Critical care bed capacity in Asian countries and regions before and during the COVID-19 pandemic: an observational study

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Summary

Background The coronavirus disease 2019 (COVID-19) pandemic highlighted the importance of critical care. The aim of the current study was to compare the number of adult critical care beds in relation to population size in Asian countries and regions before (2017) and during (2022) the pandemic.

Methods This observational study collected data closest to 2022 on critical care beds (intensive care units and intermediate care units) in 12 middle-income and 7 high-income economies (using the 2022–2023 World Bank classification), through a mix of methods including government sources, national critical care societies, personal contacts, and data extrapolation. Data were compared with a prior study from 2017 of the same countries and regions.

Findings The cumulative number of critical care beds per 100,000 population increased from 3.0 in 2017 to 9.4 in 2022 (p = 0.003). The median figure for middle-income economies increased from 2.6 (interquartile range [IQR] 1.7–7.8) to 6.6 (IQR 2.2–13.3), and that for high-income economies increased from 11.4 (IQR 7.3–22.8) to 13.9

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(IQR 10.7–21.7). Only 3 countries did not see a rise in bed capacity. Where data were available in 2022, 10.9% of critical care beds were in single rooms (median 5.0% in middle-income and 20.3% in high-income economies), and 5.3% had negative pressure (median 0.7% in middle-income and 18.5% in high-income economies).

Interpretation Critical care bed capacity in the studied Asian countries and regions increased close to three-fold from 2017 to 2022. Much of this increase was attributed to middle-income economies, but substantial heterogeneity exists.

Funding None.

Keywords: Critical care; Bed capacity; Intensive care units; COVID-19; Mortality

Research in context

Evidence before this study

To design this study initially and prepare the manuscript subsequently, we searched PubMed for studies on national and international critical care bed capacity before and during the coronavirus disease 2019 (COVID-19) pandemic. We applied no date or language restrictions, and used the search terms "critical care", "bed capacity", "intensive care unit (ICU)", "intermediate care unit (IMCU)", "high dependency unit", and "COVID-19". We had previously published the Asian Analysis of Bed Capacity in critical care (Asian ABC) study, the first and largest pre-pandemic study conducted in 2017 on the number of critical care beds (ICU and IMCU) in multiple Asian countries and regions. While there were several reports, predominantly from high-income countries in America and Europe, of surges in critical care beds in the first months of the pandemic, limited data on critical care bed capacity in different parts of the world when the outbreak had started to stabilise in 2022 exist. There was even less information on the availability of single-room and negative-pressure critical care beds.

Added value of this study

To our knowledge, this is the largest international study of critical care bed capacity in the COVID-19 era. Strengths of our study include the participation of multiple middle-income and not just high-income economies, the use of mixed methods for data collection to maximise accuracy, and the comparison of data between 2017 and 2022.

Implications of all the available evidence

The striking finding that critical care bed capacity corrected for population increased close to three-fold in the short space of time from before to during the pandemic, while arguably necessary to cope with excess mortality, raises questions on the quality of care provided with the new beds as well as the impact of diversion of resources away from other crucial aspects of healthcare. The heterogeneity of critical care bed numbers and the lack of single-rooms and negative-pressure beds across countries and regions raise concerns on how ready this part of the world is for future pandemics.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic highlighted the importance of critical care—and critical care bed capacity—as intensive care units (ICUs) across the world struggled to cope with surges in patient numbers.[1] National and local authorities sought to strengthen capacity, but the quantity and quality of response varied widely.[2–4] While interventions ranged from the creation of new ICU beds within and beyond hospitals to the conversion of existing beds within ICUs and other non-ICU wards for critically ill COVID-19, such beds are only truly useful if they are appropriately staffed and equipped.[5–7] There remains uncertainty on the optimal number of ICU beds, for even though the pandemic has finally receded after multiple waves of infection by severe acute respiratory syndrome coronavirus-2 (SARS-Cov-2) across countries, threats from new emerging pathogens and variants persist.[8]

