

Prognostic factors associated with mortality in mechanically ventilated patients in the intensive care unit

A single-center, retrospective cohort study of 905 patients

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Abstract

Data on outcomes of patients receiving mechanical ventilation (MV) in China are scarce.

To investigate factors associated with the prognosis of patients given MV in the intensive care unit (ICU).

A 12-year (January 1, 2006–December 31, 2017) retrospective cohort study.

ICU of Beijing Geriatric Hospital, China.

A total of 905 patients aged ≥ 16 years given MV during the study period.

None.

Among 905 patients included (610 men; median age, 78 years; Acute Physiology and Chronic Health Evaluation [APACHE]-II score, 27.3 ± 8.9), 585 survived (388 men; median age, 77 years; average APACHE-II score, 25.6 ± 8.4), and 320 died in the ICU (222 men; median age, 78 years; APACHE-II score, 30.6 ± 8.9). All-cause ICU mortality was 35.4%. In patients aged < 65 years, factors associated with ICU mortality were APACHE-II score (odds ratio [OR], 1.108; 95% confidence interval [95% CI], 1.021–1.202; $P = .014$), nosocomial infection (OR, 6.618; 95% CI, 1.065–41.113; $P = .043$), acute kidney injury (OR, 17.302; 95% CI, 2.728–109.735; $P = .002$), invasive hemodynamic monitoring (OR, 10.051; 95% CI, 1.362–74.191; $P = .024$), MV for cardiopulmonary resuscitation (OR, 0.122; 95% CI, 0.016–0.924; $P = .042$), duration of MV (OR, 0.993; 95% CI, 0.988–0.998; $P = .008$), successful weaning from MV (OR, 0.012; 95% CI, 0.002–0.066; $P < .001$), and renal replacement therapy (OR, 0.039; 95% CI, 0.005–0.324; $P = .003$). In patients aged ≥ 65 years, factors associated with mortality were APACHE-II score (OR, 1.062; 95% CI, 1.030–1.096; $P < .001$), nosocomial infection (OR, 2.427; 95% CI, 1.359–4.334; $P = .003$), septic shock (OR, 2.017; 95% CI, 1.153–3.529; $P = .014$), blood transfusion (OR, 1.939; 95% CI, 1.174–3.202; $P = .010$), duration of MV (OR, 0.999; 95% CI, 0.999–1.000; $P = .043$), and successful weaning from MV (OR, 0.027; 95% CI, 0.015–0.047; $P < .001$).

APACHE-II score, successful weaning, and nosocomial infection in the ICU are independently associated with the prognosis of patients given MV in the ICU.

Abbreviations: AKI = acute kidney injury, ALI = acute lung injury, APACHE = Acute Physiology and Chronic Health Evaluation, ARDS = acute respiratory distress syndrome, CLABSI = central line-associated blood stream infections, ICU = intensive care unit, IQR = interquartile range, LOS = length of stay, MV = mechanical ventilation, OR = odds ratio, RRT = renal replacement therapy, VAP = ventilator-associated pneumonia.

Keywords: intensive care unit, mechanical ventilation, mortality, prognosis, risk factor

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The Institutional Ethical Committee of Beijing Geriatric Hospital approved this study. Informed consent for inclusion in the study was waived as the study was retrospective and anonymized.

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1. Introduction

Mechanical ventilation (MV) is a commonly used mode of support in the intensive care unit (ICU). The reported rate of MV varies widely between studies, likely due to variations in the clinical characteristics of the admitted patients (e.g., age or whether medical or post-surgical admission), availability of facilities, and definition of MV (in particular, the minimum duration of MV required for inclusion in the analysis). For example, a 28-day international study including 361 ICUs from Spain, France, Canada, Argentina, England, and the USA found that the rate of MV was 32.9% in patients admitted to the ICU,^[1] and a rate of 46% was reported in Brazil.^[2] However, rates exceeding 70% have been described in China^[3] and Poland.^[4]

The reported in-hospital mortality rate in patients given MV in the ICU ranges from 23% to 51%.^[1,2,5–10] A recent analysis of 18,302 patients found that crude mortality in the ICU had decreased from 31% in 1998 to 28% in 2010,^[11] suggesting that improvements in care had reduced the risk of death in these patients. Studies of mechanically ventilated patients in Mainland China reported ICU or in-hospital mortality rates of 27.6% or

29.3%^[12] and an in-hospital mortality rate of 20.3%.^[3] Thus, the risk of death during hospitalization is high for patients receiving MV in the ICU.

