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Characteristics and management of mechanically ventilated patients in South Korea compared with other high-income Asian countries and regions

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Background: This study investigated the characteristics of mechanically ventilated patients in South Korean intensive care units (ICUs).

Methods: We conducted a subgroup analysis of a multinational observational study. Data from 271 mechanically ventilated patients in South Korean ICUs were analyzed for demographics, ventilation practices, and mortality, and were compared with those of 327 patients from other high-income Asian countries.

Results: South Korean patients were older (mean age: 67 vs. 62 years, P<0.001) and had lower ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (255.5 vs. 306.2, P<0.001). South Korean ICUs exhibited higher patient-to-nurse ratios (2.6 vs. 1.9, P<0.001) and more beds per unit (20.5 vs. 16.0, P=0.017). The use of sufficient positive end-expiratory pressure for patients (PEEP) for acute respiratory distress syndrome (ARDS) was less frequent in South Korea (62.2% vs. 91.2%, P=0.005). Mortality rates were similar between South Korean patients and those in other high-income Asian countries (38.0% vs. 34.2%, P=0.401). Significant mortality predictors in South Korea included age ≥65 years (odds ratio [OR], 4.03; P=0.039) and a Sequential Organ Failure Assessment score ≥8 (OR, 2.36; P=0.031). The presence of respiratory therapists was associated with reduced mortality (OR, 0.52; P=0.034).

Conclusions: Despite higher age and patient-to-nurse ratios in South Korean ICUs, outcomes were comparable to those in other high-income Asian countries. The suboptimal use of sufficient PEEP with ARDS indicates potential areas for improvement. Additionally, the beneficial impact of respiratory therapists on mortality rates warrants further investigation.

Key Words: artificial respiration; Asia; intensive care unit; Korea; ventilator-induced lung injury

Original Article

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INTRODUCTION

Mechanical ventilation is a cornerstone of intensive care unit (ICU) management, crucial for reducing the labor of breathing and ensuring effective gas exchange in critically ill patients [1,2]. Despite its therapeutic benefits, mechanical ventilation must be approached with caution to prevent potential iatrogenic lung injuries [3-5]. Implementing lung-protective strategies, such as appropriate tidal volume settings and adjunctive therapies, is essential for mitigating risks and enhancing patient outcomes [6-9]. Optimal ventilatory management requires vigilant monitoring and timely interventions, which underscore the importance of well-resourced and expertly staffed ICUs [10-14].

To examine the current state of mechanical ventilation practices across Asian ICUs, the Asian Critical Care Clinical Trials (ACCCT) group undertook a comprehensive multinational observational study [15]. Encompassing 190 ICUs across 19 Asian countries, the study enrolled 1,408 patients undergoing invasive mechanical ventilation and revealed noteworthy insights into regional practices and challenges. The results reveal that low-tidal volume ventilation and adequate positive end-expiratory pressure (PEEP) were underused in patients with acute respiratory distress syndrome (ARDS) in Asia. Furthermore, the study found that country income, patient age, and illness severity were significant factors influencing the mortality rates of mechanically ventilated patients.

South Korea (hereafter, Korea), classified as a high-income country by the World Bank Group, had an average ICU bed availability of 17.6 ICU beds per 100,000 population in 2022, placing it in the upper-middle range among high-income Asian countries [16]. Despite that infrastructure, prior research has highlighted a significant shortage of intensivists in Korean ICUs. As of 2014, only 40 ICUs (29.4%) employed ICU specialists working a 5-day week [17]. A nationwide registry data study further revealed that merely 42.4% of patients were admitted to ICUs staffed by trained intensivists, with 57.8% of patients treated in units lacking such expertise [18].

Given those challenges, we conducted a subgroup analysis of the ACCCT group study [15] to better understand mechanical ventilation practices within Korean ICUs. Although practices can vary significantly among individual ICUs, prior studies have shown that ICU infrastructure is closely associated with a country's income level [19]. Therefore, we used data from the original ACCCT study to compare the mechanical ventilation practices in Korean ICUs with those in other high-income Asian countries. Our objectives were to describe patient demographics, evaluate current ventilation practices, and explore factors that influence mortality among mechanically ventilated patients in Korean ICUs, with a focus on identifying differences and similarities with other high-income Asian countries.

KEY MESSAGES

- Compared to other high-income Asian countries, South Korean patients were significantly older and had a lower mean ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen; however, they had a lower mean Sequential Organ Failure Assessment (SOFA) score.
- Despite these differences, the 28-day mortality rate did not differ significantly between South Korea and other high-income Asian countries.
- The suboptimal use of sufficient positive end-expiratory pressure for patients for acute respiratory distress syndrome highlights potential areas for improvement, and the beneficial impact of respiratory therapists on mortality warrants further investigation in South Korean intensive care units.

MATERIALS AND METHODS

This study was conducted in accordance with the principles of the Declaration of Helsinki. The Institutional Review Board of each participating hospital approved patient enrollment; primary approval was granted by the Institutional Review Board of Asan Medical Center (No. 2018-0865). It involved a secondary analysis of previously collected, de-identified data; therefore, the requirement for patient informed consent was waived.

Study Design and Data Collection

We accessed data from a multicenter cross-sectional study conducted by the ACCCT group, which included 91 ICUs from the high-income Asian countries of Brunei, Japan, Saudi Arabia, Singapore, Korea, and Taiwan. To analyze ICU characteristics and staffing, we compared Korean facilities with those from other high-income Asian countries and regions.

Specifically, we compared the type of hospital (public vs. private, teaching vs. non-teaching), type of ICU (general ICU, medical ICU, surgical ICU, and others), ICU practice model (open, co-management, and closed), number of beds per ICU, patient-to-nurse ratio, presence of a designated critical care attending physician, and availability of a respiratory therapist.