The Asian Critical Care Clinical Trials (ACCCT) Group previously published the Asian Analysis of Bed Capacity in critical care (Asian ABC) study which examined the number of critical care beds per 100,000 population across 23 Asian countries and regions around the year 2017.[9] Critical care bed capacity varied widely across the continent, and was significantly lower in low- and lower-middle-income than in upper-middle-income countries and regions. It was unclear if critical care bed capacity had increased several years into the pandemic, and if so, by how much. Knowledge regarding whether and how such capacity was strengthened will provide better insights on the ability of healthcare systems to deal with strain today and in the future.

The aim of the current Asian ABC2 study was hence to compare the number of adult critical care beds in relation to population size in Asian countries and regions before and during the pandemic.

Methods

This observational study by the Asian Critical Care Clinical Trials (ACCCT) Group closely followed the methods of the first Asian ABC study, which itself adapted methods from a study on European critical care bed capacity by Rhodes and colleagues (Study Protocol, Appendix pp 3–10).[9,10] Of the investigators from the previous study, four declined to participate (from Brunei, China, Indonesia, and Laos), leaving 19 countries and regions (eTable 1, Appendix pp 37).[9] Approval by institutional review boards was obtained, if appropriate, according to local regulations in each participating country and region.

Questionnaire

Starting in April 2022, national coordinators recorded information into a questionnaire on critical care beds (number of ICUs and intermediate care units [IMCUs] and corresponding number of beds, with details on single versus cohorted ICU beds, negative versus non-negative pressure rooms, public versus private sector units, and urban versus rural locations) and acute hospital beds (number of acute hospitals and corresponding number of beds) (Study Questionnaire, Appendix pp 12–36). Data that were as close to the year 2022 as possible were sought. The questionnaire provided details on definitions of the various types of critical care beds and acute hospital beds,[11] suggestions on the mix of methods and sources to obtain the data, and fields to capture qualifiers, uncertainties, and notes on unavailable data.

We included adult critical care beds, and excluded beds from coronary care, stroke, and pure renal units, as well as paediatric and neonatal units. To ensure applicability across countries, we adapted the definition of an ICU from that of a task force convened by the World Federation of Societies of Intensive and Critical Care Medicine (WFSICCM).[11] All five of the following criteria had to be fulfilled, i.e., an ICU: (1) is based in a defined geographic area of a hospital; (2) is an organised system for the provision of care to critically ill patients that provides intensive and specialised medical and nursing care; (3) has enhanced capacity for monitoring; (4) has multiple modalities of physiologic organ support to sustain life during a period of acute organ system insufficiency; and (5) is open and staffed. This definition was taken in the context of the pandemic, during which many countries and regions had converted areas within hospitals (such as general wards and operating theatres), and sometimes beyond hospitals (such as dedicated COVID-19 treatment facilities), into ICUs. These areas could be counted as ICUs as long as all five criteria stated above were fulfilled.

We defined IMCUs (variously known as intermediate care areas, high-dependency units, step-up units, and step-down units) as units that have at least the capability of level 1 ICUs as deemed by the WFSICCM task force, i.e., they are a dedicated space within the hospital with a higher nurse-to-patient ratio than a regular ward, and are equipped to monitor vital signs and oxygen saturation intensively and the electrocardiogram continuously, and to provide non-invasive ventilation, short-term invasive mechanical ventilation, or simple mechanical ventilation for stable chronically ventilated patients.