The prognosis of patients receiving MV is influenced by many factors, including age, Acute Physiology And Chronic Health Evaluation (APACHE) II score (or other measure of functional status), severe sepsis, acute lung injury (ALI), acute respiratory distress syndrome (ARDS), acute renal, cardiovascular or hepatic failure, and requirement for neuromuscular blockers or vaso-pressors.^[1,2,5,13] A multicenter study in China reported that age, APACHE II score, a partial pressure of arterial oxygen to fraction of inspired oxygen (PaO₂/FiO₂) ratio <200, and chronic pulmonary diseases were independently associated with ICU mortality.^[12] Another study in Mainland China found that APACHE II score, severe sepsis, ALI, or ARDS and acute kidney injury (AKI) were independent risk factors for in-hospital mortality in critically ill patients in the ICU, 75% of who received MV.^[3] Knowledge of the factors affecting prognosis can assist in the management of patients given MV in the ICU. However, despite the availability of some published data,^[3,12] studies in China are lacking.

The aim of this retrospective cohort study was to investigate the factors affecting the prognosis of patients who were treated with MV in the ICU of Beijing Geriatric Hospital between January 2006 and December 2017.

2. Patients and methods

2.1. Study design and patients

This retrospective cohort study was conducted at Beijing Geriatric Hospital (Beijing, China), a tertiary hospital managed by the Beijing Hospital Administration Bureau. Beijing Geriatric Hospital has an 8-bed ICU managed by full-time ICU directors and staffed by 5 physicians and 15 nurses.

The inclusion criteria for this study were: admitted to the ICU of Beijing Geriatric Hospital between January 2006 and December 2017; received invasive MV with establishment of an artificial airway (endotracheal intubation) via the mouth, nose, or tracheotomy; and age >16 years. The exclusion criteria were: data required for the analysis were missing from the medical records; pregnancy; and treatment discontinued by the patient.

The indications for invasive MV at our hospital included: deterioration in clinical condition after active treatment of the underlying disease; disturbance of consciousness; severe abnormal respiration, such as respiratory rate >35 to 40 breaths/min or <6 to 8 breaths/min, abnormal respiratory rhythm, or weak/absent spontaneous breathing; blood gas analysis suggested severe disorders of ventilation and oxygenation (PaO₂ <50 mmHg, progressive increase in PaCO₂, and progressive acidosis). The relative contraindications for invasive MV included: pneumothorax or mediastinal emphysema that had not been drained; pulmonary bullae or cysts; inadequate treatment of hypovolemic shock; severe pulmonary hemorrhage; and tracheoesophageal fistula. There were no absolute contraindications to MV.

All medical interventions were performed with the informed consent of the patient or his/her family members. The Institutional Ethical Committee of Beijing Geriatric Hospital approved this study. Informed consent for inclusion in the study was waived as the study was retrospective and anonymized.

2.2. Collection of clinical data

The following data were obtained from the medical records: age; sex; reason for ICU admission; APACHE II score^[14]; reason for MV; duration of MV; successful weaning, defined as reintubation not required within 48 hours of extubation^[15]; nosocomial infection in the ICU, defined according to established criteria^[16]; ventilator-associated pneumonia (VAP), defined according to established criteria^[17]; central line-associated blood stream infections (CLABSI), defined according to established criteria^[18]; AKI, defined according to established criteria^[19]; renal replacement therapy (RRT); septic shock, defined according to established criteria^[20]; invasive hemodynamic monitoring; blood transfusion; and length of stay (LOS) in the ICU.

