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ORIGINAL ARTICLE

The Role of Non-invasive Ventilation and Factors Predicting Extubation Outcome in Myasthenic Crisis

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Abstract

Introduction Myasthenic crisis is a great threat to patients with myasthenia gravis. Usage of non-invasive ventilation (NIV) to prevent intubation and timing of extubating of patients in myasthenic crisis are important issues though not well documented.

Methods To explore the factors predicting NIV success and extubation outcome in myasthenic crisis, we reviewed the records of 41 episodes of myasthenia crisis.

Results NIV was applied to 14 episodes of myasthenic crisis and eight (57.1%) of them were successfully prevented from intubation. An Acute Physiology and Chronic Health Evaluation (APACHE) II score of <6 and a serum bicarbonate level of <30 mmol/l were independent predictors of NIV success. For patients undergoing invasive mechanical ventilation, extubation failure was observed in 13 (39.4%) of 33 episodes, and the most common cause was sputum impaction due to a poor cough strength (61.5%). A maximal expiratory pressure (Pemax) of $\geq$40 cmH_2O was a good predictor of extubation success. Extubation failure led to poorer outcomes.

Conclusions NIV may be applied to those patients with a low APACHE II score and a lesser degree of metabolic compensation for respiratory acidosis. For patients undergoing invasive mechanical ventilation, extubation failure is associated with significant in-hospital morbidity in myasthenic crisis. Adequate levels of Pemax and cough strength correlate significantly with extubation success.

Keywords Extubation outcome · Mechanical ventilation · Myasthenia gravis · Myasthenic crisis · Non-invasive ventilation · Weaning parameters

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Introduction

Myasthenic crisis is a life-threatening complication that occurs in approximately 8–63% of patients with myasthenia gravis (MG) during their lifetime [1–6]. The advent of effective mechanical ventilation, specialized intensive care units (ICUs), and the widespread use of immunotherapies have substantially altered the prognosis of myasthenic crisis.

There is no general consensus on how to define myasthenic crisis. It was proposed that myasthenic crisis be defined as weakness from acquired MG that is severe enough to require intubation [7, 8], a situation that corresponds to class V of the Myasthenia Gravis Foundation of America (MGFA) classification [9]. This definition of myasthenic crisis, however, was introduced before non-invasive ventilation (NIV) was widely applied to patients with hypercapnic respiratory failure in the ICU. Several recent case reports have suggested that NIV may be useful in preventing intubation as well as reintubation in patients with respiratory failure due to severe MG [10, 11]. Nevertheless, only few previous studies have systematically evaluated the role of NIV in the prognosis of these patients, and little is known about the optimal timing of extubation in myasthenic crisis.

The goals of this retrospective study were to identify factors that determine the success of NIV application in myasthenic crisis. Second, we would like to explore the values of weaning parameters in predicting the extubation outcome in myasthenic crisis, and to investigate the impact of extubation failure in these patients. In this report, the scope of the definition of myasthenic crisis is extended to include episodes of respiratory failure due to severe MG requiring NIV support in the ICU.

Patients and Methods

Patients

This is a retrospective study that involved reviewing the data of patients with MG who were admitted to National Taiwan University Hospital from January 2000 to June 2007. Patients with MG were selected from the electronic database of medical records in the hospital. The diagnosis of MG was based on clinical symptoms and serologic testing [1]. This study was approved by the Institutional Review Board.

Patients included in this analysis were intubated for mechanical ventilation or supported by NIV (definition of myasthenic crisis). The decision for intubation or NIV was made by the primary care physician based on clinical manifestations and results of arterial blood gas (ABG) analyses. Patients with the following conditions were excluded from this study: intubation for elective surgery, out hospital cardiac arrest, a duration of mechanical ventilation <48 h, and tracheostomy before admission. The medical records were reviewed and demographics, pulmonary function, treatment modalities, ABG analyses, weaning parameters, and the extubation outcomes were recorded.

Definition of Successful Application of NIV and Extubation Outcomes

For patients undergoing NIV support after onset of respiratory failure, NIV success was defined as being free from intubation. For patients who were extubated in ICU, NIV was considered successful if they did not require intubation 72 h after extubation.

