


RESEARCH

Open Access



Impact of the COVID-19 pandemic on critical care utilization in Japan: a nationwide inpatient database study

Hiroyuki Ohbe^{1*} , Yusuke Sasabuchi², Hiroki Matsui¹ and Hideo Yasunaga¹

Abstract

Background: The coronavirus disease 2019 (COVID-19) pandemic has disrupted critical care services worldwide. Examining how critical care systems responded to the COVID-19 pandemic on a national level will be useful in setting future critical care plans. The present study aimed to describe the utilization of critical care services before and during the COVID-19 pandemic using a nationwide Japanese inpatient administrative database.

Methods: All patients admitted to an intensive care unit (ICU) or a high-dependency care unit (HDU) from February 9, 2019, to February 8, 2021, in the Japanese Diagnosis Procedure Combination inpatient database were included. February 9, 2020, was used as the breakpoint separating the periods before and during COVID-19 pandemic. Hospital and patient characteristics were compared before and during the COVID-19 pandemic. Change in ICU and HDU bed occupancy before and during the COVID-19 pandemic was evaluated using interrupted time-series analysis.

Results: The number of ICU patients before and during the COVID-19 pandemic was 297,679 and 277,799, respectively, and the number of HDU patients was 408,005 and 384,647, respectively. In the participating hospitals (383 ICU-equipped hospitals and 460 HDU-equipped hospitals), the number of hospitals which increased the ICU and HDU beds capacity were 14 (3.7%) and 33 (7.2%), respectively. Patient characteristics and outcomes in ICU and HDU were similar before and during the COVID-19 pandemic except main etiology for admission of COVID-19. The mean ICU bed occupancy before and during the COVID-19 pandemic was 51.5% and 47.5%, respectively. The interrupted time-series analysis showed a downward level change in ICU bed occupancy during the COVID-19 pandemic (− 4.29%, 95% confidence intervals − 5.69 to − 2.88%), and HDU bed occupancy showed similar trends. Of 383 hospitals with ICUs, 232 (60.6%) treated COVID-19 patients in their ICUs. Their annual hospital case volume of COVID-19 ICU patients varied greatly, with a median of 10 (interquartile range 3–25, min 1, max 444).

Conclusions: The ICU and HDU bed capacity did not increase while their bed occupancy decreased during the COVID-19 pandemic in Japan. There was no change in clinicians' decision-making to forego ICU/HDU care for selected patients, and there was no progress in the centralization of critically ill COVID-19 patients.

Keywords: COVID-19 pandemic, Critical care utilization, Bed occupancy, Interrupted time-series analysis, High-dependency care unit

*Correspondence: hohbey@gmail.com

¹ Department of Clinical Epidemiology and Health Economics, School of Public Health, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

Full list of author information is available at the end of the article

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has contributed to substantial disruptions in the delivery of healthcare services around the world [1, 2]. The rapid rise in patients with COVID-19 requiring hospitalization quickly overwhelmed acute care services of health



systems and imposed a high staffing burden at least four times more than usual, including critical care [3–5].

In Japan, the first patient with COVID-19 was reported on January 16, 2020 [6], and the first patient with COVID-19 admitted to the intensive care unit (ICU) was confirmed on February 9, 2020 [7]. Since then, the number of COVID-19 cases in Japan has continued to rise with three pandemic waves where, by the end of February 2021, there had been 432,773 laboratory-confirmed COVID-19 cases and 7887 COVID-19-related deaths in Japan [8]. To prevent the collapse of the healthcare delivery system, the Japanese government invested a large amount of money in the healthcare system and announced states of COVID-19 emergency from April 7, 2020, to May 25, 2020, and from January 8, 2021, to March 21, 2021 [8].

To date, there are no studies describing critical care utilization in Japan during COVID-19 at a national level. The reported number of ICU beds per 100,000 population in Japan is about five, which is less than that in most other developed countries [9–11]. Given the increasing strain forced by COVID-19 and the relatively low availability of ICU beds in Japan, examining how the critical care system at a national level responded to the disastrous conditions of the COVID-19 pandemic will be useful in setting future critical care plans. Therefore, the present study aimed to compare the utilization of critical care services during the COVID-19 pandemic to that before the pandemic using a nationwide inpatient database.

Methods

Data source

This was a retrospective cohort study that used routinely collected nationwide inpatient administrative data in Japan to compare the utilization of critical care services during the COVID-19 pandemic to that before the pandemic. The Institutional Review Board of The University of Tokyo approved this study (approval number, 3501-3). No information allowing the identification of individual patients, hospitals, or physicians was obtained, and the requirement for informed consent was waived because of the anonymous nature of the data.

We used the Japanese Diagnosis Procedure Combination inpatient database (DPC database), which contains discharge abstracts and administrative claims data from more than 1500 participating public and private acute-care hospitals in Japan that voluntarily contribute to the database [12]. The database includes the following patient-level data for all hospitalizations: age, sex, route of admission, cognitive function before admission, admission type, diagnoses recorded using *International Classification of Diseases, Tenth Revision* (ICD-10) codes,

daily procedures recorded using Japanese medical procedure codes, daily drug administrations, and discharge status. In a previous study examining the validity of the recorded procedures and diagnoses, the sensitivity and specificity of procedures exceeded 90%, whereas the sensitivity and specificity of the primary diagnoses were 78.9% and 93.2%, respectively [13].

We also used the Survey of Medical Institutions 2019 and 2020, which include the facilities' information and statistics as of July 1, 2019 and July 1, 2020, respectively [14]. We combined this information with the data in the Japanese Diagnosis Procedure Combination inpatient database using a specific hospital identifier. The Survey of Medical Institutions included academic hospitals, tertiary emergency hospitals, types of wards [e.g., general, ICU, or high-dependency care units (HDUs)], and the number of licensed hospital beds in each ward.