2.3. Statistical analysis

Data analysis was performed using SPSS 17 (SPSS Inc., Chicago, IL). All measurement data were tested for normality. Normally distributed continuous variables are expressed as mean ± standard deviation and were compared between groups (survivors vs non-survivors) using Student *t* test. Non-normally distributed continuous variables are presented as median (interquartile range [IQR]) and were compared between groups using the Mann–Whitney *U* test. Categorical variables are expressed as number (percentage) and were compared between groups using the chi-squared test or Fisher exact test (for small sample sizes). In a stratified analysis based on patient age (<65 years and ≥65 years), multivariate logistic regression was performed to identify variables independently associated with mortality. Significant variables in the univariate analysis were included in the multivariate logistic regression analysis (using the enter method), but variables showing multicollinearity were excluded from the final logistic regression model. Odds ratios (ORs) and 95% confidence intervals (95% CIs) were calculated. A *P*-value <.05 was considered statistically significant.

3. Results

3.1. Baseline characteristics of the study participants

From January 2006 to December 2017, 916 patients were treated with invasive MV in the ICU of our hospital. Eleven patients were excluded due to missing data (*n*=4) or discontinuation of treatment (*n*=7). Therefore, 905 patients were included in the final analysis (Fig. 1).

The baseline characteristics of the study participants are shown in Table 1. The 905 patients (610 men, 67.4%) had a median age of 78 (IQR, 69.5–83) years and an average APACHE II score of 27.3 ± 8.9. The survivor group included 585 patients (388 men, 66.3%) with a median age of 77 (IQR, 67–83) years and an average APACHE II score of 25.6 ± 8.4, and the non-survivor group consisted of 320 cases (222 men, 69.4%) with a median age of 78 (IQR, 72–83) years and an average APACHE II score of 30.6 ± 8.9. The retrospective analysis of data spanned 12 years, but there were no significant differences in mortality rate between the various years. The age range of the patients admitted to the ICU in our hospital was 17 to 98 years, with most patients aged ≥61 years old. There was no significant difference in age between the survivor group and non-survivor group (Table 1).

Compared with the survivor group, the non-survivor group had a significantly higher APACHE II score (*P* < .001), a longer duration of MV (*P* = .009), higher rates of ICU admission for

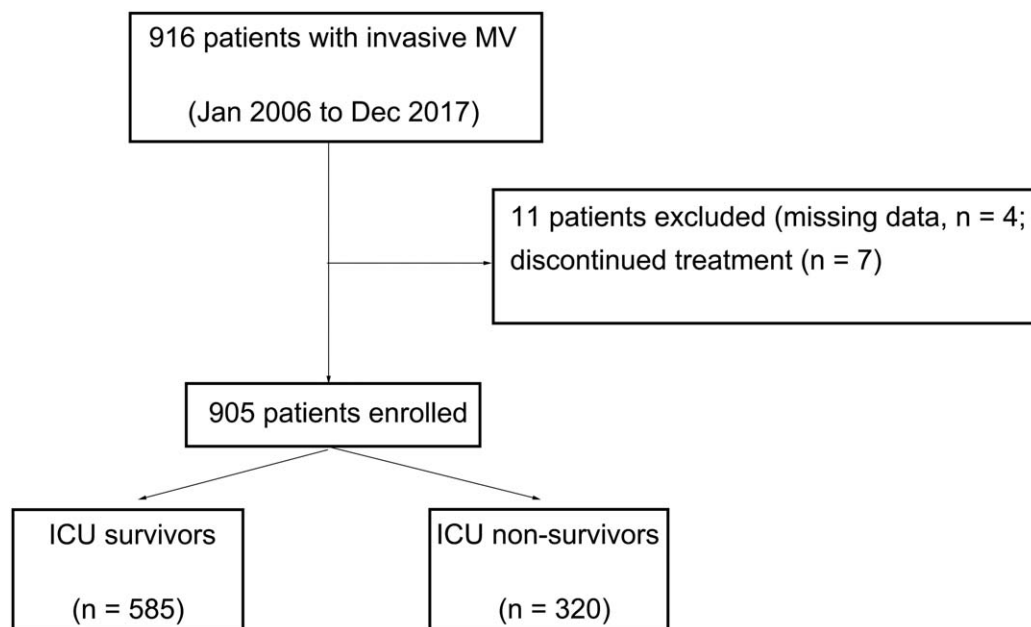


Figure 1. Flow chart showing enrolment of the study participants. ICU=intensive care unit, MV=mechanical ventilation.

shock ($P=.002$), or malignant cancer ($P=.035$), a lower rate of ICU admission after surgery ($P<.001$), higher rates of MV given for shock ($P=.002$) or CPR ($P<.001$), a lower rate of MV given

for a surgical reason ($P<.001$), a lower rate of successful weaning from MV ($P<.001$), and higher rates of nosocomial infection in the ICU ($P<.001$), VAP ($P<.001$), CLABSI

Table 1

Clinical characteristics of the study participants.

