Health Security
Volume 19, Number 5, 2021 Mary Ann Liebert, Inc.
DOI: 10.1089/hs.2020.0227

Assessment of Critical Care Surge Capacity During the COVID-19 Pandemic in Japan

Takanori Yamamoto, Masayuki Ozaki, Daisuke Kasugai, and Gilbert Burnham

Japan has the highest proportion of older adults worldwide but has fewer critical care beds than most high-income countries. Although the COVID-19 infection rate in Japan is low compared with Europe and the United States, by the end of 2020, several infected people died in ambulances because they could not find hospitals to accept them. Our study aimed to examine the Japanese healthcare system's capacity to accommodate critically ill COVID-19 patients during the pandemic. We created a model to estimate bed and staff capacity at 3 levels of pandemic response (conventional, contingency, and crisis), as defined by the US National Academy of Medicine, and the function of Japan's healthcare system at each level. We then compared our estimates of the number of COVID-19 patients requiring intensive care at peak times with the national health system capacity using expert panel data. Our findings suggest that Japan's healthcare system currently can accommodate only a limited number of critically ill COVID-19 patients. It could accommodate the surge of pandemic demands by converting nonintensive care unit beds to critical care beds and using nonintensive care unit staff for critical care. However, bed and staff capacity should not be expanded uniformly, so that the limited number of physicians and nurses are allocated efficiently and so staffing does not become the bottleneck of the expansion. Training and deploying physicians and nurses to provide immediate intensive care is essential. The key is to introduce and implement the concept and mechanism of tiered staffing in the Japanese healthcare system. More importantly, most intensive care facilities in Japanese hospitals are small-scaled and thinly distributed in each region. The government needs to introduce an efficient system for smooth dispatching of medical personnel among hospitals regardless of their founding institutions.

Keywords: COVID-19, Critical care beds, Public health preparedness/response, Medical management/response

Takanori Yamamoto, MD, is an Assistant Professor; Masayuki Ozaki, MD, PhD, is a Visiting Scholar; and Daisuke Kasugai, MD, is an Assistant Professor; all in the Department of Emergency and Critical Care Medicine, Nagoya University Hospital, Nagoya, Japan. Masayuki Ozaki is also Director, Department of Intensive Care Unit, Komaki City Hospital, Komaki, Japan. Gilbert Burnham, MD, is a Professor, Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD.

Introduction

Japan has the highest proportion of older adults in the world but has fewer critical care beds per capita than other high-income countries.[1,2] Despite the surge in demand to accommodate critically ill patients during the COVID-19 pandemic, there has been no policy discussion on the allocation of critical care resources.[3]

As the demand for critical care beds increases, fatality rates may also increase.[4,5] When COVID-19 infection rates increased in Japan, especially in Tokyo in the winter of 2020, the government declared a state of emergency for the second time during the pandemic on January 7, 2021. Although the infection rate in Japan is lower than in Europe and the United States, dozens of infected people died at home or went into cardiac arrest after ambulances waited for several hours to find a receiving hospital.[6,7] The number of new infections decreased after a state of emergency was declared, but the vaccination administration process has been slow and there are concerns that the infection rate will increase at an unprecedented pace if variants spread. Japan faced a shortage of critical care beds across the country for the first time, and no solution has yet been reached. Estimating the critical care capacity of Japan's healthcare system is vital to accommodate future surges in demand for critical care.

Critical care must be provided to severely ill individuals to minimize mortality during the COVID-19 pandemic.[8] The US National Academy of Medicine classified the medical surge capacity at 3 distinct levels: conventional, contingency, and crisis.[9] In our study, we examined how many critically ill patients the Japanese healthcare system can accommodate at each surge level.

Methods

Quantification of Healthcare Capacity

We assessed the Japanese healthcare system's capacity to accommodate critically ill COVID-19 patients at different surge levels—conventional, contingency, and crisis. Each level is defined below:

Conventional level – Space, staff, and supplies used are consistent with daily practices within the institution. These spaces and practices are used during the COVID-19 pandemic.

Contingency level – Space, staff, and supplies used are not consistent with daily practices but maintain or have minimal impact on usual patient care. These spaces or practices may be used temporarily during the COVID-19 pandemic.

Crisis level – Adaptive spaces, staff, and supplies are not consistent with usual standards of care but provide sufficiency of care during the COVID-19 pandemic.

These levels represent a continuum of patient care delivered during the pandemic.[10] As the imbalance between resource availability and demand increases, the healthcare system first maximizes conventional capacity, then moves into a contingency level, and finally reaches the crisis level.

In this study, we used 4 previously identified factors—adequate space, staff, supplies, and system—as vital components for the healthcare system to provide critical care for COVID-19 patients.[11] We categorized critical care beds as "space"; physicians, nurses, and respiratory therapists as "staff"; and ventilators as "supplies." We also examined the Japanese healthcare system and how it enables efficient use of these vital components. The estimates of space, staff, and supplies at each surge level were compared with the projected increase in the number of severe COVID-19 cases presented by the Japanese government's expert panel.

