Survey of Prolonged Mechanical Ventilation in Intensive Care Units in Mainland China

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INTRODUCTION: In mainland China, there are no special care centers (long-term acute care, weaning, chronic care facilities) for patients requiring prolonged mechanical ventilation (PMV). Our goal was to characterize the prevalence and outcome of patients undergoing PMV in Chinese intensive care units (ICUs). METHODS: A prospective 1-d prevalence study was performed at 55 ICUs, with 28-d follow-up. RESULTS: On the observation day, 622 adult patients occupied ICU beds. Enrollment criteria were met by 302 subjects receiving invasive mechanical ventilation, of which 109 (36.1%) had received ventilation for more than 21 d (median 51, 21–3,419), which was defined as PMV. During the following 28 d, another 45 subjects were classified as receiving PMV, but only 5% (3/58) of the subjects who were newly admitted to the ICU on the study day received PMV. Thirty-six (22.9%) of the 157 subjects receiving PMV were weaned, and 81 (51.6%) continued ventilation in the ICU. In the logistic regression analysis, age >74 y (odds ratio = 2.78, 95% CI 1.05–7.40, *P* = .041) and chronic congestive heart failure (odds ratio =12.23, 95% CI 1.48–101.05, *P* = .020) were associated with failure to wean in 28 d, while acute respiratory distress syndrome (ARDS) as the reason for mechanical ventilation (odds ratio = 0.14, 95% CI 0.04–0.52, *P* = .003) was associated with successful weaning. CONCLUSION: The number of subjects receiving PMV was surprisingly high in this cross-section of Chinese ICUs. In the following 28 ICU days, only a small proportion of these subjects were weaned. Age and chronic heart dysfunction were high risk factors for weaning failure. *Key words: invasive mechanical ventilation; prolonged mechanical ventilation; weaning; intensive care unit*. [Respir Care 2016;61(9):1224–1231. © 2016 Daedalus Enterprises]

Introduction

As medical technologies are developing over time, more patients are surviving episodes of critical illness. However, some patients cannot recover to live independently and require use of medical equipment, such as mechanical ventilators. When a patient requires at least 6 h/d of mechanical ventilation for ≥21 consecutive days, this is defined as prolonged mechanical ventilation (PMV).[1] A 32-bed intensive care unit (ICU) in southern Brazil reported that 42 of 453 (9.3%) patients received PMV in half a year.[2] While PMV incidence was 6.3 per 100 ventilated ICU admissions from 2002 to 2006 in the United Kingdom,[3] in Taiwan, the PMV rate fell from 94.3 to 89.38 per 100,000 persons from 2004 to 2007.[4] In the United States, a population-based study found that the incidence of tracheostomy for PMV was 24.2 per 100,000 people in 2002, and this rate had increased by nearly 200% from the previous decade.[5] Zilberberg and colleagues estimated that, based on growth trends between 1993 and 2005, the number of patients receiving PMV is expected to double between 2000 and 2020, from 252,577 to 605,898.[6] From 2004 to 2009, a population-based co-

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On behalf of the Chinese Prolonged Mechanical Ventilation study group.

The authors have disclosed no conflicts of interest.

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DOI: 10.4187/respcare.04295

hort study in 5 states showed that 5.5% of ICU patients needed PMV.[7]

With prolonged length of critical and acute care hospital stays, patients receiving PMV consume a disproportionate share of ICU resources, with median hospital costs ranging from 3–4 times the cost of short-term ventilation in acute care hospitals.[8] This prolonged care also accounts for 29.1% of the general ICU bed days.[4] In 2005, Medicare-eligible patients who required PMV ranked third in summative in-patient charges by diagnostic groups and first in charges per patient.[9] Despite receiving such a high level of care, 29–49% of PMV patients died in the hospital,[10,11] only 19% could be discharged home,[10] and <50% of PMV hospital survivors survived more than 1 y.[3,10-14] Compared with withdrawal of ventilation, providing PMV to the base-case patient costs $55,460 per life-year gained and $82,411 per quality-adjusted life-year gained.[9] As a high-cost population, patients who receive PMV should be a priority focus for hospital managers to control daily expenditures, and alternative care venues should be considered other than the ICU. Step-down and special units, such as weaning centers, long-term acute care hospitals, and nursing facilities in America,[13,15] respiratory care centers and wards in Taiwan,[14,16] and respiratory ICUs in Europe[3,17] have been established to treat patients who require PMV in a more cost-effective manner.