	Total (n=905)	Survivors (n=585)	Non-survivors (n=320)	P
Age, y, median (IQR)	78.0 (69.5–83.0)	77.0 (67.0–83.0)	78.0 (72.0–83.0)	.098
Male sex	610 (67.4%)	388 (66.3%)	222 (69.4%)	.349
APACHE II score, mean \pm SD	27.3 \pm 8.9	25.6 \pm 8.4	30.6 \pm 8.9	<.001
Reason for admission to the intensive care unit				
Respiratory disorder	502 (55.5%)	320 (54.7%)	182 (56.9%)	.529
Surgery (i.e., postoperative)	109 (12.0%)	103 (17.6%)	6 (1.9%)	<.001
Cardiopulmonary resuscitation	75 (8.3%)	41 (7.0%)	34 (10.6%)	.059
Cardiovascular disorder	47 (5.2%)	30 (5.1%)	17 (5.3%)	.905
Renal disorder	31 (3.4%)	16 (2.7%)	15 (4.7%)	.123
Neurologic disorder	41 (4.5%)	26 (4.4%)	15 (4.7%)	.867
Shock	33 (3.6%)	13 (2.2%)	20 (6.3%)	.002
Malignant cancer	21 (2.3%)	9 (1.5%)	12 (3.8%)	.035
Other	46 (5.1%)	27 (4.6%)	19 (5.9%)	.387
Reason for mechanical ventilation				
Respiratory failure	617 (68.2%)	392 (67.0%)	225 (70.3%)	.308
Heart failure	22 (2.4%)	14 (2.4%)	8 (2.5%)	.921
Shock	35 (3.9%)	14 (2.4%)	21 (6.6%)	.002
Cardiopulmonary resuscitation	100 (11.0%)	44 (7.5%)	56 (17.5%)	<.001
Surgery	131 (14.5%)	121 (20.7%)	10 (3.1%)	<.001
Duration of mechanical ventilation (h), median (IQR)	65.0 (20.5–169.5)	55.0 (20.5–144.0)	82.0 (20.3–226.0)	.009
Successful weaning	491 (54.3%)	465 (79.5%)	26 (8.1%)	<.001
Nosocomial infection in the intensive care unit	186 (20.6%)	92 (15.7%)	94 (29.4%)	<.001
Ventilator-associated pneumonia	114 (12.6%)	49 (8.4%)	65 (20.3%)	<.001
Central line-associated blood stream infection	47 (5.2%)	21 (3.6%)	26 (8.1%)	.003
Acute kidney injury	296 (32.7%)	128 (21.9%)	168 (52.5%)	<.001
Renal replacement therapy	209 (23.1%)	93 (15.9%)	116 (36.3%)	<.001
Septic shock	232 (25.6%)	86 (14.7%)	146 (45.6%)	<.001
Invasive hemodynamic monitoring	141 (15.6%)	57 (9.7%)	84 (26.3%)	<.001
Blood transfusion	332 (36.7%)	174 (29.7%)	158 (49.4%)	<.001
Length of stay in intensive care unit (d), median (IQR)	5.0 (2.0–13.5)	6.0 (2.0–13.0)	4.0 (1.0–14.0)	.136

Data are presented as n (%) unless otherwise stated. APACHE II=Acute Physiology And Chronic Health Evaluation II, IQR=interquartile range, SD=standard deviation.

($P=.003$), AKI ($P<.001$), RRT ($P<.001$), septic shock ($P<.001$), invasive hemodynamic monitoring ($P<.001$), and blood transfusion ($P<.001$; Table 1).