The process of weaning and extubation were decided by a medical team which included a neurologist and a pulmonologist. At the time of extubation, all patients had received managements involving plasma exchange and immunosuppressive therapies for myasthenic crisis, and had passed a spontaneous breathing trial (SBT). The SBTs included a trial with T-piece, a trial with low pressure support (no more than 6 cmH_2O) and low positive end expiratory pressure (no more than 5 cmH_2O), or a trial of automatic tube compensation mode. The criteria of a successful SBT were: a calm general appearance, a stable hemodynamic profile and cardiac rhythm, oxygen saturation $>90\%$ on pulse oxymetry with fraction of oxygen supplement below 40%, and infrequent need of sputum suction during SBT. Weaning parameters, including maximal inspiratory pressure (Pimax), maximal expiratory pressure (Pemax), vital capacity, tidal volume, and rapid shallow breathing index (RSBI), were checked by well-trained respiratory therapists before extubation. Arterial blood gas analyses were performed by a central laboratory.

Extubation was considered successful if patients maintained spontaneous breathing for 72 h after extubation. Otherwise they were classified into the extubation failure group. The intensive care unit (ICU) physicians determined the need for reinstitution of mechanical ventilation after extubation according to the respiratory pattern, vital signs, and arterial blood gas results. For patients who received NIV support for ≥ 6 h per day after extubation, inability to withdraw from NIV at 72 h after extubation was also classified as extubation failure in this study.

Statistical Analysis

All numerical data are reported as mean $\pm$ standard deviation (SD) unless indicated otherwise. All categorical variables were analyzed with chi-square tests, except when a small size required the use of Fisher's exact test. Means were compared between the groups by independent Student's *t* test, the Mann–Whitney's *U* test, or Kruskal–Wallis method, as appropriate. The proportion of patients remaining on invasive mechanical ventilation was compared among the study groups by Kaplan–Meier estimates and the log-rank test. Multivariate logistic regression with forward variant selection was utilized to identify parameters that independently predicted extubation outcome. Predictive performance of these parameters was also examined by the use of receiver operator characteristic (ROC) curves. Standard formulas were used to calculate the sensitivity, specificity, and positive and negative predictive values. The positive likelihood ratios (LR) were calculated using the following formula: LR = sensitivity/(1 − specificity). Statistical significance was a P value < 0.05.

Results

From January 2000 to June 2007, there were 330 hospital admissions of 199 MG patients for various reasons, and 41 episodes (12.4%) of them were due to respiratory failure. NIV were used initially in 14 patients, while the other 27 patients were intubated and received mechanical ventilation immediately (Fig. 1). Including patients who were intubated after NIV failure, a total of 33 patients received invasive mechanical ventilation.

Age, gender, and initial ABG were comparable between patients treated with NIV and those undergoing intubation without prior use of NIV (data not shown). The Acute Physiology and Chronic Health Evaluation (APACHE) II scores, which were significantly different between the two groups (8.0 for the initial NIV group vs. 12.8 for the initial intubation group, $P < 0.001$), influenced the decision to utilize NIV or intubation in our cohort. Six of the 14 (42.9%) patients required intubation in spite of initial NIV (NIV failure). The other eight (57.1%) patients were successfully prevented from intubation (NIV success) (Table 1). The initial APACHE II scores, the $PaCO_2$ values, and serum bicarbonate concentrations were lower in patients with NIV success (Table 1). Multivariate analysis revealed that independent predictors of NIV success included an initial APACHE II score of less than six (odds ratio: 2.0, 95% CI: 1.000–3.999, $P < 0.05$) and a serum bicarbonate concentration below 30 mmol/l (odds ratio: 30.0, 95% CI: 1.47–611.80, $P < 0.05$). The outcomes were significantly better in the eight patients with NIV success as compared with the other 33 patients in our study population, with NIV success group having a shortened length of stay in the ICU (2 vs. 18 days, $P < 0.001$) and a reduced duration of hospitalization (20 vs. 44 days, $P = 0.001$).