Hospital Bed Capacity

We obtained data on the number of beds available from the Ministry of Health, Labour, and Welfare reports.[12,13] We estimated the number of staffed beds available to handle a surge of COVID-19 patients requiring critical care at each capacity level. At the conventional capacity level, we assumed that staffed, vacant intensive care unit (ICU) beds would be available for critically ill COVID-19 patients. The contingency level includes ICU beds at the previous level in addition to staffed, vacant high-care unit (HCU) beds—these are intermediate-care beds such as step-down, postoperative care, and emergency care beds. The crisis level includes the previous bed types in addition to staffed, vacant general ward beds in acute care hospitals. The Japanese Ministry of Health, Labour, and Welfare indicated an annual average occupancy rate of 73.3% for ICU beds, 71.3% for HCU beds, and approximately 80.0% for general ward beds as of 2018.[14,15] Accordingly, staffed, vacant beds were allocated to critically ill COVID-19 patients.

The best way to reserve beds for critically ill patients is to postpone or cancel elective surgeries that require ICU or HCU beds.[16,17] Emergency surgery is estimated to comprise only 10% to 20% of all surgeries. Postoperative patients occupy 33% of ICU beds and 24% of HCU beds.[18] At the contingency and crisis levels, our estimate assumed that 50% and 80% of elective surgeries were postponed or canceled, respectively.

In general wards of acute care hospitals, 20% of beds are occupied by patients who require neither medical treatment nor nursing care, and 20% are occupied by patients who require only nursing care.[19] Our plan estimates a reduction in the workload of physicians, nurses, and respiratory therapists by suggesting discharging patients who require minimal medical treatment or nursing care at the contingency level and patients who require only nursing care at the crisis level. At the crisis level, a general hospital ward would be used as a critical care ward. In this case, 4 general hospital beds would be converted into 1 critical care bed,

Table 1. Bed and Staffing Capacity for Critically Ill COVID-19 Patients at Each Level

	Conventional Level				Contingency Level				Crisis Level			
	No. In Japan[a]	*Provider-Patient Ratio*[b]	*Percentage Available*[c]	*No. Patients Treatable*[d]	*No. In Japan*[a]	*Provider-Patient Ratio*[b]	*Percentage Available*[c]	*No. Patients Treatable*[d]	*No. In Japan*[a]	*Provider-Patient Ratio*[b]	*Percentage Available*[c]	*No. Patients Treatable*[d]
Beds	5.7	–	26.7	1.5	13.9	–	36.9	5.1	93.9	–	57.2	53.7
Staff												
Physicians	1.4	1:10	30	1.5	1.4	1:25	40	5.0	1.4	1:50	50	12.5
Nurses	19.3	1:1 to 1:2	30	2.1 to 4.1	33.2	1:1 to 1:2	40	4.7 to 9.5	33.2	1:3 to 1:6	50	17.8 to 35.6
Respiratory therapists	33.7	1:5	30	18.1	33.7	1:8	40	38.5	33.7	1:12	50	72.2

[a]The number of hospital beds, physicians, nurses, and respiratory therapists in Japan per 100,000 people.
[b]The ratio of critically ill COVID-19 patients per medical professional.
[c]The percentage of hospital beds and medical staff that can be mobilized for critically ill COVID-19 patients.
[d]The number of critically ill COVID-19 patients that can be treated at a given time, per 100,000 people, based on an assumed 60 hours worked per week, with about 35.7% of providers working at any given time.

which requires additional space and the reconfiguration of electricity and medical gas delivery for a single bed.

Based on these assumptions, 26.7% of beds would be available at the conventional level, 36.9% at the contingency level, and 57.2% at the crisis level (Table 1). We then projected the number of beds that would be available at the peak of the COVID-19 pandemic for the 3 capacity levels.

Medical Staff Capacity

We estimated the number of staff that might be necessary to cope with a sharp increase in patients requiring critical care. Management of critically ill COVID-19 patients requires a team of personnel including critical care physicians, critical care nurses, and respiratory therapists. Medical staff capacity could be enhanced at the contingency and crisis capacity levels by increasing the provider-to-patient ratios and raising the critical care personnel capacity with noncritical care personnel by using a tiered staffing model. In a tiered staffing model, noncritical care personnel provide critical care under the supervision of experienced critical care personnel (Figure 1).[9,16,17] We assumed that healthcare providers work a total of 60 hours a week (12 hours a day, 5 days a week), with about 35.7% of providers working at any given time.[11]

At the conventional level, healthcare providers for critically ill COVID-19 patients were limited to experienced personnel such as critical care physicians, critical care nurses, and respiratory therapists. We assumed a physician-to-patient ratio of 1 to 10, critical care nurse-to-patient ratio of 1 to 1 and 1 to 2, and respiratory therapist-to-patient ratio of 1 to 5. As we estimate to use 26.7% of the critical care beds at a maximum, 30% of each medical profession needs to be mobilized. With respect to the quality of care, it is ideal to have 1 nurse for each critically ill patient; however, when the number of patients increases, each nurse will have to be assigned to 2 critically ill patients.