3.2. Multivariate logistic regression analysis of factors associated with mortality in the ICU

Based on the univariate analysis (Table 1), the following factors were entered into the multivariate logistic regression analysis: APACHE II score, duration of MV, ICU admission for shock, ICU admission for malignant cancer, ICU admission after surgery, MV given for shock, MV given for CPR, MV given after surgery, successful weaning from MV, nosocomial infection in the ICU, AKI, RRT, septic shock, invasive hemodynamic monitoring, and blood transfusion. VAP and CLABSI were excluded from the analysis because they exhibited significant multicollinearity with nosocomial infection. In patients aged <65 years (Table 2), factors independently associated with higher odds of death in the ICU were APACHE II score (OR: 1.108; 95% CI: 1.021–1.202; $P=.014$), nosocomial infection in the ICU (OR: 6.618; 95% CI: 1.065–41.113; $P=.043$), AKI (OR: 17.302; 95% CI: 2.728–109.735; $P=.002$), and invasive hemodynamic monitoring (OR: 10.051; 95% CI: 1.362–74.191; $P=.024$), whereas factors independently associated with lower odds of death in the ICU were MV for CPR (OR: 0.122; 95% CI: 0.016–0.924; $P=.042$), duration of MV (OR: 0.993; 95% CI: 0.988–0.998; $P=.008$), successful weaning from MV (OR: 0.012; 95% CI: 0.002–0.066; $P<.001$), and RRT (OR: 0.039; 95% CI: 0.005–0.324; $P=.003$). In patients aged ≥ 65 years (Table 3), factors independently associated with higher odds of death in the ICU were APACHE II score (OR: 1.062; 95% CI: 1.030–1.096; $P<.001$), nosocomial infection in the ICU (OR: 2.427; 95% CI: 1.359–4.334; $P=.003$), septic shock (OR: 2.017; 95% CI: 1.153–3.529; $P=.014$), and blood transfusion (OR: 1.939; 95% CI: 1.174–3.202; $P=.010$), whereas factors independently associated with lower odds of death in the ICU were duration of MV (OR: 0.999; 95% CI: 0.999–1.000; $P=.043$) and

Table 3

Multivariate logistic regression analysis of factors independently associated with mortality in 738 patients aged ≥ 65 years who received invasive mechanical ventilation in the intensive care unit.

Parameter	Odds ratio	95% confidence interval	P
APACHE II score	1.062	1.030–1.096	<.001
ICU admission after surgery	0.567	0.102–3.136	.515
ICU admission for shock	0.910	0.269–3.075	.880
ICU admission for malignant cancer	4.545	0.687–30.082	.116
Mechanical ventilation for shock	0.941	0.306–2.894	.915
Mechanical ventilation for cardiopulmonary resuscitation	0.666	0.329–1.348	.259
Mechanical ventilation after surgery	1.422	0.261–7.755	.684
Duration of mechanical ventilation	0.999	0.999–1.000	.043
Successful weaning	0.027	0.015–0.047	<.001
Nosocomial infection in the intensive care unit	2.427	1.359–4.334	.003
Acute kidney injury	1.085	0.548–2.147	.816
Renal replacement therapy	0.708	0.322–1.555	.389
Septic shock	2.017	1.153–3.529	.014
Invasive hemodynamic monitoring	0.858	0.422–1.743	.672
Blood transfusion	1.939	1.174–3.202	.010

APACHE II=Acute Physiology And Chronic Health Evaluation II, ICU=intensive care unit.

successful weaning from MV (OR: 0.027; 95% CI: 0.015–0.047; $P<.001$).

4. Discussion

In this study, we investigated the factors associated with ICU mortality among patients with a median age of 78 years given MV in the ICU of our hospital in Beijing. The main findings of the analysis were that APACHE II score, successful weaning and nosocomial infection in the ICU were independent risk factors for ICU mortality in patients receiving MV.

