrators are typically used more in facilities without oxygen piping or in ones that may face more irregular deliveries of oxygen cylinders. Rural facilities also have a slightly disproportionately larger share of oxygen concentrators, with 45 percent of the total number of concentrators while making up 40 percent of all facilities.

Oxygen piping

Piping to provide oxygen from a central source to different wards of a hospital is necessary for liquid oxygen and oxygen manifold systems. Manifold systems are centrally located oxygen cylinders that provide oxygen to different wards of the hospital via piping. Table 9 displays the number and percentage of facilities that have liquid oxygen, manifold systems, and oxygen piping.

Table 9. Oxygen piping, manifold systems, and liquid oxygen.

Division	Category	# of facilities with liquid oxygen (%)	# of facilities with manifold system (%)	# of facilities with oxygen piping (%)
Region	Central	31 (19%)	85 (52%)	96 (58%)
	Central Highlands	5 (8%)	45 (70%)	47 (73%)
	North	105 (22%)	257 (55%)	303 (65%)
	South	70 (24%)	194 (66%)	208 (70%)
	Total	**211**	**581**	**654**
Facility level*	National	13 (100%)	11 (85%)	13 (100%)
	Provincial	122 (64%)	149 (78%)	176 (92%)
	District	38 (6%)	314 (49%)	343 (54%)
	Private	34 (26%)	102 (77%)	116 (88%)
Urban / rural	Urban	163 (34%)	304 (64%)	346 (72%)
	Peri-urban	27 (24%)	75 (66%)	83 (73%)
	Rural	21 (5%)	202 (50%)	225 (56%)

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.

Many facilities in Vietnam have oxygen piping systems, which is an advantage should these facilities consider upgrading to liquid oxygen systems, because the same pipes can be used for liquid oxygen systems, leading to lower installation costs relative to facilities with no oxygen piping network. Notably, **many provincial (92 percent) and district (54 percent) hospitals already have oxygen piping networks installed** and may be suitable potential candidates for the installation of liquid oxygen tanks. As would be expected, facilities in lower levels of the health system and rural facilities are less likely to have oxygen piping networks, which again highlights the role oxygen concentrators could play at these facilities.

RCE

Ventilators

In the early weeks of the COVID-19 pandemic, the world's attention became focused on ventilators as demand outpaced supply, and WHO quickly created new technical guidance focused on COVID-19.[22] Invasive and noninvasive ventilators are used for the most critical COVID-19 patients and require high-skilled, trained operators to use them correctly because of their complexity, and their complexity also makes proper maintenance essential to their upkeep. They also require an oxygen source and can provide patients with up to 70 LPM of oxygen if needed. Oxygen concentrators cannot provide high enough oxygen flow, so ventilators must rely on oxygen from piped liquid, manifold, or PSA plant oxygen systems.

Table 10 displays the number of functioning and nonfunctioning invasive ventilators and noninvasive (bi-level positive airway pressure and continuous positive airway pressure [CPAP]) ventilators.

Table 10. Number of functioning and nonfunctioning invasive, BiPAP, and CPAP ventilators, by division.

Division	Category	# of invasive (functioning / nonfunctioning)	# of BiPAP (functioning / nonfunctioning)	# of CPAP (functioning / nonfunctioning)	# (and %) of staff capable of intubation
Region	Central	1,246 / 117	290 / 028	409 / 039	2,209 (17.10%)
	Central Highlands	266 / 053	68 / 021	140 / 027	370 (2.90%)
	North	3,027 / 318	864 / 065	1,353 / 152	4,502 (34.80%)
	South	2,989 / 241	666 / 076	1,193 / 074	5,872 (45.30%)
	Total	**7,528 / 729**	**1,888 / 190**	**3,095 / 292**	**12,953**
Facility level*	National	850 / 030	208 / 014	174 / 015	1,233 (9.50%)
	Provincial	4,654 / 422	742 / 064	1,635 / 167	7,199 (55.60%)
	District	1,417 / 220	608 / 064	957 / 103	2,735 (21.10%)
	Private	478 / 011	246 / 009	311 / 007	1,647 (12.70%)
Urban / rural	Urban	5,944 / 522	1,233 / 124	2,175 / 195	10,287 (79.40%)
	Peri-urban	605 / 076	245 / 032	270 / 033	762 (5.90%)
	Rural	979 / 131	410 / 034	650 / 064	1,904 (14.75%)

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviations: BiPAP, bi-level positive airway pressure; CPAP, continuous positive airway pressure.

The survey recorded 7,529 functioning invasive ventilators and 4,983 functioning noninvasive ventilators. Approximately 10 percent of invasive and noninvasive ventilators are nonfunctioning, with district-level hospitals having the largest percentage of nonfunctioning ventilators and central-level facilities having the lowest percentage. Ventilators are generally distributed among different categories of facilities, as would be expected based on the percentage of ICU beds in these facilities. The number of staff capable of performing intubation exceeds the number of invasive ventilators in every category of health facility.

Patient monitors and pulse oximeters

Evidence shows that using pulse oximeters (POXs) can identify 20 to 30 percent more children in need of oxygen than relying on clinical signs alone.[23] Relying solely on clinical signs can lead to patients with "silent hypoxemia" (i.e., not displaying typical warning signs, like shortness of breath) being missed. Once a patient has been identified as needing oxygen, or if symptoms progress, use of patient monitors becomes essential, especially for severe and critical patients. In Vietnam, stakeholders at the national and subnational levels have told the project team that patient monitors are more heavily relied upon than POXs to check a patient's blood oxygen levels, and that fact is shown in Table 11's data, as well. However, when COVID-19 caseloads are high, home-based isolation and care may become necessary, and in those cases, inexpensive fingertip POXs may become life-saving devices for monitoring patients at home.[24] Tables 11 and 12 summarize the number of POXs and patient monitors in the 993 facilities in the analysis.

Table 11. Number of pulse oximeters (POXs) and patient monitors that can measure blood oxygen saturation (SpO2).

Division	Category	Tabletop POXs (functional / nonfunctional)	Handheld POXs (functional / nonfunctional)	Fingertip POXs (functional / nonfunctional)	Functioning patient monitors that can measure SpO2
Region	Central	316 / 28	453 / 34	420 / 27	1,965
	Central Highlands	164 / 10	100 / 13	127 / 26	374
	North	983 / 69	864 / 92	1,167 / 76	5,802
	South	1,201 / 81	2,035 / 132	1,219 / 49	4,990
	Total	**2,664 / 188**	**3,452 / 271**	**2,933 / 178**	**13,131**
Facility level*	National	225 / 1	335 / 8	105 / 13	1,156
	Provincial	1,119 / 62	1,631 / 139	1,270 / 70	6,516
	District	860 / 120	876 / 116	970 / 90	3,026
	Private	424 / 5	501 / 8	561 / 5	2,082
Urban / rural	Urban	1,896 / 93	2,662 / 170	2,049 / 113	9,945
	Peri-urban	195 / 26	235 / 34	246 / 21	1,087
	Rural	573 / 69	555 / 67	638 / 44	2,099

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.

Table 12. Number of patient monitors with and without electrocardiogram (ECG).

Division	Category	Patient monitor with ECG (functioning / nonfunctioning)	Patient monitor without ECG (functioning / nonfunctioning)	ICU beds
Region	Central	2,163 / 150	439 / 24	3,278 (19.70%)
	Central Highlands	540 / 79	76 / 8	560 (3.35%)
	North	6,393 / 387	1,310 / 52	7,028 (42.20%)
	South	5,258 / 238	625 / 49	5,779 (34.70%)
	Total	**14,354 / 854**	**2,450 / 133**	**16,654**
Facility level*	National	1,196 / 61	169 / 13	1,489 (8.90%)
	Provincial	7,252 / 395	810 / 38	7,361 (44.20%)
	District	3,397 / 349	1,005 / 75	6,339 (38.10%)
	Private	2,014 / 40	424 / 7	1,274 (7.70%)
Urban / rural	Urban	10,962 / 516	1,597 / 60	10,803 (64.90%)
	Peri-urban	1,130 / 82	247 / 21	1,758 (10.60%)
	Rural	2,262 / 256	606 / 52	4,093 (24.60%)

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: ICU, intensive care unit.

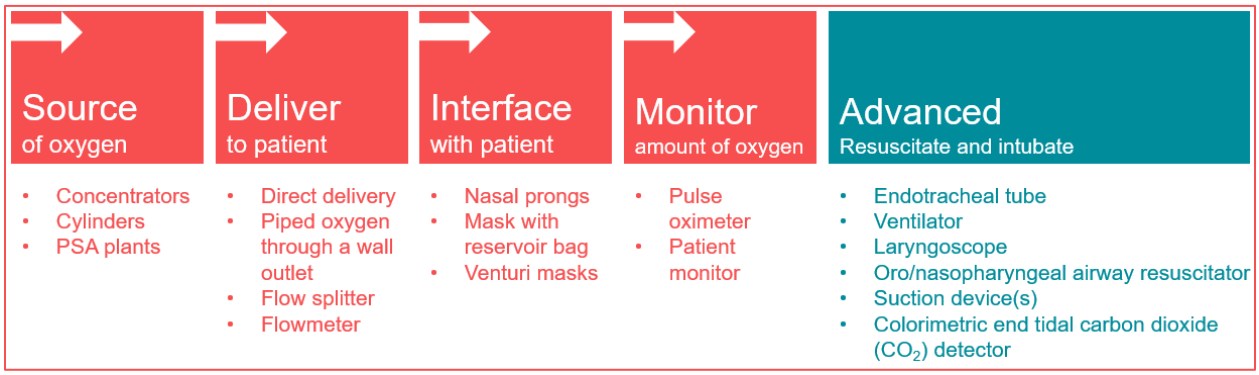
District hospitals have 44 percent more ICU beds than they do functioning patient monitors, yet overall, the number of patient monitors and ICU beds is about equal. Patient monitors are generally concentrated in higher-level facilities. Although 38.1 percent of reported ICU beds are in district hospitals, just 26.1 percent of patient monitors (functioning with ECG and without ECG) are in district hospitals, indicating that these facilities could probably use more patient monitors to maintain proper patient care for those needing intensive care. Private hospitals contain only 7.7 percent of ICU beds within the survey but have approximately 14.5 percent of all patient monitors (functioning with ECG and without ECG), indicating that these facilities are relatively well equipped. The largest regional gap in patient monitors relative to ICU beds is in the Central Region, and rural facilities also have relatively few patient monitors compared to ICU beds. Although POXs can cost much less than patient monitors, there are 84 percent

more patient monitors than POXs recorded in the survey. This may reflect the fact that patient monitors may be preferred due to their ability to measure several vital signs.

Additional respiratory equipment

Respiratory care for severe and critical COVID-19 patients is complex and requires a suite of equipment: for (1) connecting to the oxygen source, (2) delivering oxygen to the patient, (3) interfacing with the patient, (4) monitoring the patient, and (5) intubating the patient, which requires advanced equipment. This suite of equipment is represented in the Figure 8.

Figure 8. Suite of equipment for respiratory care of severe and critical COVID-19 patients.



Abbreviation: PSA, pressure swing adsorption.

Although this document does not analyze each piece of equipment listed above, **Appendix 1** contains tables that list the availability in Vietnam of other equipment necessary for proper respiratory care, such as flow splitters, flowmeters, pressure gauges, advanced intubation equipment, and oxygen interface consumables.

Supply and demand analysis

Survey supply and Decision 2626 demand

On May 28, 2021, the MOH published Decision 2626, "On the Promulgation of the List of Equipment, Consumables, and Essential Drugs for COVID-19 Treatment Areas," which offers guidance for 20 patient-bed areas for asymptomatic, moderate, and severe and critical COVID-19 patients. Table 13 shows the 11 pieces of equipment for severe and critical COVID-19 patients that overlap with data collected in the BEIT survey, along with the number of each suggested by Decision 2626.

Table 13. Equipment in both Decision 2626 and WHO Biomedical Equipment Inventory Tool conducted in Vietnam.

Equipment type	Decision 2626 suggested #
Oxygen sets (wall units and accessories)	20
Invasive ventilators	8
Noninvasive ventilators	5
Portable ventilators	1
Patient monitors	20
Oxygen systems	1
Suction devices	20
Laryngoscopes	1
Resuscitation bags	20
Oxygen masks	135
Endotracheal tubes	24

Survey data for these 11 pieces of equipment were compared to Decision 2626 to see how many hospitals met the requirements for all 11, as well as for lesser amounts. Table 14 displays how many met the Decision's guidance based on the number of individual equipment standards met. It is worth noting that the survey took place in January/February 2021, five months before Decision 2626 was published.

Table 14. Number of hospitals that fulfill Decision 2626 equipment guidance (% within category).