At the contingency level, we expanded the staff category to include acute care physicians such as anesthesiologists, emergency care physicians, cardiothoracic surgeons, neurosurgeons, general surgeons, cardiologists, and pulmonologists. Although acute care physicians are nonintensivists, many of them have experience in providing intensive care. We adopted the tiered staffing model as shown in Figure 1A, with 5 acute care physicians work under 1 intensivist. Each acute care physician treats 5 critically ill patients, meaning that 1 intensivist indirectly treats 25 critically ill patients. We did not adopt the tiered staffing model for nurses at the contingency level because HCU nurses are to some extent skilled in treating critically ill patients. Nurses may not be familiar with the care of critically ill COVID-19 patients in the early stages, however, so hospitals start with 1 nurse per patient under the guidance of an ICU nurse. If there is an increase in the number of patients, the system changes to 1 nurse for 2 patients. The number of patients served by 1 respiratory therapist increases from 5 to 8. We expect to mobilize about 40% of

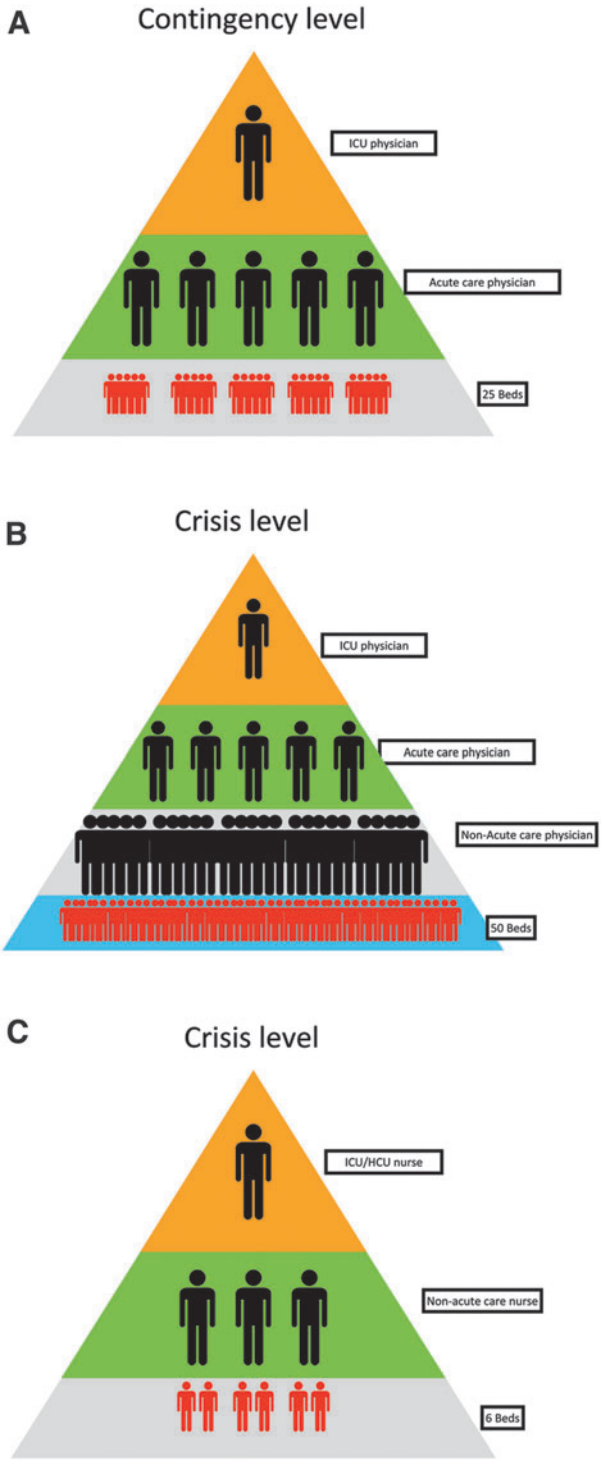

Figure 1. (A) Contingency-level tiered staffing model for physicians; (B) crisis-level tiered staffing model for physicians; and (C) crisis-level tiered staffing model for nurses. Abbreviations: HCU, high-care unit; ICU, intensive care unit.

physicians, nurses, and respiratory therapists at the contingency level and have about 40% of ICU, HCU, and general ward hospital beds available. However, general ward hospital beds would not be allocated to critical COVID-19 patients.

At the crisis level (Figure 1B), we would expand the tiered staffing model for physicians and nurses. For every acute care physician mobilized at the contingency level, 5 nonacute care physicians from various departments with little experience in intensive care are assigned to 2 critically ill COVID-19 patients. In this way, 1 intensivist indirectly cares for 50 critically ill COVID-19 patients.