Before and during the COVID-19 pandemic

In Japan, the first COVID-19-related ICU admission case was confirmed on February 9, 2020 [7]. Therefore, in this study, February 9, 2020, was used as the breakpoint separating the periods before and during COVID-19 into two 1-year periods [15]: before the COVID-19 pandemic from February 9, 2019, to February 8, 2020, and during the COVID-19 pandemic from February 9, 2020, through February 8, 2021.

Study population

We examined two separate cohorts of patients in ICUs, as well as HDUs, which are potential alternatives to ICUs [16, 17]. For the ICU patients, we included all patients admitted to an ICU between February 9, 2019, and February 8, 2021, from hospitals participating in the DPC database that also had records in the Survey of Medical Institutions and had at least one ICU bed reported in the Survey of Medical Institutions of both 2019 and 2020. In this study, an ICU was defined as a separate unit providing critical care services with at least one physician on site 24 h per day, around-the-clock nursing, the equipment necessary to care for critically ill patients, and a nurse-to-patient ratio of > 1:2 [18]. As for HDU patients, we included all patients admitted to an HDU between February 9, 2019, and February 8, 2021, from hospitals participating in the DPC database that also had records in the Survey of Medical Institutions and had at least one HDU bed in the Survey of Medical Institutions of both 2019 and 2020. The definition of an HDU in this study was almost the same as an ICU, except that the required nurse-to-patient ratio was 1:3, 1:4, or 1:5. The Japanese medical procedure codes to define ICU and HDU are listed in Additional file 1: Table S1. We did not include

patients admitted to the neonatal ICU or obstetric ICU in this study.

Statistical analysis

This study presents hospital characteristics before and during the COVID-19 pandemic. Hospital characteristics were based on the Survey of Medical Institutions 2019 before the COVID-19 pandemic and the Survey of Medical Institutions 2020 during the COVID-19 pandemic. We then compared the patient characteristics and outcomes before and during the COVID-19 pandemic. Due to the large sample size in this study, the patient characteristics and outcomes were compared using standardized mean differences, with an absolute standardized mean difference of $\leq 10\%$ denoting a negligible imbalance between the two groups [19]. Patient characteristics included age, sex, route of admission, cognitive function before admission, admission type, main etiologies for admission, and organ support at least once during ICU/HDU stay. Admission type was categorized as elective surgery, emergency surgery, or nonsurgical/acute medical problem. We defined patients who were admitted to the ICU/HDU on the day of elective or emergency surgery with general anesthesia as elective or emergency surgery patients. Main etiologies for admission were defined by the ICD-10 codes in the admission-precipitating diagnosis as follows: circulatory diseases (ICD-10 codes: I00-I99), neoplasms and diseases of the blood (C00-D89), injury, poisoning and external causes (S00-T98), abdominal diseases (K00-K93), respiratory diseases (J00-J99), COVID-19 (U071), and others. We also performed a descriptive epidemiology of COVID-19 patients. Continuous variables are presented as means and standard deviation (SD) or as medians and interquartile ranges (IQRs), as appropriate. Categorical variables are presented as frequencies and percentages. All analyses were performed using Stata/MP, Version 16.0 (StataCorp, College Station, TX, USA).

Analysis of occupancy

We calculated the daily occupancy of ICUs/HDUs by all patients in total, patients with invasive mechanical ventilation (IMV), and patients with extracorporeal membrane oxygenation (ECMO). We defined occupancy as the total number of relevant reimbursements in the cohort on a given day divided by the total number of licensed ICU/HDU beds in the participating hospitals. Change in occupancy before and during the COVID-19 pandemic was evaluated using patient-level segmented linear regression with interrupted time-series analysis [20]. The equation for the interrupted time-series analysis was as follows:

$$Y_t = \beta_0 + \beta_1 T + \beta_2 X_t + \beta_3 TX_t,$$

where Y_t is the occupancy, T is the month since the beginning of the study period (coded from 1 to 24), and X_t is a dummy variable indicating before or during the COVID-19 pandemic (coded 0 or 1). In this model, β_2 represents the level change immediately during the COVID-19 pandemic and β_3 represents the trend change during the COVID-19 pandemic compared to the baseline trend before the COVID-19 pandemic. As the sensitivity analyses for controlling for seasonality, we performed the interrupted time-series analyses stratified by the calendar month [20].

Results

There were 612 ICU-equipped hospitals with 7097 ICU beds in Japan as reported by the Survey of Medical Institutions 2019, while there were 597 ICU-equipped hospitals with 7026 ICU beds reported by the Survey of Medical Institutions 2020. After accounting for our inclusion criteria, the study cohort consisted of 573,102 patients admitted to 383 hospitals with 4945 ICU beds before the COVID-19 pandemic and 4984 ICU beds during the COVID-19 pandemic (Additional file 1: Fig. S1). Thus, 70% (4945/7097 beds) of all ICU beds in 2019 and 71% (4984/7026 beds) of all ICU beds in 2020 were included in the present study. The median number of ICU beds was 10 (IQR 8–16), and 14 (3.7%) hospitals increased their ICU beds during the COVID-19 pandemic (Table 1). The mean annual hospital revenue from ICU patients was 2400 (SD 1900) before the COVID-19 pandemic, and it decreased to 2200 (SD 1700) million yen after the pandemic, which corresponds to a difference of approximately 200 million yen.

