Original Article
Yonsei Med J 2021 Dec;62(12):1098-1106
https://doi.org/10.3349/ymj.2021.62.12.1098
Yonsei Medical Journal
YMJ
pISSN: 0513-5796 · eISSN: 1976-2437

Discrepancy between the Demand and Supply of Intensive Care Unit Beds in South Korea from 2011 to 2019: A Cross-Sectional Analysis

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Purpose: Intensive care unit (ICU) bed availability is key to critical patient care. In many countries, older patients generally account for a significant proportion of hospitalizations and ICU admissions. Therefore, considering the rapidly increasing aging population in South Korea, it is important to establish whether the demand for critical care is currently met by available ICU beds.
Materials and Methods: We evaluated a 9-year trend in ICU bed supply and ICU length of stay in South Korea between 2011 and 2019 in a population-based cross-sectional analysis, using data from the Korean Health Insurance Review & Assessment Service and Statistics database. We described the changes in ICU bed rates in adult (≥20 years) and older adult (≥65 years) populations. ICU length of stay was categorized similarly and was used to predict future ICU bed demands.
Results: The ICU bed rate per 100000 adults increased from 18.5 in 2011 to 19.5 in 2019. In contrast, the ICU bed rate per 100000 older adults decreased from 127.6 in 2011 to 104.0 in 2019. ICU length of stay increased by 43.8% for adults and 55.6% for older adults. In 2019, the regional differences in the ICU bed rate nearly doubled, and the ICU length of stay increased six-fold. The ICU bed occupancy rate in South Korea is expected to rise to 102.7% in 2030.
Conclusion: The discrepancy between the demand and supply of ICU beds in South Korea requires urgent action to anticipate future ICU demands.

Key Words: Bed supply, cross-sectional studies, Health Insurance Review & Assessment Service, intensive care unit, occupancy, population

INTRODUCTION

Access to critical care is a crucial element in contemporary healthcare systems.[1] The demand for critical care capacity is increasing worldwide due to the significant aging of populations with the accompanying increase in associated comorbidities, the development of life-sustaining treatment modalities, and the changes in perception regarding the role of intensive care units (ICUs).[2,3] In many countries, the median age of the entire population admitted to the ICU is currently >65 years.[4] Recent studies have revealed that increased ICU admission is attributable to older patients (>80 years).[5,6] As these patients account for a significant proportion of hospitalizations and ICU treatment days, this increase may profoundly affect the utilization of ICU resources.[6,7]

The growing demand for ICU resources can only be met by increasing the total capacity of ICUs.[8,9] ICU bed shortage is associated with a greater risk of early readmission and higher patient refusal rates.[10,11] As the aging population is expected to consistently create a high demand for critical care,[12] an accurate prediction of future demand levels is necessary to avoid in-

Received: June 17, 2021 **Revised:** August 18, 2021
Accepted: September 27, 2021
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•The authors have no potential conflicts of interest to disclose.

sufficient supply. In Australia, Corke, et al.[13] predicted that the expected proportion of patients aged >80 years admitted to ICUs would increase to 26.3% by 2030.

South Korea is one of the world's fastest aging countries.[14] Park, et al.[15] investigated the ICU admission rate, total cost, and utilization of management procedures, such as mechanical ventilation, renal replacement therapy, and extracorporeal membrane oxygenation in South Korea, and showed that these variables increased from 2009 to 2014. However, there has been no report regarding the relationship between the increase in the number of ICU beds and the increase in utilization of ICU facilities. Therefore, in this study, we investigated the trends in ICU bed supply and duration of ICU stay from 2011 to 2019 in the adult population as follows: 1) classifying the population into adults and older adults, 2) evaluating changes in the number of ICU beds and duration of ICU stay each year, 3) evaluating geographical differences in the number of ICU beds and duration of ICU stay, and 4) predicting future ICU demands.

MATERIALS AND METHODS

Data source

We performed a cross-sectional study of the ICU bed supply and duration of ICU days from 2011 to 2019 in South Korea. We obtained data on ICU admission from the Health Insurance Review and Assessment Service (HIRA) database (Supplementary Table 1, only online). This database encompasses South Korea's entire population, including the number of hospitals, hospital beds, and ICU beds, age of patients, and duration of ICU stay (ICU length of stay). Population data were obtained from Statistics Korea. Since the records did not contain any identifying information, this study was exempted from ethical review by the Gachon University Gil Medical Centre's ethics review board (GFIRB2021-194).