However, the prevalence of PMV and the venues to treat them in mainland China have never been reported. The aim of this study was to establish the prevalence of PMV, to report characteristics and 28-d outcomes of a PMV cohort in 55 ICUs within teaching hospitals across mainland China, and to explore the factors that affect the weaning success of patients who require PMV.

QUICK LOOK

Current knowledge

Prolonged mechanical ventilation (PMV) defined as at least 6 h/d of mechanical ventilation for ≥21 consecutive days is a global difficulty. Patients requiring PMV consume a disproportionate share of ICU resources, with greater hospital costs in acute care hospitals, and utilize significantly more ICU bed days than other patients. However, the prevalence and characteristics of patients requiring PMV in mainland China have never been reported.

What this paper contributes to our knowledge

The present observational study was conducted in 55 leading ICUs in mainland China. We found that more than one-fifth of ICU beds were occupied by ventilator-dependent patients for a long period of time, taking up a significant proportion of ICU resources but with poor weaning outcomes. We also identified high risk factors for weaning failure.

Methods

Study Subjects

Inclusion criteria were subjects who received mechanical ventilation via endotracheal intubation or tracheotomy in the ICU at 8 AM, July 10, 2007 and subjects admitted to the ICU between 8 AM, July 10 and 8 AM, July 11, 2007. Exclusion criteria were patients younger than 18 y of age.

Study Criteria

Prolonged mechanical ventilation was defined as the need for ≥21 consecutive days of mechanical ventilation for ≥6 h/d. Successful weaning was defined as off the ventilator for 7 consecutive d. Failed weaning was classified as subjects still alive who continued to need ventilation.

Study Design

The study was approved by the institutional review board of Beijing Chaoyang Hospital. The primary research site and data-coordinating center was Beijing Chaoyang Hospital, which produced data collection forms and the operations manual. Fifty-five ICUs in teaching hospitals across mainland China participated in the survey and formed the Chinese Prolonged Mechanical Ventilation group. At each site, the ICU supervisor was in charge of the study, and a physician was appointed to enroll subjects, complete case report forms, and to complete subject follow-up at 28 d. The initial study day was July 10, 2007, and all enrolled subjects received follow-up at 28 d, unless discharged from the ICU without the need for ventilation or upon the patient's death.

Information collected included: (1) facility information: ICU type, number of beds, doctors, nurses, and other medical staff on both day and night shifts; (2) subjects' demographic information: age, sex, smoking history and premorbid functional status (Zubrod score: 0, fully active; 1, restricted in strenuous activity; 2, ambulatory, self-care, no work; 3, bedridden >50% of time, limited self care; 4, bedridden, no self-care)[18]; (3) ICU admitting diagnosis and the primary reason for mechanical ventilation; (4) comorbidities; (5) artificial airway type and the tracheotomy time; (6) the ventilator mode and settings on the study day; (7) complications associated with mechanical ventilation during the following 28 d: ventilator-associated pneumo-