Of 573,102 eligible patients, 297,679 and 277,799 patients were admitted to the ICU before and during the COVID-19 pandemic, respectively (Table 2). The mean age of patients was 67.3 (SD = 18.7) and 67.8 (SD = 18.3) before and during the COVID-19 pandemic, respectively. About 60% were male in both periods. About one-third of patients were admitted to the ICU after elective surgery in both periods. In-hospital mortality rates were 12.0% and 12.1% before and during the COVID-19 pandemic, respectively. Patient characteristics and outcomes were also comparable before and during the COVID-19 pandemic except for the main etiology of ICU admission being due to COVID-19.

The mean ICU bed occupancy before the COVID-19 pandemic (51.5%) was greater than that during the COVID-19 pandemic (47.5%) (Table 3, Fig. 1). The interrupted time-series analysis showed a downward level of change in ICU bed occupancy immediately during the COVID-19 pandemic (-4.29% , 95% confidence intervals

Table 1 Characteristics of hospitals equipped with ICU and HDU beds

| Hospital characteristics | Hospitals with ICU beds | | Hospitals with HDU beds | |
|---|------------------------------------|------------------------------------|------------------------------------|------------------------------------|
| | Before COVID-19 pandemic (n = 383) | During COVID-19 pandemic (n = 383) | Before COVID-19 pandemic (n = 460) | During COVID-19 pandemic (n = 460) |
| Academic hospital, n (%) | 76 (19.8%) | 76 (19.8%) | 62 (13.5%) | 63 (13.7%) |
| Tertiary emergency hospital, n (%) | 190 (49.6%) | 191 (49.9%) | 201 (43.7%) | 203 (44.1%) |
| Number of acute hospital beds, median (IQR) | 468 (352–588) | 465 (340–588) | 396 (265–552) | 391 (265–547) |
| Hospital with ICU beds, n (%) | 383 (100%) | 383 (100%) | 276 (60.0%) | 275 (59.8%) |
| Number of ICU beds, beds | | | | |
| Total | 4945 | 4983 | 3877 | 3909 |
| Median (IQR) | 10 (8–16) | 10 (8–16) | 10 (8–18) | 10 (8–18) |
| Hospitals with increased ICU beds from 2019 to 2020, n (%) | – | 14 (3.7%) | – | 9 (2.0%) |
| Hospital with HDU beds, n (%) | 276 (72.1%) | 279 (72.8%) | 460 (100%) | 460 (100%) |
| Number of HDU beds, beds | | | | |
| Total | 5863 | 6174 | 7969 | 8311 |
| Median (IQR) | 20 (10–28) | 20 (10–28) | 14 (8–24) | 14 (8–24) |
| Hospitals with increased HDU beds from 2019 to 2020, n (%) | – | 21 (5.5%) | – | 33 (7.2%) |
| Annual hospital case volume of ICU/HDU patients* | | | | |
| Total | 297,679 | 277,799 | 408,005 | 384,647 |
| Mean (SD) | 811 (597) | 753 (570) | 911 (747) | 866 (696) |
| Annual hospital revenue from ICU/HDU patients, million yen* | | | | |
| Total | 877,000 | 804,000 | 707,000 | 660,000 |
| Mean (SD) | 2,400 (1,900) | 2,200 (1,700) | 1,600 (1,400) | 1,500 (1,300) |

ICU intensive care unit; HDU high-dependency care unit; COVID-19 coronavirus disease 2019; IQR interquartile range; HDU high-dependency care unit; SD standard deviation

*Annual hospital case volume and annual hospital revenue were calculated by using only ICU patients for hospitals with ICU beds and only HDU patients for hospitals with HDU beds

[CIs] – 5.69 to – 2.88%) followed by a small upward slope change (0.31% change in trend per month; 95% CI 0.11–0.51%). The results of interrupted time-series analysis showed that the ICU bed occupancy by patients with invasive mechanical ventilation, patients with ECMO, and patients without any organ support were similar.

During the COVID-19 pandemic, a total of 5131 COVID-19 patients were admitted to ICUs. In-hospital mortality was 16.2% (831/5131), and the median length of ICU stay was 6 days (IQR 2–12 days) (Additional file 1: Table S2). There were three pandemic waves of COVID-19 ICU patients during the observation period (Additional file 1: Fig. S2). The maximum daily number of COVID-19 patients treated in the ICUs was 351 on January 25, 2021, which represented 7.0% (351/4984) of ICU beds in 2020. Of 383 hospitals equipped with ICUs, about 150 hospitals treated COVID patients in their ICUs immediately during the first wave of the COVID-19 pandemic, and 232 (60.6%) hospitals treated COVID-19 patients in their ICUs within 1 year of the beginning of the COVID-19 pandemic (Additional file 1: Fig. S3). Meanwhile, 151 (39.4%) hospitals did not treat any COVID-19 patients in their ICUs during the 1st year of

the COVID-19 pandemic. In the 232 hospitals that were equipped with ICUs and treated COVID-19 patients in their ICUs, the annual hospital case volume of COVID-19 ICU patients varied greatly, with a median of 10 (IQR 3–25, min 1, max 444) (Additional file 1: Fig. S4).