Division	Category	Number of equipment guidance met					
		11	10	9	8	7	0–6
Region	Central	4 (2.4%)	6 (3.7%)	6 (3.7%)	7 (4.3%)	8 (4.9%)	133 (81.1%)
	Central Highlands	(0%)	1 (1.6%)	2 (3.1%)	1 (1.6%)	2 (3.1%)	58 (90.6%)
	North	8 (1.7%)	11 (2.3%)	20 (4.3%)	26 (5.5%)	15 (3.2%)	389 (82.9%)
	South	6 (2.0%)	18 (6.1%)	13 (4.4%)	16 (5.4%)	17 (5.7%)	226 (76.4%)
	Total	**18**	**36**	**41**	**50**	**42**	**806**
Facility level*	National	4 (30.8%)	6 (46.2%)	1 (7.7%)	(0%)	(0%)	2 (15.4%)
	Provincial	14 (7.3%)	25 (13.1%)	27 (14.1%)	30 (15.7%)	16 (8.4%)	79 (41.4%)
	District	(0%)	2 (0.3%)	2 (0.3%)	11 (1.7%)	10 (1.6%)	616 (96.1%)
	Private	(0%)	1 (0.8%)	11 (8.3%)	9 (6.8%)	15 (11.4%)	96 (72.7%)
Urban / rural	Urban	16 (3.4%)	33 (6.9%)	33 (6.9%)	38 (8.0%)	32 (6.7%)	325 (68.1%)
	Peri-urban	1 (0.9%)	3 (2.7%)	6 (5.3%)	4 (3.5%)	4 (3.5%)	95 (84.1%)
	Rural	1 (0.2%)	(0%)	2 (0.5%)	8 (2.0%)	6 (1.5%)	386 (95.8%)

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.

As would be expected, **national- and provincial-level hospitals are more likely to fulfill the guidance from Decision 2626**, with 11 national and 66 provincial hospitals reporting meeting the standards for 9-to-11 pieces of equipment. Rural and peri-urban hospitals are much less likely to meet the guidance from Decision 2626, with only 3 and 10, respectively, meeting the same standards.

Survey supply and WHO ESFT demand

The WHO ESFT contains estimated standards for how much RCE and medical oxygen is needed per severe and critical patient, default values that can be adjusted to fit different countries' needs. The analysis below uses the default estimated standards from the WHO ESFT and compares those to the supply of RCE and medical oxygen in surveyed hospitals to answer the question, *How many severe or critical COVID-19 patients can this amount of equipment provide treatment for?*

Patient beds

The WHO ESFT estimates that 60 percent of hospital beds could be used for COVID-19 patients during an emergency. Table 15 shows 60 percent of the total beds (Table 2), by division.

Table 15. Count of potential beds for COVID-19 patients (60% of total), by division.

Division	Category	Facility count	Total beds	ICU beds
Region	Central	164 (16.6%)	27,364 (17.4%)	1,967 (19.7%)
	Central Highlands	64 (6.4%)	6,821 (4.3%)	336 (3.6%)
	North	469 (47.2%)	75,767 (48.1%)	4,217 (42.2%)
	South	296 (29.8%)	47,605 (30.2%)	3,467 (34.7%)
	Total	**993**	**157,557**	**9,987**
Facility level*	National	13 (1.3%)	10,519 (6.7%)	893 (8.9%)
	Provincial	191 (19.3%)	65,979 (41.9%)	4,417 (44.2%)
	District	641 (64.5%)	65,806 (41.8%)	3,803 (38.1%)
	Private	132 (13.3%)	12,533 (8.0%)	764 (7.7%)
Urban / rural	Urban	477 (48.1%)	98,539 (62.5%)	6,482 (64.9%)
	Peri-urban	113 (11.4%)	16,595 (10.5%)	1,055 (10.6%)
	Rural	403 (40.5%)	42,480 (27.0%)	2,456 (24.6%)

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: ICU, intensive care unit.

In total, there are an estimated 157,557 total beds and 9,987 ICU beds within the hospital system that are available for COVID-19 patient treatment using the WHO ESFT estimated standards. Estimates within the WHO ESFT assume that 20 percent of COVID-19 cases will require hospitalization and that 25 percent of those will be critical cases in need of invasive or noninvasive ventilation and two weeks of hospitalization. Using those assumptions, all 9,987 ICU beds would be needed for critical COVID-19 patients if there were 199,840 COVID-19 cases within a two-week period, corresponding to approximately 14,000 cases a day for two weeks.

Medical oxygen

For emergency planning purposes, the WHO ESFT estimates that *10 LPM of oxygen is required for severe patients and 30 LPM for critical patients*. At those rates, a severe patient would use nearly 15 large oxygen cylinders (6,800 gas liters per cylinder) in a week, while a critical patient would need more than 44. With these figures in mind, it is easy to understand—yet extremely unfortunate—how

hospitals around the world ran out of medical oxygen during times of high COVID-19 patient demand. Severe patients could be supplied with medical oxygen from concentrators, cylinders, liquid oxygen, or PSA plants, but critical patients cannot rely on oxygen concentrators because concentrator flow rates are too low.

Table 16 displays the percentage of total oxygen by source within each category and the total oxygen available in LPM. It is assumed that oxygen cylinders and liquid oxygen could be refilled weekly. Oxygen from concentrators cannot be used with critical patients on ventilators, so oxygen availability is displayed in two separate columns, including and not including concentrators.

Table 16. Oxygen sources and total oxygen supply in liters per minute (LPM).

Category	Division	Percentage of oxygen available from source				Total oxygen supply in LPM	
		Liquid oxygen	Oxygen cylinders	Oxygen concentrators	PSA plants	Including concentrators	Not including concentrators
Region	Central	83.6%	9.4%	6.0%	1.1%	25,660	24,127
	Central Highlands	61.2%	17.8%	21.0%	0.0%	4,186	3,306
	North	77.1%	10.5%	7.8%	4.5%	77,692	71,476
	South	76.4%	8.6%	4.7%	10.3%	65,864	62,568
	Total					**173,402**	**161,477**
Facility level*	National	95.8%	3.4%	0.8%	0.0%	14,438	14,325
	Provincial	90.8%	6.4%	2.8%	0.0%	96,425	93,720
	District	42.6%	23.6%	23.3%	10.5%	34,950	26,350
	Private	67.5%	6.2%	1.2%	25.1%	24,763	24,406
Urban / rural	Urban	81.5%	7.0%	3.7%	7.7%	133,209	128,030
	Peri-urban	85.7%	8.9%	5.3%	0.0%	19,029	18,013
	Rural	42.8%	28.8%	27.1%	1.3%	21,164	15,434

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: PSA, pressure swing adsorption.

Liquid oxygen plays a significant role in being able to provide adequate oxygen. The high percentage of oxygen coming from liquid sources, as shown in the table above, indicates its overall importance for being able to treat large numbers of patients. Hospitals in the Central Highlands rely heavily on oxygen cylinders and oxygen concentrators relative to facilities in other regions, which limits the number of critical patients they could accommodate. Likewise, district hospitals rely more on oxygen cylinders and concentrators than other facility levels, decreasing their ability to handle many critical patients, as well, although critical patients could be transferred to provincial hospitals. Similar to district hospitals, those in rural settings also rely much more on oxygen cylinders and concentrators. Considering the logistical difficulties with delivering large amounts of oxygen cylinders to such settings, these facilities may face particular difficulties in times of high demand. The greatest supply of oxygen is found in provincial-level hospitals, indicating that, given a large outbreak, these facilities would play a crucial role in providing care for a larger number of critical and severe COVID-19 patients relative to national- or district-level hospitals. Table 17 displays the number of critical and severe patients that could be treated with the oxygen available in health facilities.

Table 17. Intensive care unit (ICU) bed, ventilator, and oxygen capacity to treat severe and critical patients.

Category	Division	# of ICU beds	# of ventilators	Maximum # of severe *or* critical patients that could be treated with available oxygen (O_2) at one time		Maximum # of severe *and* critical patients (1.5:1) that could be treated with available O_2 at one time*	
				Severe patients	Critical patients	Severe patients	Critical patients
Region	Central	1,967	1,246	2,489	749	763	497
	Central Highlands	336	266	388	89	96	58
	North	4,217	3,027	7,538	2,185	2,254	1,453
	South	3,467	2,989	6,456	1,977	2,016	1,319
	Total	**9,987**	**7,528**	**16,871**	**5,000**	**5,129**	**3,327**
Facility level**	National	893	850	1,436	471	475	315
	Provincial	4,417	4,654	9,548	3,032	3,089	2,032
	District	3,803	1,417	3,198	647	714	427
	Private	764	478	2,413	764	765	496
Urban / rural	Urban	6,482	5,944	13,099	4,084	4,169	2,726
	Peri-urban	1,055	605	1,843	556	565	367
	Rural	2,456	979	1,929	360	395	234

* Assumption of three severe patients for every critical patient is given by the WHO ESFT, and severe patients are under treatment for one week while critical patients are under treatment for two weeks. Given a constant number of new daily cases at the end of two weeks, the ratio of severe-to-critical patients would be 1.5:1.
** Data from 16 military, police, and university hospitals not displayed here in the facility level division.

In total, the health system has enough oxygen to treat 3,327 critical patients and 5,129 severe patients simultaneously. Stated another way, current supplies of oxygen could treat either 5,000 critical patients *or* 16,871 severe ones, but not those numbers simultaneously. The simultaneous figures are derived from the assumption, as given by the WHO ESFT, that the severe-to-critical case ratio is 3:1 and that those severe patients are treated with oxygen in the hospital for one week while critical patients are treated in the hospital an on ventilators for two weeks. Given these assumptions and a constant daily caseload, after two weeks there will be a severe-to-critical patient ratio of 1.5:1. These figures indicate that, for critical patients, medical oxygen supply would be a limiting factor before that of ICU beds or ventilators.

Aside from the aggregate figures above, it is also useful to understand the distribution of individual hospitals' capacity to provide oxygen to severe and critical patients. In other words, how many hospitals are there that can provide oxygen for more than 20 critical patients, or 1 critical patient, or not even 1? Table 18 displays what number of hospitals have enough medical oxygen on a weekly basis to treat a particular maximum number of critical and severe patients (0, 1 to 5, 6 to 20, or over 20). It is assumed that at maximum capacity there will be 1.5 severe patients for every critical patient.

Table 18. Number of surveyed hospitals (n=993) that have enough oxygen to treat severe and critical patients.

Category	Division	Maximum number of critical patients				Maximum number of severe patients			
		0	1–5	6–20	21+	0	1–5	6–20	21+
Region	Central	124	13	20	5	115	19	17	11
	Central Highlands	57	2	4		50	9	2	2
	North	343	25	82	15	294	65	72	34

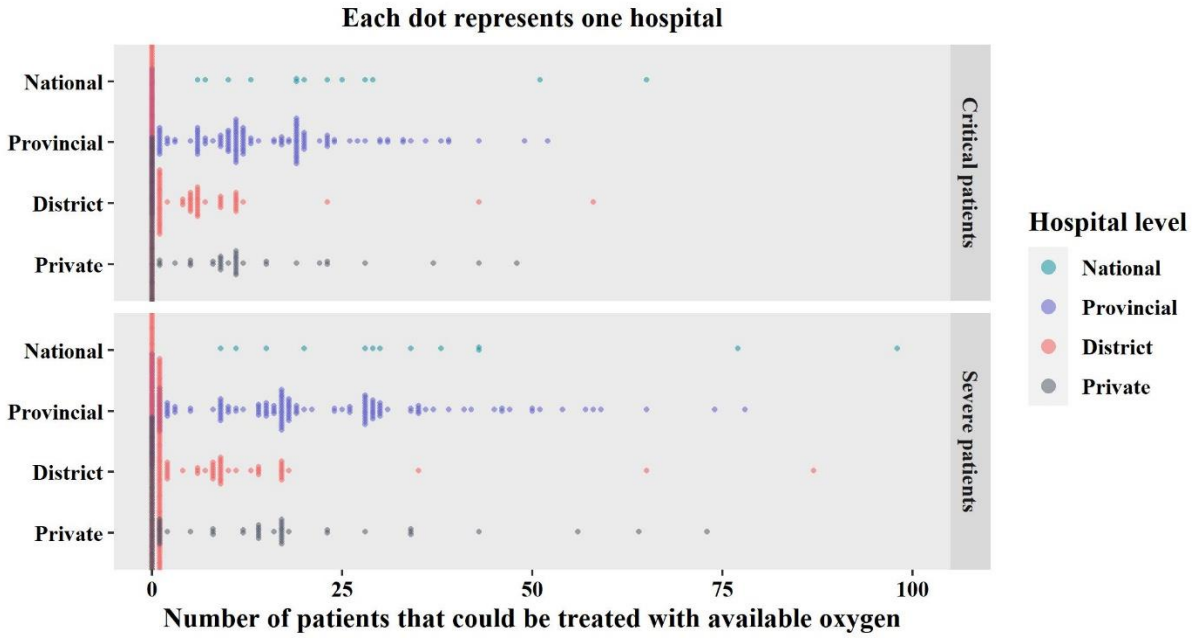
Category	Division	Maximum number of critical patients				Maximum number of severe patients			
		0	1–5	6–20	21+	0	1–5	6–20	21+
	South	200	21	45	21	637	133	126	81
	Total	**724**	**61**	**151**	**41**	**365**	**394**	**63**	**171**
Facility level*	National			7	6			4	9
	Provincial	55	17	94	25	43	28	61	59
	District	574	37	27	3	507	93	38	3
	Private	95	7	23	7	87	12	23	10
Urban / rural	Urban	280	35	112	35	239	68	82	73
	Peri-urban	82	4	23	4	75	11	21	6
	Rural	362	22	16	2	323	54	23	2

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.

Survey data indicate that there are few hospitals that have enough oxygen for more than 20 critical and severe COVID-19 patients per week. However, in a crisis situation, liquid oxygen deliveries may be able to occur more frequently than once per week, which would increase the number of hospitals with sufficient oxygen to treat more than 20 critical patients. Many district hospitals do not have enough oxygen available on a weekly basis to provide oxygen therapy treatment for even 1 critical COVID-19 patient. Many of these district hospitals are likely rural hospitals, as many rural facilities do not have enough medical oxygen to treat 1 patient with 30 LPM of oxygen for a week. However, higher-level hospitals are better equipped, and there are 31 provincial- and national-level facilities that have enough medical oxygen to maintain treatment for more than 20 critical patients.

The data from the table above are displayed in Figure 9 in more detail. Each dot represents one hospital. As can be seen, there are many district hospitals that would not be able to maintain oxygen treatment for a critical COVID-19 patient for a week; however, many of these district hospitals could treat a few severe patients for a week.

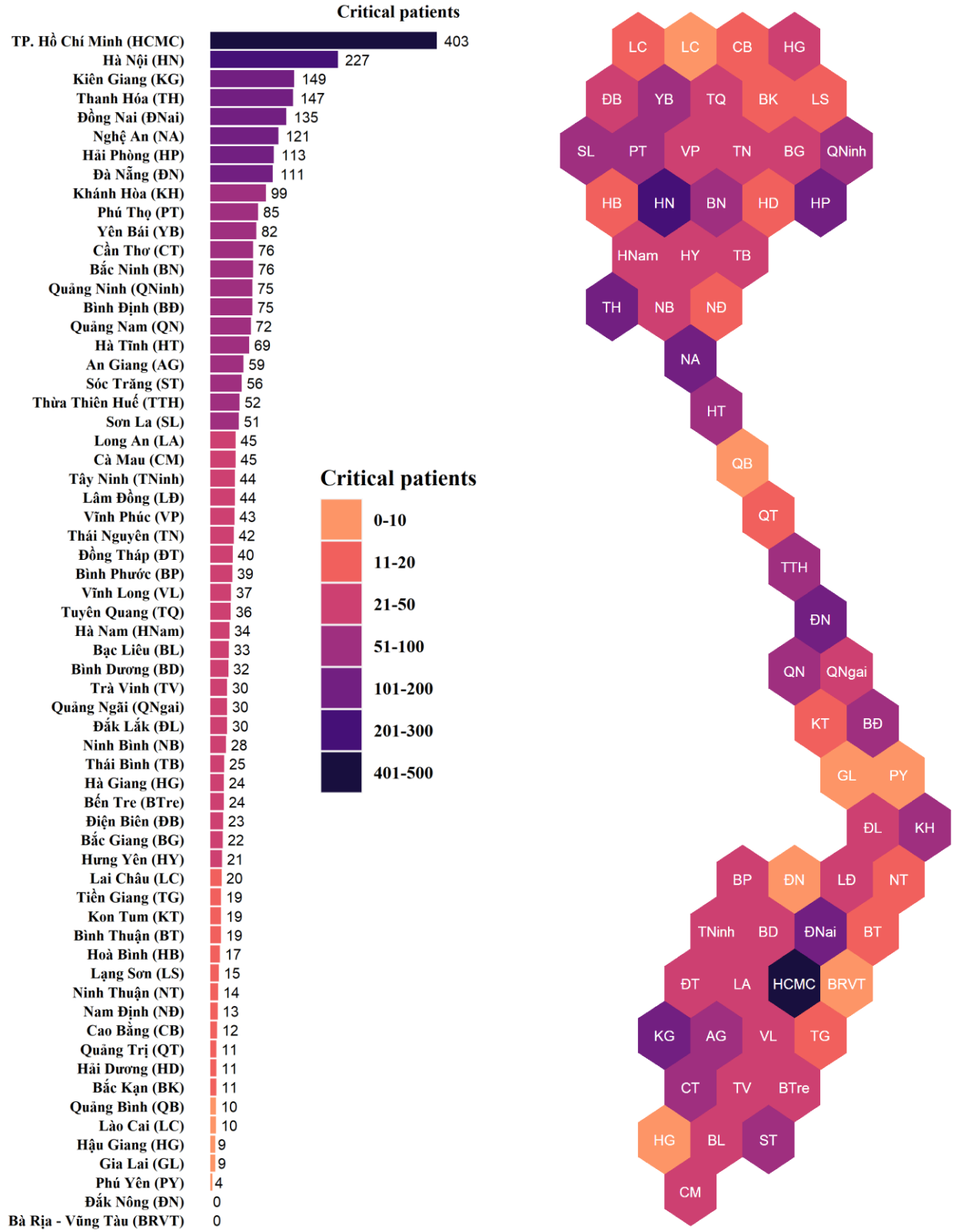
Figure 9. Number of patients that could be treated by available oxygen per hospital.



Medical oxygen by province

Identifying the most vulnerable provinces by quantifying the number of critical and severe COVID-19 patients each province could treat can help decision-makers prepare for outbreaks and allocate resources to increase capacity. Figure 10 displays how many critical COVID-19 patients each province could provide medical oxygen to (using the 1.5:1 assumption on the number of severe-to-critical patients at maximum capacity) before oxygen demand exceeds supply.

Figure 10. Number of critical patients each province could treat simultaneously before oxygen demand exceeds supply.



Assuming patients are distributed optimally among facilities, at a maximum the health system could provide oxygen simultaneously for approximately 3,300 critical patients and 5,100 severe patients. The map and plot above indicate that there are 18 provinces that cannot supply more than 20 critical COVID-19 patients with the 30 LPM of oxygen these patients need. HCMC and Hanoi can supply more than 400 and 200 critical patients with oxygen, respectively. It should be kept in mind that even though there are 993 hospitals included in this analysis, there are at least 1,332 hospitals in Vietnam, which means the above estimates may be an underestimation. Another factor that could lead to underestimation is the fact that liquid oxygen and oxygen cylinders may be delivered more than once per week. Delivering oxygen twice weekly could double the oxygen capacity at many facilities; however, this could increase stress on supply chains and might not be possible for some hospitals and oxygen suppliers.

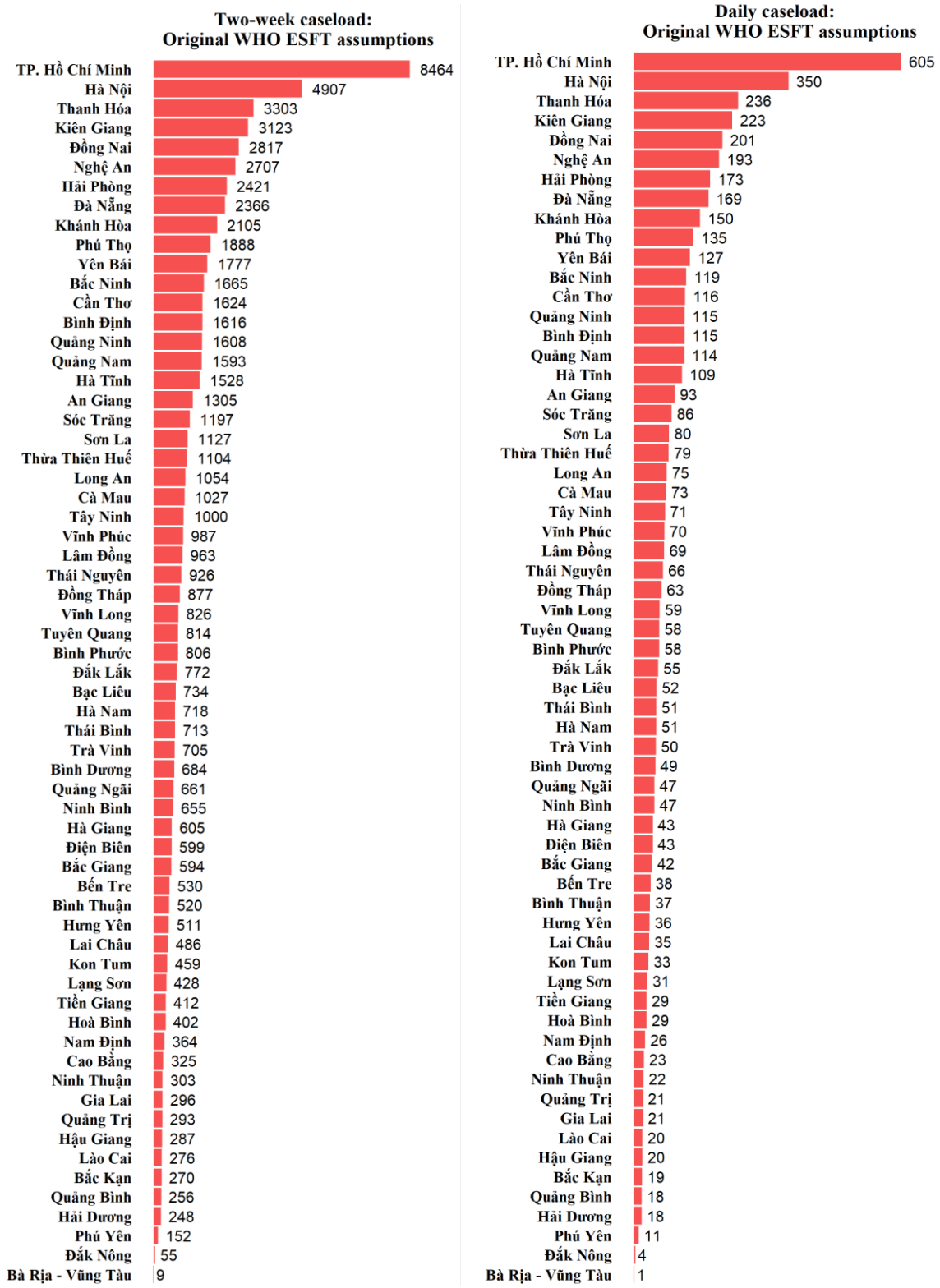
Medical oxygen and COVID-19 caseloads

One question that decision-makers will want an answer is, *How many cases can the health system handle?* The answer relies on many different factors, and a comprehensive answer is out of the scope of this analysis; however, it can provide an estimate based on the supply of medical oxygen recorded in the survey. Figures 11 and 12 display the estimated maximum number of COVID-19 cases each province could handle over a two-week period before there is insufficient oxygen for severe and critical patients. The data are also displayed in per-day values. A high estimate is provided by using the WHO ESFT assumptions that 5 percent of all COVID-19 cases will become critical patients and 15 percent will become severe patients and they will be treated with 30 LPM and 10 LPM of oxygen, respectively (Figure 11), and a low estimate was developed using data from the Vietnam MOH Department of Medical Examination and Treatment.[25] Vietnam has adopted a strategy of assigning patients to specific wards or facilities classified by “floor”, where the first floor treats the least severe patients, the second floor treats more severe patients, and finally the third floor treats the most critical patients. The data below display the percent of COVID-19 cases estimated to be treated on each floor by oxygen interface and LPM of oxygen needed. The right side of this table displays how these data were translated into parameters used to estimate how many COVID-19 cases the health system could handle in terms of medical oxygen.

Table 19: Oxygen need parameters from the Vietnam MOH

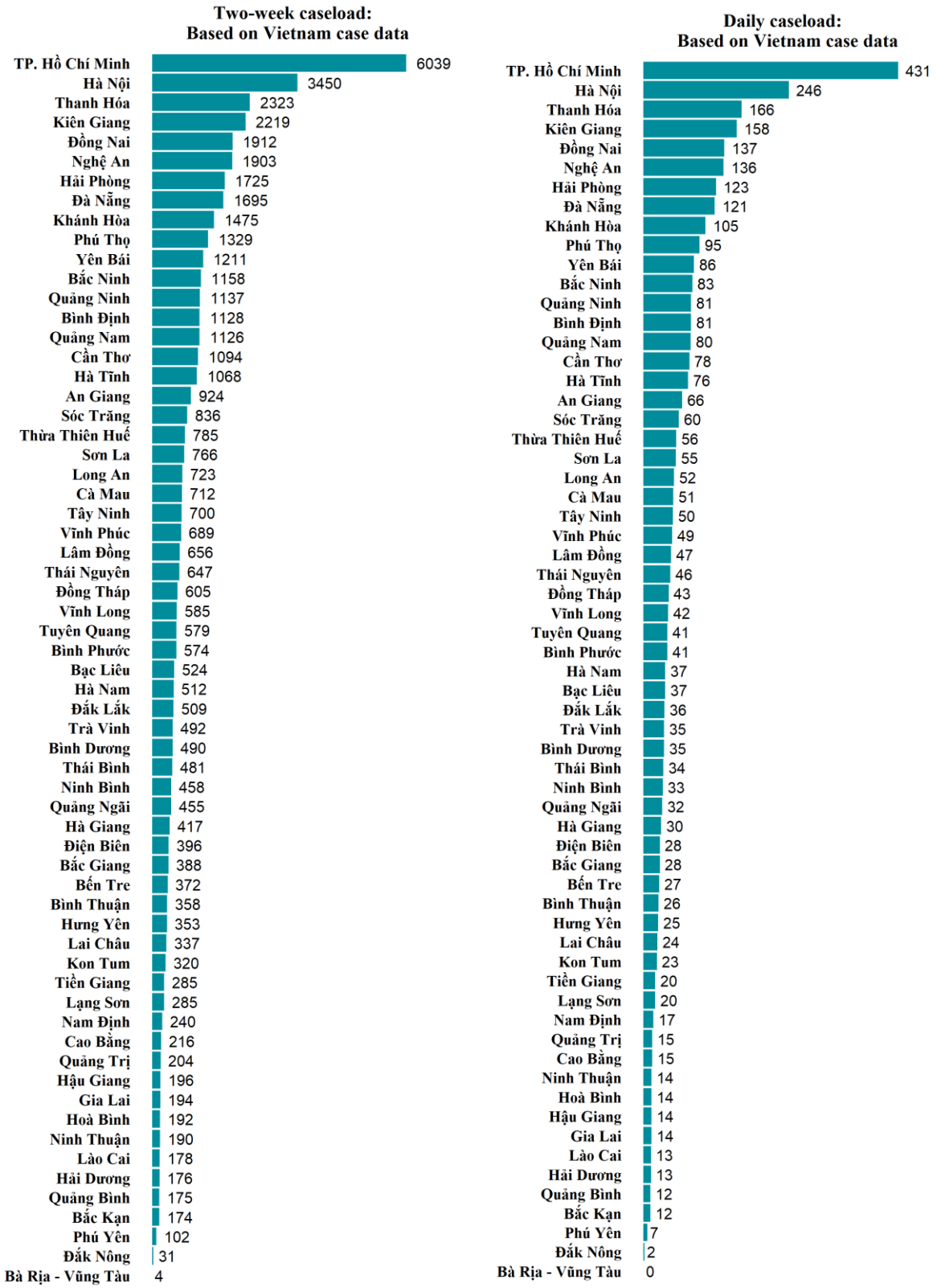
Vietnam MOH Parameters					Translation into ESFT parameters		
Floor	Oxygen interface	Percent of patients	LPM	LPM (daily average)	Percent of patients	LPM (daily average)	ESFT category
1	Nasal cannula	2.1%	5.00	1.25	8.4%	10.18	Severe
	Oxygen mask	2.1%	15.00	3.75			
2	Nasal cannula	0.6%	5.00	5.00			
	Oxygen mask	3.2%	15.00	15.00			
	High-flow nasal cannula	0.4%	60.00	60.00			
3	Non-invasive ventilator	1.5%	27.50	27.50	5.3%	43.00	Critical
	Invasive ventilator	3.7%	50.00	50.00			
	Extracorporeal membrane oxygenation	0.1%	10.00	10.00			

Figure 11. Maximum 2-week/daily caseloads (15% severe, 5% critical) before oxygen demand exceeds supply.



Abbreviations: ESFT, Essential Supplies Forecasting Tool; WHO, World Health Organization

Figure 12. Maximum 2-week/daily caseloads (8.4% severe, 5.3% critical) before oxygen demand exceeds supply.



Assuming patients are distributed optimally within the health system of Vietnam, there is enough oxygen in hospitals for a COVID-19 outbreak of 74,000 patients over a two-week period, or more about 142,000 if the percentage of critical and severe patients is half of what the WHO ESFT assumes. These numbers correspond to an average of about 5,300 and 10,000 per day, respectively, over 14 days. If daily caseloads were to exceed these figures, it may become necessary to increase the frequency of liquid oxygen and oxygen cylinder deliveries. Under this situation, ensuring that supply chains from the oxygen production sites to hospitals run smoothly will become essential. Equipping more hospitals with liquid oxygen tanks would also increase the estimated caseloads that the health system could handle. Vietnam's largest cities, HCMC and Hanoi, have the largest supply of medical oxygen and therefore could handle the largest caseloads. However, there are many provinces that could only handle minor caseloads because their medical oxygen capacity is low. HCMC has experienced caseloads higher than the figure in the plots above and yet reported no oxygen shortages, likely indicating the health system was able to respond dynamically to high demand in order to increase oxygen supplies.

RCE

The WHO ESFT estimates that a suite of 15 different pieces of RCE and consumables are needed for critical COVID-19 patients, and it provides ratios for how much equipment is needed per patient. Some consumables, like airways, are assumed to be needed in a 1.33:1 ratio per patient, while for some durable equipment it is assumed fewer than 1 is needed per critical patient. For example, the WHO ESFT estimates that 0.67 ventilators are needed per critical patient—in other words, 2 ventilators for every 3 critical patients. Using these ratios and the supply of REC counted in the survey, it can be estimated how many critical COVID-19 patients could be treated with the available equipment (Table 19).

Table 20. Number of critical COVID-19 patients that could be treated by available RCE, by hospital level.

Equipment	National	Provincial	District	Private	Total
Nasal catheter	123,840	728,940	379,900	86,000	1,318,680
High-flow nasal cannula	100,312	476,794	412,382	57,529	1,047,018
Endotracheal tube	16,607	54,881	25,999	8,721	106,208
Resuscitation bag and mask	18,358	43,879	29,515	8,306	100,058
Flowmeter	9,533	39,997	23,421	13,400	86,352
Oropharyngeal airway	27,496	36,332	11,799	8,549	84,177
Nasopharyngeal airway	1,750	18,850	5,744	3,543	29,887
CPAP	1,024	9,588	5,629	1,829	18,071
Laryngoscope	666	7,699	4,278	2,399	15,040
Patient monitor with ECG	1,196	7,253	3,397	2,014	13,860
Laryngeal mask	2,321	5,188	4,212	1,768	13,489
Ventilator	1,269	6,946	2,115	713	11,043
Pulse oximeter	665	4,011	2,706	1,486	8,868
Colorimetric end-tidal CO_2 detector	84	164	124	162	534

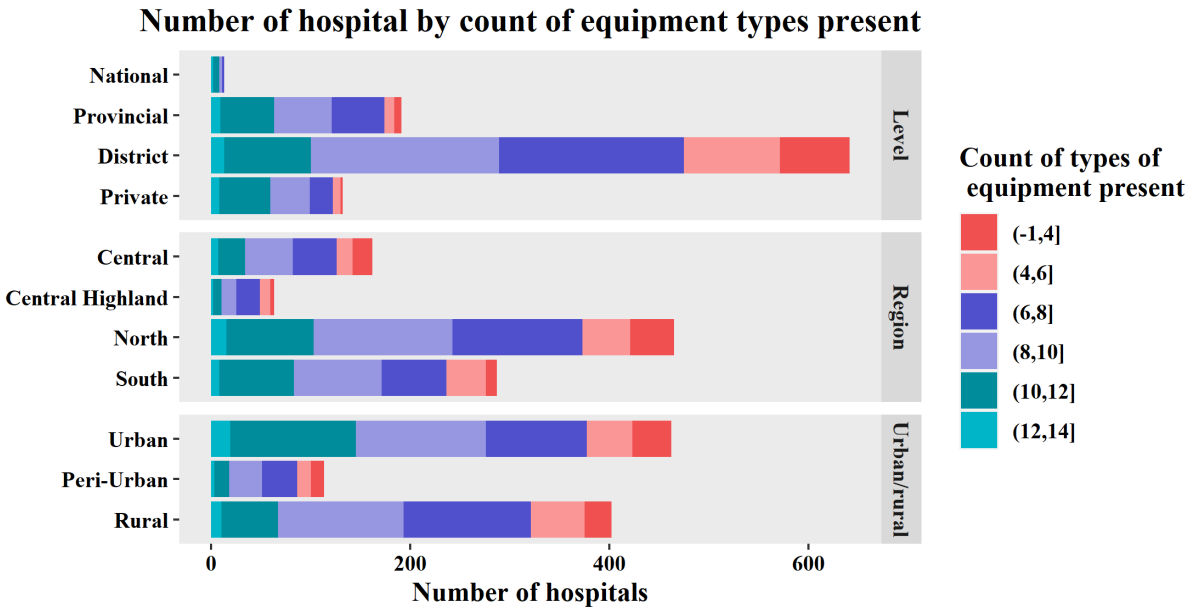
Abbreviations: CPAP, continuous positive airway pressure; ECG, electrocardiogram; RCE, respiratory care equipment.

It does not appear that RCE would be a limiting factor for treating critical COVID-19 patients, given the number of patients the current supplies of RCE are estimated to support. Stakeholders in Vietnam have mentioned that colorimetric end-tidal CO_2 detectors are not often used in favor of other equipment,

and patient monitors are often used rather than POXs. Assuming that 9,987 ICU beds, or 60 percent of all ICU beds, could be used for critical COVID-19 patients, it appears that availability of ICU beds would place a limit on the number of critical COVID-patients that could be treated before that of ventilators.

Table 19 above displays aggregate figures—that is, the sum of patients that can be treated by each piece of equipment within all hospitals. However, more important than the total sum is how many hospitals contain the entire suite of RCE needed to treat patients. The survey data indicate that many hospitals are missing one or more pieces of equipment. Figure 13 displays the number of hospitals per count of available equipment types needed for critical COVID-19 patients, as specified by the WHO ESFT.

Figure 13. Number of hospitals per count of available equipment types needed for critical COVID-19 patients.



Nearly all hospitals lack the full suite of RCE listed in the WHO ESFT for critical patients. Only 3.2 percent of hospitals had 13 or 14 of the 14 pieces of equipment needed to treat critical COVID-19 patients per the WHO ESFT. However, 23 percent had more than 10 types of REC on-site. What is notable about the plot above is the amount of pink and purple, representing facilities that have 10 or less of the 14 pieces of RCE needed to treat critical COVID-19 patients. This indicates that many hospitals are missing necessary RCE. While it is likely that the most critical patients will be transferred to national- or provincial-level facilities, the fact that so many hospitals reported having zero units of certain types of RCE may hinder the ability to treat less-critical patients where they present and to relieve pressure on higher-level facilities.

Demand under different scenarios

The path of the COVID-19 pandemic can, at best, be predicted somewhat accurately a few weeks in advance, but the accuracy of predictions diminishes precipitously as the time horizon of these estimates increases. In situations where long-term predictions are largely unreliable, the use of scenarios can help policymakers plan for the unpredictable. Hypothesizing the events and circumstances that would lead to large outbreaks of various sizes is beyond the scope of this report; however, using the tools and data this report has relied on—mainly, the WHO ESFT and MOH data—it is possible to estimate the amount of medical oxygen and RCE needed for different caseload scenarios.

Tables 20 and 21 display the liters of gas oxygen needed per week for two-week caseload scenarios at scales that are relevant for national- and provincial-level planning. The oxygen need for each scenario is estimated using WHO ESFT parameters for the percentage of severe and critical patients (15 and 5 percent, respectively) and Vietnam MOH data on the percentage of severe and critical patients (5.1 and 3.0 percent, respectively). In the two-week period ending on September 7, 2021, Vietnam recorded more than 170,000 new COVID-19 cases, which suggests the scale of the national scenarios below are appropriate. The scenarios can be multiplied accordingly to arrive at oxygen need estimates based on different caseload scenarios. As another point of reference, the survey data estimate that, in total, 1.75 billion liters of oxygen are available per week in Vietnam under routine situations (i.e., not including any increase in production or deliveries that would be prompted by the pandemic).

Table 21. Weekly oxygen needed in liters based on 2-week *national* caseload scenario.

Source for parameters	Estimated liters needed per size of 2-week caseload scenario				
	100,000 cases	200,000 cases	300,000 cases	500,000 cases	1,000,000 cases
WHO ESFT	2,268,000,000	4,536,000,000	6,804,000,000	11,340,000,000	22,680,000,000
Vietnam case data	3,160,886,400	6,321,772,800	9,482,659,200	15,804,432,000	31,608,864,000

Table 22. Weekly oxygen needed in liters based on 2-week *provincial* caseload scenario.

Parameter base source	Estimated liters needed per size of 2-week caseload scenario				
	1,000 cases	5,000 cases	10,000 cases	25,000 cases	50,000 cases
WHO ESFT	22,680,000	113,400,000	226,800,000	567,000,000	1,134,000,000
Vietnam case data	31,608,864	158,044,320	316,088,640	790,221,600	1,580,443,200

Appendix 2 of this report provides tables of RCE demand estimates for different scenarios, as well as the supply of RCE enumerated by the survey, both nationally and by province. These supply-and-demand tables can be used together by both national- and provincial-level decision-makers to understand the potential gaps in RCE and medical oxygen under different-sized COVID-19 caseload scenarios.

Dynamic responses and changing needs

As COVID-19 grew more serious in Vietnam, the GoV in general, and the MOH specifically, responded in a rapid and dynamic fashion. These actions should be kept in mind when reading and interpreting this report, because the data recorded in the survey do not necessarily represent the current capabilities of the health system after implementing responses to the outbreak. These dynamic response activities have been impressive and involved great efforts by all divisions of government and segments of society. A few of the critical responses include:

- Establishing field hospitals capable of treating thousands of patients close to outbreak centers.
- Mobilizing human and material resources from across the country to temporarily locate to HCMC during times of large patient caseloads.
- Organizing coordination meetings with oxygen suppliers to understand their supply capabilities, as well as difficulties the government can help them overcome to ensure supply chain functioning.
- Writing and publishing guidance and promulgating legal documents on supplying medical oxygen to health facilities.
- Holding workshops to disseminate guidance, for example the “Vietnam MOH meeting on implementing the program to improve medical oxygen supply and use at COVID-19 treatment facilities” was held in September 2021.
- Creating a tiered system (“floor 1, 2, and 3”) to help allocate patients efficiently to facilities with the proper standard of care.
- Rapidly developing an online system to track the daily amount of used and unused critical RCE at individual facilities to help assign patients to hospitals with available equipment.