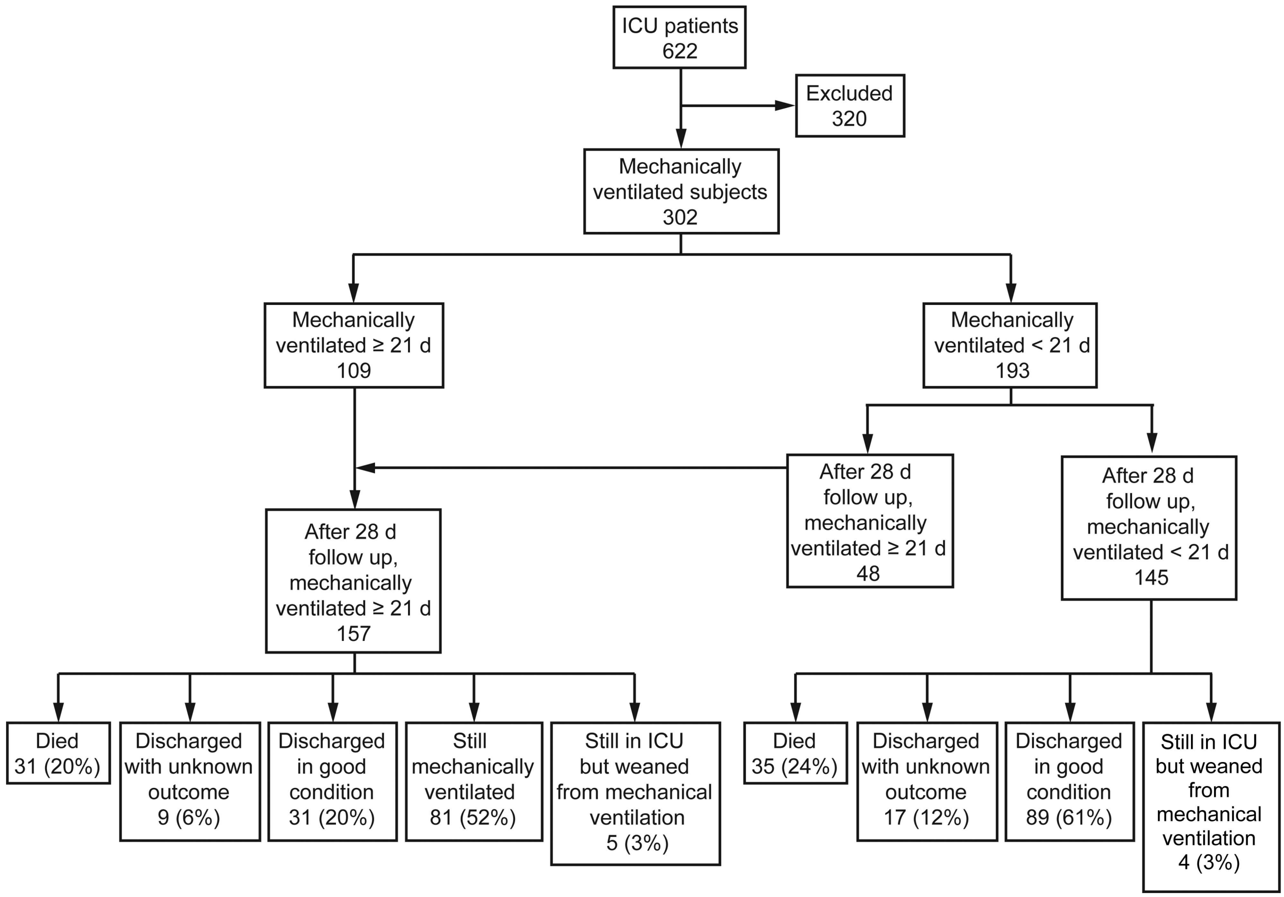

Fig. 1. Flow chart.

nia (VAP), pneumothorax, and subcutaneous emphysema; and (8) ICU outcome in the following 28 d.

Diagnosis criteria for VAP were[19]: a new and persistent (>48 h) or a progressive radiographic infiltrate plus 2 of the following: temperature of > 38°C or < 36°C, blood leukocyte count of > 10,000 cells/mL or < 5,000 cells/mL, purulent tracheal secretions, and gas exchange degradation.

Statistical Analysis

Population-weighted descriptive statistics were calculated (means, standard deviations, median, tabulations, and proptions) for all questions. Kolmogorov-Smirnov statistical tests were used to determine the normality of distribution for the considered variables. Continuous variables between the 2 groups of subjects are expressed as mean (SD or SEM) or median (minimum to maximum) and compared with the parametric (Student *t* test) or nonparametric (2-independent samples tests, Mann-Whitney U) test based on distribution of variables, whereas differences in categorical variables were assessed using the chi-square test. Binary stepwise logistic regression analyses were used to explore relationships between successfully weaned and failed weaning subjects undergoing PMV. A P value of $< .05$ was considered statistically significant for all tests. Data analysis was conducted with SPSS statistical software (SPSS 16.0 for Windows; SPSS; Chicago, Illinois).