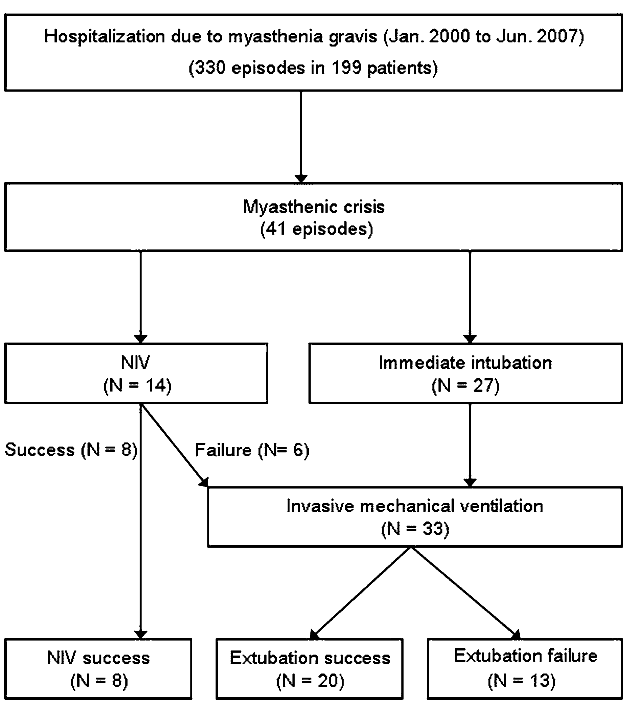

Fig. 1 Flow chart of this study

Table 1 Demographics and outcome of patients with myasthenic crisis initially undergoing non-invasive ventilation[a]

Variables	NIV failure ($n = 6$)	NIV success ($n = 8$)	P Value
Age, yrs	69 (59)	50 (61)	0.243
Male, %	1 (16.6%)	1 (12.5%)	0.825
SOFA score[b]	1 (7)	1 (4)	0.488
APACHE II score[b]	9 (15)	6 (5)	0.100
Anti-acetylcholine antibody, nmol/l[b]	14.9 (28.5)	15.9 (11.4)	0.855
Arterial blood gas[b]			
pH	7.33 (0.26)	7.34 (0.16)	0.476
PaO_2/FiO_2, mmHg	408 (218)	410 (233)	0.576
$PaCO_2$, mmHg	66.5 (57.2)	54.0 (78.6)	0.081
HCO_3^-, mmol/l	33.5 (7.6)	27.6 (13.6)	0.027
Outcome			
ICU length of stay, days	18 (21)	2 (9)	0.002
Duration of hospitalization, days	44 (168)	20 (28)	0.005

Definition of abbreviations: NIV = non-invasive ventilation; SOFA = Sequential Organ Failure Assessment; APACHE = Acute Physiology and Chronic Health Evaluation; ICU = intensive care unit

[a] Numbers in this table are expressed as median (range)

[b] Measured upon NIV initiation

Among the 33 episodes of intubation and mechanical ventilation, extubation success was achieved in 20 patients (60.6%). The remaining 13 were classified into the extubation failure group. The causes leading to reintubation included poor cough power with sputum impaction ($n = 8$), respiratory distress ($n = 5$), CO_2 retention ($n = 5$), and deoxygenation ($n = 1$) (some patients had multiple causes of reintubation). None of the patients in the extubation failure group had a previous diagnosis of asthma, chronic obstructive pulmonary disease, or congestive heart failure.

There were no differences in the demographic and physiological data on ICU admission between extubation success group and extubation failure group (Table 2). The weaning parameters, physiological data, and pneumonia or lung atelectasis before first extubation are shown in Table 3. Patients with extubation success had significant higher values of Pimax and Pemax as compared to those in the failure group. The treatment modalities and outcomes of these patients are listed in Table 4. The duration of mechanical ventilation, ICU length of stay, and

Table 2 Demographics and physiological data on ICU admission in patients with myasthenia crisis requiring invasive mechanical ventilation