Along with the nature of the response activities, the needs of the health system are also changing as the pandemic progresses. In the early days of the pandemic Vietnam, like all other countries, scrambled to procure first personal protective equipment, then ventilators, and now, in September 2021, vaccines. Pertinent to this report, Vietnam also has a need for different types of medical oxygen equipment. As the MOH set up more field hospitals, the need arose for oxygen cylinders for these temporary facilities, as well as smaller, portable cryogenic liquid oxygen tanks that could more efficiently provide large quantities of liquid oxygen to these field hospitals. Global donors also have started to focus more on oxygen since the pandemic began, and Vietnam has sought to take advantage of funding opportunities to procure more equipment for liquid oxygen systems to enable more hospitals to handle larger patient caseloads.

Limitations of survey results

There are several limitations to keep in mind when considering the survey results and the comparison between supply and demand:

- The most important one is that this is a static analysis, yet any response to COVID-19 will be dynamic and will affect the health system in ways not considered by this report. Vietnam's MOH has pursued a pragmatic and dynamic campaign to tackle the challenges of COVID-19, including the use of quarantine areas and field hospitals, which this analysis cannot take into account. Responses by the MOH that utilize increased resources will likely result in an increased capacity to treat larger caseloads. For example, the use of field hospitals would increase the capacity of the health system to handle COVID-19 cases beyond what the analysis in this report would predict.
- The survey results only represent one snapshot in time. These data were collected from January to February 2021 during the COVID-19 pandemic, when many hospitals may have been procuring new equipment and discarding old, broken equipment. There are likely changes in the amount of equipment in hospitals today compared to what was recorded when the survey took place.
- WHO puts the number of hospitals in Vietnam at 1,332; however, this analysis only accounts for 993 hospitals. The implication of this is that the estimates within this report are likely to be an underestimate.
- The WHO ESFT estimated standards might not be a perfect fit for Vietnam, but they at least serve as benchmarks.
- Decision 2626 was published in late May 2021, months after the survey took place, so many hospitals may not meet the equipment standards stipulated by Decision 2626 simply because these standards did not exist at the time of the survey.
- The survey was answered online by staff at each hospital, and the project team was available to answer any questions from these staff on how to fill out the survey. However, given that different staff for each hospital filled in the survey, there may be data entry errors.

Discussion

Relative to other countries its size, Vietnam has had few COVID-19 cases, which is attributable to fast and effective action by the GoV to quicky close borders, contain outbreaks, and treat patients. However, since May 2021 the country has experienced its largest outbreak yet, which is testing the limits of its health system.

The analysis above indicates that the first limiting factor to treating critical COVID-19 patients would be medical oxygen, with the health system having access to enough medical oxygen on a weekly basis to provide treatment for 3,300 critical and 5,100 severe COVID-19 cases simultaneously. Using the assumptions from the WHO ESFT that 20 percent of patients would require hospitalization and 25 percent of those would require ventilation, there would need to be approximately 5,300 new cases a day to reach 3,300 critical patents within the hospital system. However, it is possible that the actual percentage of critical COVID-19 cases is lower than the WHO ESFT estimate.

Although medical oxygen is the first limiting factor indicated by the analysis above, Vietnam has a robust supply of liquid oxygen, with manufacturers able to produce large amounts of medical oxygen. Logistical factors permitting (e.g., number of trucks capable of delivering liquid oxygen), hospitals that rely on liquid oxygen could increase delivery frequency to increase the amount of oxygen they have available for patients. However, there are far more facilities that rely on cylinders, which store lower densities of oxygen, and they would face increased supply challenges. In a period of peak demand, critical patients could quickly use up available cylinders, and resupplying the many facilities that rely on cylinders could easily result in the challenges seen in India during April and May of 2021.

The second factor that could limit the number of critical patients served is the number of ICU beds. In total, the survey recorded 16,645 ICU beds, and it is assumed by the WHO ESFT that 60 percent (or 9,988) of these beds could be made available for critical COVID-19 patients. Using field hospitals or sufficiently equipping other beds within hospitals could help rapidly increase the number of ICU beds.

The third limiting factor is the number of ventilators. The survey recorded enough invasive ventilators to treat 11,043 critical COVID-19 patients. However, 2,115 (19 percent) of these would be for patients in district hospitals, and only 67 district hospitals recorded enough oxygen available on a weekly basis to meet the oxygen demands of even 1 critical COVID-19 patient (Table 17). This is likely because only 6 percent of district hospitals have liquid oxygen tanks; they mainly rely on oxygen concentrators (which cannot be used with ventilators) and oxygen cylinders (which would be used up quickly by patients on ventilators).

A final factor that would limit the number of critical COVID-19 patients that could be treated is not having a complete set of RCE needed to treat these patients. As seen in the comparison to Decision 2626 (Table 14) and to the WHO ESFT (Figure 13), there are many hospitals that lack the complete set of equipment suggested by these tools. However, it is possible that other equipment could act as a substitute (e.g., patient monitors for POXs).

Planning for emergencies is essential and being aware of where the limiting factors exist in the health system can help avoid disasters. Knowing that availability of first oxygen, then ICU beds, and finally RCE would limit treatment to patients in respiratory distress can help decision-makers prioritize actions and resources.

Recommendations

Based on this analysis, the survey team has the following recommendations for increasing Vietnam's capacity to treat the range of ongoing COVID-19 cases, as well as handle any future disease outbreaks:

- Equip more provincial- and district-level hospitals with liquid oxygen, which will strengthen the health system in areas beyond treatment of COVID-19 (e.g., pneumonia, surgery, obstetric emergencies, and other respiratory illnesses):
    - Starting with provinces that can treat the least number of critical COVID-19 patients, install liquid oxygen tank systems in hospitals, focusing on hospitals that already have oxygen piping installed because installation in these facilities will be relatively cheaper and quicker.
    - Focus on BR-VT, Đắk Nông, Phú Yên, Gia Lai, Hải Dương, and Lào Cai, the provinces that can treat the least number of patients with sufficient oxygen in absolute and per capita terms; expand focus to more provinces if resources are available.
    - Expand use of standard 6 m^3 liquid oxygen tanks, which can provide enough oxygen on a weekly basis for 11 critical patients and 17 severe patients simultaneously, which roughly corresponds to a two-week caseload of 227 patients, or 16 per day.
- Create a liquid oxygen and oxygen cylinder emergency supply plan to quickly increase access to oxygen during a crisis:
    - Contact hospitals and liquid oxygen suppliers in or near outbreak areas to ensure they can increase the frequency of liquid oxygen deliveries (i.e., if liquid oxygen deliveries are doubled, some hospitals could double the number of patients they could treat with medical oxygen).
    - Alert hospitals to the dangers of increased oxygen usage, like icing near the evaporator or pressure drops from increased demand.
    - Require hospitals to track oxygen consumption and report back daily to an emergency operation center to calculate aggregate health system oxygen demand to ensure supplies are sufficient. [Note: UNICEF and PATH have both developed hospital-level tools to track oxygen consumption.]
    - Forecast oxygen demand weeks to months in advance based on consumption data from hospitals to ensure suppliers can continue supplying oxygen in sufficient quantities.
- Create a real-time equipment management system that can track how much medical equipment is in all public health facilities:
    - Continuously track data that the survey from this analysis recorded and, during a pandemic, help health authorities quickly mobilize and reallocate resources.
    - Assemble a team to search for the most promising electronic equipment management systems already being used in different hospitals in Vietnam and to assess their strengths and weaknesses; compare them against guidance from the WHO's Medical Device Technical Series.
    - Pilot either the most promising equipment management system or multiple systems within a sample of health facilities and ensure that central-level monitoring of local medical equipment inventories is feasible with these systems.

- Scale the piloted system(s) nationwide, allowing central-level tracking of medical equipment inventories and enabling both the reallocation of equipment during pandemics and the monitoring of equipment standards.

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Appendices

Appendix 1: Additional tables on respiratory care equipment

Tables 23 through 27 detail availability of additional respiratory care equipment in Vietnam.

Table 23. Availability of flow splitters per number of outlets and flow rate.

Division	Category	Number of outlets and flow rate						
		2 outlets, 1 LPM	2 outlets, 2 LPM	3 outlets, 2 LPM	4 outlets, 1 LPM	4 outlets, 2 LPM	5 outlets, 1 LPM	5 outlets, 2 LPM
Region	Central	586	216	0	0	1	0	0
	Central Highlands	13	7	0	50	25	0	0
	North	327	214	42	24	18	11	9
	South	102	248	30	0	0	6	11
	Total	**1,028**	**685**	**72**	**74**	**44**	**17**	**20**
Facility level*	National	0	1	0	0	0	0	0
	Provincial	725	437	30	10	11	0	5
	District	139	96	30	14	8	12	10
	Private	162	151	12	50	25	5	5
Urban / rural	Urban	864	532	31	60	36	6	6
	Peri-urban	53	56	12	0	0	0	5
	Rural	111	97	29	14	8	11	9

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: LPM, liters per minute.

Table 24. Flowmeters by max flow rate (functional/nonfunctional).

Division	Category	2 LPM	5 LPM	10 LPM	15 LPM	15+ LPM
Region	Central	161 / 1	566 / 17	1,781 / 49	2,999 / 196	217 / 5
	Central Highlands	43 / 21	113 / 25	206 / 39	527 / 4	121 / 24
	North	989 / 20	2,639 / 318	5,475 / 225	5,362 / 263	1,336 / 187
	South	396 / 140	1,853 / 71	2,929 / 86	7,006 / 492	787 / 124
	Total	**1,589 / 182**	**5,171 / 431**	**1,0391 / 399**	**15,894 / 955**	**2,461 / 340**
Facility level*	National	0 / 0	300 / 0	1,060 / 5	1,620 / 131	466 / 60
	Provincial	814 / 110	2,207 / 283	3,610 / 108	8,738 / 509	905 / 193
	District	449 / 17	2,216 / 139	4,445 / 279	2,888 / 224	396 / 8
	Private	266 / 55	448 / 9	1,165 / 2	2,613 / 86	644 / 79
Urban / rural	Urban	998 / 145	3,197 / 324	6,341 / 193	12,427 / 754	1,876 / 247
	Peri-urban	215 / 5	842 / 30	1,281 / 34	1,274 / 36	82 / 9
	Rural	376 / 32	1,132 / 77	2,769 / 172	2,193 / 165	503 / 84

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: LPM, liters per minute.

Table 25. Flow splitters, valves, pressure gauges, and flow regulator sets for wall units.

Division	Category	Flow splitters	Valves, pressure gauges, and flow regulator sets	Total beds	ICU beds
Region	Central	853	6,530	45,607	3,278
	Central Highlands	146	1,101	11,369	560
	North	5,177	15,010	126,279	7,028
	South	3,345	14,622	79,343	5,779
	Total	**9,521**	**37,263**	**262,689**	**16,654**
Facility level*	National	73	2,852	17,531	1,489
	Provincial	4,160	19,466	109,965	7,361
	District	2,876	7,989	109,677	6,339
	Private	2,394	5,759	20,888	1,274
Urban / rural	Urban	6,299	29,080	164,231	10,803
	Peri-urban	1,069	3,293	27,658	1,758
	Rural	2,153	4,890	70,800	4,093

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.
Abbreviation: ICU, intensive care unit.

Table 26. Equipment needed for advanced respiratory care.

Division	Category	Colorimetric end-tidal CO_2 detector	Endo-tracheal tube	Laryngeal mask	Laryngo-scope	Naso-pharyngeal airway	Oro-pharyngeal airway
Region	Central	195	24,415	2,306	2,388	2,177	14,310
	Central Highlands	59	3,372	412	375	436	1,361
	North	221	63,241	9,883	3,731	10,371	17,641
	South	246	52,922	5,371	3,757	27,087	80,858
	Total	**721**	**143,950**	**17,972**	**10,251**	**40,071**	**114,170**
Facility level*	National	112	22,084	3,087	446	2,327	36,544
	Provincial	218	73,364	6,900	5,208	25,071	48,658
	District	165	34,578	5,602	2,866	7,640	15,691
	Private	215	11,599	2,352	1,607	4,712	11,370
Urban / rural	Urban	543	108,157	9,850	7,534	32,051	98,419
	Peri-urban	67	10,897	1,980	833	2,389	4,645
	Rural	111	24,896	6,142	1,884	5,631	11,106

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.

Table 27. Patient-oxygen interface equipment.

Division	Category	High-flow nasal cannula	Nasal cannula	Nasal catheter	Oxygen mask	Resuscitation bag and mask	Venturi mask
Region	Central	44,424	131,615	6,426	27,819	6,614	5,603
	Central Highlands	6,300	22,749	1,217	3,291	978	811
	North	64,672	219,907	19,970	48,482	10,364	9,720
	South	75,577	249,681	43,305	72,321	16,277	21,516
	Total	**190,973**	**623,952**	**70,918**	**151,913**	**34,233**	**37,650**
Facility level*	National	17,053	34,913	6,192	8,100	6,056	945
	Provincial	81,055	294,693	36,447	76,398	14,514	20,384
	District	70,105	215,048	18,995	51,280	9,740	13,973
	Private	9,780	57,981	4,300	12,941	2,741	2,348
Urban / rural	Urban	120,585	416,176	51,665	101,111	25,299	23,416
	Peri-urban	22,563	58,718	6,134	17,245	3,277	3,251
	Rural	47,825	149,058	13,119	33,557	5,657	10,983

* Data from 16 military, police, and university hospitals not displayed here in the facility level division.

Appendix 2: **Respiratory care equipment and oxygen need based on different scenarios**

Tables 28 through 34 summarize respiratory care equipment and oxygen supply recorded in the survey and demand under various parameters.

Table 28. RCE needed under different provincial-scale scenarios, WHO ESFT severe/critical case parameters.

Equipment	WHO ESFT estimated amount needed per patient		Amount of equipment needed given different COVID-19-positive caseloads within a two-week period *(assumes 5% of patients are critical and 15% severe)*				
	Severe patient	Critical patient	1,000	5,000	10,000	25,000	50,000
Oxygen source*	1.00	1.00	88	438	875	2,188	4,375
Pulse oximeter	1.00	1.00	88	438	875	2,188	4,375
Colorimetric end-tidal CO_2 detector	0.00	1.33	67	333	665	1,663	3,325
Endotracheal tube	0	1.33	67	333	665	1,663	3,325
Laryngeal mask	0	1.33	67	333	665	1,663	3,325
Nasopharyngeal airway	0	1.33	67	333	665	1,663	3,325
Oropharyngeal airway	0	1.33	67	333	665	1,663	3,325
Nasal cannula	0.67	0	50	251	503	1,256	2,513
Oxygen mask	0.67	0	50	251	503	1,256	2,513
Venturi mask	0.67	0	50	251	503	1,256	2,513
Patient monitor with ECG	0	1.00	50	250	500	1,250	2,500
Patient monitor without ECG	1.00	0	38	188	375	938	1,875
Laryngoscope	0	0.67	34	168	335	838	1,675
Ventilator	0	0.67	34	168	335	838	1,675
Flow meter	0	0.33	17	83	165	413	825
Resuscitation bag and mask	0	0.33	17	83	165	413	825
CPAP	0	0.17	9	43	85	213	425
High-flow nasal cannula	0	0.17	9	43	85	213	425
Nasal catheter	0.05	0.05	6	31	63	156	313

Abbreviations: CPAP, continuous positive airway pressure; ECG, electrocardiogram; ESFT, Essential Supplies Forecasting Tool; RCE, respiratory care equipment; WHO, World Health Organization.

Table 29. RCE needed under different provincial-scale scenarios, Vietnam MOH severe/critical case parameters.

Equipment	WHO ESFT estimated amount needed per patient		Amount of equipment needed given different COVID-19-positive caseloads within a two-week period *(assumes 3.0% of patients are critical and 5.1% severe)*				
	Severe patient	Critical patient	1,000	5,000	10,000	25,000	50,000
Oxygen source*	1.00	1.00	43	214	428	1,069	2,138
Pulse oximeter	1.00	1.00	43	214	428	1,069	2,138
Colorimetric end-tidal CO_2 detector	0	1.33	40	200	399	998	1,995
Endotracheal tube	0	1.33	40	200	399	998	1,995
Laryngeal mask	0	1.33	40	200	399	998	1,995
Nasopharyngeal airway	0	1.33	40	200	399	998	1,995
Oropharyngeal airway	0	1.33	40	200	399	998	1,995
Patient monitor with ECG	0	1.00	30	150	300	750	1,500
Laryngoscope	0	0.67	20	101	201	503	1,005
Ventilator	0	0.67	20	101	201	503	1,005
Nasal cannula	0.67	0	17	85	171	427	854
Oxygen mask	0.67	0	17	85	171	427	854
Venturi mask	0.67	0	17	85	171	427	854
Patient monitor without ECG	1.00	0	13	64	128	319	638
Flow meter	0	0.33	10	50	99	248	495
Resuscitation bag and mask	0	0.33	10	50	99	248	495
CPAP	0	0.17	5	26	51	128	255
High-flow nasal cannula	0	0.17	5	26	51	128	255
Nasal catheter	0.05	0.05	3	14	28	69	139

Abbreviations: CPAP, continuous positive airway pressure; ECG, electrocardiogram; ESFT, Essential Supplies Forecasting Tool; MOH, Ministry of Health; RCE, respiratory care equipment; WHO, World Health Organization.

Table 30. RCE needed under different national-scale scenarios, WHO ESFT severe/critical case parameters.

Equipment	WHO ESFT estimated amount needed per patient		Amount of equipment needed given different COVID-19-positive caseloads within a two-week period *(assumes 5% of patients are critical and 15% severe)*				
	Severe patient	Critical patient	100,000	200,000	300,000	500,000	1,000,000
Oxygen source*	1.00	1.00	8,750	17,500	26,250	43,750	87,500
Pulse oximeter	1.00	1.00	8,750	17,500	26,250	43,750	87,500
Colorimetric end-tidal CO_2 detector	0	1.33	6,650	13,300	19,950	33,250	66,500
Endotracheal tube	0	1.33	6,650	13,300	19,950	33,250	66,500
Laryngeal mask	0	1.33	6,650	13,300	19,950	33,250	66,500
Nasopharyngeal airway	0	1.33	6,650	13,300	19,950	33,250	66,500
Oropharyngeal airway	0	1.33	6,650	13,300	19,950	33,250	66,500
Nasal cannula	0.67	0	5,025	10,050	15,075	25,125	50,250

Oxygen mask	0.67	0	5,025	10,050	15,075	25,125	50,250
Venturi mask	0.67	0	5,025	10,050	15,075	25,125	50,250
Patient monitor with ECG	0	1.00	5,000	10,000	15,000	25,000	50,000
Patient monitor without ECG	1.00	0	3,750	7,500	11,250	18,750	37,500
Laryngoscope	0	0.67	3,350	6,700	10,050	16,750	33,500
Ventilator	0	0.67	3,350	6,700	10,050	16,750	33,500
Flow meter	0	0.33	1,650	3,300	4,950	8,250	16,500
Resuscitation bag and mask	0	0.33	1,650	3,300	4,950	8,250	16,500
CPAP	0	0.17	850	1,700	2,550	4,250	8,500
High-flow nasal cannula	0	0.17	850	1,700	2,550	4,250	8,500
Nasal catheter	0.05	0.05	625	1,250	1,875	3,125	6,250

Abbreviations: CPAP, continuous positive airway pressure; ECG, electrocardiogram; ESFT, Essential Supplies Forecasting Tool; RCE, respiratory care equipment; WHO, World Health Organization.

Table 31. RCE needed under different national-scale scenarios, MOH ESFT severe/critical case parameters.

Equipment	WHO ESFT estimated amount needed per patient		Amount of equipment needed given different COVID-19-positive caseloads within a two-week period *(assumes 3.0% of patients are critical and 5.1% severe)*				
	Severe patient	Critical patient	100,000	200,000	300,000	500,000	1,000,000
Oxygen source*	1.00	1.00	4,275	8,550	12,825	21,375	42,750
Pulse oximeter	1.00	1.00	4,275	8,550	12,825	21,375	42,750
Colorimetric end-tidal CO_2 detector	0	1.33	3,990	7,980	11,970	19,950	39,900
Endotracheal tube	0	1.33	3,990	7,980	11,970	19,950	39,900
Laryngeal mask	0	1.33	3,990	7,980	11,970	19,950	39,900
Nasopharyngeal airway	0	1.33	3,990	7,980	11,970	19,950	39,900
Oropharyngeal airway	0	1.33	3,990	7,980	11,970	19,950	39,900
Patient monitor with ECG	0	1.00	3,000	6,000	9,000	15,000	30,000
Laryngoscope	0	0.67	2,010	4,020	6,030	10,050	20,100
Ventilator	0	0.67	2,010	4,020	6,030	10,050	20,100
Nasal cannula	0.67	0	1,709	3,417	5,126	8,543	17,085
Oxygen mask	0.67	0	1,709	3,417	5,126	8,543	17,085
Venturi mask	0.67	0	1,709	3,417	5,126	8,543	17,085
Patient monitor without ECG	1.00	0	1,275	2,550	3,825	6,375	12,750
Flow meter	0	0.33	990	1,980	2,970	4,950	9,900
Resuscitation bag and mask	0	0.33	990	1,980	2,970	4,950	9,900
CPAP	0	0.17	510	1,020	1,530	2,550	5,100
High-flow nasal cannula	0	0.17	510	1,020	1,530	2,550	5,100
Nasal catheter	0.05	0.05	278	555	833	1,388	2,775

Abbreviations: CPAP, continuous positive airway pressure; ECG, electrocardiogram; ESFT, Essential Supplies Forecasting Tool; MOH, Ministry of Health; RCE, respiratory care equipment; WHO, World Health Organization.

Table 32. RCE recorded in the BEIT survey in January and February 2021 (part 1).

Province	Ventilator	CPAP	Patient monitor with ECG	Patient monitor without ECG	Endotracheal tube	Laryngeal mask	Laryngoscope	Oropharyngeal airway	Colorimetric end-tidal CO_2 detector
An Giang	156	79	269	57	4,121	131	151	4,392	2
Bạc Liêu	78	18	221	31	1,332	25	149	9,183	-
Bắc Giang	116	46	223	25	3,085	566	112	528	12
Bắc Kạn	60	20	92	8	119	42	7	-	2
Bắc Ninh	133	60	212	108	3,425	549	254	491	12
Bến Tre	14	10	39	-	124	41	44	130	-
BR-VT	4	1	4	-	14	8	13	2	-
Bình Định	181	39	206	144	2,225	131	150	3,591	4
Bình Dương	105	20	218	33	248	25	121	167	19
Bình Phước	37	27	54	5	465	115	75	1,490	2
Bình Thuận	44	28	101	34	1,691	372	156	1,049	2
Cần Thơ	240	86	312	39	901	32	158	2,067	3
Cà Mau	231	52	189	65	1,070	1,006	192	8,914	-
Cao Bằng	67	62	131	17	2,701	47	59	90	-
Đắk Lắk	108	32	276	17	920	293	122	634	43
Đắk Nông	31	12	38	22	48	9	42	185	-
Đồng Nai	237	190	521	124	6,860	152	440	3,455	11
Đồng Tháp	95	32	161	19	3,263	91	170	813	14
Đà Nẵng	266	47	472	32	2,715	144	748	1,705	33
Điện Biên	51	42	136	70	1,342	52	114	338	6
Gia Lai	44	60	113	10	1,967	73	112	316	12
Hải Dương	21	13	9	14	73	18	18	12	-
Hải Phòng	173	46	441	63	1,973	228	197	1,433	5
Hậu Giang	68	16	167	20	651	317	85	586	8
Hà Giang	59	45	117	36	1,949	45	83	462	1
Hà Nội	364	103	863	75	7,377	195	386	3,772	5
Hà Nam	33	22	111	3	1,233	101	53	24	2
Hà Tĩnh	101	37	197	51	682	143	102	479	1
Hoà Bình	89	49	160	111	1,246	276	88	307	5
Hưng Yên	45	31	88	19	599	16	28	571	11
Khánh Hòa	125	52	227	59	1,389	153	648	4,676	1
Kiên Giang	245	30	133	10	1,308	1,194	481	834	9
Kon Tum	83	36	113	27	437	37	99	226	4

Province	Ventilator	CPAP	Patient monitor with ECG	Patient monitor without ECG	Endotracheal tube	Laryngeal mask	Laryngoscope	Oropharyngeal airway	Colorimetric end-tidal CO_2 detector
Lạng Sơn	65	19	136	52	1,054	47	73	239	1
Lai Châu	37	22	95	5	875	10	61	117	-
Lâm Đồng	75	60	174	6	538	92	125	2,281	1
Lào Cai	45	9	123	14	863	180	61	156	5
Long An	85	65	169	4	1,705	182	172	1,252	4
Nam Định	47	35	100	37	3,292	63	51	1,265	3
Nghệ An	291	111	520	84	4,506	642	365	1,042	16
Ninh Bình	80	75	140	34	1,910	136	168	204	6
Ninh Thuận	60	4	115	4	1,721	4	70	51	-
Phú Thọ	192	86	478	101	4,828	299	281	775	63
Phú Yên	27	19	57	9	999	42	28	25	2
Quảng Bình	50	16	103	35	3,378	242	65	802	5
Quảng Nam	183	60	337	31	7,143	50	162	1,177	16
Quảng Ngãi	84	32	179	3	1,370	764	67	35	10
Quảng Ninh	102	35	295	22	3,008	77	146	740	16
Quảng Trị	61	21	155	15	734	39	141	607	12
Sóc Trăng	106	44	273	17	687	144	121	480	20
Sơn La	118	68	131	31	1,956	1,307	97	350	18
Tây Ninh	100	21	252	76	648	87	53	2,900	54
Thừa Thiên Huế	165	84	106	73	672	365	103	244	110
Thái Bình	57	42	185	55	2,447	228	147	363	1
Thái Nguyên	151	34	272	70	2,226	1,623	81	101	2
Thanh Hóa	245	91	569	76	6,296	2,776	438	2,606	22
Tiền Giang	30	19	57	3	558	70	88	260	1
TP. Hồ Chí Minh	933	325	1,787	94	24,678	1,569	970	40,765	79
Trà Vinh	78	78	169	11	3,038	50	84	614	-
Tuyên Quang	66	23	164	19	1,399	29	76	503	4
Vĩnh Long	72	22	89	11	718	40	65	313	19
Vĩnh Phúc	127	69	217	53	600	112	88	205	-
Yên Bái	92	58	188	57	2,182	76	97	468	2

Abbreviations: BEIT, Biomedical Equipment Inventory Tool; BR-VT, Bà Rịa – Vũng Tàu; CPAP, continuous positive airway pressure; ECG, electrocardiogram; RCE, respiratory care equipment.