Results

This prospective prevalence study was performed throughout 55 ICUs within 51 teaching hospitals in 26 major cities, such as Beijing, Shanghai, Guangzhou, and others, representing 780 beds, 377 physicians and 503 nurses on the day shift, and 114 physicians and 317 nurses on the night shift.

PMV Prevalence

At 8 AM on July 10, 2007, 536 adult patients occupied ICU beds, with 242 subjects receiving invasive ventilation. Of those, 109 (45.0%, 109/242) subjects had required ventilation for more than 21 d (median 51 d, ranging from 21–3,419 d) in ICU (Fig. 1). Of the remaining 133 subjects, 45 were classified as requiring PMV 28 d later. From

8 AM July 10 to 8 AM July 11, 86 subjects were admitted to the ICUs, with 60 subjects receiving invasive mechanical ventilation. Two of these subjects had already received ventilation outside of the ICU for 1 d and 5 d, respectively. The total duration of invasive ventilation for the 2 subjects was 4 d and 12 d. Of the 58 subjects newly receiving invasive ventilation, only 3 (5.2%, 3/58) needed PMV at the end of the following 28 d (Fig. 1).

PMV Subjects' Characteristics

The characteristics and data for the 157 subjects requiring PMV are shown in Table 1. Multiple comorbidities involving the respiratory, cardiovascular, and neuromuscular systems were noted with an average of 1.85 major comorbidities in each subject. Hypertension was the most common disease charted (45.2%) followed by COPD (33.7%). Acute respiratory failure was the main reason for mechanical ventilation: 41 (26.1%) subjects for nonaspirated pneumonia, 35 (22.3%) for exacerbation of COPD, and 30 (19.1%) for ARDS. Some subjects might have had more than one reason for mechanical ventilation. On the study day, SIMV+PSV (synchronized intermittent mandatory ventilation + pressure support ventilation) was the most popular ventilation mode (45.2%), and only 26% of subjects were supported with PSV/CPAP. During the following 28 d, 37.6% of subjects developed VAP, and 1.9% had pneumothorax. Eight subjects received paralytics and 14 received high-dose corticosteroids. The time to tracheotomy for 131 subjects was 13.5 (median, ranging from 5–57 d) d. Of the 157 subjects receiving PMV, 9 had a previous diagnosis of neuromuscular diseases and 6 of these had already received ventilation for more than 1 y. The 6 subjects' invasive mechanical ventilation duration were 518, 815, 1,108, 2,460, 3,402, and 3,419 d respectively; 5 subjects had amyotrophic lateral sclerosis, and 1 subject had a motor neuron disease. Another 11 subjects had received ventilation for more than 1 y.

Subjects' 28-d Outcome

Of the 157 subjects enrolled, 31 (19.7%) died in the ICU, 9 (5.7%) were discharged from the hospital at the request of the subjects or their surrogates with unknown outcomes, 36 (22.9%) were weaned, and the remaining 81 continued ventilation in the ICU. Of the 36 subjects who were weaned, 31 were discharged from the ICU in good condition, and 5 were still in the ICU.

After 28 d, 81 subjects required assisted ventilation in the ICU. We excluded the 20 subjects who were described above (11 receiving more than 1 y of ventilation and 9 subjects with neuromuscular disease) from the analysis, because it was unlikely that they could be weaned.[16] We compared the remaining 61 subjects requiring assisted ventilation with the 36 successfully weaned subjects. The weaned subjects were younger [62.5 (median, ranging from 19–85) vs 78 (median, ranging from 18–103), $P < .001$], and had a higher ratio of good premorbid functional status with a Zubrod score 0–2 (72.2% vs 52.5%, $P = .055$). Moreover, they had fewer comorbidities, especially chronic congestive heart failure (2.8% vs 29.5%, $P = .001$) and COPD (13.9% vs 44.3%, $P = .002$), a smaller proportion of them required ventilation for COPD exacerbation (13.9% vs 36.1%, $P = .019$) while more required it for ARDS (38.9% vs 8.2%, $P < .001$). For the subjects whose ventilation duration was longer than 90 d, the proportion was much smaller in successfully weaned subjects (11.1% vs 29.5%, $P = .037$) (Table 2). There was no difference between the 2 groups in APACHE II scores, sex, smoking history, or facility information, including the ratio of medical staff to subjects during day and night shifts.