Using patient data from the ACCCT group study, Korean patients were compared with a pooled dataset of patients from other high-income Asian countries and regions (Brunei, Japan, Saudi Arabia, Singapore, and Taiwan). Subjects for whom the reason for mechanical ventilation was postoperation care were excluded from this analysis (Figure 1). We examined demographics, disease severity, reasons for mechanical ventilation, adjunctive treatments, mechanical ventilation practices, use of lung-protective strategies, and clinical outcomes.

The original ACCCT study enrolled patients older than 18 years who were undergoing invasive mechanical ventilation on the day of data collection. Patient characteristics and mechanical ventilation data were gathered at 10 AM on November 4, 2019, and clinical outcomes were tracked 28 days later, with final data collection at 10 AM on December 3, 2019. The detailed data collection protocol is described in the original study [15].

Suitable PEEP levels for ARDS patients are defined in the original ACCCT study, which adopted the ARDSNet study protocol [6]: PEEP ≥5 cm H_2O for FiO_2, 0.21–0.49; PEEP ≥8 cm H_2O for FiO_2, 0.50–0.59; PEEP ≥10 cm H_2O for FiO_2, 0.60–0.79; PEEP ≥14 cm H_2O for FiO_2, 0.80–0.99; and PEEP ≥18 cm H_2O for FiO_2, 1.0. In the ACCCT study, patients recorded with ARDS as the reason for mechanical ventilation and patients who met the Berlin criteria [20] were classified as having ARDS.

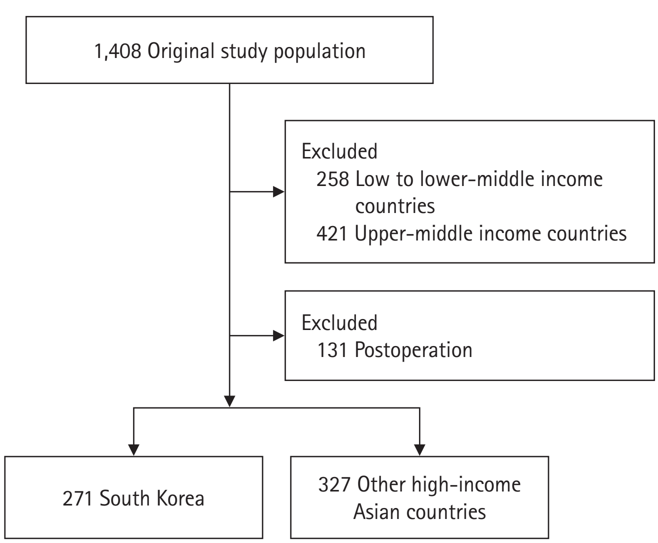

Figure 1. Flowchart of study population selection.

Statistical Analysis

We analyzed the data using proportions (percentages) for categorical variables and means±standard deviations for continuous variables. Fisher's exact test was used to compare categorical variables between groups, and the t-test was used to assess significant differences in continuous variables. To compare mortality rates, propensity score matching was used with the following variables: age, sex, body mass index (BMI), Sequential Organ Failure Assessment (SOFA) score, the ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (P/F ratio), ARDS, use of steroid or neuromuscular blocker, prone position, number of vasopressors used, patients enrolled from teaching hospital, and type of ICU (general, medical, surgical, and others).

To identify predictors of 28-day mortality, we conducted both univariable and multivariable logistic regression analyses. The potential factors were patient age; sex; BMI; SOFA scores; presence of ARDS; P/F ratio; use of low-tidal volume ventilation; limited plateau pressure; and use of vasopressors, steroids, neuromuscular blockers, analgesics, sedatives, antipsychotics, and bronchodilators. Additionally, we included hospital type (public vs. private), ≥20 ICU beds, patient-to-nurse ratio <2, closed ICU, availability of respiratory therapists, and presence of a designated critical care attending physician.

The multivariable logistic regression included variables with P-values <0.1 in the univariable analysis. Patients with missing outcome data were excluded from these analyses. For all the analyses, statistical significance was set at a P-value of 0.05. All analyses except propensity score matching were conducted using Stata version 16.1 (StataCorp.). The propensity score matching was performed with R software version 4.4.1 (R Foundation for Statistical Computing, 2024).

RESULTS

Demographic Characteristics

We enrolled 271 mechanically ventilated patients from 31 ICUs

Table 1. Demographic characteristics, reasons for mechanical ventilation, and adjunctive treatments of mechanically ventilated patients in South Korean intensive care units compared to other high-income Asian countries

Variable	South Korea (n=271)	Other high-income Asian countries (n=327)	P-value
Age (yr)	67±15	62±18	<0.001
Male sex	168 (62.0)	212 (64.8)	0.495
Body mass index (kg/m^2)	22.3±4.19	24.9±6.29	<0.001
SOFA score	7.44±4.36	8.47±4.98	0.008
P/F ratio	255.5±134.4	306.2±145.8	<0.001
ARDS	37 (13.7)	34 (10.4)	0.253
Reason for mechanical ventilation			
Airway protection	14 (5.2)	36 (11.0)	
Altered mental status	47 (17.3)	60 (18.3)	
Aspiration	23 (8.5)	18 (5.5)	
Cardiac arrest	30 (11.1)	50 (15.3)	
Congestive heart failure	12 (4.4)	12 (3.7)	
COPD exacerbation	9 (3.3)	5 (1.5)	
Hematemesis	2 (0.7)	3 (0.9)	
Hemoptysis	6 (2.2)	2 (0.6)	
Hypercapnic respiratory failure	40 (14.8)	25 (7.6)	
Hypoxic respiratory failure	57 (21.0)	50 (15.3)	
Neurologic cause	31 (11.4)	67 (20.5)	
Pneumonia	110 (40.6)	76 (23.2)	
Pulmonary edema	23 (8.5)	24 (7.3)	
Pulmonary embolism	3 (1.1)	3 (0.9)	
Pulmonary fibrosis	3 (1.1)	3 (0.9)	
Pulmonary hemorrhage	1 (0.3)	2 (0.6)	
Respiratory distress	91 (33.6)	81 (24.8)	
Sepsis	45 (16.6)	71 (21.7)	
Shock	38 (14.0)	60 (18.3)	
Trauma	7 (2.6)	23 (7.0)	
Adjunctive treatment			
Analgesia	156 (57.8)	215 (65.8)	0.051
Sedative	128 (47.2)	160 (48.9)	0.682
Vasopressors	96 (35.4)	124 (37.9)	0.307
Steroid	71 (26.3)	82 (25.1)	0.778
Neuromuscular blocker	18 (6.6)	13 (4.0)	0.194
Prone position	1 (0.4)	5 (1.54)	0.228
Antipsychotics	38 (14.1)	24 (7.3)	0.010
Bronchodilator	84 (31.0)	38 (11.6)	<0.001