Variables	All (*n* = 33)	Extubation success (*n* = 20)	Extubation failure (*n* = 13)	*P* value
Age, yrs	53.7 ± 21.3	53.6 ± 22.1	54.2 ± 20.8	0.957
Sex (Male:Female)	4:29	1:19	3:10	0.120
SOFA score	2.3 ± 1.8	2.4 ± 1.9	2.3 ± 1.8	0.758
APACHE II	12.3 ± 5.3	12.4 ± 6.2	12.0 ± 3.4	0.525
Arterial blood gas				
pH	7.26 ± 0.15	7.26 ± 0.13	7.25 ± 0.19	0.636
PaO_2/FiO_2, mmHg	395.8 ± 90.0	394.8 ± 93.4	397.4 ± 88.3	0.892
$PaCO_2$, mmHg	71.0 ± 28.7	72.9 ± 26.1	67.9 ± 33.6	0.589
HCO_3^-, mmol/l	29.0 ± 8.1	31.0 ± 9.0	25.9 ± 5.2	0.115
Thymoma, %	6 (18.2)	4 (20.0)	2 (15.4)	0.737
Malignancy, %	7 (21.2)	5 (25.0)	2 (15.4)	0.509
Other autoimmune disease, %	3 (9.1)	3 (15.0)	0 (0)	0.103

Definition of abbreviations: ICU = intensive care unit; SOFA = Sequential Organ Failure Assessment; APACHE = Acute Physiology and Chronic Health Evaluation

Table 3 Data before first extubation in patients with myasthenic crisis undergoing invasive mechanical ventilation

Variables	All (*n* = 33)	Extubation success (*n* = 20)	Extubation failure (*n* = 13)	*P* Value
Body temperature, °C	36.5 ± 0.5	36.6 ± 0.4	36.5 ± 0.5	0.813
Weaning parameters				
Pimax, cmH_2O	40.5 ± 14.7	46.6 ± 10.8	29.9 ± 14.9	0.002
Pemax, cmH_2O	42.0 ± 9.0	52.0 ± 8.8	27.3 ± 13.5	<0.001
RSBI, ml min	83.7 ± 46.9	74.5 ± 41.3	101.2 ± 53.9	0.228
Vital capacity, ml	895 ± 409	942 ± 447	783 ± 310	0.547
Tidal volume, ml	327 ± 119	352 ± 122	280 ± 103	0.115
Compliance, ml/cmH_2O	44.2 ± 11.7	42.7 ± 3.0	46.1 ± 9.9	0.464
Resistance, cmH_2O/l/s	13.9 ± 4.8	13.3 ± 5.3	14.7 ± 4.2	0.434
SOFA score	2.9 ± 0.7	2.8 ± 0.7	3.0 ± 0.7	0.478
APACHE II score	9.8 ± 4.9	9.9 ± 5.4	9.8 ± 4.2	0.870
Anti-acetylcholine antibody, nmol/l	15.0 ± 7.3	16.2 ± 7.4	13.4 ± 7.2	0.324
Pneumonia	0	0	0	–
Lung atelectasis, %	4 (12.0)	2 (10.0)	2 (15.4)	0.751
Arterial blood gas				
pH	7.44 ± 0.08	7.43 ± 0.09	7.45 ± 0.34	0.326
PaO_2/FiO_2, mmHg	384.9 ± 98.2	400.3 ± 91.2	359.3 ± 108.0	0.346
$PaCO_2$, mmHg	40.2 ± 5.9	40.9 ± 6.1	39.0 ± 5.5	0.346
HCO_3^-, mmol/l	26.3 ± 4.2	26.4 ± 4.9	26.1 ± 2.9	0.350

Definition of abbreviations: Pimax = maximal inspiratory pressure; Pemax = maximal expiratory pressure; RSBI = rapid shallow breathing index; SOFA = Sequential Organ Failure Assessment; APACHE = Acute Physiology and Chronic Health Evaluation

hospitalization days were all significantly longer in patients who failed the first extubation, and there was also a higher incidence of ventilator-associated pneumonia (VAP) in this group (Table 4 and Fig. 2). Two (4.9%) patients in the extubation failure group died because of multiple organ failure. Tracheostomy was performed in four (9.8%) patients after being ventilated for a median duration of 26 days (range: 20–30 days). All these four patients were finally liberated from MV, with durations of MV for 36, 100, 30, and 30 days, respectively.