In the logistic regression analysis, age more than 74 y (Odds Ratio = 2.78, 95% CI [CI] 1.05–7.40, $P = .041$) and COPD (Odds Ratio = 12.23, 95% CI 1.48–101.05, $P = .02$) were associated with failure to wean in 28 d, while ARDS as the reason for mechanical ventilation (Odds Ratio = 0.14, 95% CI 0.04–0.52, $P = .003$) was associated with successful weaning.

Discussion

This was the first study to report the prevalence and characteristics of patients requiring PMV in mainland China. The 55 ICUs that completed surveys were located in teaching hospitals with advanced equipment and highly skilled and experienced medical personnel; critically ill patients might be more likely to survive in such an environment. Moreover, these ICUs were prone to accept severely ill patients and difficult-to-wean patients transferred from community hospitals. This may contribute to the high prevalence of PMV in our survey. In fact, if we exclude the subjects who had already undergone PMV before the day of the survey, the proportion of new subjects was only 5.2%, similar to the incidence rate in the United States (3–7%)[1,7] and the United Kingdom (4.4%).[3]

Once patients become classified as requiring PMV, it is very hard for them to be transferred to other venues in mainland China. In our study, no subject receiving invasive ventilation could be transferred out of the ICU, and this inability to transition patients out of the ICU resulted in longer ICU stays of 52 d (median). Results from the European,[3,20-22] American[8,13,15] and Taiwan[14,16] case series would suggest that patients whose primary problem is ventilatory dependence can be managed in less intensive step down units, thereby reducing costs and facilitating a focus on ventilatory care and rehabilitation. Because the transfer policy of "failure to wean" patients was adopted,[16] ICU stay for subjects undergoing PMV decreased from

Table 1. Characteristics of Subjects Who Required PMV

Subject characteristics	ProVent study[23]		Present study
	Development	Validation	
n	200	100	157
Age, y	58 (42–69)	57 (44–66)	74 (18–103)
Sex, male (%)	120 (60)	49 (49)	103 (66)
APACHE II score when admitted to ICU	20.6 ± 7.3	25.3 ± 6.8	20.1 ± 7.4
Good pre-morbid functional status (Zubrod score 0–2), *n* (%)	143 (82)	60 (76)	82 (52)
Smoking, *n* (%)			54 (34.4)
Charlson Comorbidity Index Score, mean ± SD	2.7 ± 2.2	3.1 ± 2.3	2.8 ± 1.6
Co-morbidities, *n* (%)			
Respiratory	22 (11)	14 (14)	72 (46)
COPD			53 (34)
Asthma			3 (2)
Interstitial lung disease, pulmonary fibrosis			3 (2)
Pulmonary tuberculosis			9 (6)
Others (bronchiectasis, pulmonary embolism, obstructive sleep apnea syndrome)			4 (3)
Cardiovascular			159
Hypertension			71 (45)
Chronic congestive heart failure	30 (15)	15 (15)	36 (23)
Coronary artery disease	16 (8)	7 (7)	18 (12)
Cardiac arrhythmia			31 (20)
Others (rheumatic heart disease, aortic coarctation)			3 (2)
Neurologic			59 (38)
Cerebral infarction			26 (17)
Cerebral hemorrhage			9 (6)
Neuromuscular disease (amyotrophic lateral sclerosis, motor neuron diseases, Guillain-Barré)			11 (7)
Parkinson			6 (4)
Others (vascular dementia, cerebral arteriosclerosis, epilepsia, hypophysoma)			7 (5)
Diabetes mellitus			42 (27)
Hypothyroidism			2 (1)
Renal insufficiency/failure			12 (8)
Malignant tumor			12 (8)
Hospital surgery, *n* (%)			50 (32)
Emergency			29 (19)
Schedule			21 (13)
Causes due to mechanical ventilation, *n* (%)			
Acute respiratory failure			143 (91)
ARDS	10 (5)	5 (5)	30 (19)
Acute cardiogenic pulmonary edema	2 (1)	4 (4)	12 (8)
Pneumonia (nonaspiration)	13 (7)	14 (14)	41 (26)
Aspiration			16 (10)
Exacerbation of COPD	4 (2)	2 (2)	35 (22)
Trauma	32 (16)	10 (10)	9 (6)
Head trauma with or without multiple injuries	4 (2)	0	4 (3)
Chest trauma with flail chest or hemopneumothorax			5 (3)
Sepsis			19 (12)
Cardiopulmonary resuscitation	8 (4)	7 (7)	14 (9)
Coma			30 (19)