Values are presented as mean±standard deviation or number (%).
SOFA: Sequential Organ Failure Assessment; P/F ratio: the ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen; ARDS: acute respiratory distress syndrome; COPD: chronic obstructive pulmonary disease.

in Korea. As detailed in Table 1, the mean age of these patients was 67 years, and 62.0% were male. The mean P/F ratio was 255.5, and 13.7% of the patients were classified as having ARDS according to our criteria. The most prevalent reason for mechanical ventilation was pneumonia (40.6%), followed by respiratory distress (33.6%) and hypoxic respiratory failure (21.0%). As adjunctive treatments, analgesics were administered to 57.8% of patients, and 47.2% received sedatives. Furthermore, 35.4% of patients received vasopressors, 26.3% were given steroids, 6.6% received neuromuscular blockers, and 0.4% were in the prone position. Additionally, 14.1% were given antipsychotics, and 31.0% were treated with bronchodilators.

Compared with 327 patients from 60 ICUs in the other high-income Asian countries, Korean patients were significantly older (66.6 years vs. 61.7 years, P<0.001) and had a significantly lower BMI (22.3 vs. 24.9, P<0.001), a lower mean SOFA score (7.44 vs. 8.47, P=0.008), and a lower mean P/F ratio (255.5 vs. 306.2, P<0.001). Higher proportions of Korean patients received antipsychotics (14.1% vs. 7.3%, P=0.010) and bronchodilators (31.0% vs. 11.6%, P<0.001).

Mortality Rate

The mortality rates before and after propensity matching are described in Table 2. The 28-day mortality rate before propensity matching for patients in Korean ICUs was 38.0%. No significant differences in mortality rates were observed between Korean patients and those from other high-income Asian countries (38.0% vs. 34.2%, P=0.401). After propensity score matching, the mortality rates remained comparable between the two groups (36.7% vs. 40.0%, P=0.759).

Mechanical Ventilation Practices and Lung-Protective Ventilation

Table 3 provides a comprehensive overview of mechanical ventilation parameters and lung-protective ventilation practices in Korean ICUs and compares them with those in other high-income Asian countries. In Korea, pressure control was the most frequently used ventilation mode (47.3%), followed by pressure support (20.7%) and synchronized intermittent mandatory ventilation (pressure control) (19.7%). In other high-income Asian countries, pressure control (28.7%) was the most common mode, followed by pressure support (28.0%) and volume control (26.6%).

Table 2. Mortality rates with propensity score matching between mechanically ventilated patients in South Korean intensive care units and those in other high-income Asian countries

Variable	Before PMS			After PMS		
	South Korea (n=271)	Other high-income Asian countries (n= 327)	P-value	South Korea (n=90)	Other high-income Asian countries (n= 90)	P-value
Age (yr)	67±15	62±18	<0.001	66±15	64±16	0.333
Male sex	168 (62.0)	212 (64.8)	0.495	62 (68.9)	55 (61.1)	0.348
Body mass index (kg/m^2)	22.3±4.19	24.9±6.29	<0.001	22.7±4.2	23.2±5.2	0.395
SOFA score	7.44±4.36	8.47±4.98	0.008	7.8±4.0	8.2±5.1	0.593
P/F ratio	255.5±134.4	306.2±145.8	<0.001	273.5±129.3	280.9±111.5	0.683
ARDS	37 (13.7)	34 (10.4)	0.253	9 (10.0)	7 (7.8)	0.793
Steroid	71 (26.3)	82 (25.1)	0.778	27 (30.0)	33 (36.7)	0.429
NM blocker	18 (6.6)	13 (4.0)	0.194	6 (6.7)	5 (5.6)	1.000
Prone position	1 (0.4)	5 (1.54)	0.228	0	2 (2.2)	0.497
No. of vasopressors			0.324			0.494
0	174 (64.4)	203 (62.1)		55 (611)	52 (57.8)	
1	73 (27.0)	102 (31.2)		28 (31.1)	27 (30.0)	
2	17 (6.3)	20 (6.1)		6 (6.7)	11 (12.2)	
3	5 (1.9)	1 (0.3)		1 (1.1)	0	
4	1 (0.4)	1 (0.3)		-	-	
Teaching hospital	271 (100)	287 (87.8)	< 0.001	90 (100)	90 (100)	1.000
Type of ICU			< 0.001			0.446
General	53 (19.6)	213 (65.1)		36 (40.0)	40 (44.4)	
Medical	198 (73.1)	60 (18.3)		42 (46.7)	42 (46.7)	
Surgical	13 (4.8)	30 (9.2)		9 (10.0)	8 (8.9)	
Others	7 (2.6)	24 (7.3)		3 (3.3)	0	
Mortality rate	85 (38.0)	96 (34.2)	0.401	33 (36.7)	36 (40.0)	0.759

Values are presented as mean±standard deviation or number (%).
PMS: propensity score matching; SOFA: Sequential Organ Failure Assessment; P/F ratio: the ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen; ARDS: acute respiratory distress syndrome; NM: neuromuscular; ICU: intensive care unit.

The mean tidal volume for mechanically ventilated patients in Korean ICUs was 7.17 ml/kg predicted body weight (PBW), significantly lower than the 7.86 ml/kg PBW observed in other high-income Asian countries (P<0.001). The mean plateau pressure was 19.8 cm H_2O in Korea, which was not significantly different from the 19.6 cm H_2O recorded in other high-income countries (P=0.713). The mean PEEP was 6.43 cm H_2O in Korea, with no significant difference from the 6.54 cm H_2O recorded in other high-income Asian countries (P=0.504).

For patients with ARDS, Korean ICUs used a mean tidal volume of 6.96 ml/kg PBW, comparable to the 7.37 ml/kg PBW used in other high-income Asian countries (P=0.496). The mean plateau pressure and PEEP values for ARDS patients in Korean ICUs were 24.00 cm H_2O and 7.49 cm H_2O, respectively, with no significant differences from the 23.18 cm H_2O and 8.34 cm H_2O in other high-income Asian countries (plateau pressure, P=0.635; PEEP, P=0.163). Among ARDS patients, 73.0% in Korea were on low-tidal volume ventilation (tidal volume, ≤8 ml/kg PBW), and 83.7% were on limited plateau pressure (plateau pressure <30 cm H_2O). The use of low tidal volume and limited plateau pressure was comparable to other high-income Asian countries. However, only 62.2% of Korean ICU patients were on sufficient PEEP, which was significantly lower than the 91.2% reported in other high-income Asian countries (P=0.005).

For non-ARDS patients, the mean tidal volume in Korean ICUs was 7.16 ml/kg PBW, which was lower than the 7.81 ml/kg PBW in other high-income countries (P=0.002). The mean plateau pressure and PEEP values were 19.52 cm H_2O and 6.33 cm H_2O, respectively, and were not significantly different

Table 3. Mechanical ventilation parameters and lung-protective ventilation compliance rate

	South Korea	Other high-income Asian countries	P-value
Total	(n=271)	(n=327)	
MV mode			<0.001
Pressure support	62 (20.7)	120 (28.0)	
Pressure control	142 (47.3)	123 (28.7)	
Volume control	17 (5.7)	114 (26.6)	
SIMV (pressure control)	59 (19.7)	34 (7.9)	
SIMV (volume control)	13 (4.3)	22 (5.1)	
Others	7 (2.3)	16 (3.7)	
MV parameter			
Tidal volume (ml/kg PBW)	7.17±2.20	7.86±2.47	0.001
Plateau pressure (cm H_2O)	19.8±6.81	19.6±6.54	0.713
PEEP (cm H_2O)	6.43±2.27	6.54±2.24	0.504
Mortality rate	85 (38.0)	96 (34.2)	0.401
ARDS	(n=37)	(n=34)	
MV parameter			
Tidal volume (ml/kg PBW)	6.96±2.51	7.37±2.44	0.496
Plateau pressure (cm H_2O)	24.00±6.42	23.18±7.70	0.635
PEEP (cm H_2O)	7.49±2.43	8.34±2.69	0.163
Lung-protective ventilation			
Low tidal volume (TV ≤8 ml/kg PBW)	27 (73.0)	19 (55.9)	0.146
Limited plateau pressure (Pplat <30 cm H_2O)	28 (83.7)	27 (85.0)	0.781
Sufficient PEEP	23 (62.2)	31 (91.2)	0.005
Mortality rate	13 (37.1)	10 (35.7)	1.000
Non-ARDS	(n=234)	(n=293)	
MV parameter			
Tidal volume (ml/kg PBW)	7.16±2.20	7.81±2.42	0.002
Plateau pressure (cm H_2O)	19.52±6.63	19.26±6.26	0.663
PEEP (cm H_2O)	6.33±2.14	6.28±2.20	0.767
Lung-protective ventilation			
Intermediate tidal volume (TV ≤10 ml/kg PBW)	209 (89.3)	244 (83.3)	0.016
Limited plateau pressure (Pplat <30 cm H_2O)	202 (86.3)	223 (76.1)	0.004
Mortality rate	72 (38.1)	86 (34.0)	0.422

Values are presented as number (%) or mean±standard deviation.
MV: mechanical ventilator; SIMV: synchronized intermittent mandatory ventilation; PBW: predicted body weight; PEEP: positive end-expiratory pressure; ARDS: acute respiratory distress syndrome; TV: tidal volume; Pplat: plateau pressure.

from the 19.26 cm H_2O and 6.28 cm H_2O in other high-income Asian countries (plateau pressure, P=0.663; PEEP, P=0.767). A higher proportion of non-ARDS patients in Korea was on intermediate tidal volume ventilation (tidal volume, ≤10 ml/kg PBW) (89.3% vs. 83.3%, P=0.016) and limited plateau pressure (plateau pressure, <30 cm H_2O) (86.3% vs. 76.1%, P=0.004).

Staffing and Infrastructure in ICUs

The organizational characteristics, practice models, staffing, and ancillary services of the 31 ICUs from Korea and 60 ICUs from other high-income Asian countries and regions are described in Table 4. In Korea, all participating ICUs were based in teaching hospitals, with a notable predominance of private institutions (67.7%) compared to public ones (32.3%). This contrasts sharply with the other high-income Asian countries, where public teaching hospitals were more common (73.3%), and private teaching hospitals were significantly fewer (11.7%). In Korean ICUs, the co-management model involving a consultant intensivist was most common (51.6%), whereas the closed ICU model, in which a full-time intensivist oversees most patient care, was the most common model in other high-income Asian ICUs (73.3%).

Regarding infrastructure, Korean ICUs had a significantly higher average number of beds per unit (20.5 beds) than ICUs in other high-income Asian countries (16.0 beds) (P=0.017). The number of patients designated to each nurse (patient-to-nurse ratio) was also higher in Korea (2.6) than in other high-income Asian countries (1.9) (P<0.001). Notably, fewer Korean ICUs had patient-to-nurse ratios of 1:1 and 2:1 than ICUs in other high-income Asian countries (3.2% vs. 25.0% and 48.4% vs. 70.0%, respectively). Meanwhile, more Korean ICUs had a patient-to-nurse ratio of 3:1 (45.2% vs. 1.7%).

The proportion of ICUs with designated critical care attending physicians was similar between Korea (87.1%) and other high-income Asian countries (91.7%) (P=0.484). Although fewer Korean ICUs had respiratory therapists (41.9%) than those in other high-income Asian countries (60.0%), this difference was not significant (P=0.123).

Factors Associated with Mortality

Table 5 shows the results of univariable and multivariable logistic regression analyses identifying predictors of 28-day mortality. In Korean ICUs, the univariable logistic regression analysis identified age, specifically age 65 years or older, as a significant predictor of 28-day mortality (OR, 4.24; 95% CI, 1.17–15.41; P=0.028). In the multivariable logistic regression

Table 4. Organization characteristics, practice models, staffing, and ancillary services of intensive care units in South Korea compared to other high-income Asian countries

	South Korea (n=31)	Other high-income Asian countries (n=60)	P-value
Type of hospital			<0.001
Public teaching	10 (32.3)	44 (73.3)	
Private teaching	21 (67.7)	7 (11.7)	
Public non-teaching	-	6 (10.0)	
Private non-teaching	-	3 (5.0)	
Type of ICU			<0.001
General ICU (mixed specialty)	7 (22.6)	42 (70.0)	
Medical (including respiratory ICU)	19 (61.3)	8 (13.3)	
Surgical (including trauma ICU)	3 (9.7)	6 (10.0)	
Others (coronary, neurology, emergency ICU)	2 (6.5)	4 (6.7)	
Practice model of ICU			<0.001
Open	2 (6.5)	-	
Co-management	16 (51.6)	16 (26.7)	
Closed	13 (41.9)	44 (73.3)	
Number of beds per ICU			
Mean±SD	20.5±8.5	16.0±8.5	0.017
No. (%)			0.038
1–10	2 (6.5)	18 (30.0)	
11–20	16 (51.6)	29 (48.3)	
21–30	10 (32.3)	10 (16.7)	
31–40	2 (6.5)	2 (3.3)	
41–50	1 (3.2)	1 (1.7)	
Patient-to-nurse ratio			
Mean±SD	2.6±0.6	1.9±0.6	<0.001
No. (%)			<0.001
1 Patient per nurse	1 (3.2)	15 (25.0)	
2 Patients per nurse	15 (48.4)	42 (70.0)	
3 Patients per nurse	14 (45.2)	1 (1.7)	
4 Patients per nurse	1 (3.2)	2 (3.3)	
Designated critical care attending physician	27 (87.1)	55 (91.7)	0.484
Respiratory therapist	13 (41.9)	36 (60.0)	0.123

Values are presented as number (%) or mean±standard deviation.
ICU: intensive care unit; SD: standard deviation.

analysis, the following covariates were included based on P-value <0.1 in univariable analysis: age, SOFA score, antipsychotic use, and respiratory therapist. The multivariable analysis confirmed that age ≥65 years (OR, 4.03; 95% CI, 1.07–15.14; P=0.039), SOFA score 8–11 (OR, 2.36; 95% CI, 1.08–5.14; P=0.031), and SOFA score 12–24 (OR, 2.47; 95% CI, 1.02–6.00; P=0.045) were significantly associated with increased 28-day mortality. The presence of a respiratory therapist was associated with decreased 28-day mortality (OR, 0.52; 95% CI, 0.28–0.95; P=0.034). The multivariable model for Korean ICUs had a P-value of 0.002 and an area under the receiver operating characteristic curve (AUROC) of 0.678.

Among patients in other high-income Asian ICUs, univariable analysis found significant associations between 28-day mortality and age 41–64 (OR, 3.01; 95% CI, 1.07–8.45; P=0.036), age ≥ 65 (OR, 4.44; 95% CI, 1.64–12.07; P=0.003), SOFA score 8–11 (OR, 3.36; 95% CI, 1.51–7.47; P=0.003), SOFA score 12–24 (OR, 5.57; 95% CI, 2.52–12.32; P<0.001), P/F ratio 100–199 (OR, 2.88; 95% CI, 1.30–6.40; P=0.009), plateau pressure <30 cm H_2O (OR, 0.55; 95% CI, 0.31–0.99; P=0.049), and use of steroids (OR, 2.62; 95% CI, 1.52–4.52; P=0.001) and bronchodilators (OR, 2.27; 95% CI, 1.07–4.81; P=0.033). In the multivariable logistic regression analysis, the following covariates were included based on P-value <0.1 in univariable analysis: age; SOFA score; P/F ratio; plateau pressure <30 cm H_2O; use of vasopressors, steroids, or bronchodilators; and patient-to-nurse ratio <2. The multivariable analysis revealed that age 41–64 (OR, 5.04; 95% CI, 1.51–16.82; P=0.009), age ≥65 (OR, 8.16; 95% CI, 2.49–26.73; P=0.001), SOFA score 8–11 (OR, 2.73; 95% CI, 1.13–6.62; P=0.026), SOFA score 12–24 (OR, 5.10; 95% CI, 2.00–12.97; P=0.001), and use of steroids (OR, 2.82; 95% CI, 1.50–5.28; P=0.001) were significantly associated with increased 28-day mortality. The P-value for this multivariable model was <0.001, with an AUROC of 0.754.

DISCUSSION

This subgroup analysis examines the characteristics of mechanically ventilated patients and ventilator practices in Korean ICUs. Compared with patients in other high-income Asian countries, Korean patients were significantly older and had a lower mean P/F ratio. However, they also showed a lower mean SOFA score. Despite those differences, 28-day mortality did not differ significantly between Korea and other high-income Asian countries. In terms of ventilation practices, Korean ICUs applied lower PEEP levels and showed weaker adherence to sufficient PEEP in ARDS patients, though the use of low tidal volumes was similar. Regarding infrastructure, Kore-

Table 5. Predictors of 28-day mortality with univariable and multivariable logistic analysis of the mechanically ventilated patients in South Korea and other high-income Asian countries

	South Korea				Other high-income Asian countries			
	Univariable		Multivariable		Univariable		Multivariable	
	Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value
Age (yr)		0.012		0.012		0.004		<0.001
18–40	Reference		Reference		Reference		Reference	
41–64	2.24 (0.60–8.42)	0.232	1.92 (0.49–7.50)	0.346	3.01 (1.07–8.45)	0.036	5.04 (1.51–16.82)	0.009
≥65	4.24 (1.17–15.41)	0.028	4.03 (1.07–15.14)	0.039	4.44 (1.64–12.07)	0.003	8.16 (2.49–26.73)	0.001
Male sex	1.12 (0.64–1.97)	0.696	-	-	0.97 (0.58–1.61)	0.897	-	-
Body mass index ≥30 kg/m^2	0.48 (0.15–1.52)	0.188	-	-	1.39 (0.75–2.58)	0.300	-	-
SOFA score		0.075		0.081		<0.001		<0.001
0–4	Reference		Reference		Reference		Reference	
5–7	1.00 (0.44–2.25)	0.991	1.33 (0.56–3.19)	0.521	2.20 (0.96–5.03)	0.063	1.78 (0.73–4.33)	0.204
8–11	2.11 (1.02–4.40)	0.045	2.36 (1.08–5.14)	0.031	3.36 (1.51–7.47)	0.003	2.73 (1.13–6.62)	0.026
12–24	2.01 (0.90–4.46)	0.088	2.47 (1.02–6.00)	0.045	5.57 (2.52–12.32)	<0.001	5.10 (2.00–12.97)	0.001
ARDS	0.96 (0.46–2.02)	0.915	-	-	1.07 (0.48–2.44)	0.855	-	-
P/F ratio		0.511				0.025		0.121
≥300	Reference				Reference		Reference	
200–299	0.71 (0.31–1.60)	0.406	-	-	1.05 (0.54–2.03)	0.895	0.82 (0.43–1.56)	0.542
100–199	1.15 (0.53–2.52)	0.723	-	-	2.88 (1.30–6.40)	0.009	1.85 (0.82–4.17)	0.138
0–99	1.28 (0.45–3.70)	0.644	-	-	3.11 (0.65–14.98)	0.157	5.60 (0.67–46.53)	0.111
Tidal volume ≤8 ml/kg PBW	1.00 (0.56–1.82)	0.989	-	-	0.93 (0.57–1.52)	0.759	-	-
Plateau pressure <30 cm H_2O	0.60 (0.29–1.26)	0.182	-	-	0.55 (0.31–0.99)	0.049	0.87 (0.44–1.74)	0.693
Vasopressors	1.46 (0.84–2.54)	0.179	-	-	1.61 (0.98–2.66)	0.061	0.80 (0.43–1.48)	0.477
Steroid	1.28 (0.70–2.37)	0.425	-	-	2.62 (1.52–4.52)	0.001	2.82 (1.50–5.28)	0.001
Neuromuscular blocker	1.69 (0.57–5.01)	0.342	-	-	1.68 (0.55–5.14)	0.371	-	-
Analgesics	1.30 (0.74–2.29)	0.356	-	-	1.14 (0.66–1.95)	0.638	-	-
Sedatives	0.88 (0.51–1.50)	0.632	-	-	0.91 (0.56–1.49)	0.708	-	-
Antipsychotics	0.52 (0.23–1.16)	0.099	0.45 (0.19–1.06)	0.068	0.34 (0.10–1.20)	0.173	-	-
Bronchodilators	0.81 (0.44–1.48)	0.484	-	-	2.27 (1.07–4.81)	0.033	1.72 (0.68–4.40)	0.254
Private hospital	0.64 (0.34–1.20)	0.167	-	-	0.84 (0.40–1.73)	0.630	-	-
ICU beds ≥20	1.01 (0.54–1.91)	0.971	-	-	0.72 (0.43–1.20)	0.206	-	-
Patient-to-nurse ratio <2	0.60 (0.33–8.41)	0.541	-	-	1.59 (0.94–2.70)	0.084	1.72 (0.93–3.19)	0.082
Closed ICU	1.26 (0.81–1.95)	0.303	-	-	0.70 (0.33–1.46)	0.330	-	-
Respiratory therapist	0.58 (0.34–1.02)	0.057	0.52 (0.28–0.95)	0.034	1.26 (0.73–2.20)	0.402	-	-
Designated critical care attending physician	0.64 (0.26–1.59)	0.340	-	-	0.82 (0.26–2.59)	0.740	-	-

SOFA: Sequential Organ Failure Assessment; ARDS: acute respiratory distress syndrome; P/F ratio: the ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen; PBW: predicted body weight; ICU: intensive care unit.

an ICUs had a significantly higher average number of beds per unit than ICUs in other high-income Asian countries, and the patient-to-nurse ratio was also higher in Korea. Age ≥65 years and SOFA score ≥8 were associated with increased 28-day mortality. Notably, the presence of a respiratory therapist in Korean ICUs was associated with decreased 28-day mortality.

One prominent demographic observation in our data is the significantly higher proportion of elderly patients in Korean ICUs. We found that 23.6% of mechanically ventilated patients in Korean ICUs were aged 80 or older, nearly double the rate observed in other high-income Asian countries (13.2%, P=0.001). This higher prevalence of very old patients can be attributed to cultural norms in Korea, where end-of-life decisions are frequently made by families rather than by patients themselves [21-23]. The familial inclination toward "full treatment," which includes intubation and mechanical ventilation, can lead to increased use of these interventions among older patients. This cultural context likely contributes to the higher rates of mechanical ventilation in the elderly population.

The infrastructure and staffing of Korean ICUs also present noteworthy challenges. Our data indicate that Korean ICUs have a higher number of beds per unit and a greater patient-to-nurse ratio than ICUs in other high-income Asian countries. In Korea, the scarcity of intensivists typically results in each unit being supported by a single designated intensivist. According to a 2020 government report, the average number of ICU beds per intensivist in Korea was 22.2 [24]. Our study yielded similar results, with a mean of 20.5 beds per ICU in Korea, significantly higher than the average of 16.0 in other high-income Asian countries. Additionally, the number of designated patients per ICU nurse was significantly higher in Korea, with 2.6 designated patients per ICU nurse compared to 1.9 in other high-income Asian countries.

Despite the older patient demographic and possibly higher workload faced by ICU staff in Korea, the 28-day mortality rate remained comparable to that in other high-income Asian countries. Similar to those countries, age and illness severity were key factors associated with mortality in Korean ICUs. Interestingly, our analysis shows that the presence of a respiratory therapist in a Korean ICU significantly reduced 28-day mortality. However, because the role of respiratory therapists is not standardized in Korea, it is challenging to attribute this benefit solely to their presence.

Upon reviewing the dataset to understand this finding, we found that hospitals employing respiratory therapists tended to be larger facilities and had the highest bed capacities in Korea. These hospitals likely have superior human resources, including more intensivists, trainee physicians, nurses, and ancillary staff, as well as advanced operating systems such as rapid response teams [25] and 24-hour interventional radiology services. Unfortunately, those variables were not captured in our dataset, representing a limitation in our ability to explain the observed mortality benefit. Further research is needed to identify the factors that contribute to the improved clinical outcomes associated with the presence of a respiratory therapist in Korean ICUs.

We observed no significant association between the presence of a designated attending physician in the ICU and patient mortality. Although many studies have shown that intensivists are associated with improved outcomes in critically ill patients [26-28], some studies have reported differing results [29-33]. Factors such as ICU characteristics, number and expertise of intensivists, multidisciplinary team rounds, and broader structural variations in facility and healthcare systems likely influence these outcomes. In our study, detailed data on intensivist qualifications and roles were not collected, potentially introducing residual confounding that could affect our results. The imbalance in the enrolled ICUs, with most having designated critical care medicine attendants (87.1% of Korean ICUs and 91.7% in other high-income Asian countries) and most patients coming from those ICUs (91.4% of Korean patients and 96.0% in other high-income Asian countries) might also have contributed to our inability to effectively capture the effects of intensivists.

In terms of mechanical ventilation practices, our analyses show that Korean ICUs do not differ from other high-income Asian countries in their use of low-tidal volume ventilation and limited plateau pressure for ARDS patients. However, less frequent use of sufficient PEEP is a significant difference in Korea, although the mortality rate for ARDS patients did not differ significantly from that in the other countries (37.1% vs. 35.7%, P=1.000) (Table 3).

As adjunctive treatments, more patients in Korea received bronchodilators than in other high-income Asian countries. That might suggest that mechanically ventilated patients in Korea have more frequent underlying reactive airway diseases, or bronchodilators might be routinely administered to mechanically ventilated patients [34]. Another significant finding is that more patients received antipsychotics in Korea than in other high-income Asian countries. However, the use of sedatives did not differ significantly [35].

This study has some limitations. First, due to the design, the enrolled ICUs and mechanically ventilated patients do not represent all ICUs or patients in any studied country. Second, confounding variables such as severity of illness, presence of comorbidities, duration of mechanical ventilation, and detailed information about intensivists and respiratory therapists were not controlled in this study. Third, missing data for clinical outcomes might have compromised the precision of our multivariable regression analyses.

This study compared the characteristics and ventilation practices of mechanically ventilated patients in Korean ICUs with those in other high-income Asian countries. Korean ICUs were characterized by older patients, higher patient-to-nurse ratios, and more beds per unit, reflecting a greater burden on ICU staff. Despite those challenges, clinical outcomes in Korean ICUs were comparable to those in other high-income Asian countries. Although adherence to many recommended ventilation strategies was observed, mortality predictors highlight the significant effects of age and illness severity. The sub-optimal use of sufficient PEEP for ARDS indicates a potential area for improvement. Additionally, the beneficial effects of respiratory therapists on mortality rates in Korean ICUs warrant further investigation.

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CONFLICT OF INTEREST

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REFERENCES

1. Tobin MJ. Advances in mechanical ventilation. N Engl J Med 2001;344:1986-96.
2. Walter JM, Corbridge TC, Singer BD. Invasive mechanical ventilation. South Med J 2018;111:746-53.
3. Slutsky AS, Ranieri VM. Ventilator-induced lung injury. N Engl J Med 2013;369:2126-36.
4. Goligher EC, Ferguson ND, Brochard LJ. Clinical challenges in mechanical ventilation. Lancet 2016;387:1856-66.
5. Marini JJ, Rocco PR, Gattinoni L. Static and dynamic contributors to ventilator-induced lung injury in clinical practice: pressure, energy, and power. Am J Respir Crit Care Med 2020;201:767-74.
6. Acute Respiratory Distress Syndrome Network; Brower RG, Matthay MA, Morris A, Schoenfeld D, Thompson BT, et al. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. N Engl J Med 2000;342:1301-8.
7. Guérin C, Reignier J, Richard JC, Beuret P, Gacouin A, Boulain T, et al. Prone positioning in severe acute respiratory distress syndrome. N Engl J Med 2013;368:2159-68.
8. Papazian L, Forel JM, Gacouin A, Penot-Ragon C, Perrin G, Loundou A, et al. Neuromuscular blockers in early acute respiratory distress syndrome. N Engl J Med 2010;363:1107-16.
9. Guérin C, Mancebo J. Prone positioning and neuromuscular blocking agents are part of standard care in severe ARDS patients: yes. Intensive Care Med 2015;41:2195-7.
10. Rackley CR. Monitoring during mechanical ventilation. Respir Care 2020;65:832-46.
11. Roshdy A. Respiratory monitoring during mechanical ventilation: the present and the future. J Intensive Care Med 2023;38:407-17.
12. Bloos F, Müller S, Harz A, Gugel M, Geil D, Egerland K, et al. Effects of staff training on the care of mechanically ventilated patients: a prospective cohort study. Br J Anaesth 2009;103:232-7.
13. Castellanos I, Martin M, Kraus S, Bürkle T, Prokosch HU, Schüttler J, et al. Effects of staff training and electronic event monitoring on long-term adherence to lung-protective ventilation recommendations. J Crit Care 2018;43:13-20.
14. Borges LG, Savi A, Teixeira C, de Oliveira RP, De Camillis ML, Wickert R, et al. Mechanical ventilation weaning protocol im-

proves medical adherence and results. J Crit Care 2017;41:296-302.

15. Nam KH, Phua J, Du B, Ohshimo S, Kim HJ, Lim CM, et al. Mechanical ventilation practices in Asian intensive care units: a multicenter cross-sectional study. J Crit Care 2024;79:154452.
16. Phua J, Kulkarni AP, Mizota T, Hashemian SM, Lee WY, Permpikul C, et al. Critical care bed capacity in Asian countries and regions before and during the COVID-19 pandemic: an observational study. Lancet Reg Health West Pac 2023;44:100982.
17. Lim CM, Kwak SH, Suh GY, Koh Y. Critical care in Korea: present and future. J Korean Med Sci 2015;30:1540-4.
18. Oh TK, Song IA. Trained intensivist coverage and survival outcomes in critically ill patients: a nationwide cohort study in South Korea. Ann Intensive Care 2023;13:4.
19. Arabi YM, Phua J, Koh Y, Du B, Faruq MO, Nishimura M, et al. Structure, organization, and delivery of critical care in Asian ICUs. Crit Care Med 2016;44:e940-8.
20. ARDS Definition Task Force; Ranieri VM, Rubenfeld GD, Thompson BT, Ferguson ND, Caldwell E, et al. Acute respiratory distress syndrome: the Berlin Definition. JAMA 2012;307:2526-33.
21. Mo HN, Shin DW, Woo JH, Choi JY, Kang J, Baik YJ, et al. Is patient autonomy a critical determinant of quality of life in Korea? End-of-life decision making from the perspective of the patient. Palliat Med 2012;26:222-31.
22. Park SY, Lee B, Seon JY, Oh IH. A national study of life-sustaining treatments in South Korea: what factors affect decision-making? Cancer Res Treat 2021;53:593-600.
23. Shin DW, Lee JE, Cho B, Yoo SH, Kim S, Yoo JH. End-of-life communication in Korean older adults: with focus on advance care planning and advance directives. Geriatr Gerontol Int 2016;16:407-15.
24. Health Insurance Review and Assessment Service. 2019 Intensive care unit quality assessment results. 3rd. Health Insurance Review and Assessment Service; 2020.
25. Hyun DG, Lee S, Choi S, Son J, Park SH, Hong SB, et al. Impact of the National Early Warning Score-based sepsis response system on hospital-onset sepsis in a tertiary hospital in South Korea. Acute Crit Care 2025;40:186-96.
26. Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremsizov TT, Young TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. JAMA 2002;288:2151-62.
27. Lee SH, Hong JH, Kim YS, Park EC, Lee SM, Han CH. Impact of intensivist and nursing staff on critically ill patient mortality: a retrospective analysis of the Korean NHIS Cohort Data, 2011-2015. Yonsei Med J 2021;62:50-8.
28. Fuchs RJ, Berenholtz SM, Dorman T. Do intensivists in ICU improve outcome? Best Pract Res Clin Anaesthesiol 2005;19:125-35.
29. Costa DK, Wallace DJ, Kahn JM. The association between daytime intensivist physician staffing and mortality in the context of other ICU organizational practices: a multicenter cohort study. Crit Care Med 2015;43:2275-82.
30. Kerlin MP, Adhikari NK, Rose L, Wilcox ME, Bellamy CJ, Costa DK, et al. An official American Thoracic Society systematic review: the effect of nighttime intensivist staffing on mortality and length of stay among intensive care unit patients. Am J Respir Crit Care Med 2017;195:383-93.
31. Levy MM, Rapoport J, Lemeshow S, Chalfin DB, Phillips G, Danis M. Association between critical care physician management and patient mortality in the intensive care unit. Ann Intern Med 2008;148:801-9.
32. Yoo EJ, Edwards JD, Dean ML, Dudley RA. Multidisciplinary critical care and intensivist staffing: results of a statewide survey and association with mortality. J Intensive Care Med 2016;31:325-32.
33. Ohbe H, Matsui H, Yasunaga H. Intensive care unit versus high-dependency care unit for patients with acute heart failure: a nationwide propensity score-matched cohort study. J Intensive Care 2021;9:78.
34. Pierson DJ. Which mechanically ventilated patients should receive bronchodilators? [Internet]. Clinician.com; 2007 [cited 2025 Jun 5]. Available from: https://www.reliasmedia.com/articles/103286-which-mechanically-ventilated-patients-should-receive-bronchodilators
35. Kim HH, Choi SC, Ahn JH, Chae MK, Heo J, Min YG. Analysis of trends in usage of analgesics and sedatives in intensive care units of South Korea: a retrospective nationwide population-based study. Medicine (Baltimore) 2018;97:e12126.