As for nurses (Figure 1C), 3 general ward hospital bed nurses would be assigned to each ICU or HCU nurse at the crisis level. Initially, each general ward hospital bed nurse would be responsible for 1 critically ill COVID-19 patient; once they are fully oriented, each nurse will take charge of 2 patients. In this way, 1 ICU or HCU nurse could indirectly lead the care of 3 to 6 critically ill patients. This also increases the number of critically ill COVID-19 patients that 1 respiratory therapist is responsible for from 8 to 12. At the crisis level, we expect to use 40% to 60% of the ICU, HCU, and general ward beds and mobilize 50% of the physicians, nurses, and respiratory therapists, respectively.

Assessment of Ventilator Supplies

We obtained the number of available ventilators from the Japanese Society of Respiratory Care Medicine and the Japan Association of Clinical Engineers.[20] We also estimated the number of available anesthesia apparatuses, which medical staff could use as mechanical ventilators in case of emergencies.[21]

Assessment of System

We used data from the Japanese Ministry of Health, Labour, and Welfare; previous surveys; and news reports to examine the extent to which Japan effectively uses its medical resources in the current pandemic. We analyzed the legal aspects, success or failure of the system in terms of disaster response functionality, differences between urban and rural medical institutions, differences in the size of medical institutions and ICUs, and aspects related to finances of medical institutions and salaries of medical personnel.

Estimated Number of Critically Ill COVID-19 Patients at Peak

According to government data, as of mid-March 2020, Tokyo's reproduction number was estimated to be around 1.7.[22,23] We used the government's projections with reproduction numbers of 1.4, 1.7, and 2. Data for the estimated number of critically ill patients at peak pandemic were extracted from the official website of the Japanese Ministry of Health, Labour, and Welfare.[22] The ministry states that the range of reproduction numbers depends on how quickly the government and society take nonpharmacological action to control the situation. We compared the estimated number of patients with 3 different reproduction numbers and constraining factors at the 3 capacity levels.

Results

Estimated COVID-19 Patient Bed and Staff Capacity

Table 1 shows how many critically ill COVID-19 patients can be absorbed per 100,000 people at the conventional, contingency, and crisis levels by indicating each value of number of bed and staff, employed provider-to-patient ratio, and employed percentage available. The number of critically ill COVID-19 patients that can be treated is summarized below.

The smallest number at the conventional, contingency, and crisis levels, as calculated in Table 1, defines the number of critically ill COVID-19 patients that can be accommodated at a given time per 100,000 people. At the conventional level, the number of intensive care beds and intensivists (critical care physicians) determines the maximum number of critically ill patients that could be treated. At this level, critical care physicians would treat 1.5 patients per 100,000 people, nurses would care for 2.1 to 4.1 patients per 100,000 people, and respiratory therapists would ventilate 18.1 patients per 100,000 people. At the contingency capacity level, critical care physicians would treat 5.0 patients per 100,000 people, nurses would care for 4.7 to 9.5 patients per 100,000 people, and respiratory therapists would ventilate 38.5 patients per 100,000 people. At the crisis capacity level, critical care physicians would treat 12.5 patients per 100,000 people, nurses would care for 17.8 to 35.6 patients per 100,000 people, and respiratory therapists would ventilate 72.2 patients per 100,000 people.

Assessment of Ventilator Supplies

According to an emergency survey conducted by the Japanese Society of Respiratory Care Medicine and the Japan Association of Clinical Engineers, acute care hospitals in Japan have 45,293 full-featured mechanical ventilators.[20] At the time of the survey, 15,202 (33.6%) ventilators were allocated to pediatric and neonatal patients, leaving 30,091 (66.4%) available for adults, which would be adequate for 24.1 patients per 100,000 people. As stated previously, medical staff can use anesthesia apparatuses as mechanical ventilators in emergencies. According to private estimates in 2019, the number of anesthetic machines purchased annually in Japan was about 1,300.[21] Given the 10-year upgrade cycle, approximately 13,000 (10.3 ventilators per 100,000 people) anesthesia apparatuses could be allocated to patients with COVID-19.

At the contingency and crisis levels, we assumed the postponement or cancellation of 60% and 80% of elective surgeries, respectively. With this assumption, operating rooms could be converted into ICUs and the anesthesia machines could be used as ventilators. Theoretically, 37,800 (30.2 per 100,000 people) ventilators can be used at the contingency level and 40,400 (32.3 per 100,000 people) at the crisis level. These ventilators are used not only for patients with severe COVID-19 but also for respiratory management of patients with respiratory failure and severe illnesses from other diseases and general anesthesia for surgical patients. Even considering these factors, however, it is unlikely that a shortage of ventilators will affect the care of critically ill COVID-19 patients if the ventilators are properly distributed.

Assessment of System

The Japanese healthcare system has a large number of acute care beds but a small number of ICU and HCU beds, compared with other high-income countries.[24,25] However, only a fraction of acute care beds are used by patients requiring acute medical care. The number of acute care beds per 1,000 people is 3.3 in Japan, 6.0 in Germany, 3.0 in France, 2.6 in Italy, 2.5 in the United States, and 2.0 in the United Kingdom.[14,24] The number of ICU beds in Japan is 5.6 per 100,000 people—even less than in the United Kingdom (8.9 per 100,000 people), which has been rated as having relatively few ICU beds compared with other high-income countries.[26] Japan has the lowest number of physicians and nurses per bed because it has more long-term care beds compared with other Organisation for Economic Co-operation and Development countries.

Another characteristic of the Japanese healthcare system is the small size of hospitals. In particular, private hospitals are very small and account for 55.2% of the total number of hospital beds. In Japan, only 51.6% of public hospitals and 6.9% of private hospitals have more than 400 beds.[27] ICUs and HCUs are also small in Japan: only 22.8% of ICUs and 23.8% of HCUs have more than 11 beds.[14]

Japan's Act on Special Measures for Pandemic Influenza and New Infectious Diseases Preparedness and Response (The Special Measures Act)[28] clearly states that state and local prefectures can request all medical personnel to attend to COVID-19 patients, and if they do not respond to the request without a valid reason, the prefecture can direct the medical personnel to provide such care. However, there have been few cases where the local prefectures have directed medical institutions to accept COVID-19 patients. On February 3, 2021, the Special Measures Act was amended to allow prefectures to recommend rather than direct medical institutions, and to publicize the names of those institutions that do not follow their recommendations without a valid reason.[28]

During the pandemic, the Japanese government has heavily subsidized medical institutions and substantially increased their medical payments. The income of medical institutions has fallen across the board following the pandemic, however, especially among hospitals treating COVID-19 patients. In addition, the salaries of medical personnel have declined substantially.[29] Hospitals designated to treat only COVID-19 patients have seen several physicians and nurses leave their jobs.[30]

Even at the conventional level, the Japanese healthcare system should be able to accommodate 1.5 critically ill

COVID-19 patients per 100,000 people. Tokyo has 14 million people and 1,100 ICU beds, but it could not accommodate 105 critically ill COVID-19 patients (0.75 per 100,000 people). Instead, patients had to be transferred to hospitals in neighboring prefectures in April and May 2020.[31]

The Japanese medical system currently can accommodate only a limited number of critically ill COVID-19 patients. We point out 3 possible reasons the system does not work.[32] The first is the absence of an efficient system to use the dispersed medical resources in an integrated manner. The second is the lack of an appropriate strategy for a pandemic, resulting in medical care not being provided to patients who truly need it. The third is inadequate public funding for medical institutions and personnel that cope with the pandemic.

Estimated Number of Critically Ill COVID-19 Patients

The number of critically ill COVID-19 patients at the peak of the pandemic was estimated at 1.2 to 2.03, 2.16 to 4.53, and 3.95 to 10.95 (per 100,000 people) with reproduction numbers of 1.4, 1.7, and 2.0 (per 100,000 people), respectively. If the system worked well, it would, theoretically, work as follows—at the conventional level, the healthcare system would likely not be able to accommodate critically ill COVID-19 patients even with a reproduction number of 1.4 if there were delays in nonpharmacologic interventions. In contrast, the Japanese healthcare system could accommodate critically ill COVID-19 patients at the contingency level even if the reproduction number is 1.7. If the reproduction number is 2 and nonpharmacological measures are too slow, the Japanese healthcare system could accommodate critically ill COVID-19 patients only at the crisis level of response.

Discussion

Japan is known to have citizens with the longest life expectancy in the world and an excellent healthcare system in terms of accessibility and quality.[33] It has the highest number of hospital beds based on the population among Organisation for Economic Co-operation and Development countries,[24] and small private hospitals and clinics support the health of the local population.

Japan is also known for its disaster resilience. In particular, after the Great Hanshin–Awaji Earthquake and the sarin gas incident on the subway, acute care providers in Japan learned the concept of triage to save the lives of those who can be saved.[34] The Disaster Medical Assistance Team (DMAT) was created as a mechanism to immediately rush to the disaster area from all over Japan, leaving the routine emergency and intensive care work to their colleagues.[35]

However, Japan's healthcare system and disaster response capabilities have not functioned well in the face of the COVID-19 pandemic. Despite having fewer critically ill COVID-19 patients than Western countries, the Japanese medical system is overwhelmed.[7] Why has Japan fallen into this situation?

The first reason is the small size of medical institutions in Japan. Large ICUs with many beds are common in Europe and the United States, but most ICUs in Japan have less than 10 beds.[36] Smaller ICUs make it difficult to be flexible in accepting critically ill patients.

The second reason is the lack of cooperation among various medical institutions. In Japan, each small medical institution focuses on protecting the health of local residents. Although hospitals rush assistance to local areas affected by disasters, there is no system in place for medical institutions to work together to confront a pandemic.[32] Japan should establish a policy that unites small hospitals and complements functions to continue medical services in each local area, regardless of their organizational type (eg, national, municipal, private).

The third reason is that many medical institutions have a weak financial base due to their small size. The number of patients receiving treatment for diseases other than COVID-19 has decreased due to the pandemic, resulting in the inability of individual medical institutions to generate sufficient operating income with current government subsidies alone. [32] Salaries for healthcare workers are therefore relatively low.[37] Healthcare workers, especially nurses, nursing assistants, and caregivers, work in difficult environments under high stress.[30]

However, these problems can be solved. People in Japan have always tended to prefer mutual help to competition. First, the government needs to design an integrated and efficient way of using Japan's dispersed medical resources. The government should remind healthcare providers that a pandemic is a disaster for all Japanese people and use this theme to build a cooperative system.

The everchanging situation during COVID-19 pandemic requires a functional command and control system with effective communications.[38] In Japan, the DMAT prioritizes the C3: command, control, and communication. DMAT headquarters or similar offices should be established in each prefecture across Japan to coordinate the strategic use of local medical resources and engage in a wide range of activities.[39,40] For example, the flexible operation of hospital beds and tiered staffing models need to be introduced in medical institutions.[41] Additionally, the criteria for admission, discharge, and transfer of COVID-19 infected patients need to be harmonized for the effective use of acute care hospitals. Japan also needs to create a system that would immediately recognize sudden changes occurring in patients with mild COVID-19 who are staying at home or in institutions. Further, they need to provide guidance on infection prevention measures for

nursing homes and specify steps to be taken in the event of disease outbreak. This can be achieved only by flexibly using the medical resources of the community. Thus, a series of commands and controls would be essential to control disease outbreaks. The redistribution of medical resources would be more feasible if medical institutions and medical personnel are not forced to worry about financial concerns.

Furthermore, as Japan experiences many natural disasters, the country needs to be prepared to respond simultaneously to a pandemic and a natural disaster. In particular, evacuation centers need to be managed while preventing the spread of infection.

The Japanese government should guarantee the operation of all healthcare institutions and continuously augment the salaries of healthcare workers, especially nurses, nursing assistants, and caregivers, with heavy workloads during the pandemic.[42,43] If the number of COVID-19 cases increases substantially and a contingency- or crisis-level response becomes necessary, establishing temporary medical facilities and consolidating medical personnel to use resources in a more integrated and efficient manner would be necessary. Although its current medical structure is vulnerable to a pandemic, with proper government leadership, financial support, and effective use of medical resources through DMAT, Japan could effectively respond to the pandemic even now.

This assessment has some potential limitations. The assumptions and data used in our estimate at the contingency and crisis capacity levels are largely untested. Furthermore, we made simplified model assumptions to approximate surge capacity predictions. We also recognized that rising numbers of COVID-19 hospitalizations will not affect the country evenly, which could push some hospitals quickly into crisis-level care while leaving other locations relatively unaffected, at least initially. The pandemic also affects healthcare workers and their families, potentially reducing the availability of critical hospital staff, which we have not included in our estimates.

Conclusion

Japan has demonstrated that it has a responsive disaster medicine and medical healthcare system. Due to its dispersed medical resources, however, Japan has failed to cope with the rapid increase of critically ill COVID-19 patients. The Japanese government should view the pandemic as a disaster rather than a medical emergency, and it should exercise leadership to strengthen the DMAT headquarters' function, flexibly operate hospital beds, adopt a tiered staffing model, integrate and efficiently operate local medical resources, establish a common financial base, and increase salaries to compensate nurses and other medical personnel. By doing so, Japan will be able to greatly enhance the capabilities of its healthcare system to cope with the pandemic.

Acknowledgments

We would like to thank Editage for their English-language editing services.

References

1. United Nations (UN). *World Population Ageing 2019*. New York: UN; 2019. Accessed March 27, 2020. https://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2019-Highlights.pdf
2. Halpern NA, Tan KS. United States resource availability for COVID-19. Society of Critical Care Medicine. Published March 13, 2020. Accessed March 27, 2020. https://www.sccm.org/Blog/March-2020/United-States-Resource-Availability-for-COVID-19
3. Norisue Y, Deshpande GA, Kamada M, et al. Allocation of mechanical ventilators during a pandemic: a mixed-methods study of perceptions among Japanese health care workers and the general public. *Chest*. 2021;159(6):2494-2502.
4. Grasselli G, Pesenti A, Cecconi M. Critical care utilization for the COVID-19 outbreak in Lombardy, Italy: early experience and forecast during an emergency response. *JAMA*. 2020;323(16):1545-1546.
5. World Health Organization (WHO). *Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19)*. Geneva: WHO; 2020. Accessed March 27, 2020. https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf
6. 18 COVID-19 patients die while self-isolating in their homes. *The Asahi Shimbun*. January 23, 2021. Accessed June 12, 2021. http://www.asahi.com/ajw/articles/14130936
7. Tsukimori O. Overwhelmed by virus, hospitals in Japan struggle to treat other emergency patients. *The Japan Times*. January 26, 2021. Accessed June 12, 2021. https://www.japantimes.co.jp/news/2021/01/26/national/coronavirus-hospitals-emergency-patients-japan/
8. Shang Y, Pan C, Yang X, et al. Management of critically ill patients with COVID-19 in ICU: statement from front-line intensive care experts in Wuhan, China. *Ann Intensive Care*. 2020;10(1):73.
9. Institute of Medicine. *Medical Surge Capacity: Workshop Summary*. Washington, DC: The National Academies Press; 2010. Accessed July 20. 2021. https://doi.org/10.17226/12798
10. Hick JL, Barbera JA, Kelen GD. Refining surge capacity: conventional, contingency, and crisis capacity. *Disaster Med Public Health Prep*. 2009;3(suppl 2):S59-S67.
11. Ajao A, Nystrom SV, Koonin LM, et al. Assessing the capacity of the US health care system to use additional mechanical ventilators during a large-scale public health emergency. *Disaster Med Public Health Prep*. 2015;9(6):634-641.
12. Ministry of Health, Labour, and Welfare. Status of notification of main facility standards. Document in Japanese. Published September 11, 2019. Accessed March 27, 2020. https://www.mhlw.go.jp/content/12404000/000546464.pdf
13. Ministry of Health, Labour, and Welfare. The fiscal year 2018 hospital bed function report. Document in Japanese. Published May 16, 2019. Accessed March 27, 2021. https://www.mhlw.go.jp/content/10800000/000509330.pdf

14. Ministry of Health, Labour, and Welfare. The 9th meeting of fiscal year 2017 Subcommittee on Investigation and Evaluation of Inpatient Care. Document in Japanese. Published October 5, 2017. Accessed February 16, 2021. https://www.mhlw.go.jp/file/05-Shingikai-12404000-Hokenkyoku-Iryouka/0000179719.pdf
15. Ministry of Health, Labour, and Welfare. Results of the fiscal year 2017 hospital bed function report (part 1). Document in Japanese. Published March 28, 2018. Accessed March 27, 2020. https://www.mhlw.go.jp/file/05-Shingikai-10801000-Iseikyoku-Soumuka/0000200020.pdf
16. Hanley ME, Bogdan GM. Mechanical ventilation in mass casualty scenarios. Augmenting staff: project XTREME. *Respir Care*. 2008;53(2):176-188.
17. Rubinson L, Nuzzo JB, Talmor DS, O'Toole T, Kramer BR, Inglesby TV. Augmentation of hospital critical care capacity after bioterrorist attacks or pandemic: recommendations of the Working Group on Emergency Mass Critical Care. *Crit Care Med.* 2005;33(10):2393-2403.
18. Ministry of Health, Labour, and Welfare. The 11th meeting of the Subcommittee on the Study and Evaluation of Inpatient Care. Document in Japanese. Published November 2, 2017. Accessed February 14, 2021. https://www.mhlw.go.jp/file/05-Shingikai-12404000-Hokenkyoku-Iryouka/0000183192.pdf
19. Ministry of Health, Labour, and Welfare. Central Social Insurance Medical Council report. Document in Japanese. Published November 24, 2017. Accessed February 14, 2021. https://www.mhlw.go.jp/file/05-Shingikai-12404000-Hokenkyoku-Iryouka/0000185955.pdf
20. Japanese Society of Intensive Care Medicine. Emergency survey on the number of ventilators and ECMO equipment handled. Published March 9, 2020. Accessed February 16, 2021. https://www.jsicm.org/news/upload/COVID-19-ECMOnet-report-20200304.pdf
21. Yano Research Institute Ltd. 2019 medium-term forecast and maker share of medical engineering devices by function (therapeutic devices edition). Published October 4, 2019. Accessed March 27, 2020. https://www.yano.co.jp/market_reports/C61109000
22. Ministry of Health, Labour, and Welfare. New epidemic scenarios for ensuring healthcare delivery systems for novel coronavirus infections. Document in Japanese. Published June 19, 2020. Accessed February 16, 2021. https://www.mhlw.go.jp/content/000641703.pdf
23. Ministry of Health, Labour, and Welfare. New epidemic scenarios for ensuring healthcare delivery systems for novel coronavirus infections (Appendix). Document in Japanese. Published June 19, 2020. Accessed February 16, 2021. https://www.mhlw.go.jp/content/10900000/000641698.pdf
24. Organisation for Economic Co-operation and Development. Health at a Glance 2019: Hospital beds (indicator). Published November 7, 2019. Accessed December 31, 2020. http://data.oecd.org/healtheqt/hospital-beds.htm
25. Organisation for Economic Co-operation and Development. Intensive care beds capacity. Published April 20, 2020. Accessed March 5, 2021. https://www.oecd.org/coronavirus/en/data-insights/intensive-care-beds-capacity
26. Ewbank L, Thompson J, McKenna H. NHS hospital bed numbers: past, present, future. The King's Fund. Published September 2017. Updated March 26, 2020. Accessed December 21, 2020. https://www.kingsfund.org.uk/publications/nhs-hospital-bed-numbers
27. Japan Medical Association Research Institute (JMARI). Japan Medical Association WP443 Appendix 1-2 number of public and private hospital beds by hospital size (by prefecture) (general hospital beds). Document in Japanese. Published April 2, 2020. Accessed February 16, 2021. https://www.jmari.med.or.jp/download/WP443/WP443-appendix1-2.pdf
28. Japanese Law Translation. Ministry of Justice. Outline of the Act Partially Amending the Act on Special Measures against Novel Influenza, etc., and Other Relevant Acts. Enacted February 13, 2021. Accessed June 12, 2021. http://www.japaneselawtranslation.go.jp/common/data/outline/2104191631 35_905R207.pdf
29. JIJI. Over 40% of Japan's hospitals cutting bonuses as pandemic bites. *The Japan Times*. November 25, 2020. Accessed June 12, 2021. https://www.japantimes.co.jp/news/2020/11/26/national/hospitals-cut-bonuses/
30. Virus-designated hospital in Osaka in crisis after medical staff quit. The Asahi Shimbun. December 3, 2020. Accessed June 12, 2021. http://www.asahi.com/ajw/articles/13985445
31. Saito M. On duty at Japan's "last-chance" hospital for coronavirus. *Japan Times*. May 22, 2020. Accessed July 29, 2021. https://www.japantimes.co.jp/news/2020/05/22/national/coronavirus-hospital/
32. Watanabe S, Yoshikawa A. [*Reality in Healthcare System Collapse in Japan*.] Book in Japanese. Tokyo; MdN; 2020.
33. GBD 2016 Healthcare Access and Quality Collaborators. Measuring performance on the Healthcare Access and Quality Index for 195 countries and territories and selected subnational locations: a systematic analysis from the Global Burden of Disease Study 2016. *Lancet*. 2018;391(10136):2236-2271.
34. Tanaka H, Iwai A, Oda J, et al. Overview of evacuation and transport of patients following the 1995 Hanshin-Awaji earthquake. *J Emerg Med*. 1998;16(3):439-444.
35. Ushizawa H, Foxwell AR, Bice S, et al. Needs for disaster medicine: lessons from the field of the Great East Japan Earthquake. *Western Pac Surveill Response J*. 2013;4(1):51-55.
36. Committee of Japanese ICU Evaluation, Japanese Society of Intensive Care Medicine, Imanaka Y, Hayashida K, Murakami G, Matsuda S. Physician staffing and patient outcome in Japanese ICUs. Article in Japanese. *Jpn Soc Intensive Care Med*. 2010;17:227-232.
37. Organisation for Economic Co-operation and Development. Health at a Glance 2019: Remuneration of nurses (indicator). Published November 7, 2019. Accessed June 12, 2021. https://www.oecd-ilibrary.org/sites/a44d2e24-en/index.html?itemId=/content/component/a44d2e24-en
38. Hutchings SD, Perry J, Mills A, Bartley F, Park CL. Command, control and communication (C3) during the COVID-19 pandemic; adapting a military framework to crisis response in a tertiary UK critical care centre. *J Intensive Care Soc*. January 11, 2021. doi:10.1177/1751143720982191
39. Department of Health and Social Care. COVID-19 contain framework: a guide for local decision-makers. GOV.UK. Updated March 18, 2021. Accessed June 12, 2021. https://www.gov.uk/government/publications/containing-and-managing-local-coronavirus-covid-19-outbreaks/covid-19-contain-framework-a-guide-for-local-decision-makers
40. Farcas A, Ko J, Chan J, Malik S, Nono L, Chiampas G. Use of incident command system for disaster preparedness: a

model for an emergency department COVID-19 response. *Disaster Med Public Health Prep*. June 24, 2020. doi: 10.1017/dmp.2020.210
41. Society of Critical Care Medicine (SCCM). *Fundamental Disaster Management*. 3rd ed. Mount Prospect, IL: SCCM; 2009.
42. Ministry of Health, Labour, and Welfare. Grant of severance pay to the healthcare workers responding to COVID-19 pandemic. Document in Japanese. Published June 16, 2020. Accessed June 13, 2021. https://www.mhlw.go.jp/content/10800000/000641418.pdf
43. Over 50% of nurses at COVID hospital wards in Japan consider quitting. *Kyodo News*. May 23, 2021. Accessed June 13, 2021. https://english.kyodonews.net/news/2021/05/b8e4b190d850-over-50-of-nurses-at-covid-hospital-wards-in-japan-consider-quitting.html

Manuscript received November 27, 2020;
revision returned April 13, 2021;
accepted for publication April 16, 2021.

Address correspondence to:
Masayuki Ozaki, MD, PhD
Director of Intensive Care Unit
Komaki City Hospital
1-20 Johbushi
Komaki 485-8520, Aichi
Japan

Email: mozaki@med.nagoya-u.ac.jp