The predictive values of parameters for extubation outcome in our patients are shown in Table 5. A Pemax of ≥40 cmH_2O was a good predictor of extubation success, with a high specificity of 91.0% and a likelihood ratio up to 8.77. A Pimax of ≥30 cmH_2O was 100% sensitive in predicting extubation success but its specificity was low

Table 4 Treatment and outcome in patients with myasthenia crisis requiring invasive mechanical ventilation

	All ($n = 33$)	Extubation success ($n = 20$)	Extubation failure ($n = 13$)	*P* Value
Therapy				
Steroid, %	31 (93.9)	19 (95.0)	12 (92.3)	0.751
Immunosuppressant, %	9 (27.3)	6 (30.0)	3 (23.1)	0.663
Plasmapheresis (courses)	5.6 ± 3.0	5.5 ± 3.1	5.6 ± 2.6	0.770
Mortality, %	2 (6.1)	0 (0)	2 (15.4)	0.07
Tracheostomy, %	4 (12.1)	0 (0)	4 (30.8)	0.008
Duration of MV, days	24.7 ± 30.5	10.9 ± 4.6	45.9 ± 40.7	<0.001
ICU length of stay, days	25.7 ± 12.8	18.9 ± 10.2	36.2 ± 8.8	<0.001
Duration of hospitalization, days	53.1 ± 42.7	43.2 ± 39.0	68.4 ± 45.1	0.005
Ventilator-associated pneumonia, %	7 (21.2)	1 (5.0)	6 (46.2)	0.005

Definition of abbreviations: ICU = intensive care unit; MV = invasive mechanical ventilation

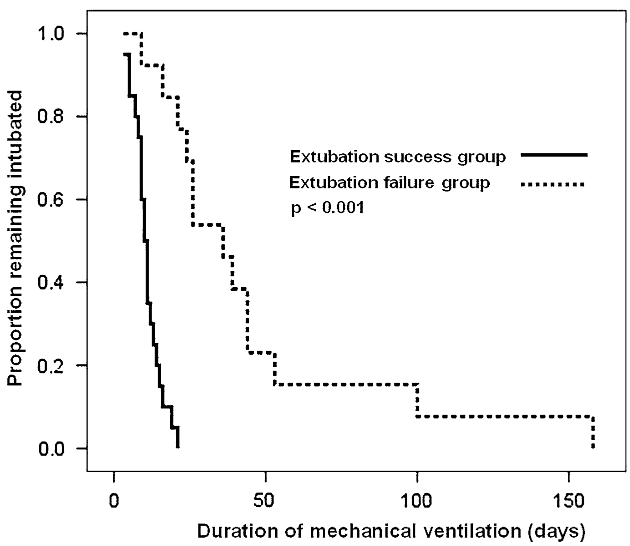

Fig. 2 Proportion of patients remaining on invasive mechanical ventilation (33 episodes)

(45.5%). Multivariate logistic regression was performed using variants with *P* values less than 0.15 in the univariant analyses (Table 6). The included variables were gender, presence of other autoimmune disorders, serum bicarbonate concentrations on admission, Pimax, and Pemax. We also add the RSBI, vital capacity, and tidal volume in this statistical model, although these parameters did not meet the criteria of inclusion. We found that a Pemax $\geq$ 40 cmH_2O was the only independent predictor for extubation success in these patients. Other parameters, such as vital capacity or rapid shallow breathing index, did not predict extubation success well as in patients of other disease categories. Furthermore, failure of the first attempt of extubation was a risk factor for prolonged ICU length of stay ($\geq$30 days) (Tables 6).

We also analyzed NIV application after extubation. Intermittent NIV support was applied to 10 (30.3%) of the 33 patients undergoing invasive mechanical ventilation after extubation. Seven (70%) of them received NIV support less than 6 h per day and were successfully prevented from reintubation. The other three (30%) patients became NIV-dependent immediately after extubation and were re-intubated 24, 30, and 60 h after extubation, respectively. However, there were no significant differences in demographics and physiological parameters between these two groups with post-extubation success or failure (data not shown).