(continued)

Table 1. Continued

Subject characteristics	ProVent study[23]		Present study
	Development	Validation	
Neurologic diseases	8 (4)	0	36 (23)
New cerebrovascular accident or intracranial hemorrhage			22 (14)
New onset or progression of neuromuscular diseases			11 (7)
Others			3 (2)
Respiratory support after surgery	54 (27)	26 (26)	17 (11)
Cardiovascular	20 (10)	5 (5)	2 (1)
Thoracic	13 (7)	6 (6)	2 (1)
Gastrointestinal	13 (7)	13 (13)	8 (5)
Neurological	8 (4)	2 (2)	5 (3)
Paralysis, *n* (%)			8 (5)
High dose of corticosteroid, *n* (%)			14 (9)
Complications of invasive ventilation, *n* (%)			62 (40)
Pneumothorax			3 (2)
VAP			59 (38)
Tracheostomy, *n* (%)	167 (84)	77 (77)	135 (86)
Time to tracheotomy, d	17 (12–22)	19 (12–26)	14 (5–57)
Mechanical ventilation duration, d	35 (26–51)	35 (27–54)	51 (21–3494)
ICU stay, d	37 (28–52)	36 (30–54)	52 (14–3494)

ARDS = acute respiratory distress syndrome
APACHE = Acute Physiology and Chronic Health Evaluation
ICU = intensive care unit
VAP = ventilator-associated pneumonia

55.7 ± 92.8 to 21.4 ± 12.7 d in Taiwan[16]. Similarly, ICU stays were 25–37 d in America[11,15,23] and 26 d in Europe.[21] However, currently no special unit for patients requiring PMV exists in mainland China. Only 22.9% of subjects were weaned from mechanical ventilation in our study, compared with the high ratio of successful weaning (43–53%) in American hospitals,[23] 54.1% in the 23 American weaning centers,[15] and 64.2% in Taiwan weaning centers.[14] It might be due to lack of trained multidisciplinary professionals, such as respiratory therapists, as shown in our previous study.[24]

It is very important to identify the possibility of successful weaning in patients requiring PMV. Dermot Frengley et al[25] recently found that weaning success decreased with age, higher comorbidity burden, and more-severe illness, which was in agreement with our findings. We also found that chronic congestive heart failure was a significant predictor of weaning failure. Weaning from positive-pressure ventilation increases venous return and left ventricular afterload. Such increases may not be tolerated by patients with compromised heart function, which becomes the cause or a cofactor of weaning failure,[26] described as "weaning-induced cardiovascular compromise."[26,27]

One limitation of our study was that we did not acquire more comprehensive information to decide whether subjects could be transferred out of the ICU or not. Additionally, we only followed the subjects for 28 d in the ICU, and we did not collect subject data on the 14th or 21st day of mechanical ventilation. Consequently, we could not use the prognostic model proposed by Carson et al[23] to predict our subjects' 1-y mortality.[11] However, a comparison of subject characteristics is shown in table 1. Also, despite the small sample size and the design of our study, the risk factors for weaning that it revealed are consistent with current evidence; a follow-up study with a larger sample size is needed to verify our findings. The other limitation was that we did not investigate the actual reason why subjects were not transferred out of ICU. Because Chinese medical insurance reimbursement, environment, and systems are different from those in western society, future studies are needed to understand the benefits and opportunities to manage patients requiring PMV outside of the ICU environment. We are also aware that our study was performed 8 years ago, but the result is still valid, because no weaning center or specific chronic care facility has been established in mainland China as of the publication date of this paper.