Table 33. RCE recorded in the BEIT survey in January and February 2021 (part 2).

Province	Pulse oximeter	Flow meter	Oxygen mask	Nasal cannula	Nasal catheter	Venturi mask	High-flow nasal cannula	Nasopharyngeal airway	Resuscitation bag and mask
An Giang	219	531	1,594	5,652	226	162	1,749	509	289
Bạc Liêu	136	466	527	6,812	70	8	2,319	469	294
Bắc Giang	87	262	4,420	9,573	3,677	456	1,880	490	323
Bắc Kạn	32	110	114	865	8	2	497	52	110
Bắc Ninh	183	284	1,967	10,701	360	682	3,977	315	273
Bến Tre	36	161	1,018	6,451	9	705	1,098	10	82
BR-VT	11	9	134	1,121	2	2	900	11	39
Bình Định	204	362	5,999	12,743	990	270	1,600	948	655
Bình Dương	110	322	622	1,289	182	-	375	35	171
Bình Phước	65	174	897	5,297	309	289	944	771	405
Bình Thuận	94	500	1,914	10,151	296	1,229	1,334	1	757
Cần Thơ	337	870	5,070	14,140	2,760	554	5,027	1	851
Cà Mau	214	147	5,356	17,859	6,338	85	2,657	9,702	2,591
Cao Bằng	128	97	495	5,747	20	73	2,953	27	258
Đắk Lắk	136	278	940	9,564	495	579	1,008	210	376
Đắk Nông	43	78	108	596	351	33	304	50	94
Đồng Nai	307	976	9,417	29,373	1,474	14,398	4,821	1,809	1,394
Đồng Tháp	192	392	1,094	12,930	413	352	3,994	530	356
Đà Nẵng	344	1,105	2,901	39,999	776	315	2,914	54	650
Điện Biên	64	116	682	2,294	365	215	1,470	223	567
Gia Lai	134	246	726	7,095	247	173	1,275	62	270
Hải Dương	2	44	291	1,309	-	130	29	-	523
Hải Phòng	89	765	533	22,141	701	73	8,591	1,384	510
Hậu Giang	80	155	5,781	10,010	3,534	546	916	512	230
Hà Giang	168	236	1,764	4,057	495	414	906	498	265
Hà Nội	300	2,034	10,766	33,456	1,364	1,940	8,222	890	1,460
Hà Nam	30	127	230	1,433	9	187	474	2	50
Hà Tĩnh	99	521	268	3,799	121	451	1,618	32	257
Hoà Bình	21	43	429	1,859	341	-	1,533	265	296
Hưng Yên	38	165	1,025	4,082	995	-	1,339	422	151
Khánh Hòa	101	659	9,752	5,932	230	2,486	2,806	307	498
Kiên Giang	230	877	2,034	15,235	3,743	295	4,309	4,879	761
Kon Tum	78	252	1,517	5,494	124	26	3,713	114	238

Province	Pulse oximeter	Flow meter	Oxygen mask	Nasal cannula	Nasal catheter	Venturi mask	High-flow nasal cannula	Nasopharyngeal airway	Resuscitation bag and mask
Lạng Sơn	58	154	1,263	2,746	305	11	67	223	167
Lai Châu	82	118	466	4,613	60	23	211	60	133
Lâm Đồng	91	167	1,236	6,702	163	773	490	100	279
Lào Cai	79	74	423	794	75	10	339	170	209
Long An	192	307	4,753	11,739	610	641	5,566	1,634	310
Nam Định	48	176	541	14,943	425	100	374	50	139
Nghệ An	155	1,061	4,348	9,894	1,995	1,013	3,123	824	740
Ninh Bình	119	540	1,363	4,293	1,041	70	2,351	60	408
Ninh Thuận	49	217	1,012	4,517	8	-	226	3	223
Phú Thọ	224	942	2,206	10,399	554	200	2,122	498	357
Phú Yên	38	91	604	4,200	100	6	1,223	31	82
Quảng Bình	77	321	549	9,154	776	26	4,720	313	223
Quảng Nam	92	611	3,144	28,295	2,199	1,019	17,187	147	2,821
Quảng Ngãi	50	610	375	11,648	370	45	8,806	55	205
Quảng Ninh	229	914	663	16,741	200	107	1,256	96	276
Quảng Trị	17	140	613	1,704	178	28	2,585	159	161
Sóc Trăng	93	454	4,859	7,227	1,359	122	3,266	95	188
Sơn La	76	340	1,552	6,309	1,779	117	857	313	231
Tây Ninh	250	645	2,157	11,332	352	200	1,096	25	261
Thừa Thiên Huế	114	326	956	3,272	503	179	1,023	159	304
Thái Bình	102	379	2,421	5,293	1,672	58	2,488	368	413
Thái Nguyên	74	362	1,811	6,212	1,121	756	2,807	200	257
Thanh Hóa	179	1,067	4,774	15,996	1,121	773	8,121	2,294	863
Tiền Giang	71	129	1,049	4,030	412	23	269	90	203
TP. Hồ Chí Minh	1,604	3,255	16,593	57,919	13,698	1,735	28,581	5,567	7,172
Trà Vinh	106	303	788	8,046	4,646	606	6,128	194	194
Tuyên Quang	93	440	923	9,504	380	1,299	3,456	382	577
Vĩnh Long	111	382	7,342	16,517	3,005	20	1,072	144	210
Vĩnh Phúc	71	196	908	3,695	630	10	1,237	105	343
Yên Bái	184	607	1,836	7,159	156	550	2,374	128	208

Abbreviations: BEIT, Biomedical Equipment Inventory Tool; BR-VT, Bà Rịa – Vũng Tàu; RCE, respiratory care equipment.

Table 34. Source and amount of medical oxygen, by province.

Province	Percentage of oxygen available by source				Liters of oxygen available per week
	Liquid oxygen	Oxygen cylinders	Oxygen concentrators	PSA plants	
An Giang	87%	12%	1%	0%	29,600,000
Bạc Liêu	85%	11%	3%	0%	17,100,000
Bắc Giang	54%	32%	14%	0%	14,300,000
Bắc Kạn	63%	18%	19%	0%	6,840,000
Bắc Ninh	91%	6%	4%	0%	38,000,000
Bến Tre	82%	11%	7%	0%	12,600,000
BR-VT	0%	38%	62%	0%	376,000
Bình Định	88%	8%	4%	0%	37,300,000
Bình Dương	93%	5%	2%	0%	15,700,000
Bình Phước	94%	5%	1%	0%	18,400,000
Bình Thuận	50%	34%	6%	10%	12,000,000
Cần Thơ	81%	7%	12%	0%	39,100,000
Cà Mau	86%	8%	6%	0%	24,000,000
Cao Bằng	42%	14%	43%	0%	12,200,000
Đắk Lắk	64%	16%	20%	0%	20,200,000
Đắk Nông	0%	39%	61%	0%	2,490,000
Đồng Nai	84%	7%	9%	0%	66,400,000
Đồng Tháp	76%	13%	11%	0%	21,500,000
Đà Nẵng	94%	5%	1%	0%	54,100,000
Điện Biên	54%	25%	21%	0%	16,000,000
Gia Lai	51%	22%	28%	0%	8,500,000
Hải Dương	88%	7%	5%	0%	5,860,000
Hải Phòng	92%	7%	1%	0%	55,400,000
Hậu Giang	61%	27%	11%	0%	7,050,000
Hà Giang	72%	20%	9%	0%	14,400,000
Hà Nội	88%	7%	5%	0%	115,000,000
Hà Nam	95%	4%	1%	0%	16,400,000
Hà Tĩnh	86%	10%	4%	0%	35,100,000
Hoà Bình	42%	8%	50%	0%	12,200,000
Hưng Yên	78%	14%	8%	0%	12,100,000
Khánh Hòa	93%	4%	3%	0%	48,200,000
Kiên Giang	68%	7%	1%	24%	71,000,000
Kon Tum	78%	13%	9%	0%	11,000,000

Province	Percent of oxygen available by source				Liters of oxygen available per week
	Liquid oxygen	Oxygen cylinders	Oxygen concentrators	PSA plants	
Lạng Sơn	69%	22%	10%	0%	10,000,000
Lai Châu	68%	16%	16%	0%	12,700,000
Lâm Đồng	78%	7%	14%	0%	24,200,000
Lào Cai	63%	19%	17%	0%	6,800,000
Long An	71%	19%	10%	0%	25,500,000
Nam Định	49%	22%	29%	0%	10,600,000
Nghệ An	83%	14%	3%	0%	62,200,000
Ninh Bình	82%	10%	9%	0%	15,800,000
Ninh Thuận	64%	11%	25%	0%	8,120,000
Phú Thọ	86%	10%	4%	0%	43,800,000
Phú Yên	0%	80%	20%	0%	4,010,000
Quảng Bình	52%	15%	33%	0%	8,270,000
Quảng Nam	89%	8%	3%	0%	36,900,000
Quảng Ngãi	72%	9%	8%	11%	15,600,000
Quảng Ninh	94%	4%	2%	0%	36,500,000
Quảng Trị	75%	19%	6%	0%	6,850,000
Sóc Trăng	68%	23%	10%	0%	29,300,000
Sơn La	79%	10%	11%	0%	27,100,000
Tây Ninh	84%	10%	6%	0%	23,400,000
Thừa Thiên Huế	85%	6%	9%	0%	27,300,000
Thái Bình	62%	22%	17%	0%	18,200,000
Thái Nguyên	85%	11%	4%	0%	21,300,000
Thanh Hóa	85%	9%	6%	0%	77,900,000
Tiền Giang	89%	4%	7%	0%	9,650,000
TP. Hồ Chí Minh	83%	7%	1%	9%	192,000,000
Trà Vinh	79%	10%	10%	0%	17,400,000
Tuyên Quang	76%	14%	11%	0%	20,500,000
Vĩnh Long	90%	7%	4%	0%	19,200,000
Vĩnh Phúc	76%	16%	8%	0%	23,700,000
Yên Bái	45%	6%	9%	40%	42,200,000

Abbreviations: BR-VT, Bà Rịa – Vũng Tàu; PSA, pressure swing adsorption.

Appendix 3. Lists of equipment required by Decision 2626

With the exception of the table titles, all content in this appendix, including Tables 35 through 37, are taken directly from the Vietnam Ministry of Health's Decision 2626.[8]

Phụ lục số 3.1. DANH MỤC NHU CẦU TRANG THIẾT BỊ Y TẾ THIẾT YẾU

Khu vực 3: 01 Đơn vị 20 giường bệnh trong Khoa Hồi sức tích cực, điều trị 20 người bệnh COVID-19 nặng, nguy kịch (Khoa Hồi sức tích cực của Bệnh viện có hệ thống oxy trung tâm và nhân lực đủ năng lực kỹ thuật)
(Ban hành kèm theo Quyết định số 2626/QĐ-BYT ngày 28 tháng 5 năm 2021 của Bộ trưởng Bộ Y tế)

Table 35. List of essential medical equipment needs for Area 3.

STT	Tên trang thiết bị	Đơn vị	Số lượng
1.	Bộ dụng cụ thở oxy (bình làm ẩm, đồng hồ đo lưu lượng...): 20 ổ thở oxy, khí nén, có thể mua loại chia đôi, cắm 01 ổ chia hai: 10 ổ oxy, khí nén.	Bộ	20
2.	Máy thở chức năng cao	Cái	8
3.	- Máy thở không xâm nhập, hoặc - Máy thở xâm nhập và không xâm nhập. Cân nhắc có thể lựa chọn thay thế HFNO nếu điều kiện của cơ sở triển khai được.	Cái	5
4.	Hệ thống oxy dòng cao HFNO, có thể chọn máy thở không xâm nhập nếu ô xy khí nén không phù hợp, cũng như RAM thở hiếm trên thị trường	Cái	3
5.	Máy thở xách tay kèm van PEEP, 2 bộ dây	Cái	1
6.	Máy lọc máu liên tục (cho đơn vị đã có đủ năng lực thực hiện)	Cái	3
7.	Hệ thống ECMO (cho đơn vị đã có đủ năng lực kỹ thuật thực hiện, dùng chung cho 01 bệnh viện)	Hệ thống	1
8.	Máy X quang di động	Cái	1
9.	Máy siêu âm Doppler màu ≥ 3 đầu dò	Cái	1
10.	Máy đo khí máu (đo được điện giải đồ, lactat, hematocrite)	Cái	1
11.	Máy theo dõi BN ≥ 5 thông số	Cái	20
12.	Hệ thống oxy (có thể thay bằng bình ô xy hoặc ô xy hoá lỏng)	Hệ thống	1
13.	Bơm tiêm điện	Cái	64
14.	Máy truyền dịch	Cái	28
15.	Máy hút đờm	Cái	20
16.	Máy hút dịch liên tục áp lực thấp	Cái	2
17.	Bình hút dẫn lưu màng phổi kín di động	Cái	4
18.	Bộ đèn đặt nội khí quản thường	Bộ	2
19.	Bộ đèn đặt nội khí quản có camera (bao gồm 04 cỡ lưỡi)	Bộ	1
20.	Bộ khí dung kết nối máy thở	Bộ	8
21.	Máy khí dung thường	Cái	1
22.	Máy phá rung tim có tạo nhịp	Cái	1
23.	Máy điện tim ≥ 6 kênh	Cái	1
24.	Bộ mở khí quản	Bộ	1
25.	Đèn thủ thuật	Cái	2

26.	Bóng ambu có van PEEP		2
27.	Bóng Ambu (quả)		20
28.	Lưỡi đèn đặt nội khí quản	Bộ	2
	Trang thiết bị khác nếu cần thiết, sử dụng từ nguồn sẵn có của Cơ sở khám, chữa bệnh		
	Lưu ý: *- Căn cứ kế hoạch mua sắm hàng năm, số lượng bệnh nhân đến khám, chữa bệnh vì các bệnh khác (có thể giảm) và tình hình BN COVID-19 để dự trù.* *- Các trang thiết bị có thể là thiết bị chung của Khoa Hồi sức tích cực hoặc của bệnh viện.*		

Phụ lục 3.2. DANH MỤC NHU CẦU VẬT TƯ TIÊU HAO THIẾT YẾU

Khu vực 3: 01 Đơn vị 20 giường bệnh trong Khoa Hồi sức tích cực, điều trị 20 người bệnh COVID-19 nặng, nguy kịch (Khoa Hồi sức tích cực của Bệnh viện có hệ thống oxy trung tâm và nhân lực đủ năng lực kỹ thuật)

(Ban hành kèm theo Quyết định số 2626/QĐ-BYT ngày 28 tháng 5 năm 2021 của Bộ trưởng Bộ Y tế)

Table 36. List of essential consumables for Area 3.