Discussion

Myasthenic crisis is a life-threatening complication of MG. When treated aggressively, myasthenic crisis has been associated with improved outcome [12]. Results from our study show that successful application of NIV in these patients may improve outcomes. Furthermore, extubation failure is associated with prolonged duration of mechanical ventilation and a higher incidence of VAP in these patients. Our data also indicate that adequate levels of Pemax and cough strength are essential for extubation success. These data may provide insights into the optimal management of these patients in the ICU.

The application of NIV can augment airflow and prevents airway collapse by offering positive airway pressure both in the inhalation and exhalation phases of respiration. It has been effective in patients with slowly progressive neuromuscular diseases, such as Duchenne muscular dystrophy or amyotrophic lateral sclerosis [13, 14]. Predictors of NIV success in these patients included younger age, lower acuity of disease, better neurological score, and moderate respiratory acidosis [15, 16].

Table 5 Predictive values of parameters for extubation outcome in patients with myasthenic crisis

Variable	Criteria	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	Likelihood ratio
RSBI, 1/min ml	≤105	80.0	40.0	71.4	55.6	58.6	1.33
RSBI, 1/min ml	≤80	68.4	60.0	76.5	50.0	65.5	1.71
Vital capacity, ml/kg	≥10	92.0	20.0	71.4	33.3	60.0	1.15
Tidal volume, ml/kg	≥5	68.4	40.0	73.3	40.9	58.6	1.14
Pimax, cmH_2O	≥30	100.0	45.5	76.0	100.0	80.0	1.83
Pemax, cmH_2O	≥40	78.9	91.0	93.6	71.4	83.3	8.77

Definition of abbreviations: PPV = positive predict value; NPV = negative predict value; RSBI = rapid shallow breathing index; Pimax = maximal inspiratory pressure; Pemax = maximal expiratory pressure

Table 6 Summary of multivariate logistic regression

Outcome/variable	Odds ratio	95% confidence	*P* value
Extubation success			
RSBI ≤ 105, 1/min ml	2.5	0.5–13.4	0.524
RSBI ≤ 80, 1/min ml	3.25	0.7–16.0	0.140
Vital capacity ≥ 10 ml/kg	1.3	0.2–9.8	0.756
Tidal volume ≥ 5 ml/kg	2.1	0.4–9.8	0.605
Pemax ≥ 40 cmH_2O	37.5	3.6–386.5	<0.001
Duration of mechanical ventilation ≥14 days			
Ventilator-associated pneumonia	40.0	3.4–468.1	<0.001
Intensive care unit length of stay ≥30 days			
Extubation failure	18.9	3.2–112.1	0.001

Definition of abbreviations: RSBI = rapid shallow breathing index; Pemax = maximal expiratory pressure

NIV can also be useful in the management of myasthenic crisis. Although some previous studies concluded that early intubation for mechanical ventilation is an important step in the management of these patients [12], data from other reports suggested that NIV could prevent intubation in MG patients with respiratory failure [10, 17]. In a recent study reported by Seneviratne and Rabinstein, NIV was the initial ventilatory support in 24 episodes of myasthenic crisis and intubation was prevented in 14 episodes [17]. In that study, severe hypercapnia ($PaCO_2 >$ 45 mmHg) was a predictor for NIV failure [17]. In our study, NIV can be safely applied to prevent intubation in myasthenic crisis if the initial serum bicarbonate concentration was below 30 mmol/l and the APACHE II score was less than six. Our data suggest that serum bicarbonate is superior to $PaCO_2$ in predicting NIV failure. None of the patients in this study had renal failure when admitted to the ICU. The initial serum level of bicarbonate might be a better indicator of the severity and chronicity of respiratory acidosis, and thereby the capacity of the respiratory muscles. It is notable that the patients in our study are more hypercapnic than patients in the study conducted by Seneviratne and Rabinstein. Further clinical data was required to access whether earlier use of NIV can improve its success rate.