Other data

We obtained data on each country and region's population in 2022 (number of people living within, including both citizen and non-citizen residents) from the Central Intelligence Agency World Factbook,[12] data on the gross domestic product (GDP) per capita from the World Bank,[13] data on the reported number of cases of COVID-19 from the start of 2020 to the end of 2021 from the Johns Hopkins University & Medicine Coronavirus Resource Centre,[14] and data on the reported number of deaths from COVID-19 as well as the estimated true number of excess deaths due to the pandemic from the start of 2020 to the end of 2021 from a systematic analysis by the COVID-19 Excess Mortality Collaborators.[15]

Statistical analyses

We present data as numbers, percentages, medians, and interquartile ranges (IQR). We categorised countries and regions into middle-income and high-income groups according to the 2022–2023 World Bank income classification which is based on gross national income (GNI) per capita,[16] because the first Asian ABC study found an association of critical care bed numbers with national wealth.[9] All countries and regions stayed in the same broad categories between 2017 and 2022 (eTable 2, Appendix pp 38). We merged nine lower-middle-income and three upper-middle-income economies into the middle-income group due to the small number of countries of upper-middle-income. We used the Mann–Whitney U test to compare data between groups. We used the Wilcoxon signed-rank test to compare data in 2017 from the first Asian ABC study versus data in 2022 from the current study.[9] We expressed critical care bed capacity as the number of critical care beds (sum of ICU and IMCU beds) per 100,000 population. We performed an exploratory analysis for trend relationships between change in bed capacity from 2017 to 2022 expressed as a percentage and estimated excess mortality due to the pandemic using Spearman's correlation for middle-income economies and high-income economies. We then adjusted the analyses for the reported number of COVID-19 cases as well as deaths. We considered a p value of less than 0.05 to be statistically significant. We performed analyses using IBM SPSS Statistics for Windows (version 20.0; IBM Corp., Armonk, NY).

Role of the funding source
This research did not receive any specific grant.

Results

Out of the participating countries and regions, 12 were in the middle-income category (Bangladesh, India, Iran, Kazakhstan, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, and Sri Lanka, and Thailand), and seven were in the high-income category (Hong Kong, Japan, Oman, Saudi Arabia, Singapore, South Korea, and Taiwan) (eTable 2, Appendix pp 38).

All countries and regions have ICUs, but Sri Lanka does not have IMCUs (eTable 3, Appendix pp 39). All countries and regions have an understanding or definitions of an ICU and an IMCU that are aligned with the WFSICCM definition except the Philippines (eTables 4 and 5, Appendix pp 40–42). Data on the number of IMCU beds in India, Kazakhstan, Malaysia, Mongolia, Saudi Arabia, South Korea, and Thailand are unavailable (eTable 3, Appendix pp 39). The mix of sources used to tabulate critical care bed numbers included official government censuses or contacts for 15 countries and regions, counting through personal contacts for 10, extrapolation of data for 7, national critical care societies for 2, and other means for 1. Details on approaches used to obtain data on critical care and acute hospital bed numbers and their timelines and limitations are described in eTables 6–9, Appendix pp 43–48.

In the current study, there were cumulatively 9.4 critical care beds per 100,000 population in the studied countries and regions (233,423 beds for a total population of 2,488,791,003) (Table 1). The number of critical care beds per 100,000 population per country and region was numerically though not statistically significantly lower in middle-income economies (median 6.6, IQR 2.2–13.3) than in high-income economies (median 13.9, IQR 10.7–21.7) (p = 0.063). This number ranged from 1.0 per 100,000 population in Myanmar to 34.4 per 100,000 population in Kazakhstan. Across 10 countries where data were available, 10.9% of critical care beds were in single rooms (median 5.0%, IQR 2.2%–10.8% in middle-income economies versus median 20.3%, IQR 18.8%–47.1% in high income economies, p = 0.030), and 5.3% of critical care beds had negative pressure (median 0.7%, IQR 0.3%–1.6% in middle-income economies versus median 18.5%, IQR 10.7%–28.3% in high income economies, p = 0.030) (Table 2). There was a large variation in the proportion of critical care beds in the public versus the private sector (eTable 10, Appendix pp 49), in urban versus rural areas (eTable 11, Appendix pp 50), and with respect to the number of acute hospital beds (eTable 12, Appendix pp 51) across countries and regions.

In the first Asian ABC study in 2017, there were cumulatively 3.0 critical care beds per 100,000 population in the studied countries and regions (77,576 beds for a total population of 2,282,012,832) (eTable 13, Appendix pp 51). The number of critical care beds per 100,000 population per country and region was statistically significantly lower in middle-income economies (median 2.6, IQR 1.7–7.8) than in high-income economies (median 11.4, IQR 7.3–22.8) (p = 0.005).

From 2017 to 2022, there was a cumulative 175.9% increase in the number of critical care beds per 100,000 population (p = 0.003), and a cumulative 200.9% increase in the absolute number of critical care beds (p < 0.001) in the studied countries and regions (eTable 13, Appendix pp 52 and Fig. 1). All but three countries and regions saw an increase in critical care beds per 100,000 population: Myanmar saw a decrease in the absolute number of beds, while Oman and Saudi Arabia saw an increase in the absolute number that was proportionately smaller than the increase in population size. The increase in the number of critical care beds per 100,000 population per country and region was numerically though not statistically significantly higher in middle-income economies (median +49.3%, IQR +11.6% to +186.6%) than in high-income economies (median +2.7%, IQR −4.3% to +47.1%) (p = 0.063).

The median number of COVID-19 cases per 100,000 population in 2020 and 2021 was 2617.0 (IQR 1338.3–6737.1) in middle-income economies and 1395.7 (IQR 172.5–4718.7) in high-income economies (p = 0.205). There were higher reported COVID-19 mortality (median 21.5, IQR 15.8–36.3 versus median 7.0, IQR 2.0–12.0, p = 0.014) and higher estimated excess mortality (median 117.8, IQR 81.8–152.6 versus median 11.5, IQR −5.9 to 46.4, p = 0.011) per 100,000 population in middle-income economies than high-income economies (eTable 14, Appendix pp 53). In the exploratory analysis, there was a correlation between estimated excess mortality per 100,000 population and the percentage increase in critical care beds per 100,000 population from 2017 to 2022 in middle-income economies (r = 0.741, p = 0.006) but not in high-income economies (r = 0.357, p = 0.432). This correlation in middle-income economies held after adjustment for the number of COVID-19 cases and deaths (r = 0.688, p = 0.028).

Discussion

This is the largest international survey of critical care bed capacity of the COVID-19 era. We found a 175.9% increase in the number of critical care beds per 100,000 population from before to during the pandemic (2017–2022), with 16 out of 19 studied countries and regions seeing an expansion of capacity. Much of this increase was attributed to middle-income economies.

The optimal number of critical care beds at the population level is unclear, with proponents of more beds citing evidence associating capacity strain with inappropriate rationing and increased mortality, and

Country and region	ICUs	ICU beds	IMCUs	IMCU beds	Critical care beds[a]	Critical care beds/100,000 population
Middle-income countries and regions						
Bangladesh	190	2177	88	738	2915	1.8
India	[b]	151,196	[b]	[b]	151,196	10.9
Iran	1850	12,119	4	35	12,154	14.0
Kazakhstan	652	5956	16	720	6676	34.4
Malaysia	82	1413	[b]	[b]	1413	4.2
Mongolia	47	375	54	127	502	15.6
Myanmar	73	403	49	171	574	1.0
Nepal	185	1773	123	971	2744	8.9
Pakistan	220	3969	118	1128	5097	2.1
Philippines	450	3096	2	[b]	3096	2.7
Sri Lanka	108	549	0	0	549	2.4
Thailand	629	7853	[b]	[b]	7853	11.3
High-income countries and regions						
Hong Kong	26	309	58	247	556	7.6
Japan	634	5733	770	7618	13,351	10.7
Oman	42	241	67	284	525	13.9
Saudi Arabia	1000[c]	7665	[b]	[b]	7665	21.7
Singapore	42	343	27	350	693	11.7
South Korea	876	9123	[b]	[b]	9123	17.6
Taiwan	369	5938	59	803	6741	29.0

[a]Critical care beds refer to the sum of IMCU beds and ICU beds. [b]Data not available. [c]Number of ICUs estimated from the number of ICU beds.

Table 1: **Number of critical care beds.**

proponents of less beds warning against over-servicing and unaffordable healthcare.[17–19] The drastic increase in critical care beds we found over a mere five years suggests that in general, governments, healthcare systems, and hospitals did not subscribe to the less-is-more argument. While our data centred around 2017 and 2022, and not immediately before the pandemic in early 2020, we are aware from discussions with our national coordinators that the spike in bed numbers was predominantly in response to COVID-19. Indeed, in the first months of the pandemic, nations rushed to strengthen critical care capacity, with many introducing surge beds and converting non-ICU areas for the critically ill.[1,4,7,20,21] Of note, however, our national coordinators commenced data collection in April 2022, more than two years after the outbreak in Wuhan and

Country and region[a]	Single-room ICU beds (%)	Negative-pressure ICU beds (%)	Single-room IMCU beds (%)	Negative-pressure IMCU beds (%)	Single-room critical care beds (%)[b]	Negative-pressure critical care beds[b] (%)
Middle-income countries and regions						
Bangladesh	60 (2.8)	21 (1.0)	0 (0)	0 (0)	60 (2.1)	21 (0.7)
Iran	258 (2.1)	7 (0.1)	12 (34.3)	0 (0)	270 (2.2)	7 (0.1)
Malaysia	338 (23.9)	156 (11.0)	[c]	[c]	338 (23.9)	156 (11.0)
Mongolia	25 (6.7)	10 (2.7)	0 (0)	0 (0)	25 (5.0)	10 (2.0)
Myanmar	81 (20.1)	3 (0.7)	0 (0)	0 (0)	81 (14.1)	3 (0.5)
Nepal	203 (11.4)	30 (1.7)	0 (0)	0 (0)	203 (7.4)	30 (1.1)
Thailand	1559 (19.9)	974 (12.4)	[c]	[c]	1559 (19.9)	974 (12.4)
High-income countries and regions						
Hong Kong	105 (34.0)	101 (32.7)	8 (3.2)	2 (0.8)	113 (20.3)	103 (18.5)
Oman	82 (34.0)	15 (6.2)	9 (3.2)	0 (0)	91 (17.3)	15 (2.9)
Singapore	325 (94.8)	149 (43.4)	187 (53.4)	114 (32.6)	512 (73.9)	263 (38.0)

[a]Data not available for India, Pakistan, the Philippines, Sri Lanka, Kazakhstan, Japan, Saudi Arabia, South Korea, and Taiwan. [b]Critical care beds refer to the sum of IMCU beds and ICU beds. [c]Data not available.

Table 2: **Single-room and negative-pressure critical care beds.**

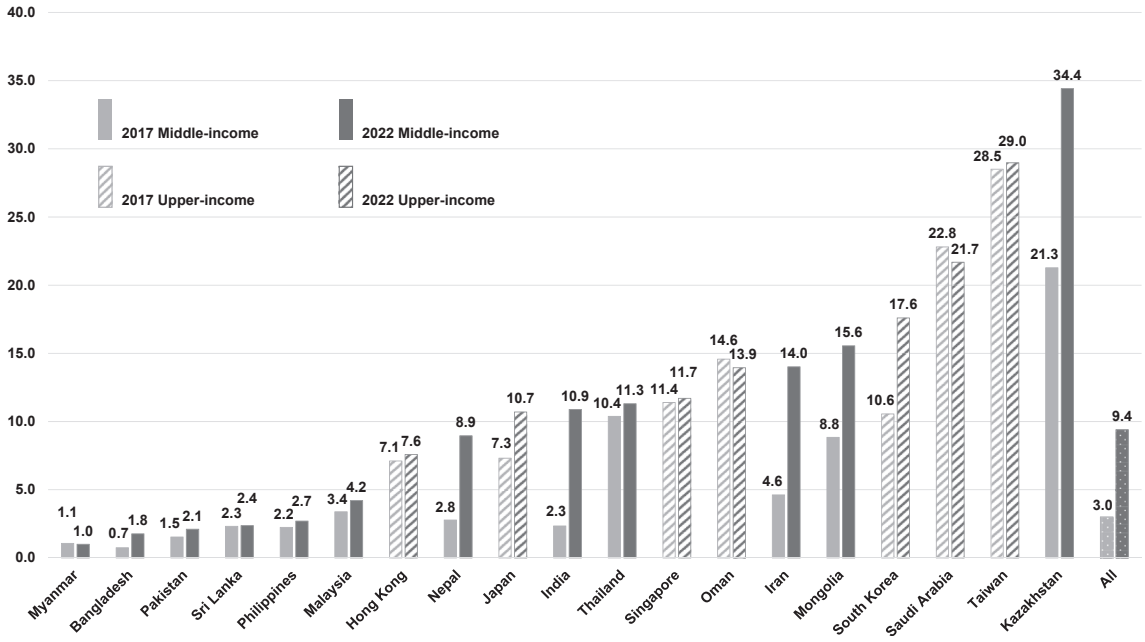

Fig. 1: Number of critical care beds per 100,000 population in 2017 and 2022. Saudi Arabia saw a seeming reduction in capacity only because paediatric and neonatal units were teased out in national data in 2022 but not 2017—they were hence excluded in 2022 as per the current study protocol.

when the Delta and Omicron waves had begun to subside in most parts of the world, including Asia. Given that our study methodology required that critical care beds only be counted if they met the WFSICCM definition and were open and staffed (an exception was made for the Philippines), it is likely that our findings reflect a situation that had reached a steady state in the pandemic.

Reports have been published on efforts by some of the countries and regions we studied to cope with inadequate critical care capacity, including for example the rapid development of a national guideline for resource allocation in Thailand,[22] providing invasive mechanical ventilation in IMCUs and not just ICUs as a matter of routine in Japan,[23] and rapid discharge of less sick patients from ICUs in Mongolia.[24] Our findings add to the literature through demonstrating how the pandemic triggered various countries and regions to play catch-up for sheer bed capacity, with the gap between the number of beds per 100,000 population between middle-income and high-income economies narrowing substantially from 2017 (median of 2.6 versus 11.4) to 2022 (median of 6.6 versus 13.9). This was arguably necessary, when considering the substantially lower number of beds in middle-income economies than in high-income ones, and the higher number of COVID-19 cases and deaths as well as estimated excess mortality in middle-income economies than in high-income ones.

Estimated excess mortality reflects all-cause mortality, not just from COVID-19 but also from other non-COVID acute and chronic disease that did not lighten in general during the pandemic.[15] It is therefore a marker of strain to healthcare systems. Although we found a correlation between estimated excess mortality from 2020 to 2021 and the increase in critical care beds between 2017 and 2022, specifically in middle-income and not high-income economies, it should be emphasised that correlation implies neither cause nor effect. While several studies during the pandemic have shown a link between a mismatch between critical care demand and supply and more deaths,[25,26] excess mortality may be influenced by multiple other critical care factors such as quality of care and non-critical care factors such as population characteristics, social distancing, vaccination status, and outpatient management. We can only hypothesise that healthcare systems most affected by excess deaths as a result of a confluence of adverse contributing factors were attempting to mitigate the situation by adding more critical care beds.