APACHE II score is currently the most widely used method of severity scoring in the critically ill and an important parameter used to evaluate the prognosis of patients in the ICU. It is generally believed that APACHE II score is positively correlated with the mortality rate of critically ill patients, with a higher APACHE II score indicative of a poorer health status and a worse prognosis. Consistent with our findings, previous studies have reported that APACHE II score (or an alternative disease severity score) was associated with mortality in patients treated with MV in the ICU.^[1–3,5,12] However, another investigation found that APACHE II score could not reliably predict whether patients receiving prolonged MV could be successfully weaned.^[21] In addition, research from Germany concluded that APACHE II score did not predict in-hospital mortality in patients with prolonged MV, although a corrected APACHE II score was able to predict whether MV could be successfully removed from patients in <25 days.^[22] The apparent inconsistency of these latter studies^[21,22] with our findings and those of others^[1–3,5,12] may be due to differing inclusion criteria resulting in different patient populations.

It was discovered over 20 years ago that failure to wean patients with MV was an independent risk factor for increased risk of death.^[23] Failure of weaning of MV was significantly associated with poor outcomes in patients in the ICU.^[24] The successful withdrawal of MV from a patient in the ICU indicates that their clinical condition has improved, which in turn would be

Table 2

Multivariate logistic regression analysis of factors independently associated with mortality in 167 patients aged <65 years who received invasive mechanical ventilation in the intensive care unit.

Parameter	Odds ratio	95% confidence interval	P
APACHE II score	1.108	1.021–1.202	.014
ICU admission after surgery	0.146	0.005–4.057	.257
ICU admission for shock	0.000	–	1.000
ICU admission for malignant cancer	1.891	0.087–41.025	.685
Mechanical ventilation for shock	0.000	–	.999
Mechanical ventilation for cardiopulmonary resuscitation	0.122	0.016–0.924	.042
Mechanical ventilation after surgery	0.368	0.054–2.511	.308
Duration of mechanical ventilation	0.993	0.988–0.998	.008
Successful weaning	0.012	0.002–0.066	<.001
Nosocomial infection in the intensive care unit	6.618	1.065–41.113	.043
Acute kidney injury	17.302	2.728–109.735	.002
Renal replacement therapy	0.039	0.005–0.324	.03
Septic shock	0.760	0.173–3.332	.716
Invasive hemodynamic monitoring	10.051	1.362–74.191	.024
Blood transfusion	0.396	0.099–1.582	.190

APACHE II=Acute Physiology And Chronic Health Evaluation II, ICU=intensive care unit.

expected to increase the chances of a good prognosis and reduce the risk of death. Failure of weaning or failure to reach the criteria for weaning extends the duration of MV. Typical complications of MV include increased incidences of tracheal and laryngeal injuries, hemodynamic suppression, nosocomial infections, increased work of breathing, and ventilator-induced diaphragmatic dysfunction, while patients with prolonged MV have a high risk of VAP. The above complications would be expected to increase mortality, hence active treatment of the primary disease and early removal of MV are considered beneficial. A previous study observed that a quantified score based on sex, Glasgow Coma Scale, sedative dosage, cough reflex, and duration of MV could predict the rate of failed extubation in patients with traumatic brain injury: the rate of extubation failure rose from 3.5% in those with a score of 0 to 3 to 42.9% in patients with a score of 8 to 17.^[25] It will be important to determine whether this scoring method could be used clinically to predict the rate of extubation failure in patients without traumatic brain injury, as this would help to select a more appropriate time for extubation and thereby increase the success rate of MV. Some clinical researchers used the decision support system software accompanying the ventilator to set a pressure support level and work of breathing level that were suited to the individual patient, thereby shortening the time to MV removal.^[26] A study published last year concluded that the application of a weaning program for patients undergoing MV could improve the success rate of weaning compared with the use of clinical experience, and the implementation of multiple strategies including continuing education and regular feedback could improve the compliance of clinicians with weaning programs.^[27] Furthermore, a multicenter randomized controlled trial in Spain determined that delaying extubation by 1 hour after a successful spontaneous breathing test could reduce the tracheal re-intubation rate in critically ill patients as compared with immediate extubation.^[28]