In general, medical patients undergoing invasive mechanical ventilation have exhibited a failure rate of extubation ranging from 3% to 19% [18, 19], whereas this percentage was much higher in patients with neuromuscular diseases. The reintubation rate in myasthenic crisis is still unknown. To our knowledge, only one previous study on 26 episodes of myasthenic crisis has reported a reintubation rate of 27% [20]. The high percentage of reintubation in our study (39.2%) was not unexpected. Extubation failure occurred in 68.2% of patients with Guillain-Barré syndrome [21], and 30–45% of them required tracheostomy [21, 22]. In another study on seven patients with motor neuron diseases the reintubation rate was 100% [23]. Therefore, special attention should be paid to decision making when patients with neuromuscular diseases have passed an SBT.

It has been suggested that aggressive airway suction and chest physiotherapy should be used in myasthenic crisis to diminish the risk for prolonged respiratory complications [3]. Meticulous attention to anticholiesterase is required because its continuous use would increase airway secretions. In this study, we found that poor cough power with impaired airway clearance was the most common cause of extubation failure in myasthenic crisis. Further studies are needed to examine the associations between the sputum quality, suction frequency, and extubation outcome in these patients.

Ventilation failure is a common cause of mortality among MG patients [8, 24, 25], but few previous studies have examined the impact of extubation failure. In a study of general medical patients in a tertiary teaching hospital, Epstein et al. reported that extubation failure was associated with a higher mortality, a longer ICU stay, and the requirement to transfer them to a long-term care or rehabilitation facility [18]. Patients with myasthenic crisis, however, have some characteristics such as a younger age, a lower APACHE II score, and fewer comorbidities in comparison to patients with general medical diseases. Patients with myasthenic crisis usually can be eventually liberated from mechanical ventilation if adequate medical therapies are administered. Prolonged intubation, however, may lead to several complications such as atelectasis, anemia, urinary tract infection, congestive heart failure [8], and, in this study, VAP. Thus, strategies to facilitate the success of extubation may reduce the morbidity and mortality of these patients in the ICU.

Some weaning parameters such as rapid shallow breathing index and vital capacity were reported to predict successful extubation in neuromuscular disorders [22, 26]. However, the optimal predictors and timing of extubation in myasthenic crisis remains controversial. Ventilatory muscle strength, expressed by Pimax and Pemax, are reduced in generalized MG patients [27]. Thomas et al. [2] reported three independent predictors of prolonged intubation in myasthenic crisis, including: (1) pre-intubation serum bicarbonate $\geq$30 mg/dl, (2) peak vital capacity from day 1 to day 6 with post-intubation $<$25 ml/kg, and (3) age $>$50 years. Pemax represents the integration of exhalation muscle strength, and sufficient cough flows have to be generated by expiratory muscles to allow airway clearance. In a study of neuromuscular diseases conducted by Perez [28], Pemax below 45 cmH_2O was associated with compromised cough efficiency. Studies on patients with Duchenne muscular dystrophy, amyotrophic lateral sclerosis, and multiple sclerosis [29–31] concluded that peak cough flow and peak expiratory flow may be useful in monitoring expiratory muscle strength. Cough power is a well-documented predictor of extubation outcomes in general medical [32, 33] and in neurosurgical patients [34]. Our results indicate that Pemax is superior to vital capacity and Pimax in predicting cough strength which is required to maintain airway patency after extubation in patients with myasthenic crisis. Therefore, we recommend that a sustained and adequate level of Pemax should be a major goal of medical therapies for these patients in the ICU.

Data on post-extubation NIV support in myasthenic crisis are also limited. One previous study reported that NIV could prevent reintubation in five patients after extubation [11]. The success rate of NIV in our study was 70%, suggesting that NIV may be useful in assisting extubation by allowing some patients with myasthenic crisis additional time to recover respiratory strength. However, we could not identify any predictors for NIV success after extubation in these patients. One major concern for the use of NIV after extubation is that it may increase the risk of aspiration in patients with a poor cough power.

Some limitations of this study must be addressed. First, this was a single-centered, retrospective study and the sample size was small. To our knowledge, only few previous reports on extubation outcome in myasthenic crisis had a study population of more than 50 patients [2, 4–6, 17]. