

The Impact of Mechanical Ventilation Duration on the Readmission to Intensive Care Unit: A Population-Based Observational Study

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Background: If the duration of mechanical ventilation (MV) is related with the intensive care unit (ICU) readmission must be clarified. The purpose of this study was to elucidate if prolonged MV duration increases ICU readmission rate.

Methods: The present observational cohort study analyzed national healthcare claims data from 2006 to 2015. Critically ill patients who received MV in the ICU were classified into five groups according to the MV duration: MV for <7 days, 7–13 days, 14–20 days, 21–27 days, and ≥28 days. The rate and risk of the ICU readmission were estimated according to the MV duration using the unadjusted and adjusted analyses.

Results: We found that 12,929 patients had at least one episode of MV in the ICU. There was a significant linear relationship between the MV duration and the ICU readmission ($R^2=0.85$, $p=0.025$). The total readmission rate was significantly higher as the MV duration is prolonged (MV for <7 days, 13.9%; for 7–13 days, 16.7%; for 14–20 days, 19.4%; for 21–27 days, 20.4%; for ≥28 days, 35.7%; $p<0.001$). The analyses adjusted by covariables and weighted with the multinomial propensity scores showed similar results. In the adjusted regression analysis with a Cox proportional hazards model, the MV duration was significantly related to the ICU readmission (hazard ratio, 1.058 [95% confidence interval, 1.047–1.069], $p<0.001$).

Conclusion: The rate of readmission to the ICU was significantly higher in patients who received longer durations of the MV in the ICU. In the clinical setting, closer observation of patients discharged from the ICU after prolonged periods of MV is required.

Keywords: Critical Illness; Mechanical Ventilation; Intensive Care Units; Patient Readmission; Mortality

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Introduction

The prognosis of critically ill patients is poor when they are readmitted to the intensive care unit (ICU) after being discharged from the ICU. ICU readmission is related to longer hospital stays, higher hospital mortality rates, and higher medical costs¹⁻⁴. It is possible that the readmission rate could be lowered if the risk factors for readmission were identified and addressed. Therefore, elaborate efforts have been made to determine the risk factors for readmission to the ICU^{2,3} and to identify the patients at a higher risk of readmission in advance^{5,6}. Most of the risk factors for ICU readmission are associated with impaired consciousness, severity of disease, and impaired cardiopulmonary function at discharge^{4,5,7}. However, an accurate predictive model for ICU readmission has not yet been developed because of the complicated medical conditions of ICU patients^{5,6,8}. Therefore, modifiable factors related to ICU readmission need further investigation.

Several studies have reported a relationship between prolonged mechanical ventilation (PMV) and poor post-discharge clinical outcomes. A PMV of ≥ 21 days has been reportedly associated with a greater post-discharge mortality rate⁹. Even if patients with PMV survive in the ICU, the weaning rate is only about 50% and the probability of discharge to home is only about 20%¹⁰. Low quality of life has been reported in surviving patients after PMV¹¹. Although, the patients who stay in the ICU for a longer period are more likely to be readmitted to the ICU^{5,7}, limited data exists to clarify whether the duration of mechanical ventilation (MV) is independently related to ICU readmission. Considering that the duration of MV can be reduced through better practice of the clinicians^{12,13}, the relationship between duration of MV and ICU readmission rate needs to be identified. The purpose of this study was to analyze whether there is a difference in ICU readmission rates according to the duration of MV.

Materials and Methods

1. Study design, setting, and data sources

We followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for designing the present study¹⁴. This historic cohort study was conducted using the National Sample Cohort (NSC) database (version 2.0) developed by the National Health Insurance Sharing Service. The NSC database selected 1,025,340 patients who claimed hospital charges from 2002 to 2015 by systematic stratified random sampling with proportional allocation and includes socio-demographic, clinical, and procedural information¹⁵. We analyzed 997,173 patients who were followed up from 2006 to 2015 with the informative data on readmission to ICU and post-discharge mortality. An MV

event was identified by specific KCD-7 (7th revision of Korean Standard Classification of Diseases) codes in the claim database, which were considered highly accurate and exclusive (Supplementary Table S1)¹⁶.

2. Patients

The eligibility criteria were as follows: (1) critically illness, (2) age ≥ 18 years, and (3) at least one MV code claim in ICU, regardless of the duration of MV. To exclude patients who required MV without critical illnesses, we only included patients who stayed for 3 or more days or those who expired in the ICU¹⁶. The patients were classified into five categories based on the duration of MV: MV for < 7 days, 7–13 days, 14–20 days, 21–27 days, and ≥ 28 days.

3. Variables

We evaluated the socio-demographic characteristics including age, sex, residence in urban or rural areas, decile of income, admission to tertiary referral hospital, comorbidities, and Charlson comorbidity index (CCI). Patients were divided into three groups based on CCI (0–1, 2–3, and ≥ 4). To evaluate the clinical features, we analyzed main diagnosis at the initiation of MV, number of days spent in the hospital and ICU, number of days of MV, bedside therapeutic exercise, and rehabilitative breathing therapy.

We assessed clinical outcomes including the result of ICU management, the number of ICU readmission, total deaths during follow-up, time to ICU readmission, the rate of ICU readmission, and the source of ICU readmission. ICU readmission was defined as the second episode of ICU readmission after the first episode of ICU admission in a patient who had more than two admissions to ICUs during 10 years of observation period. All the patients were observed for at least 1 year. Cases of intra- or inter-hospital transfer between ICUs were considered one episode of ICU admission. Time to readmission was classified into five categories: within 2 days, 3 days, 7 days, 28 days, and total. The source of ICU readmission was classified into the ICU readmission after hospital discharge and the ICU readmission from a general ward before hospital discharge. Multinomial propensity scores were estimated with variables including age, sex, area of residence, income, admission to tertiary referral hospital, comorbidities, CCI, and main diagnosis at the initiation of MV¹³.

4. Statistical methods

Descriptive analyses were conducted to present the characteristics of the patients. Categorical variables were described as percentages and continuous variables were described as mean and standard deviation. The linear association between categorical variables and MV duration was evaluated using

the linear-by-linear test for categorical variables and Spearman's correlation analysis for continuous variables. Pearson's correlation coefficient was estimated to reveal the association between MV duration and ICU readmission rate. A Poisson regression analysis was performed to estimate the unadjusted and adjusted incidence rate of ICU readmission in each group. A Kaplan-Meier curve with a log-rank test was used to assess differences in cumulative rates of ICU readmission. A multinomial propensity score-weighted logistic regression analysis was conducted to adjust for the putative risk of bias due to different baseline characteristics¹⁷. After the proportional hazards assumption were tested, univariable and multivariable analyses with a Cox proportional hazards model were conducted to reveal the adjusted impact of MV duration on ICU readmission.

The risk of ICU readmission was evaluated based on the group with an MV <7 days. Multicollinearity was measured with a variance inflation factor, and a cut-off value of 4 was regarded as high. Statistical significance was considered when $p < 0.05$. All the analyses were conducted using R for Statistical Computing software, version 3.4.3 (R Core Team [2017], Vienna, Austria).

5. Ethical statement

The Institutional Review Board Committee of Bundang Seoul National University Hospital examined and approved the protocol of this study, and the need for informed consent was waived given that we only accessed electronic medical records (Institutional Review Board number: X-1906-544-902).

Results

Among the 997,173 patients in the NSC database, 49,414 (5.0%) had at least one episode of ICU stay for ≥ 3 days or died in ICU and 12,929 (1.3%) had at least one episode of MV in 837 ICUs (Figure 1). The median MV duration was 3 days (interquartile range [IQR], 1–8 days). Based on MV duration, patients were classified into five groups: 8,915 (70.0%) patients with MV for <7 days, 2,171 (16.8%) patients with MV for 7–13 days, 868 (6.7%) patients with MV for 14–20 days, 378 (2.9%) patients with MV for 21–27 days, and 597 (4.6%) patients with

MV for ≥ 28 days.

1. Socio-demographic characteristics of the study population

In the 12,929 patients with MV, a larger proportion of male and high income patients was found as MV duration increased (Table 1). The patients with longer MV duration were more found at tertiary referral hospitals. There were significant correlations between MV duration and several comorbidities. The patients with longer MV duration had a higher CCI score and were more likely to have a respiratory disorder at the initiation of MV. Rehabilitative breathing therapy was only conducted in about 6% of the included subjects and was performed more often in patients with longer periods of MV.

2. Comparison of clinical outcomes

The patients with longer MV duration were less likely to be discharged to home (Table 2). More patients were died in hospital as MV duration was prolonged in the subpopulation with MV ≥ 7 days ($p < 0.001$). Among the survived 6,967 patients, 2,056 (29.5%) were eventually readmitted to ICU for 10 years. The median time to readmission was 48 days (IQR, 23–822 days). Total ICU readmission rate and ICU readmission rate within 28 days was higher in the groups with longer MV duration ($p < 0.001$). We did not find a significant relationship between MV duration and readmission to ICU until 7 days after discharge to the ward. In both sources of ICU readmission (from a general ward before hospital discharge and after hospital discharge), longer MV duration was significantly related with a higher ICU readmission rate. In addition, mortality (including in- and out-of-hospital death) was found to have a significant positive correlation with MV duration ($p < 0.001$).

In the analysis of patients who survived in ICU and were discharged to the ward, ICU readmission rates increased according to MV duration ($R^2 = 0.85$, $p = 0.025$) (Figure 2A). In particular, patients with MV for ≥ 28 days showed a more than 3-fold higher readmission rate than those with MV for <7 days and a 2-fold higher readmission rate than those with MV for 14–20 days. The mortality rate increased according to MV duration, and more than half of the patients with MV for ≥ 21 days died during the observation period (Figure 2B).

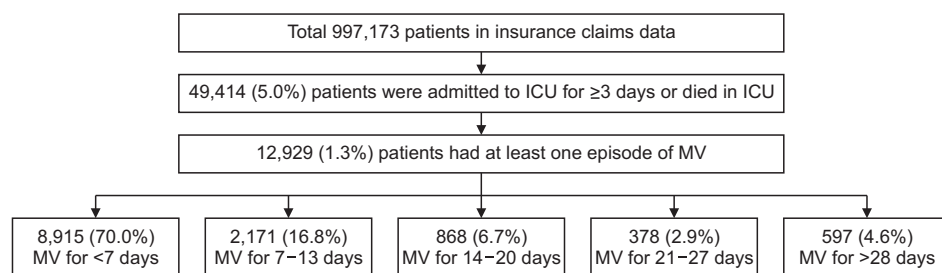


Figure 1. Flow chart of the patient inclusion according to the operational definition. ICU: intensive care unit; MV: mechanical ventilation.

Table 1. Socio-demographic and clinical characteristics according to MV duration in the ICU

	MV for <7 days (n=8,915)	MV for 7–13 days (n=2,171)	MV for 14–20 days (n=868)	MV for 21–27 days (n=378)	MV for ≥28 days (n=597)	p-value for trend
Age, yr	65.19±14.96	64.91±15.30	65.19±15.28	66.67±14.63	66.16±15.56	0.102
Male sex	5,259 (59.0)	1,344 (61.9)	531 (61.2)	241 (63.8)	376 (63.1)	0.002
Residence in rural areas	3,903 (42.7)	932 (42.9)	375 (43.2)	161 (42.6)	252 (42.2)	0.993
Income, decile						
1st and 2nd	1,168 (13.1)	288 (13.3)	111 (12.8)	37 (9.8)	78 (13.1)	0.406
3rd and 4th	1,127 (12.6)	263 (12.1)	113 (13.0)	46 (12.2)	53 (8.9)	0.039
5th and 6th	1,288 (14.4)	326 (15.0)	97 (11.2)	63 (16.7)	66 (11.1)	0.044
7th and 8th	1,735 (19.5)	416 (19.2)	178 (20.5)	70 (18.5)	115 (19.3)	0.957
9th and 10th	2,503 (28.1)	625 (28.8)	268 (30.9)	117 (31.0)	205 (34.3)	<0.001
Not recorded	1,094 (12.3)	253 (11.7)	101 (11.6)	45 (11.9)	80 (13.4)	-
Admission to tertiary referral hospital	2,474 (27.8)	702 (32.3)	276 (31.8)	116 (30.7)	241 (40.4)	<0.001
Comorbidities						
Cerebrovascular accident	936 (10.5)	253 (11.7)	117 (13.5)	46 (12.2)	82 (13.7)	<0.001
Moderate to severe chronic kidney disease	790 (8.9)	177 (8.2)	83 (9.6)	39 (10.3)	87 (14.6)	<0.001
Chronic liver disease	3,307 (37.1)	940 (43.3)	382 (44.0)	184 (48.7)	321 (53.8)	<0.001
COPD	1,248 (14.0)	434 (20.0)	177 (20.4)	87 (23.0)	154 (25.8)	<0.001
Congestive heart failure	1,870 (21.0)	479 (22.1)	190 (21.9)	77 (20.4)	169 (28.3)	<0.001
Connective tissue disease	87 (1.0)	26 (1.2)	17 (2.0)	9 (2.4)	5 (0.8)	0.053
Diabetes mellitus	4,682 (52.5)	1,253 (57.7)	533 (61.4)	258 (68.3)	401 (67.2)	<0.001
Malignancy	2,108 (23.6)	521 (24.0)	220 (25.3)	87 (23.0)	168 (28.1)	0.003
Myocardial infarction	1,158 (13.0)	231 (10.6)	99 (11.4)	44 (11.6)	83 (13.9)	0.377
Peripheral vascular disorder	1,375 (15.4)	298 (13.7)	153 (17.6)	65 (17.2)	133 (22.3)	<0.001
Charlson comorbidity index						
0–1	704 (7.9)	206 (9.5)	66 (7.6)	13 (3.4)	15 (2.5)	<0.001
2–4	3,853 (43.2)	833 (38.4)	335 (38.6)	142 (37.6)	207 (34.7)	<0.001
>4	4,358 (48.9)	1,132 (52.1)	467 (53.8)	223 (59.0)	375 (62.8)	<0.001
Main diagnosis at the initiation of MV						
Respiratory disorder	1,375 (15.4)	526 (24.2)	220 (25.3)	94 (24.9)	192 (32.2)	<0.001
Cardiovascular disorder	3,098 (34.8)	555 (25.6)	205 (23.6)	83 (22.0)	116 (19.4)	<0.001
No. of days spent in the hospital	20.87±22.09	29.18±24.95	37.24±25.22	46.25±27.40	74.49±53.67	<0.001
No. of days spent in the ICU	7.05±9.10	14.65±10.44	22.50±14.04	30.95±16.28	62.86±51.20	<0.001
No. of days using mechanical ventilator	2.33±1.59	9.43±1.97	16.46±1.99	23.77±1.97	51.86±41.93	<0.001
Bedside therapeutic exercise	3,944 (99.2)	1,109 (99.2)	498 (99.0)	234 (98.3)	398 (98.3)	0.023
Rehabilitative breathing therapy	196 (4.9)	71 (6.4)	27 (5.4)	23 (9.7)	39 (9.6)	<0.001

Values are presented as mean±standard deviation or as number of patients (%).

MV: mechanical ventilation; ICU: intensive care unit; COPD: chronic obstructive pulmonary disease.

3. Rate of ICU readmission

The rate of ICU readmission increased as MV duration increased (Table 3). Compared to patients with MV for <7 days,

the unadjusted incidence rate ratio (IRR) was higher in the patients with longer MV duration (patients with MV for 7–13 days, 1.30 [95% confidence interval (CI), 1.24–1.35]; patients with MV for 14–20 days, 1.63 [95% CI, 1.53–1.74]; patients with

Table 2. Clinical outcomes of ICU management according to the MV duration

	MV for <7 days (n=8,915)	MV for 7–13 days (n=2,171)	MV for 14–20 days (n=868)	MV for 21–27 days (n=378)	MV for ≥28 days (n=597)	p-value for trend
Result of ICU management						
Discharge to home	2,619 (29.4)	695 (32.0)	238 (27.4)	95 (25.1)	161 (27.0)	<0.001
Transfer to other hospital	113 (1.3)	37 (1.7)	21 (2.4)	12 (3.2)	11 (1.8)	0.001
Return to previous health care unit	102 (1.1)	48 (2.2)	11 (1.3)	5 (1.3)	15 (2.5)	0.004
In-hospital death	4,210 (47.2)	885 (40.8)	383 (44.2)	177 (46.8)	307 (51.4)	0.810
Readmission to the ICU						
Readmission within 2 days after discharge to ward	12 (0.1)	5 (0.2)	1 (0.1)	1 (0.3)	1 (0.2)	0.840
Readmission within 3 days after discharge to ward	14 (0.2)	7 (0.3)	2 (0.2)	1 (0.3)	3 (0.5)	0.283
Readmission within 7 days after discharge to ward	33 (0.4)	18 (0.8)	5 (0.6)	3 (0.8)	4 (0.7)	0.060
Readmission within 28 days after discharge to ward	63 (0.7)	42 (1.9)	14 (1.6)	13 (3.4)	24 (4.0)	<0.001
Total readmission after discharge to ward	1,236 (13.9)	362 (16.7)	168 (19.4)	77 (20.4)	213 (35.7)	<0.001
Source of readmission to the ICU						
From a general ward before hospital discharge	925 (10.4)	253 (11.7)	130 (15.0)	58 (15.3)	177 (29.6)	<0.001
After hospital discharge	311 (3.5)	109 (5.0)	38 (4.4)	19 (5.0)	36 (6.0)	<0.001
Total death	5,560 (62.4)	1,396 (64.3)	615 (70.9)	281 (74.3)	457 (76.5)	<0.001

Values are presented as number (%).

ICU: intensive care unit; MV: mechanical ventilation.

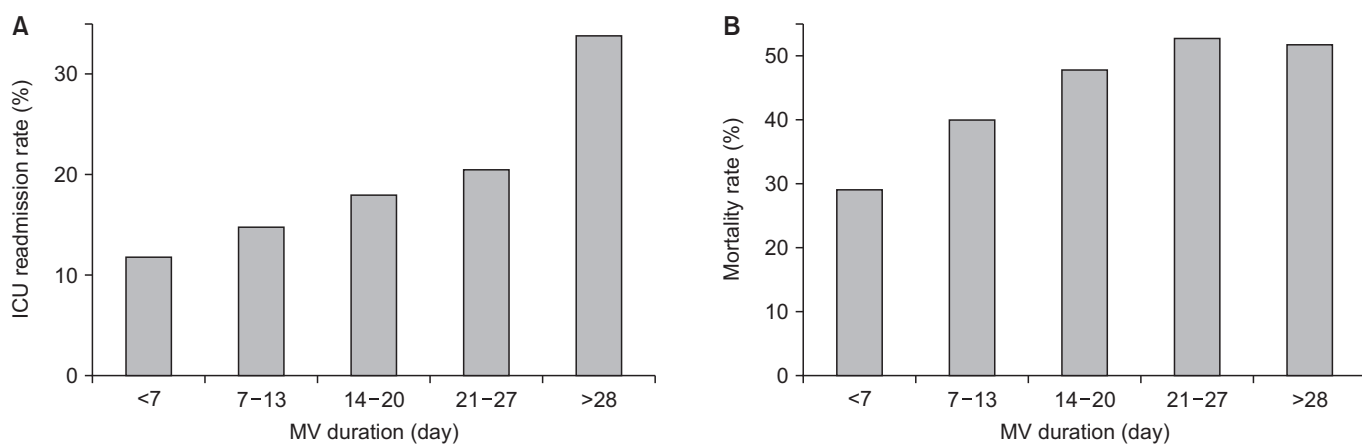


Figure 2. The intensive care unit (ICU) readmission and total death after discharge to the ward in surviving ICU patients. (A) The ICU readmission rate increases according to the mechanical ventilation (MV) duration, especially in patients with the MV for ≥28 days. (B) The mortality rate after the ICU discharge increases according to the MV duration, with more than half of patients with the MV for ≥21 days dying after discharge to the ward even though they survived in the ICU.

MV for 21–27 days, 1.75 [95% CI, 1.60–1.93]; patients with MV for ≥28 days, 2.82 [95% CI, 2.62–3.03]). Although attenuated, the adjusted IRR in patients with longer MV was significantly

higher in patients with longer MV duration (patients with MV for 7–13 days, 1.01 [95% CI, 1.00–1.03]; patients with MV for 14–20 days, 1.03 [95% CI 1.01–1.06]; patients with MV for

Table 3. Comparison of the unadjusted and adjusted incidence rates of the ICU readmission according to the MV duration

	MV for <7 days (n=8,915)	MV for 7-13 days (n=2,171)	MV for 14-20 days (n=868)	MV for 21-27 days (n=378)	MV for ≥28 days (n=597)
ICU readmission					
Total events	1,236	362	168	77	213
Total person-time (person-year)	17,903	3,445	1,120	458	507
Incidence rate (per 1,000 person-years)	69	105	150	168	420
Incidence rate ratio (95% CI)	1.00	1.30 (1.24–1.35)	1.63 (1.53–1.74)	1.75 (1.60–1.93)	2.82 (2.62–3.03)
Adjusted incidence rate ratio* (95% CI)	1.00	1.01 (1.00–1.03)	1.03 (1.01–1.06)	1.04 (1.00–1.07)	1.15 (1.11–1.18)

Incidence rate ratio was estimated based on the incidence rate of the patients with MV for <7 days.

*Poisson regression analysis was conducted with variables, including age, sex, income, admission to tertiary referral hospital, Charlson comorbidity index, main diagnosis at the initiation of the MV, and the follow-up duration.

ICU: intensive care unit; MV: mechanical ventilation; CI: confidence interval.

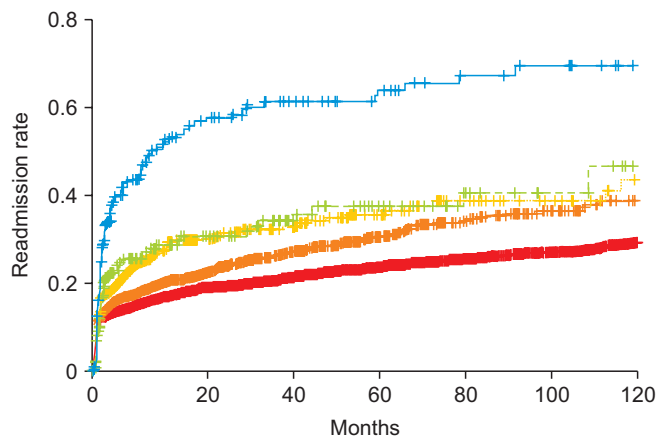


Figure 3. The Kaplan-Meier curve to evaluate the time to readmission according to mechanical ventilation duration. Red line, MV for <7 days; orange line, MV for 7–13 days; yellow line, MV for 14–20 days; green line, MV for 21–27 days; blue line, MV for >27 days. Log-rank test in comparison with <7 days (red line) vs. 7–13 days (orange line): $p=0.003$. Log-rank test in comparison with <7 days (red line) vs. 7–13 days (yellow line): $p<0.001$. Log-rank test in comparison with <7 days (red line) vs. 7–13 days (green line): $p<0.001$. Log-rank test in comparison with <7 days (red line) vs. 7–13 days (blue line): $p<0.001$. Log-rank test in comparison with 7–13 days (orange line) vs. 14–20 days (yellow line): $p=0.055$. Log-rank test in comparison with 7–13 days (orange line) vs. 21–27 days (green line): $p=0.083$. Log-rank test in comparison with 7–13 days (orange line) vs. >27 days (blue line): $p<0.001$. Log-rank test in comparison with 14–20 days (yellow line) vs. 21–27 days (green line): $p=0.811$. Log-rank test in comparison with 14–20 days (yellow line) vs. >27 days (blue line): $p<0.001$. Log-rank test in comparison with 21–27 days (green line) vs. >27 days (blue line): $p<0.001$.

21–27 days, 1.04 [95% CI 1.00–1.07]; patients with MV for ≥28 days, 1.15 [95% CI 1.11–1.18]).

In the Kaplan-Meier curves, the length of time to ICU readmission was significantly longer in patients with MV for <7 days and shorter in those with MV for ≥28 days (Figure 3).

There was no significant difference between patients with MV for 7–13 days, 14–20 days, and 21–27 days. The results of the log-rank test are described in the footnote of Figure 3.

In the analysis weighted with multinomial propensity scores, ICU readmission was significantly associated with MV for 7–13 days (odds ratio [OR], 1.02 [95% CI, 1.01–1.02]; $p<0.001$), MV for 14–20 days (OR, 1.03 [95% CI, 1.02–1.05]; $p<0.001$), and MV for >27 days (OR, 1.19 [95% CI, 1.13–1.26]; $p<0.001$), but not MV for 21–27 days (OR, 1.04 [95% CI, 0.99–1.09]; $p=0.122$). In the unadjusted regression analysis with a Cox proportional hazards model, we found that age, income, admission to tertiary hospital, CCI >4, respiratory disorder as main diagnosis at the initiation of MV, MV duration, and rehabilitative breathing therapy were significantly related to ICU readmission (Table 4). Similar results were found in the multivariable analysis (MV duration: hazard ratio, 1.058 [95% CI, 1.047–1.069]; $p<0.001$).

Discussion

We found that the ICU readmission rate was significantly related to MV duration. About 30% of critically ill patients with MV who survived in ICU were eventually readmitted to ICU. There was a significant linear relationship between MV duration and ICU readmission. The IRR of ICU readmission was higher in patients with longer MV and similar results were found in the survival analysis and the analyses adjusted by multinomial propensity scores. The regression analysis with a Cox proportional hazards model showed a higher risk of ICU readmission in patients with PMV. Considering that the event of MV definitely preceded the event of ICU readmission, a causal relationship can be established, and prolonged MV duration should be regarded as one of the preceding risk factors for ICU readmission.

The reason why PMV increases ICU readmission has not been well discussed before. Cohort study has been rarely

Table 4. Results of the unadjusted and adjusted regression analysis with the Cox proportional hazards model to evaluate the risk of intensive care unit readmission

Variable	Univariable analysis		Multivariable analysis	
	HR (95% CI)	p-value	HR (95% CI)	p-value
Age	1.029 (1.026–1.033)	<0.001	1.027 (1.022–1.032)	<0.001
Male sex	1.003 (0.919–1.096)	0.943	-	-
Residence	0.932 (0.854–1.017)	0.115	-	-
Income, decile	0.976 (0.963–0.988)	<0.001	0.971 (0.956–0.987)	<0.001
Admission to tertiary referral hospital	1.781 (1.63–1.947)	<0.001	1.355 (1.159–1.583)	<0.001
Charlson comorbidity index > 4	2.126 (1.937–2.332)	<0.001	1.864 (1.654–2.101)	<0.001
Respiratory disorder as main diagnosis at the initiation of MV	1.899 (1.721–2.095)	<0.001	1.300 (1.096–1.541)	0.003
MV duration, week	1.076 (1.067–1.085)	<0.001	1.058 (1.047– 1.069)	<0.001
Bedside therapeutic exercise	1.161 (0.603–2.235)	0.656	-	-
Rehabilitative breathing therapy	1.301 (1.063–1.594)	0.011	1.234 (1.007–1.513)	0.042

HR: hazard ratio; CI: confidence interval; MV: mechanical ventilation.

carried out and only case-control studies showing PMV as a risk factor for ICU readmission has been reported^{9,18}. PMV increased ICU length of stay (LOS)¹⁹ and a risk of infection, acute kidney injury, coagulopathy, respiratory failure, and shock²⁰. Prolonged LOS in ICU was associated with a higher 1-year mortality rate²¹. We made hypotheses for the mechanism of relationship between PMV and prolonged ICU LOS. First, patients with PMV often have relatively lower respiratory muscle performance that cannot compensate for increased respiratory demand^{22,23}. Second, diaphragm atrophy has been described as one of the reasons for the poor prognosis in PMV²⁴. Third, systemic muscle weakness is more common in ICU patients with acute respiratory distress syndrome who needed to stay in bed for longer periods with MV²⁵. PMV increased a risk of ICU-acquired weakness or critical illness myopathy that attributes sepsis, immobility, multi-organ failure, and hyperglycemia²⁶. Lastly, patients with long-term MV may experience a decline in cognitive function and require additional hospitalization²⁷. Early-onset delirium is associated with PMV²⁸. A lower rate of successful extubation and a higher rate of neurocognitive and psychological dysfunction have been found when MV duration was prolonged^{1,29-31}. Therefore, the patients with PMV may be readmitted to the ICU because of their reduced physiologic reservoirs to fight against new respiratory problems.

The clinical severity of patient condition in ICU has a considerable influence on MV duration. In a previous study, MV duration and clinical severity on day 1 had an inverted U shape relationship³². A higher grade of initial clinical severity does not necessarily mean that the MV duration will be prolonged, because shorter MV duration due to early death is usually observed in patients with severe respiratory failure³³. Rather, the clinical condition over the course of MV has been

considered as a more important issue than the initial clinical severity³⁴. In fact, when the intensivist predicts MV duration based on the clinical information within 48 hours of MV, the accuracy of prediction is not high³⁵. In contrast, a small observational study showed that clinical severity scores identified after 48 hours of MV better predicted which patients would have an MV duration >7 days³⁶. MV duration is a factor that reflects the overall clinical course rather than the clinical severity at a particular time, which would be one of the explanations why ICU readmission can be predicted by MV duration.

The first strength of the present study is its well-verified cohort with a large sample population and 10-year follow-up duration¹⁵. Because of cohort design, causality can be clarified. The second strength is the reliability of the socio-demographic data, which is difficult to obtain from individual research institutes⁷. We used the credible socio-demographic information which was collected by the Korean Health and Welfare Department. The third strength is that, even though patients were admitted to different hospitals, we were able to accurately verify ICU readmission, duration of MV, ICU stay, and hospitalization for all patients in the cohort.

There were some limitations to this study. First, clinical condition and severity were not addressed in our study. As mentioned before, it is important to understand the clinical severity at the time of discharge from ICU, which cannot be ascertained from claim data. Second, our study cohort could not provide the reasons for MV implementation or ICU readmission. Although limited, we used the main diagnosis at the time of MV to determine the reason for MV. Third, we could not elucidate any specific treatments that can affect the MV duration. The specific methods for intensive care were not distinguishable in this claim data.

In conclusion, the patients who are discharged from the ICU

following long periods of MV need closer monitoring. This finding is important when formulating an accurate model to predict ICU readmission and planning surveillance of patients discharged from the ICU. Our findings also provide a perspective for future studies investigating the impact of alternative interventions to conventional MV.

Authors' Contributions

Conceptualization: Lee HW. Formal analysis: Lee HW, Cho YJ. Investigation: Lee HW. Writing - original draft preparation: Lee HW. Writing - review and editing: Cho YJ. Approval of final manuscript: all authors.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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Supplementary Material

Supplementary material can be found in the journal homepage (<http://www.e-trd.org>).

Supplementary Table S1. Admission and treatment codes used to identify the patients who met the operational definition used in this study.

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