Compared with those in general wards, patients admitted to an ICU have a higher risk of hospital-acquired infections.^[29] ICU-acquired infection is an independent risk factor for hospital mortality even after adjustment for APACHE II or Sequential Organ Failure Assessment scores and age.^[30] Therefore, reducing the incidence of nosocomial infection in patients in the ICU could improve prognosis. The nosocomial infections in the ICU observed in this study were mainly VAP and CLABSI. VAP and CLABSI had a significant impact on prognosis in the univariate analysis, but both factors were excluded from the regression analysis due to the detection of multicollinearity. VAP was reported to be the most common infection in patients receiving MV, and the morbidity was 9% to 27%.^[31] VAP increases the mortality rate as well as healthcare costs.^[32] Many factors might contribute to the development of VAP, including trauma, prior surgery, ARDS, chronic obstructive pulmonary disease, upper airway colonization, duration of MV, and administration of proton pump inhibitors.^[33] Early identification of potential risk factors and active prevention of controllable factors could reduce the occurrence of VAP. The main pathogens responsible for VAP in patients in the ICU are Gram-negative *Enterobacter* and *Pseudomonas*,^[34] so it is particularly important to select appropriate antibiotics in the treatment of VAP. Recently, a meta-analysis of 1158 patients found that the prophylactic use of nebulized antibiotics could reduce the incidence of VAP in patients undergoing MV.^[35] A Spanish “VAP zero-generation project” including 181 ICUs recommended that the use of 10 measures could reduce the incidence of

VAP from 9.83 cases/1000 days of MV to 4.34 cases/1000 days of MV.^[36] CLABSI is also a common infection in the ICU. Large-scale data have suggested that evidence-based clustering interventions could reduce the incidence of catheter-related bloodstream infections by 66%.^[37] In addition, the Centers for Disease Control and Prevention have recommended the preventative use of antibiotic-coated central venous catheters, daily chlorhexidine total body scrubs, sponge dressings containing chlorhexidine, and antibiotic locks in the presence of higher CLABSI rates.^[38] It was also proposed recently that the use of a central venous catheter maintenance kit could significantly reduce the incidence of CLABSI.^[39]

Although the reason for ICU admission, reason for MV, AKI, RRT, septic shock, hemodynamic monitoring, and blood transfusions were excluded from the final regression model in this study, all 7 of these indexes were related to prognosis in the univariate analysis. Age was not a significant factor in the univariate analysis, indicating that it was not predictive of prognosis in our patients who received MV. Previous research found that although older age decreased the rate of successful weaning in patients undergoing prolonged MV, age was not the dominant factor predicting outcomes.^[40] Importantly, individuals undergoing prolonged MV who had better respiratory physiology and lower comorbidity burdens were more likely to be weaned and have longer survival, no matter their age.^[40] However, other studies have concluded that age can affect the mortality rate in patients receiving MV. Increasing age is associated with reduced organ reserve and compensatory function and a higher incidence of chronic diseases, which can detrimentally affect survival rate. A multicenter cohort study of patients undergoing MV found that the incidence of VAP in patients aged ≥ 65 years was similar to that in patients aged 45 to 64 years, but the mortality rate was higher in older patients.^[41] Another study, which included 1661 patients treated with MV in Spain, also found that older patients (≥ 75 years) had a significantly higher ICU mortality than younger patients without any differences in the duration MV.^[42] Consistent with the above research, studies conducted in the USA^[5] and Brazil^[43] also concluded that age was an independent predictor of mortality in patients given MV. An advantage of the present study was that the sample size was sufficiently large to allow a stratified analysis of the factors affecting survival in patients receiving MV in the ICU. It was notable that some factors were significantly associated with outcome in both age groups (≥ 65 years and < 65 years), including APACHE II score, nosocomial infection, and successful weaning from MV. However, AKI and invasive hemodynamic monitoring were significant factors for younger patients, while septic shock and blood transfusion were significant factors for older patients.

AKI is one of the most common organ dysfunctions seen in patients in the ICU, and its incidence and mortality rate have increased year-on-year.^[44] The incidence of AKI in patients in the ICU is about 60%.^[45] Sepsis and shock are among the most important causes of AKI, and when both are present the incidence of AKI is as high as 80%.^[46] The risk factors for AKI in elderly patients include certain drugs, a history of hypertension and sepsis,^[47] and AKI is more difficult to treat in patients admitted to the ICU. Although AKI was excluded from the multivariate regression analysis in this study, the univariate analysis revealed a significantly higher incidence of AKI in the non-survivor group (52.5%) than in the survivor group (21.9%), suggesting that AKI may be an important factor increasing the risk of death in patients

undergoing MV in the ICU. Therefore, the earlier diagnosis and treatment of AKI may improve the prognosis of patients in the ICU. A study involving >800 patients who underwent cardiac surgery determined that the incidence of postoperative AKI was strongly correlated with the postoperative increase in the level of endogenous ouabain,^[48] which is a biological marker of renal vascular damage. Another study concluded that the urinary levels of two cell cycle arrest markers (tissue inhibitor of metalloproteinases-2 and insulin-like growth factor-binding protein-7) could predict the risk of AKI.^[49] Although several biomarkers show promise in the prediction of RRT use in critically ill patients with AKI, the strength of evidence currently precludes their routine use to guide decision-making on when to initiate RRT.^[50] In the present study, the univariate analysis indicated that RRT affected prognosis. Although we did not analyze the dosing of RRT, a large retrospective cohort study confirmed that RRT dosing had no effect on the prognosis of patients in ICU.^[51]

Sepsis occurs when the host response to infection causes organ dysfunction.^[20] Septic shock is a severe stage of sepsis involving circulatory dysfunction, abnormal cell metabolism, cellular hypoxia, and mitochondrial dysfunction that leads to a significant increase in mortality.^[20] In the present study, the univariate analysis showed that 45.6% of non-survivors had septic shock compared with 14.7% of survivors. Furthermore, the multivariate analysis revealed that septic shock was significantly associated with higher odds of death in patients aged ≥ 65 years, suggesting that septic shock is an important risk factor for mortality in elderly patients receiving MV in the ICU.

In the current study, the rate of blood transfusion also differed between survivors and non-survivors in the univariate analysis, and blood transfusion was significantly associated with mortality in patients aged ≥ 65 years. This indicates that blood transfusion may be a risk marker for increased mortality in elderly patients given MV in the ICU. A previous study found that ICU mortality and 28-day mortality were higher in patients who received transfusion therapy, even in patients with similar levels of organ failure.^[52] Of course, blood transfusion is a necessary treatment for many patients with critical illness, and transfusion therapy itself can improve the prognosis of patients with critical illness. However, blood transfusion is likely a marker of more severe critical illness, which would explain its association with mortality.

Our study identified successful weaning as a very strong predictor of survival both in patients aged <65 years and those aged ≥ 65 years. However, it was notable that the duration of MV was significantly associated with reduced mortality, albeit very weakly. This would be inconsistent with previous studies showing that a longer duration of MV was associated with a reduced rate of successful weaning and a higher mortality rate.^[53] And, a systematic review and meta-analysis found that only 50% of patients who received MV for >14 days were successfully weaned from MV, with a mortality rate at 1 year of 62%.^[54] There was also study with different findings that duration of MV did not affect successful weaning and survival.^[55] Indeed, this result, increase in duration of MV will reduce the odds of mortality, is counter-intuitive. The reason for the apparent discrepancy between our findings and these previous studies is that the duration of MV likely correlated with successful weaning, which may have affected the outcome of the multivariate analysis. In addition, the OR is very close to 1, which means that duration of MV may not be associated with mortality.

Of course, our study has some limitations. This was a retrospective study, so there is a possibility of information or/and selection bias. Since this was a single-center study, the underlying disease types were limited, and the generalizability of the findings is not known. In addition, the analysis may have been influenced by unknown confounding factors that affected prognosis. It is hoped that a multicenter, randomized controlled study with a large sample size will be carried out in the near future to better clarify the factors affecting the prognosis of patients receiving MV in the ICU.

In conclusion, this study identified several factors that were independently associated with the survival of patients treated with MV in the ICU, including APACHE II score, successful weaning, and nosocomial infection. Therefore, weaning from MV as early as possible and preventing the occurrence of nosocomial infection are important approaches to improving the prognosis of patients given MV in the ICU.

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