Definitions and variables

We defined hospitals as tertiary general hospitals and general hospitals. Other hospitals were excluded as their ICUs do not typically provide critical care. Hospital beds were defined as licensed hospital beds. ICU beds included an aggregation of all ICU beds, excluding neonatal ICU beds (Fig. 1). In South Korea, pediatric ICUs are extremely limited, and most pediatric patients who require intensive care are admitted to the general ICUs. The available length of stay was calculated as the total number of beds multiplied by 365 days, assuming that every bed was available for daily use.[16] Occupancy rates were defined as the ICU length of stay divided by the available ICU length of stay.

The changes in ICU beds were described at the national level and in a 16-administrative-district level with two population groups: adults (aged ≥20 years) and older adults (aged ≥65 years). South Korea comprises of 17 administrative districts.

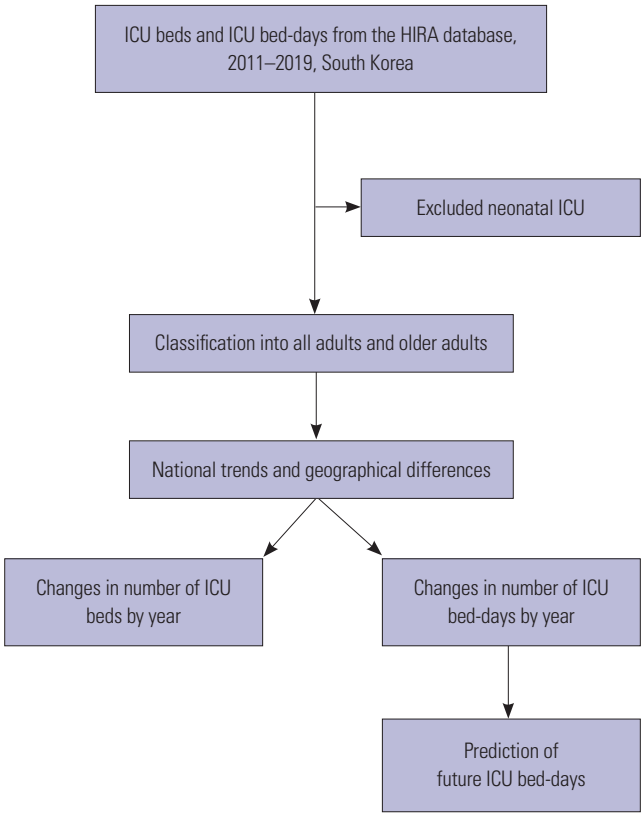

Fig. 1. Flow chart of the study design. HIRA, Health Insurance Review and Assessment; ICU, intensive care unit.

However, due to the relocation of central administrative agencies in 2012, the Sejong-si region did not have an ICU hospital; therefore, its data was merged with that of the adjacent administrative district, Chungcheongnam-do. The annual ICU bed rates were calculated as population-based rates by weighing raw values to national and administrative district populations for each year in the study. Annual changes in counts of ICU length of stay in national and administrative districts are described for both adults and older adults. Since the number of admissions do not represent the utilization of ICU resources, we evaluated occupied ICU length of stay.

Statistical analysis

Data were analyzed using R (version 3.6.0, Vienna, Austria). We examined temporal trends in ICU bed number growth at the national and regional levels. At the national level, we summarized the annual number of hospitals, hospital beds, ICU beds, adult and older adult population sizes, ICU beds per adult population, ICU beds per older adult population, ICU length of stay for the whole population, ICU length of stay per adult population, ICU length of stay per older adult population, and occupancy rates. At the regional level, we calculated the number of ICU beds, ICU beds per adult population, ICU beds per older adult population, ICU length of stay per adult population, and ICU length of stay per older adult population.

We reported the temporal trends in the national and administrative district averages for each variable using the Joinpoint regression analysis (version 4.8.0.1; National Cancer Institute).[17] Trends spanning from 2011 to 2019 were computed as the mean annual percentage change. Shorter time segment trends were computed as the annual percentage change. This annual percentage change and the mean annual percentage change for each variable were expressed as the percentage change with a 95% confidence interval (CI). All hypothesis testing was two-tailed, and statistical significance was set at $p<0.05$.

The geographic inequality in ICU beds and ICU length of stay was quantified at the administrative district level by comparing the 10th and 90th percentiles for each variable among all administrative districts.[18] The difference between these two percentiles was used to indicate the degree of absolute geographic inequality, representing the absolute magnitude of the gap between high- and low-prescribing administrative districts for each variable. The ratio between the 90th and 10th percentiles was used to assess the relative degree of geographic inequality between administrative districts for each variable.

We projected the ICU length of stay in 2020, 2030, and 2040 based on the national and regional ICU length of stay between 2011 and 2019, using a time-series statistical procedure, the Autoregressive Integrated Moving Average (ARIMA) model.[19] The 95% CI of all population parameters was also derived. The R package "forecast" was used for the analysis.

RESULTS

National temporal trends

Temporal trends in ICU bed number growth and ICU length of stay are shown in Table 1. From 2011 to 2019, there was an increase in the number of hospitals providing critical care in South Korea (from 319 to 356; 11.6% growth), hospital beds (from 137392 to 152977; 11.3%), and ICU beds (from 7274 to 8344; 14.7%). In 2011, the adult population in South Korea was 39377310, resulting in an overall rate of 18.5 ICU beds per 100000 persons. By 2019, the adult population had increased to 42723937, which resulted in an overall rate of 19.5 ICU beds per 100000 adults. The older adult population was 5700972 in 2011, resulting in an overall rate of 127.6 ICU beds per 100000 older adults. In 2019, the older adult population increased to 8026915, resulting in a substantial decrease to 104.0 per 100000 population. In 2011, the ICU length of stay for the adult population were 1493585 days, which increased to 2148167 days in 2019. The ICU length of stay for the older adult population were 903638 days in 2011, which increased to 1406104 days in 2019. There was an increase in occupancy rate by 42.8%, from 58.7% in 2011 to 72.9% in 2019.

Regional differences in ICU bed-numbers

Over 9 years, the ICU bed rate per 100000 adult population increased by a mean and standard deviation (SD) of 7.4% (10.7%) among administrative districts, while the absolute geographic inequality decreased from 12.0 in 2011 to 11.7 in 2019, respectively. However, the relative geographic inequality was not different (1.8) (Table 2). With regards to the 16 administrative districts, the Joinpoint analysis indicated that the ICU bed rate per 100000 adult population increased in eight administrative districts (50.0%), and no significant difference was observed in the eight administrative districts (50.0%). The most significant increase in the annual average percentage change in the ICU bed rate per 100000 adult population was 25.8%, observed

Table 1. Hospitals, Hospital Beds, ICU Beds, Population, and Occupancy Rate between 2011 and 2019

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Hospitals	319	332	324	330	337	341	344	353	356
Hospital beds	137392	138556	140384	144438	146803	148808	150160	152104	152977
ICU beds	7274	7281	7368	7497	7692	7897	7998	8135	8344
ICU bed proportion	0.053	0.053	0.052	0.052	0.052	0.053	0.053	0.053	0.055
Population aged ≥20 years (100 K)	393.8	398.3	402.9	407.5	412.1	416.5	420.4	423.9	427.2
Population aged ≥65 years (100 K)	57.0	59.8	62.5	65.2	67.8	70.0	73.6	76.5	80.3
Hospital beds per 100 K									
Population aged ≥20 years	348.9	347.8	348.5	354.5	356.2	357.3	357.2	358.8	358.1
Population aged ≥65 years	2410.0	2317.0	2245.8	2215.1	2166.8	2127.1	2041.3	1988.2	1905.8
ICU beds per 100 K									
Population aged ≥20 years	18.5	18.3	18.3	18.4	18.7	19.0	19.0	19.2	19.5
Population aged ≥65 years	127.6	121.8	117.9	115.0	113.5	112.9	108.7	106.3	104.0
ICU length of stay (K)									
Population aged ≥20 years (K)	1493.6	1568.1	1628.0	1704.9	1849.1	1965.0	2037.4	2129.1	2148.2
Population aged ≥65 years (K)	903.6	971.1	1012.0	1065.5	1170.5	1248.1	1314.6	1394.1	1406.1
Occupancy rate (%)	58.7	61.4	63.0	64.8	68.3	70.6	72.2	74.0	72.9

ICU, intensive care unit; K, thousand.

https://doi.org/10.3349/ymj.2021.62.12.1098

in Incheon (95% CI, 2.4–3.6) (Fig. 2A and Supplementary Table 2, only online). Furthermore, the highest ICU bed rates per 100000 adult population were found in Jeju-do (29.4) in 2011 and Gwangju (29.0) in 2019. The lowest ICU bed rates per 100000 adult population were found in Gyeongsangnam-do, 13.5 and 14.3 in 2011 and 2019, respectively (Fig. 2A and Supplementary Table 2, only online).

There was a decrease in the ICU bed rates per 100000 older adults by a mean (SD) of 16.4% (9.7%) among administrative districts. The absolute geographic inequality decreased from 100.9 to 57.9 from 2011 to 2019, and the relative geographic inequality decreased from 2.2 to 1.7 (Table 2). Joinpoint analysis indicated that the ICU bed rate per 100000 older adults decreased in 11 administrative districts (68.8%). The most significant decrease in the annual average percentage change in ICU bed rate per 100000 adult population was observed in Jeju-do: 4.1% (95% CI, -6.9 to -1.4) (Supplementary Table 3, only online). The highest ICU bed rates per 100000 older adult population were found in Gwangju; they were 199.4 and 172.9 in 2011 and 2019, respectively. The lowest ICU bed rates per 100000 people in the older adult population were found in Chungcheongnam-do; they were 74.9 and 69.5 in 2011 and 2019, respectively (Fig. 2B and Supplementary Table 3, only online).

Regional differences in ICU length of stay

The ICU length of stay for the adult population increased by a mean (SD) of 62.2% (54.0%) among administrative districts, while the absolute geographic inequality increased from 180.1 in 2011 to 235.9 in 2019. However, the relative geographic inequality decreased from 6.5 to 5.7 (Table 2). Joinpoint analysis indicated that the ICU length of stay for the adult population increased in 15 administrative districts (93.8%), and no significant difference was observed in the one administrative district (6.2%). The most significant increase in the annual average percentage change in ICU length of stay in the adult population was 16.6% in Gwangju (95% CI, 11.1–22.5) (Supplementary Table 4, only online). The longest ICU length of stay for the adult population was observed in Seoul; it was 415757 days and 508129 days in 2011 and 2019, respectively. In contrast, the shortest ICU length of stay for the adult population was 30435 days in Ulsan in 2011 and 34452 days in Jeju-

Table 2. Trends in ICU Beds and Length of Stay for Administrative Districts in South Korea, 2011–2019*

Characteristics by year	Mean (SD) [median]†	Percentile		Geographical inequality		Administrative districts with statistically significant change		
		10th	90th	Absolute‡	Relative§	Decrease¶	Steady‖	Increase**
ICU bed rate per 100 K of population ≥20 years								
2011	19.5 (5.0) [18.0]	14.3	26.2	12.0	1.8			
2019	20.8 (4.6) [20.9]	14.5	26.1	11.7	1.8			
Change (2011–2019), %	7.4 (10.7) [5.2]	0.4	19.2					
Trend (2011–2019), n (%)						0 (0)	8 (50.0)	0 (50.0)
ICU bed rate per 100 K of population ≥65 years								
2011	130.9 (40.8) [128.5]	85.6	186.5	100.9	2.2			
2019	107.0 (27.8) [99.5]	77.3	135.2	57.9	1.7			
Change (2011–2019), %	-16.4 (9.7) [-15.6]	-27.7	-7.1					
Trend (2011–2019), n (%)						11 (68.8)	5 (31.2)	0 (0)
ICU length of stay of population ≥20 years (K)								
2011	93.3 (108.3) [56.8]	32.7	212.7	180.1	6.5			
2019	134.2 (132.3) [89.0]	50.1	285.9	235.9	5.7			
Change (2011–2019), %	62.2 (54.0) [35.9]	18.4	130.3					
Trend (2011–2019), n (%)						0 (0)	1 (6.2)	15 (93.8)
ICU length of stay of population ≥65 years (K)								
2011	56.4 (59.6) [36.2]	21.4	127.1	105.7	5.9			
2019	87.9 (81.7) [61.4]	33.0	184.1	151.1	5.6			
Change (2011–2019), %	69.8 (52.4) [45.1]	23.2	136.0					
Trend (2011–2019), n (%)						0 (0)	1 (6.2)	15 (93.8)

ICU, intensive care unit; K, thousand.
*Total of 16 administrative districts were involved. Sejong-si was merged with Chungcheongnam-do; †Means were calculated from the values from 16 administrative districts. This mean does not reflect the value at the national level; ‡Absolute geographic inequality was calculated by subtracting the 10th percentile from the 90th percentile; §Relative geographic inequality was calculated as the ratio of the 90th percentile to the 10th percentile; ¶Indicates that a trend was significantly different from zero at the α=0.05 level (p<0.05) and that the mean annual percentage change had a negative value according to the Joinpoint regression analysis; ‖Indicates that a trend was not significantly different from zero at the α=0.05 level (p≥0.05) according to the Joinpoint regression analysis; **Indicates that a trend was significantly different from zero at the α=0.05 level (p<0.05) and that the mean annual percentage change had a positive value according to the Joinpoint regression analysis.

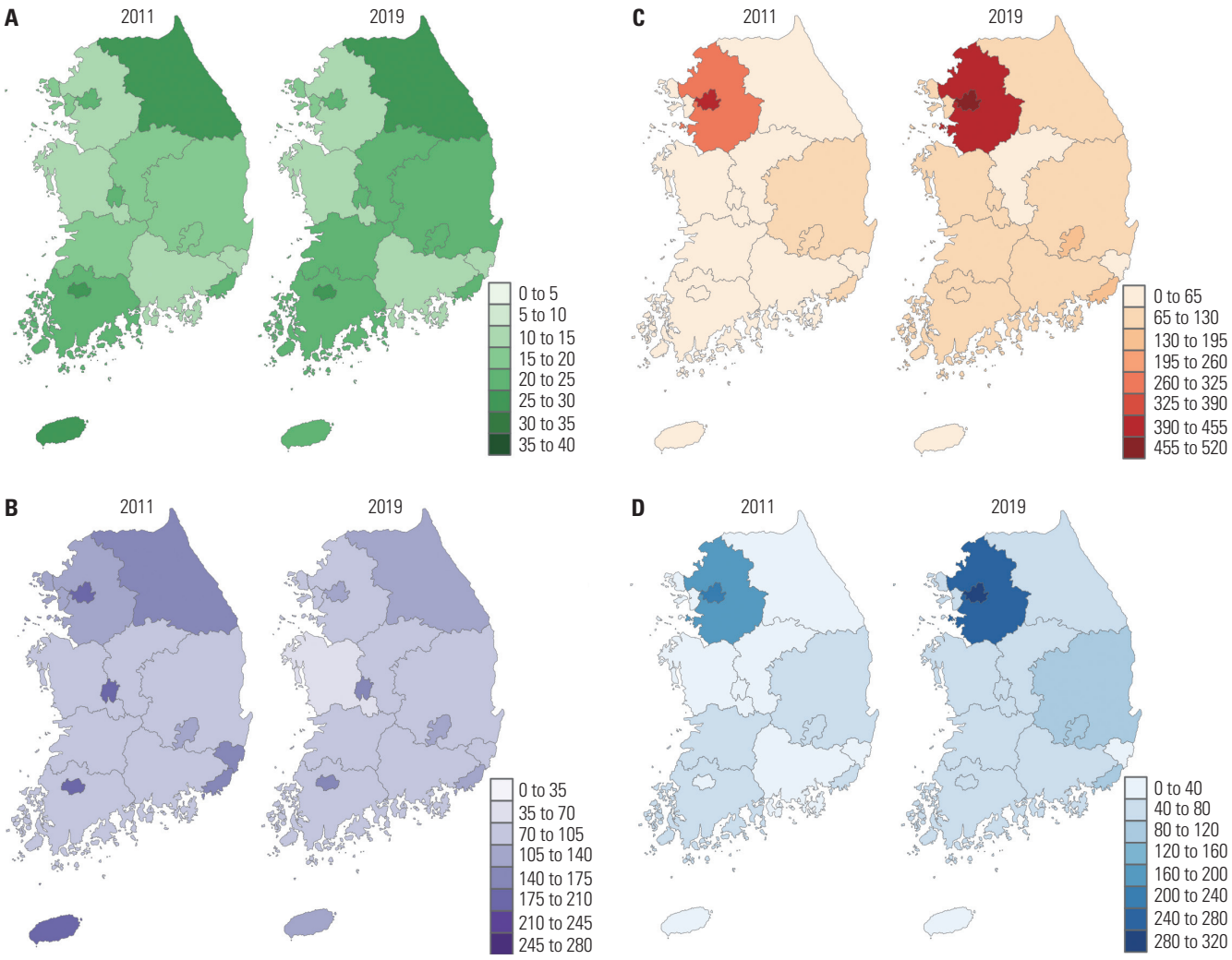

Fig. 2. Changes in ICU bed rate and ICU length of stay from 2011 to 2019. (A) ICU bed rate per 100000 of the adult population. (B) ICU bed rate per 100000 of the older adult population (100 K). (C) ICU length of stay of the adult population (×1000). (D) ICU length of stay of the older adult population (×1000). ICU, intensive care unit.

do in 2019 (Fig. 2C and Supplementary Table 4, only online).

The ICU length of stay in the older adult population increased by a mean (SD) of 69.8% (52.4%) among administrative districts from 2011 to 2019. The absolute geographic inequality increased from 105.7 in 2011 to 151.1 in 2019, while the relative geographic inequality decreased from 5.9 to 5.6 during this period (Table 2). Joinpoint analysis indicated that the ICU length of stay in the older adult population increased in 15 administrative districts (93.8%), while no significant difference was observed in one administrative district (6.2%). The most significant increase in the annual average percentage change in the ICU length of stay in the older adult population was observed in Gwangju, which was 15.9% (95% CI, 11–21.1) (Supplementary Table 5, only online). The largest numbers of ICU length of stay in the older adult population were 226281 days and 314548 days in 2011 and 2019, respectively; both of these numbers were observed in Seoul. The shorter ICU length of stay in the older adult population were 20117 days in Gwangju in 2011 and 20878 days in Jeju-do in 2019 (Fig. 2D and Supplementary Table 5, only online).

Future ICU demands in South Korea

Based on the ICU length of stay from 2011 to 2019 using the ARIMA model, we analyzed and predicted the ICU length of stay for the years 2020, 2030, and 2040. At a national level, the predicted ICU length of stay of the population aged under 45 years remained stable over the prediction period. However, the ICU length of stay for the population aged 45 years and older was predicted to increase. Specifically, the population aged ≥80 years was expected to account for the largest share of ICU length of stay by the year 2030 (Fig. 3A). Summing the total ICU length of stay for each age group provided the total number of expected ICU length of stay (Fig. 3B). In 2030, the ICU length of stay was expected to increase by 40.9%, to 3126800 days from 2219100 days in 2019 (Supplementary Table 6, only online). Assuming there is no change in the number of ICU

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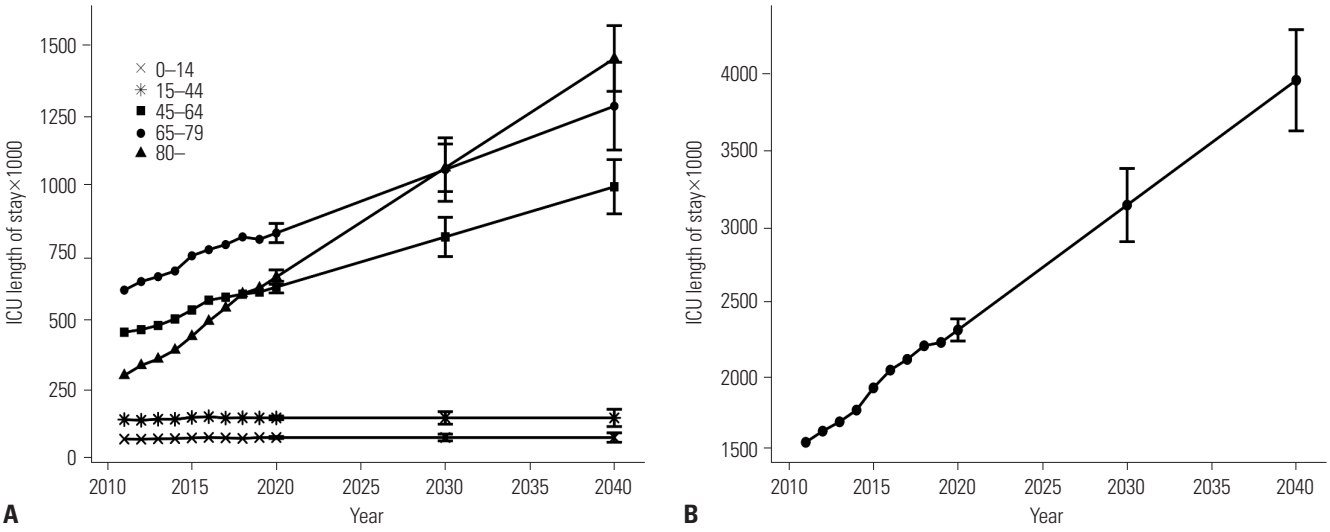

Fig. 3. ICU length of stay from 2011 to 2019 and projections for 2020, 2030, and 2040. (A) Each age group over time. (B) Sum of ICU length of stay in each age group. ICU, intensive care unit.

beds in 2030, the occupancy rate was calculated as 102.7% (95% CI, 94.7–110.6). A higher occupancy rate, particularly over 80%, has been reported to directly correlate with ICU and hospital mortality and ICU readmission within seven days of discharge.[20] Therefore, we calculated the predicted ICU beds in 2030, assuming an occupancy rate of 80%, which was 10708.2, representing a 28.3% increase from 2019. There were seven administrative districts (43.8%) at the regional level, predicting over 80% of an occupancy rate of lower 95% CI of predicted ICU beds in 2030 (Supplementary Table 6, only online). The administrative districts with expected occupancy rates of lower 95% CI of predicted ICU beds over 100% in 2030 included Daegu (104.1%), Chungcheongnam-do (112.7%), and Gyeongsangnam-do (103.0%).

DISCUSSION

This study demonstrated the changes in the number of ICU beds and duration of ICU stay at a national and administrative district level over a 9-year period. The number of ICU beds available serve as a cornerstone for providing life-saving support for critically ill patients.[21] We investigated whether there was a discrepancy between the demand for critical care and ICU bed supply based on this concept. We showed that the number of hospitals providing critical care and their bed capacity increased nationally. Although the number of ICU beds and the ICU bed rate per adult population increased, the ICU bed rate per older adult population decreased over the 9 years of investigation. The ICU length of stay in the adult and older adult population increased during the same period. Moreover, a significant discrepancy was found between the supply and demand of ICU beds in the older adult population of South Korea.

In the United States, the number of acute care hospitals decreased, while the number of ICU beds substantially increased from 2000 to 2009 (15.1%).[22] The ICU bed rate for individuals aged ≥20 years remained constant, while that for individuals aged ≥65 years decreased by 2.0% over this period in the US. In South Korea, the number of ICU beds and ICU bed rate per adult population increased from 2011 to 2019 by 14.7% and 7.4%; however, ICU bed rate per older adult population decreased from 2011 to 2019 by 16.4%. The reason for this decline may be attributed to the aging of the population. The population of South Korea is aging rapidly, and the population aged 65 years or older is expected to comprise 20% of the total population by 2025.[23] In the US, the increase in the percentage of older adult patients affected ICU bed and specialist utilization.[7,9] In the Netherlands, the percentage of hospital admissions of older adults rose between 2005 and 2014; however, the percentage of ICU length of stay remained stable. In our study, the older adult population size and their ICU length of stay increased by 40.9% and 55.6%, respectively, from 2011 to 2019.

Our data also revealed some regional disparities in the number of ICU beds and ICU length of stay among the adult and older adult populations. The 90th percentile values of the ICU bed rate per adult population and per older adult population were 1.8 and 1.7 times higher than the value of the 10th percentile in 2019, respectively. Significant disparities in the ICU length of stay for the adult population and older adult population between administrative districts were noted in 2019 (5.7 and 5.6 times of the 90th percentile to the 10th percentile, respectively). We expressed the intensity of ICU bed rates and ICU length of stay visually using a map of South Korea (Fig. 2) and observed that areas with high-intensity ICU bed rates were different from those with high-intensity ICU length of stay. In 2019, the sum of the ICU length of stay of the adult population in two regions, Seoul and Gyeonggi-do, constituted 42.9% of the total ICU length of stay of the adult population (Supple-

mentary Table 3, only online) and 41.0% of the total ICU length of stay of the older adult population (Supplementary Table 5, only online). As the ICU beds of Seoul and Gyeonggi-do constitute 41.9% of the total number of ICU beds in South Korea, these regional disparities may reflect centralization within the healthcare system.

We projected future ICU demands using the ARIMA model, based on the ICU length of stay in the 9 years recorded in the HIRA database. This model has been adopted in previous studies to forecast the length of stay by analyzing the retrospective Medicare Health Maintenance Organization data[24] and the Australian and New Zealand Intensive Care Society Core Database,[13] which are structurally similar to the HIRA database. We predicted that ICU bed demands would surmount ICU bed supply in 2030, not only in Seoul and Gyeonggi-do, where healthcare resources are concentrated, but also in Daegu, Chungcheongnam-do, and Gyeongsangnam-do. Among them, Chungcheongnam-do and Gyeongsangnam-do have the lowest ICU bed rates per older adult population in 2019 (Supplementary Table 7, only online). Notably, as Chungcheongnam-do has the lowest hospital and ICU bed rate per older adult population nationally, the expansion of medical institutions providing critical care require special attention in this district. Furthermore, to resolve the centralization of healthcare resources and shortage of ICU beds, the ratio of ICU beds to total hospital beds specified in the medical law should be increased by at least 5% in administrative districts with a shortage of ICU beds.

Studies regarding ICU bed availability have been conducted extensively, revealing considerable variability worldwide,[9,25] even within individual countries.[22,26] In Europe, there were 11.5 critical care beds per 100000 population, with significant differences between countries (Germany: 29.2 and Portugal: 4.2).[25] There were 3.6 critical care beds per 100000 population in Asia, with marked differences according to the World Bank income classification, i.e., a median of 2.3 and 12.3 critical care beds per 100000 low- and high-income populations, respectively.[27] Among the high-income countries, in 2017, South Korea was ranked third-lowest after Japan (7.3) in terms of the number of ICU beds per population. Ohbe, et al.[28] reported that the 4-year mean ICU bed occupancy rate did not change from 2015 to 2018 in Japan. In contrast, our results revealed that the occupancy rate increased annually in South Korea.

The proportion of the older adult population is fast approaching 20% of the entire population of South Korea. However, the proportion of the population aged 65 years and older in Japan was already 23.1% in 2010.[29] There were attempts to reform the national healthcare system to accommodate the country's fast-aging population.[30,31] South Korea's national health insurance, which covers its whole population, utilizes fee-for-service payment with a contract-based healthcare reimbursement system.[32] The reimbursement rate is generally low, particularly the cost for ICU resources, and hospital administrators are reluctant to invest in ICU resources, including hospital beds.[33] Our study revealed that occupancy rate may exceed 100% in 2030 if the number of ICU beds remain the same.

This study had several limitations. First, we did not exclude pediatric ICUs. Since 2018, the HIRA has provided the number of adult ICU beds separately from pediatric ICU beds; but before 2018, it only provided a sum of pediatric ICUs and adult ICUs. However, as the ICU length of day of 0 to 14-year-old patients only comprised a small portion of the total ICU length of days, we believe this had an insignificant impact on the overall outcomes. Second, the occupancy rates were calculated by dividing the ICU length of stay by the number of available ICU length of stay. The term "available length of stay" indicates "potential" length of stay and is not derived from individual-level data. Third, day-based occupancy calculations can cause a misinterpretation of the hospital's capacity.[34] Fourth, our prediction of future ICU demands was based on a study over a relatively short period. Lastly, we did not consider the importance of personnel, such as intensivists and ICU nurses. Due to the high-quality care of intensivists and ICU nurses, ICU bed utilization can be increased. Increasing the number of ICU beds without expanding ICU personnel would not suffice in anticipating for the aging society in South Korea. However, we believe our results can be a precedent to suggest the importance of increasing ICU personnel.

In conclusion, our study may inform government organizations about the necessity of planning and preparing for future ICU demands and anticipating their short supply. Without implementing proper healthcare policies in the near future, the healthcare system in South Korea may collapse due to the shortage of ICU beds. Moreover, the situation may be worse in some administrative districts than in others. In today's climate, the COVID-19 pandemic has demonstrated how quickly ICU bed spaces can become insufficient; and if another situation similar to COVID-19 occurs, inevitable and adverse outcomes could affect South Korea's healthcare system. Therefore, reports at the individual level from individual hospitals and each administrative district should be published to help government organizations reform healthcare policies in South Korea.

ACKNOWLEDGEMENTS

This research was supported by grants from the Basic Science Research Program (NRF-2020R1A2C1102433) through the National Research Foundation of Korea Grant funded by the Korean government, Young Medical Scientist Research Grant through the Daewoong Foundation (DY20111P), and the Korea Medical Institute.

AUTHOR CONTRIBUTIONS

Conceptualization: Dai Sik Ko and Sang Tae Choi. Data curation: Noo Ree Cho and Dai Sik Ko. Formal analysis: Noo Ree Cho, Dai Sik Ko,

https://doi.org/10.3349/ymj.2021.62.12.1098

and Wol Seon Jung. Funding acquisition: Noo Ree Cho and Dai Sik Ko. Investigation: Noo Ree Cho, Hee Yeon Park, and Jin Mo Kang. Methodology: Noo Ree Cho, Jin Mo Kang, Dai Sik Ko, and Wol Seon Jung. Project administration: Sang Tae Choi. Resources: Noo Ree Cho and Sang Tae Choi. Software: Noo Ree Cho and Dai Sik Ko. Supervision: Sang Tae Choi. Validation: Wol Seon Jung and Hee Yeon Park. Visualization: Noo Ree Cho, Hee Yeon Park, and Jin Mo Kang. Writing—original draft: Noo Ree Cho. Writing—review & editing: Dai Sik Ko and Sang Tae Choi. Approval of final manuscript: all authors.

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https://doi.org/10.3349/ymj.2021.62.12.1098