STT	Tên vật tư tiêu hao	Đơn vị	Số lượng
1.	Hộp đựng mẫu bệnh phẩm	Hộp	10
2.	Týp đựng môi trường vận chuyển bệnh phẩm	Hộp 50 cái	180
3.	Que lấy mẫu ngoáy dịch tỵ hầu và que lấy mẫu dịch ngoáy họng	Hộp 100 cái	100
4.	Dây hút đờm kín	Chiếc	48
5.	Dây hút đờm thường	Chiếc	1700
6.	Mask có túi	Chiếc	135
7.	Mask thở máy không xâm nhập	Chiếc	45
8.	RAM thở không xâm nhập (NCPAP)	Chiếc	50
9.	Bộ dây và mask khí dung dùng 1 lần	Chiếc	135
10.	Dây thở oxy	Chiếc	135
11.	Quả lọc máu liên tục (1 quả/ngày/bn X 2 bn lọc máu X 12 ngày)	Quả	26
12.	Catheter lọc máu	Cái	26
13.	Quả ECMO	Quả	2
14.	Catheter ECMO động mạch và tĩnh mạch	Bộ	3
15.	Dây máy thở dùng một lần	Bộ	48
16.	Bộ đo huyết áp động mạch xâm nhập	Bộ	24
17.	Catheter động mạch (theo dõi HA xâm lấn)	Chiếc	24
18.	Túi đựng dịch thải lọc máu	Túi	24
19.	Ống nội khí quản hút trên cuff (Hi-Lo EVAC)	Cái	24
20.	Catheter đặt tĩnh mạch trung tâm 3 nòng	Cái	32
21.	Catheter dẫn lưu màng phổi	Cái	25
22.	Túi đo nước tiểu	Túi	40

23.	Sonde foley	Cái	40
24.	Điện cực dính	Cái	500
25.	Phin lọc khuẩn và vi rút dây máy thở	Cái	48
26.	Canuyn mở khí quản cỡ từ 3,5, 4, 4,5, 5, 5,5, 6, 6,5, 7, 7,5 và 8 (mỗi loại 02 cái)	Chiếc	20
27.	Bộ điện cực máy tạo nhịp ngoài	Bộ	3
28.	Dây nối máy thở	Chiếc	24
29.	Tấm che MIKA (khi đặt ống NKQ)	Cái	5
30.	Kit xét nghiệm PCR COVID-19	Test	170
	Vật tư tiêu hao khác nếu cần thiết, sử dụng từ nguồn sẵn có của Cơ sở KCB		
	Lưu ý: Căn cứ kế hoạch mua sắm hàng năm, số lượng bệnh nhân đến khám, chữa bệnh vì các bệnh khác (có thể giảm) và tình hình bệnh nhân COVID-19 để dự trù.		

Phụ lục 3.3. DANH MỤC NHU CẦU THUỐC THIẾT YẾU

Khu vực 3: 01 Đơn vị 20 giường bệnh trong Khoa Hồi sức tích cực, điều trị 20 người bệnh COVID-19 nặng, nguy kịch (Khoa Hồi sức tích cực của Bệnh viện có hệ thống oxy trung tâm và nhân lực đủ năng lực kỹ thuật)
(Ban hành kèm theo Quyết định số 2626/QĐ-BYT ngày 28 tháng 5 năm 2021 của Bộ trưởng Bộ Y tế)

Table 37. List of essential drug needs for Area 3.

STT	Tên thuốc, nồng độ - hàm lượng	Đường dùng	Thể tích của đơn vị đóng gói nhỏ nhất (đối với thuốc dạng lỏng)	Đơn vị	Số lượng
1.	Immunoglobulin tĩnh mạch 2,5 g hoặc 5g	Tiêm/truyền		Lọ	448
2.	Vancomycin 500mg	Tiêm/truyền		Lọ	1200
3.	Meropenem 500mg	Tiêm/truyền		Lọ	200
4.	Imipenem/Cilastatin 500mg +500mg	Tiêm/truyền		Lọ	200
5.	Ceftriaxon 1g/Cefotaxime 1g	Tiêm/truyền		Lọ	200
6.	Levofloxacin 0,5 g	Tiêm/truyền	100ml	Lọ	600
7.	Cefazidime 500mg	Tiêm/truyền		Lọ	400
8.	Ertapenem 1g	Tiêm/truyền		Lọ	200
9.	Amikacin 0,5 g	Tiêm/truyền	2ml	Lọ	300
10.	Azithromycin 500mg	Uống		Viên	200
11.	Azithromycin sirô 200mg/5ml	Uống		Gói	10
12.	Linezolid 600mg/300 ml	Tiêm/truyền		Túi	20
13.	Adrenalin 1mg/ml	Tiêm/truyền	1 ml	ống	3000
14.	Nor-adrenalin 1mg/ml	Tiêm/truyền	10ml	Ống	3000
15.	Milrinon 1mg/ml	Tiêm/truyền		Lọ	1200
16.	Dopamin 200mg/5ml	Tiêm/truyền	5ml	Ống	480
17.	Dobutamin 250mg/20m (hoặc 250mg/5ml, 250mg/250ml)			Ống	480

18.	Midazolam 5mg/ml	Tiêm/truyền	1ml	Ống	6000
19.	Fentanyl 0,5mg/10ml; 0,1mg/2ml	Tiêm/truyền	10ml; 2ml	Ống	720
20.	Atracurium 2mg/ml	Tiêm/truyền	2,5ml	Ống	3000
21.	Phenobacbital 100mg/1ml/ống	Tiêm/truyền	1ml	Ống	120
22.	Heparin 5000 UI/ml	Tiêm/truyền	5 ml	Lọ	120
23.	Heparin trọng lượng phân tử thấp Lovenox 40mg/lọ	Tiêm/truyền		Lọ	600
24.	Kali clorid 10% ống	Tiêm/truyền	10ml	Ống	3000
25.	Calci gluconat/calci clorua 10%	Tiêm/truyền		Ống	1200
26.	Natri bicacbonat 8,4% ống	Tiêm/truyền		Ống	240
27.	Magie sulphat 15% ống 5ml	Tiêm/truyền	5 ml	Ống	600
28.	Albumin 20%/50ml	Tiêm/truyền	50ml	Lọ	800
29.	Dịch lọc máu liên tục theo máy			Túi	480
30.	Natri clorid 0,9% 500ml	Tiêm/truyền	500ml	Chai	1560
31.	Glucose 5% 500ml	Tiêm/truyền	500ml	Chai	600
32.	Glucose 10% 500ml	Tiêm/truyền	500ml	Chai	240
33.	Ringer lactat	Tiêm/truyền		Chai	480
34.	Ringer lactat + Glucose	Tiêm/truyền		Chai	1200
35.	Hydrocortison 100mg	Tiêm/truyền		Lọ	120
36.	Dexamethasone 4mg/ống	Tiêm/truyền	1ml	Ống	400
37.	Methylprednisolon 125mg/lọ	Tiêm/truyền		Lọ	240
38.	Colistin 1 triệu UI	Tiêm/truyền		Lọ	720
39.	Ceftazidim + avibactam 2,5g	Tiêm/truyền		Lọ	360
40.	Sulfamethoxazole 400mg và trimethoprim 80mg/lọ	Tiêm/truyền		Lọ	2400
41.	Fluconazol 200mg /100 ml	Tiêm/truyền		Lọ	30
42.	Amphotericin 50mg/lọ	Tiêm/truyền		Lọ	120
43.	Amphotericin B 50mg/lọ	Tiêm/truyền		Lọ	120
44.	Cancidas 70mg	Tiêm/truyền		Lọ	60
45.	Micafungin 50mg	Tiêm/truyền		Lọ	180
	Thuốc khác khi cần thiết, sử dụng từ nguồn thuốc sẵn có của Cơ sở khám, chữa bệnh				
	Lưu ý: *1) Khi không có các thuốc có hàm lượng trong danh mục trên, các cơ sở có thể lựa chọn các thuốc với hàm lượng khác và quy đổi tương đương.* *2) Khi không có các thuốc trong danh mục trên, các cơ sở có thể chọn thuốc khác cùng nhóm tác dụng điều trị.* *3) Căn cứ kế hoạch mua sắm hàng năm, số lượng bệnh nhân đến khám, chữa bệnh vì các bệnh khác (có thể giảm) và tình hình bệnh nhân COVID-19 để dự trù.*				

Appendix 4. WHO Essential Supplies Forecasting Tool estimated standard amounts of respiratory care equipment

Table 38. WHO ESFT estimated equipment standard amounts.

Item	Unit	Severe patient	Critical patient	Total patients	Beds / severe	Beds / critical	Total beds
Infrared thermometer	Each						0.05
Pulse oximeter (adult + pediatric probes)	Each						1.00
Patient monitor, multiparametric with ECG, with accessories	Each					1.00	
Patient monitor, multiparametric without ECG, with accessories	Each				0.25		
Oxygen source (i.e., concentrator, cylinder, or pipe supply)	Each						1.00
Laryngoscope (direct or video type)	Each					0.67	
Patient ventilator, intensive care, with breathing circuits and patient interface	Each					0.67	
CPAP, with tubing and patient interfaces, with accessories	Each					0.17	
High Flow Nasal Cannula, with tubing and patient interfaces	Each					0.17	
Electronic drop counter, IV fluids	Each				1.00		
Infusion pump	Each				0.25		
Blood Gas Analyzer, portable with cartridges and control solutions	Each						0.03
Ultrasound, portable, w/ transducers and trolley	Each						0.03
Drill, for vascular access, w/ accessories, w/ transport bag	Each						0.03
Electrocardiograph, portable w/accessories	Each						0.03
Suction pump	Each				0.25	1.00	
Bubble humidifier, non-heated	Each				1.10		
Tubing, medical gases, int. diam. 5 mm	Each						0.03
Flow splitter, 5 flowmeters 0-2 L/min, for pediatric use	Each						0.03
Flowmeter, Thorpe tube, for pipe oxygen 0-15 L/min	Each					0.33	
Filter, heat and moisture exchanger (HMEF), high efficiency, with connectors, for adult	Each		1.98				
Conductive gel, container	Each		0.05				

Catheter, nasal, 40 cm, with lateral eyes, sterile, single use; different sizes: 10 Fr, 12 Fr, 14 Fr, 16 Fr, 18 Fr	Each			0.05			
Nasal oxygen cannula, with prongs, adult and pediatric	Each	0.67					
Mask, oxygen, with connection tube, reservoir bag and valve, high-concentration single use (adult)	Each	0.67					
Venturi Mask, with percent O_2 Lock and tubing (adult)	Each	0.67					
Compressible self-refilling ventilation bag, capacity > 1500 mL, with masks (small, medium, large)	Each					0.33	
Airway, nasopharyngeal, sterile, single use, set with sizes of: 20 Fr, 22 Fr, 24 Fr, 26 Fr, 28 Fr, 30 Fr, 32 Fr, 34 Fr, 36 Fr	Each		1.33				
Airway, oropharyngeal, Guedel, set with sizes of: No. 2 (70 mm), No. 3 (80 mm), No. 4 (90 mm), No. 5 (100 mm)	Each		1.33				
Colorimetric End Tidal CO_2 detector single use (adult)	Each		1.33				
Cricothyrotomy, set, emergency, 6 mm, sterile, single use	Each					0.67	
Endotracheal tube introducer	Each		1.33				
Tube, endotracheal	Each		1.33				
Laryngeal mask airway (LMA)	Each		1.33				
Lubricating jelly - for critical patient gastro-enteral feeding and airway management & intubation	Each		0.05				

Abbreviations: CPAP, continuous positive airway pressure; ECG, electrocardiogram; ESFT, Essential Supplies Forecasting Tool; Fr, standard French scale; WHO, World Health Organization.
Source: World Health Organization Essential Supplies Forecasting Tool v2.