The study cohort of HDU patients consisted of 792,652 patients admitted to 460 hospitals with 7969 HDU beds before the COVID-19 pandemic and 8311 HDU beds during the COVID-19 pandemic, representing 62% (7969/12,949 beds) of all HDU beds in 2019 and 61% (8311/13,546 beds) of all HDU beds in 2020 (Table 1, Additional file 1: Fig. S5). The median number of HDU beds was 14 (IQR 8–24) in 2020, and 33 (7%) hospitals increased their HDU beds from 2019 to 2020. Characteristics and outcomes of HDU patients were similar before and during the COVID-19 pandemic except for the main etiology for ICU admission being due to COVID-19 (Table 2). The mean HDU bed occupancy before the COVID-19 pandemic (46.9%) was greater than that during the pandemic (44.8%) (Table 3, Fig. 2). The interrupted time-series analysis of HDU bed occupancy showed a downward level of change immediately after the COVID-19 pandemic (–8.12%, 95% confidence

Table 2 Characteristics and outcomes of ICU and HDU patients

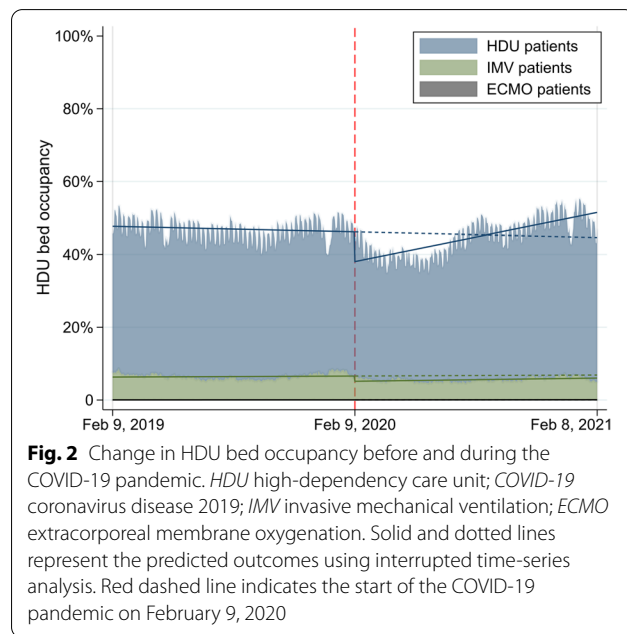
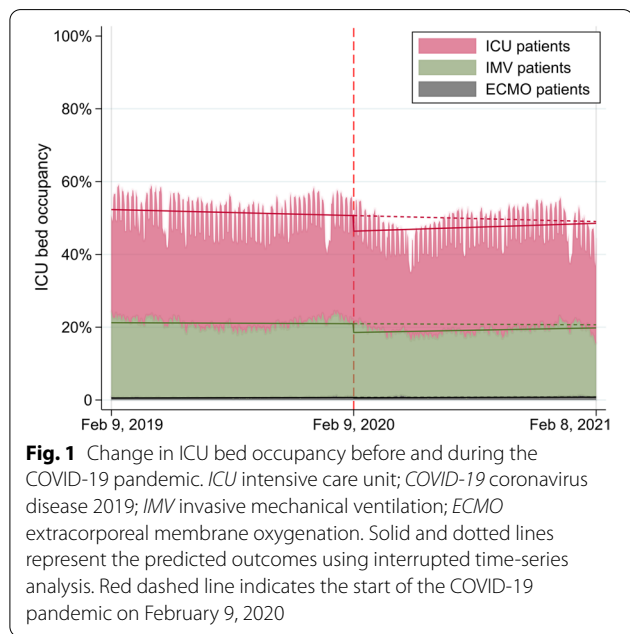
| Characteristics and outcomes | ICU patients | | | HDU patients | | |
|---|--|--|--------|--|--|--------|
| | Before COVID-19 pandemic (n = 297,679) | During COVID-19 pandemic (n = 275,423) | SMD, % | Before COVID-19 pandemic (n = 408,005) | During COVID-19 pandemic (n = 384,647) | SMD, % |
| Age, year, mean (SD) | 67.3 (18.7) | 67.8 (18.3) | 2.7 | 70.9 (17.4) | 71.2 (17.3) | 0.1 |
| Male, % | 180,260 (60.6%) | 167,806 (60.9%) | 0.8 | 232,993 (57.1%) | 220,091 (57.2%) | 0.2 |
| Route of admission, % | | | | | | |
| Home | 268,903 (90.3%) | 249,076 (90.4%) | − 0.8 | 359,513 (88.1%) | 338,379 (88.0%) | − 0.9 |
| Another hospital | 21,661 (7.3%) | 19,562 (7.1%) | | 23,191 (5.7%) | 21,595 (5.6%) | |
| Nursing home | 7113 (2.4%) | 6785 (2.5%) | | 25,298 (6.2%) | 24,672 (6.4%) | |
| Dementia, % | | | | | | |
| None | 263,892 (88.6%) | 241,643 (87.7%) | − 2.8 | 321,092 (78.7%) | 299,986 (78.0%) | − 1.9 |
| Mild dementia | 21,533 (7.2%) | 21,404 (7.8%) | | 46,577 (11.4%) | 44,593 (11.6%) | |
| Moderate-to-severe dementia | 12,254 (4.1%) | 12,376 (4.5%) | | 40,336 (9.9%) | 40,068 (10.4%) | |
| Admission type, n (%) | | | | | | |
| Elective surgery | 102,700 (34.5%) | 95,001 (34.5%) | − 0.1 | 67,826 (16.6%) | 59,879 (15.6%) | − 3.0 |
| Emergency surgery | 33,125 (11.1%) | 30,545 (11.1%) | | 29,472 (7.2%) | 27,459 (7.1%) | |
| Nonsurgical/acute medical problem | 161,852 (54.4%) | 149,877 (54.4%) | | 310,704 (76.2%) | 297,308 (77.3%) | |
| Main etiologies for admission, n (%) | | | | | | |
| Circulatory diseases | 132,736 (44.6%) | 120,295 (43.7%) | − 1.8 | 163,073 (40.0%) | 150,981 (39.3%) | − 1.5 |
| Neoplasms and diseases of the blood | 73,572 (24.7%) | 68,601 (24.9%) | 0.4 | 62,604 (15.3%) | 56,448 (14.7%) | − 1.9 |
| Injury, poisoning and external causes | 19,570 (6.6%) | 17,747 (6.4%) | − 0.5 | 47,490 (11.6%) | 42,618 (11.1%) | − 1.8 |
| Abdominal diseases | 17,659 (5.9%) | 16,388 (6.0%) | 0.1 | 36,911 (9.0%) | 33,466 (8.7%) | − 1.2 |
| Respiratory diseases | 12,721 (4.3%) | 10,168 (3.7%) | − 3.0 | 33,973 (8.3%) | 26,450 (6.9%) | − 5.5 |
| COVID-19 | 0 (0.0%) | 5131 (1.9%) | 19.5 | 0 (0.0%) | 18,888 (4.9%) | 32.1 |
| The others | 41,419 (13.9%) | 37,093 (13.5%) | − 1.3 | 63,951 (15.7%) | 55,795 (14.5%) | − 3.3 |
| Organ support during ICU/HDU stay, n (%) | | | | | | |
| Invasive mechanical ventilation | 98,700 (33.2%) | 87,603 (31.8%) | − 2.8 | 53,026 (13.0%) | 48,752 (12.7%) | − 1.0 |
| Noradrenaline | 92,024 (30.9%) | 88,533 (32.1%) | 2.6 | 33,490 (8.2%) | 34,792 (9.0%) | 3.0 |
| Continuous renal replacement therapy | 14,592 (4.9%) | 12,824 (4.7%) | − 1.2 | 3492 (0.9%) | 3283 (0.9%) | 0.0 |
| Intra-aortic balloon pumping | 8360 (2.8%) | 7532 (2.7%) | − 0.4 | 2007 (0.5%) | 1875 (0.5%) | − 0.1 |
| Extracorporeal membrane oxygenation | 4064 (1.4%) | 3701 (1.3%) | − 0.2 | 750 (0.2%) | 669 (0.2%) | − 0.2 |
| Left ventricular assist device | 22 (0.0%) | 30 (0.0%) | 0.4 | 2 (0.0%) | 1 (0.0%) | − 0.1 |
| Intracranial pressure monitoring | 977 (0.3%) | 813 (0.3%) | − 0.6 | 366 (0.1%) | 316 (0.1%) | − 0.3 |
| ICU/HDU mortality, n (%) | 17,770 (6.0%) | 17,023 (6.2%) | 0.9 | 23,557 (5.8%) | 23,851 (6.2%) | 1.8 |
| Discharge status, n (%) | | | | | | |
| In-hospital mortality | 35,714 (12.0%) | 33,386 (12.1%) | − 0.8 | 48,306 (11.8%) | 46,448 (12.1%) | − 0.8 |
| Home | 201,418 (67.7%) | 186,582 (67.7%) | | 248,489 (60.9%) | 233,694 (60.8%) | |
| Another hospital | 56,433 (19.0%) | 51,521 (18.7%) | | 93,782 (23.0%) | 87,916 (22.9%) | |
| Nursing home | 4112 (1.4%) | 3934 (1.4%) | | 17,425 (4.3%) | 16,588 (4.3%) | |
| Length of hospital stay, days, median (IQR) | 17 (10–31) | 16 (9–30) | − 5.1 | 14 (7–27) | 14 (7–25) | − 4.4 |
| Length of ICU/HDU stay, days, median (IQR) | 2 (1–4) | 2 (1–4) | − 1.3 | 2 (1–4) | 2 (1–4) | 3.3 |
| Hospitalization costs, million yen, mean (SD) | 2.1 (1.3–3.7) | 2.1 (1.4–3.7) | − 0.9 | 1.3 (0.7–2.1) | 1.3 (0.7–2.1) | − 1.0 |

ICU intensive care unit; HDU high-dependency care unit; COVID-19 coronavirus disease 2019; SMD standardized mean difference; SD standard deviation; IQR interquartile range

Table 3 The results of interrupted time-series analysis for ICU and HDU patients

| Variables | Before COVID-19 pandemic | During COVID-19 pandemic | Level change, % (95% CIs) | Trend change, % per month (95% CIs) |
|--|--------------------------|--------------------------|---------------------------|-------------------------------------|
| ICU | | | | |
| ICU bed occupancy, % | 51.5 | 47.5 | - 4.29 (- 5.69, - 2.88) | 0.31 (0.11, 0.51) |
| Invasive mechanical ventilation, % | 21.1 | 19.2 | - 2.40 (- 2.80, - 2.01) | 0.13 (0.07, 0.18) |
| Extracorporeal membrane oxygenation, % | 0.6 | 0.7 | - 0.08 (- 0.13, - 0.04) | 0.00 (0.00, 0.01) |
| Without any organ support, % | 24.1 | 22.3 | - 1.58 (- 2.41, - 0.75) | 0.17 (0.05, 0.29) |
| HDU | | | | |
| HDU bed occupancy, % | 46.9 | 44.8 | - 8.12 (- 9.02, - 7.22) | 1.23 (1.10, 1.36) |
| Invasive mechanical ventilation, % | 6.5 | 5.6 | - 1.44 (- 1.64, - 1.24) | 0.05 (0.02, 0.08) |
| Extracorporeal membrane oxygenation, % | 0.0 | 0.1 | 0.00 (- 0.01, 0.00) | 0.00 (0.00, 0.00) |
| Without any organ support, % | 38.8 | 37.6 | - 6.46 (- 7.22, - 5.70) | 1.16 (1.05, 1.26) |

ICU intensive care unit; HDU high-dependency care unit; COVID-19 coronavirus disease 2019; CI confidence interval



intervals [CIs] - 9.02 to - 7.22%) followed by an upward slope change (1.23% change in trend per month; 95% CI 1.10-1.36%). The results of sensitivity analyses for controlling for seasonality were similar with those in the main analyses (Additional file 1: Table S3).

During the COVID-19 pandemic, a total of 18,888 COVID-19 patients were admitted to an HDU, and their in-hospital mortality was 7.6% (1431/18,888) (Additional file 1: Table S2). The maximum daily number of COVID-19 patients treated in HDUs was 1179 on January 18, 2021, which represented 14.2% (1179/8311) of all HDU beds in 2020 (Additional file 1: Fig. S6). Of 460 hospitals equipped with HDUs, 292 (63.5%) hospitals treated

COVID-19 patients in their HDUs within 1 year of the COVID-19 pandemic start, while 168 (36.5%) hospitals did not treat any COVID-19 patients during that period (Additional file 1: Fig. S7). In the 292 hospitals that were equipped with HDUs and treated COVID-19 patients in their HDUs, the annual hospital case volume of COVID-19 HDU patients varied greatly, with a median of 20 (IQR 5-82, min 1, max 1434) (Additional file 1: Fig. S8).

Discussion

The present study describes in detail the utilization of critical care services in Japan at a national level before and during the COVID-19 pandemic and presents several key

findings. First, most hospitals with ICUs and HDUs did not increase the bed capacity of their licensed critical care beds in response to COVID-19 by July 1, 2020. Second, the number of ICU/HDU admissions and that of ICU/HDU bed occupancies declined significantly during the COVID-19 pandemic. Due to the decrease in ICU patients, hospitals experienced a decrease in revenue of 200 million yen per year on average. Third, there was no change in clinicians' decision-making to forego ICU care for selected patients in Japanese ICUs. The ICU/HDU bed occupancy by patients requiring organ support such as IMV and ECMO decreased, which was also the case for patients undergoing elective surgeries. Mortality and length of ICU stay remained unchanged before and during COVID-19. Fourth, within 1 year from the start of the COVID-19 pandemic, the number of COVID patients treated in the ICUs was still low, and about 40% of ICUs did not treat any COVID-19 patients. The hospital volume of COVID-19 patients in the ICU was very limited in most hospitals, and patients were dispersed among many ICUs. A significant number of COVID-19 patients were treated in HDUs, including those who required organ support.

In the context of prior literature

The previous study in Alberta, Canada, where the critical care surge of COVID-19 did not exceed the ICU bed capacity, showed the substantial decline of ICU admissions during COVID-19 lockdown [21]. However, contrary to the results of this study, they reported marked reductions in the numbers of ICU admissions for elective surgery and avoidable waiting time before ICU discharge during the COVID-19 pandemic compared with those during historical periods. Notably, this adequate critical care utilization was achieved despite no concomitant policy change in ICU admission criteria, and the authors hypothesized that lockdown had a major contribution to this effect. These same trends of reduced ICU admissions were also reported in pediatric ICUs [22, 23]. Nevertheless, further data on the impact of critical care utilizations during the COVID-19 pandemic are limited, and further studies are needed to elucidate this effect.

Implications for clinicians and policy

There are several possible options for responding to surges in demand for care for critically ill patients during a pandemic, including critical care triage, rationing of resources, provision of intensive care outside the ICU, rapidly building new hospitals with ICUs, and centralization of critically ill patients in designated hospitals with ICUs [24, 25]. Guidelines for critical care utilization during the COVID-19 pandemic recommend reorganizing critical care structure in readiness for potential surges in COVID-19-related critical illness and suspending elective

medical and surgical procedures once ongoing chains or community transmission of COVID-19 has been documented within a State/Province/Country [26, 27]. Combined with the results of this study describing critical care utilization before and during COVID-19 in Japan, several implications can be drawn. First, Japan failed to increase the ICU bed capacity in preparation for the COVID-19 pandemic. The number of ICU beds per 100,000 population in Japan was 5.7 in 2020, which is lower than that in other countries, and an increase in ICU beds has been anticipated since the beginning of the COVID-19 pandemic. To strengthen the healthcare delivery system for COVID-19, the Japanese government invested a total of 6 trillion yen to secure hospital beds and medical personnel [28]; however, this did not lead to an increase in critical care recourses. Therefore, the expansion of the ICUs could not have been accomplished simply by investing money; some other methods might have been necessary. Second, in reducing ICU demand in preparation for the COVID-19 pandemic, there was no change in clinicians' decision-making regarding ICU/HDU admission and discharges, which is in contrast to the recommendations by the guidelines to suspend elective surgery and ICU admissions related to them or discharge ICU patients earlier. This might be attributed to the fact that Japan did not issue guidelines or statements on ICU triage during the COVID-19 pandemic as other countries did [26, 27]. Third, centralization of critically ill COVID-19 patients did not occur in Japan. For a hospital to accept critically ill COVID-19 patients, it required a large fixed budget, regardless of the number of patients. This suggests that it is more efficient to concentrate patients in large hospitals to achieve economies of scale [24, 25]. However, the Japanese healthcare system is characterized by "few large hospitals and many small hospitals", which makes centralization difficult. This highlights the necessity of designing incentives to promote inter-hospital transport in the future in anticipation of any pandemic or healthcare crisis.

Strengths and limitations

The present study had several strengths. First, it successfully created a nationally representative cohort of a large number of ICU and HDU patients, representing 70% of all ICU beds and 60% of all HDU beds in Japan. To the best of our knowledge, this is the first study to compare critical care utilization in Japan on a national scale before and during the COVID-19 pandemic. Second, this study is specific to the intensive care field. Critically ill COVID-19 patients need advanced medical treatment such as respiration and circulation. To examine and describe the ICU and HDU bed occupancy and capacity are useful in national critical care system.

The present study had several limitations. First, the calculated occupancy rates depended on the number of ICU and HDU beds that were reimbursed through insurance claims. However, the cost of ICU and HDU stays can be billed only for up to 14 days and 21 days, respectively, and up to 35 days for COVID-19 patients with ECMO. Thus, the calculated occupancy rates in our study may be underestimated. Second, the number of ICU and HDU beds may have fluctuated depending on the burden of COVID-19 and differed from that reported number in the Survey of Medical Institutions 2020, which may have underestimated or overestimated occupancy rates. Third, because the beginning of the COVID-19 pandemic was not clear and differed among prefectures within Japan, the definition of before and after the COVID-19 pandemic using February 9, 2020, as the identified breakpoint in this study may have biased the results of the interrupted time-series analyses. Fourth, although population-based, our study from Japan reflects a single country and may not be generalizable to other countries.

Conclusion

Using a nationwide inpatient database, we revealed that the ICU and HDU bed capacity did not increase during the COVID-19 pandemic in Japan, whereas their occupancy decreased. There was no change in clinicians' decision-making to forego ICU care for selected patients, and there was no progress in centralization of critically ill COVID-19 patients. These results will influence health-care providers, hospital administrators, and policymakers to provide better critical care utilization in anticipation of any pandemics or healthcare crises in the future.

Abbreviations

COVID-19: Coronavirus disease 2019; ICU: Intensive care unit; HDU: High-dependency care unit; DPC: Diagnosis Procedure Combination; ICD: International Classification of Diseases; IMV: Invasive mechanical ventilation; ECMO: Extracorporeal membrane oxygenation.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s40560-022-00645-0>.

Additional file 1: Figure S1. Flow chart of the ICU patients' selection. **Figure S2.** Daily number of COVID-19 patients treated in ICUs. **Figure S3.** Cumulative number of hospitals treating COVID-19 patients in ICUs. **Figure S4.** Annual hospital case volume of COVID-19 patients in ICUs per year. **Figure S5.** Flow chart of the HDU patients' selection. **Figure S6.** Daily number of COVID-19 patients treated in HDUs. **Figure S7.** Cumulative number of hospitals treating COVID-19 patients in HDUs. **Figure S8.** Annual hospital case volume of COVID-19 patients in HDUs per year. **Table S1.** Codes used to define ICUs and HDUs using the Japanese medical procedure codes. **Table S2.** Characteristics and outcomes of COVID-19 patients admitted to ICUs and HDUs. **Table S3.** The results of sensitivity interrupted time-series analysis stratified by the calendar month.

Acknowledgements

Not applicable.

Author contributions

HO designed the research; HO and HM conducted the research; HO, YS, and HY analyzed the data; HO, YS, and HY wrote the paper; and HO had primary responsibility for the final content. All authors read and approved the final manuscript.

Funding

This work was supported by grants from the Ministry of Health, Labour and Welfare, Japan (Grant Nos. 21AA2007 and 20AA2005) and the Ministry of Education, Culture, Sports, Science and Technology, Japan (Grant No. 20H03907).

Availability of data and materials

The dataset analyzed in the current study is not publicly available because of contracts with the hospitals providing data to the database.

Declarations

Ethics approval and consent to participate

The Institutional Review Board of The University of Tokyo approved this study. The procedures used in this study adhere to the tenets of the Declaration of Helsinki. No information allowing the identification of individual patients, hospitals, or physicians was obtained, and the requirement for informed consent was waived because of the anonymous nature of the data.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

¹Department of Clinical Epidemiology and Health Economics, School of Public Health, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. ²Data Science Center, Jichi Medical University, 3311-1 Yakushiji, Shimotsuke-shi, Tochigi-ken 329-0498, Japan.

Received: 4 October 2022 Accepted: 18 November 2022

Published online: 02 December 2022

References

- Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020;395:497–506.
- Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A novel coronavirus from patients with pneumonia in China, 2019. *N Engl J Med*. 2020;382:727–33.
- Uppal A, Silvestri DM, Siegler M, Natsui S, Boudourakis L, Salway RJ, et al. Critical care and emergency department response at the epicenter of the COVID-19 pandemic. *Health Aff (Millwood)*. 2020;39:1443–9.
- Grasselli G, Greco M, Zanella A, Albano G, Antonelli M, Bellani G, et al. Risk factors associated with mortality among patients with COVID-19 in intensive care units in Lombardy, Italy. *JAMA Intern Med*. 2020;180:1345–55.
- Gupta S, Hayek SS, Wang W, Chan L, Mathews KS, Melamed ML, et al. Factors associated with death in critically ill patients with coronavirus disease 2019 in the US. *JAMA Intern Med*. 2020;180:1436–47.
- Furuse Y, Ko YK, Saito M, Shobugawa Y, Jindai K, Saito T, et al. Epidemiology of COVID-19 outbreak in Japan, from January–March 2020. *Jpn J Infect Dis*. 2020;73:391–3.
- Japan ECMOnet for COVID-19, Shime N. Save the ICU and save lives during the COVID-19 pandemic. *J Intensive Care*. 2020;8:40.
- Ministry of Health, Labour and Welfare, Japan. Coronavirus disease (COVID-19) situation report in Japan. [Internet]. https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/0000164708_00079.html. Accessed 22 Sept 2022.