Conclusion

The ratio of subjects requiring PMV was surprisingly high in the Chinese ICUs surveyed, with the majority of these subjects occupying ICU beds throughout their course of ventilation, using a disproportionate amount of ICU

Table 2. Comparison Between Successful and Failed Weaning PMV Subjects

	Wean failure	Wean success	Died/discharged with unknown outcome	Neuromuscular disease/mechanical ventilation >1 y
n	61	36	40	20
Age	78 (18–103)	62.5 (19–85)	77 (24–88)	67.5 (31–86)
Female/male sex, %	29.5/70.5	33.3/66.7	40/60	40/60
APACHE II score when admitted to ICU	21 (6–38)	18 (6–44)	19 (6–45)	18 (9–29)
"Good" pre-morbid functional status (Zubrod score 0–2)	32 (52.5)	26 (72.2)	20 (50)	4 (20)
Smoking, %	37.7	33.3	30	35
Co-morbidities, *n* (%)				
Chronic congestive heart failure	18 (29.5)	1 (2.8)	13 (33)	4 (20)
COPD	27 (44.3)	5 (13.9)	7 (17.5)	4 (20)
Charlson comorbidity index	2.95 ± 1.55	2.64 ± 1.57		
Hospital surgery, *n* (%)	17 (22.7)	16 (38.1)	17 (42.5)	3 (15)
Causes due to acute respiratory failure				
ARDS	5 (8.2)	14 (38.9)	11 (27.5)	0
Trauma	1 (1.6)	5 (13.9)	2 (5)	1 (5)
COPD exacerbation	22 (36.1)	5 (13.9)	5 (12.5)	4 (20)
High dose of corticosteroid	3 (4.9)	7 (19.4)	3 (7.5)	1 (5)
Paralysis, *n* (%)	1 (1.6)	3 (8.3)	4 (10)	0
Complications of invasive ventilation, *n* (%)	27 (44.3)	11 (30.6)	17 (42.5)	7 (35)
Pneumothorax	0	1 (2.4)	2 (5)	0
VAP	26 (42.6)	11 (30.6)	15 (37.5)	7 (35)
Time to tracheotomy, d	11 (8–43)	27 (10–31)	16 (5–57)	
ICU stay, d	55 (28–357)	41.5 (21–1015)	39 (14–220)	663 (62–3494)
Mechanical ventilation duration, d	61 (29–358)	37.5 (21–301)	40 (21–168)	708.5 (63–3494)
Mechanical ventilation duration already ≥90 d on study day, %	18 (29.5)	4 (11.1)	6 (15.0)	17 (85)

ARDS = acute respiratory distress syndrome
APACHE = Acute Physiology and Chronic Health Evaluation
ICU = intensive care unit
VAP = ventilator-associated pneumonia

resources. Even with a high ratio of ICU staff, only a small portion of subjects could be weaned in the following 28 ICU days. Younger subjects, ARDS PMV patients, with fewer pre-morbid diseases were more prone to be successfully weaned. The optimal venue for taking care of patients requiring PMV needs to be investigated.

ACKNOWLEDGMENTS

Jie Li, Qingyuan Zhan and Chen Wang conceived and designed the study, Qingyuan Zhan and Chen Wang organized the Chinese prolonged mechanical ventilation study group, and the group members collected data. Jie Li analyzed and interpreted the data, and wrote the manuscript; Qingyuan Zhan and Chen Wang provided critical revisions and approved the final version of the manuscript. Jie Li is responsible for the entire manuscript.

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