The degree of heterogeneity that exists both for critical care bed capacity in 2022 and for the percentage increase in capacity from 2017 to 2022 is striking. Difference circumstances may explain the three countries where an increase in capacity was not captured: Myanmar suffered from unrest in recent years; Oman had reconverted many of their recently-added critical care beds back to their original status in general and

other wards as its COVID-19 situation had stabilised by the time data collection commenced; and Saudi Arabia was only able to tease out paediatric and neonatal units from their government data as required by the study protocol in 2022 and not 2017. Myanmar, Bangladesh, Pakistan, and Sri Lanka continued to have fewer than 2.6 beds per 100,000 population in 2022, and Myanmar actually had fewer beds during than before the pandemic. In addition, just as a report published by our group in 2016 had highlighted the lack of pandemic-ready beds in Asia,[27] our current study found that only 1 in 10 beds were in single rooms and only 1 in 20 beds had negative pressure in 2022, with the proportions being even smaller in middle-income economies.

Our study has several limitations, most of which relate to the fact that counting the number and type of critical care beds during the pandemic was extremely arduous for some countries and regions. First, multiple engagements notwithstanding, we were unable to find national coordinators from four countries represented in the first Asian ABC study from 2017, including from China and Indonesia where the scale of the study was deemed too large.[28] Second, a few countries and regions could only provide data from slightly before or after the year 2022. Variation in complexity and methods of data collection existed across countries and regions, the result of which was heterogeneity in the time taken to tabulate results. Third, despite our best attempts, data on IMCU, single-room, and negative-pressure beds were categorically unavailable for 32%, 47%, and 47% of countries and regions, respectively, and in the interest of ensuring timely publication of our findings we opted to forego these results rather than spend more time on data collection. Fourth, although our data are centred around the year 2022 when the pandemic had reached a relatively steady state, we do not know the exact nature of each and every critical care bed counted, including whether they were new beds created within or beyond existing ICUs, IMCUs, and hospitals. Our results also do not reveal the number of beds that had already been closed or converted for other uses due to stabilisation of the outbreaks in various countries and regions prior to 2022. Indeed, now that the World Health Organization has declared the end to COVID-19 as a global health emergency in May 2023,[8] we are unable to state with any certainty if the recorded beds added to the various healthcare systems will be sustained. Given that the aim of our study was to compare capacity before and during the pandemic, documentation of post-pandemic capacity will require another investigation.

We now offer several reflections on our findings. First, many countries and regions clearly have the ability to increase critical care bed capacity when there is a burning platform like a pandemic. However, and despite an inclusion criterion being beds that were open and staffed, what remains unclear is the quality of care provided with these beds and their impact on patient outcomes, which are dependent on multiple factors such as the number of staff versus workload, training of healthcare workers, processes and infrastructure for infection prevention, and availability of equipment, consumables, and pharmaceuticals.[1,7,17,19,29] Moreover, the risk of unintended consequences when resources are diverted from other areas of hospitals and healthcare to critical care cannot be dismissed. Second, several countries and regions, especially those in middle-income settings, continue to have a worryingly low number of critical care beds per 100,000 population and should refrain from closing the newly-opened beds post-pandemic if at all possible. Meanwhile, most countries and regions continue to have insufficient single-room and negative-pressure beds. All of these point to the fact that unless more is done to close these gaps, many healthcare systems are likely to struggle, not just during future pandemics, but in peacetime. Finally, just as with the original Asian ABC study from 2017,[9] we have once again shown that it is possible to record critical care bed capacity, even in large countries and regions. We urge authorities across the world to continue to do so, as we inevitably move from the COVID-19 pandemic towards the next devastating one. Such data provide benchmarks for comparisons across nations and justifications for strengthening of capacity for those which are lagging behind.

In conclusion, critical care bed capacity in relation to population size in the studied Asian countries and regions increased close to three-fold from 2017 to 2022. Much of this increase was attributed to middle-income economies, but substantial heterogeneity exists.

Contributors

JP designed the study. All authors participated in data collection. JP and YHC accessed and verified the data and did the statistical analysis. JP wrote the first draft of the manuscript. All authors revised the manuscript, and read and approved the final version before submission. All authors accept responsibility for submitting the final manuscript for publication.

Data sharing statement

All data provided in the study questionnaires are available immediately after publication upon request.

Declaration of interests

We declare no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2023.100982.

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