9. Ohbe H, Sasabuchi Y, Kumazawa R, Matsui H, Yasunaga H. Intensive care unit occupancy in Japan, 2015–2018: a nationwide inpatient database study. *J Epidemiol*. 2021. <https://doi.org/10.2188/jea.JE20210016>.
10. Sirio CA, Tajimi K, Taenaka N, Ujike Y, Okamoto K, Katsuya H. A cross-cultural comparison of critical care delivery: Japan and the United States. *Chest*. 2002;121:539–48.
11. Phua J, Faruq MO, Kulkarni AP, Redjeki IS, Detleuxay K, Mendsaikhan N, et al. Critical care bed capacity in Asian countries and regions. *Crit Care Med*. 2020;48:654–62.
12. Yasunaga H. Real world data in Japan: Chapter II The Diagnosis Procedure Combination Database. *Ann Clin Epidemiol*. 2019;1:76–9.
13. Yamana H, Moriwaki M, Horiguchi H, Kodan M, Fushimi K, Yasunaga H. Validity of diagnoses, procedures, and laboratory data in Japanese administrative data. *J Epidemiol*. 2017;27:476–82.
14. The Ministry of Health, Labour and Welfare, Japan. Survey of Medical Institutions. [Internet]. <https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/0000055891.html>. Accessed 22 Sept 2022.
15. Onozuka D, Tanoue Y, Nomura S, Kawashima T, Yoneoka D, Eguchi A, et al. Reduced mortality during the COVID-19 outbreak in Japan, 2020: a two-stage interrupted time-series design. *Int J Epidemiol*. 2022;51:75–84. <https://doi.org/10.1093/ije/dyab216>.
16. Ohbe H, Sasabuchi Y, Iwagami M, Ogura T, Ono S, Matsui H, et al. Intensive care unit versus high-dependency care unit for COVID-19 patients with invasive mechanical ventilation. *Ann Am Thorac Soc*. 2022. <https://doi.org/10.1513/AnnalsATS.202206-475OC>.
17. Ohbe H, Sasabuchi Y, Yamana H, Matsui H, Yasunaga H. Intensive care unit versus high-dependency care unit for mechanically ventilated patients with pneumonia: a nationwide comparative effectiveness study. *Lancet Reg Health West Pac*. 2021;13: 100185. <https://doi.org/10.1016/j.lanwpc.2021.100185>.
18. Iwashyna TJ. Critical care use during the course of serious illness. *Am J Respir Crit Care Med*. 2004;170:981–6.
19. Amrhein V, Greenland S, McShane B. Scientists rise up against statistical significance. *Nature*. 2019;567:305–7.
20. Wagner AK, Soumerai SB, Zhang F, Ross-Degnan D. Segmented regression analysis of interrupted time series studies in medication use research. *J Clin Pharm Ther*. 2002;27:299–309.
21. Bagshaw SM, Zuege DJ, Stelfox HT, Opgenorth D, Wasylak T, Fraser N, et al. Association between pandemic coronavirus disease 2019 public health measures and reduction in critical care utilization across ICUs in Alberta, Canada. *Crit Care Med*. 2022;50:353–62.
22. Graciano AL, Bhutta AT, Custer JW. Reduction in paediatric intensive care admissions during COVID-19 lockdown in Maryland, USA. *BMJ Paediatr Open*. 2020;4: e000876. <https://doi.org/10.1136/bmjpo-2020-000876>.
23. Kruizinga MD, Peeters D, van Veen M, van Houten M, Wieringa J, Noordzij JG, et al. The impact of lockdown on pediatric ED visits and hospital admissions during the COVID19 pandemic: a multicenter analysis and review of the literature. *Eur J Pediatr*. 2021;180:2271–9.
24. Hick JL, Christian MD, Sprung CL, European Society of Intensive Care Medicine's Task Force for intensive care unit triage during an influenza epidemic or mass disaster. Chapter 2. Surge capacity and infrastructure considerations for mass critical care. Recommendations and standard operating procedures for intensive care unit and hospital preparations for an influenza epidemic or mass disaster. *Intensive Care Med*. 2010;36(Suppl 1):11–20.
25. Papali A, Schultz MJ, Dünser MW, European Society of Intensive Care Medicine (ESICM) Global Intensive Care working group and The Mahidol-Oxford Research Unit (MORU) in Bangkok, Thailand. Recommendations on infrastructure and organization of adult ICUs in resource-limited settings. *Intensive Care Med*. 2018;44:1133–7.
26. Aziz S, Arabi YM, Alhazzani W, Evans L, Citerio G, Fischkoff K, et al. Managing ICU surge during the COVID-19 crisis: rapid guidelines. *Intensive Care Med*. 2020;46:1303–25.
27. Phua J, Weng L, Ling L, Egi M, Lim C-M, Divatia JV, et al. Intensive care management of coronavirus disease 2019 (COVID-19): challenges and recommendations. *Lancet Respir Med*. 2020;8:506–17.
28. Ministry of Finance Japan [Internet]. Ministry of Finance. <https://www.mof.go.jp/english/index.htm>. Accessed 22 Sept 2022.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Ready to submit your research? Choose BMC and benefit from:

- fast, convenient online submission
- thorough peer review by experienced researchers in your field
- rapid publication on acceptance
- support for research data, including large and complex data types
- gold Open Access which fosters wider collaboration and increased citations
- maximum visibility for your research: over 100M website views per year

At BMC, research is always in progress.

Learn more biomedcentral.com/submissions

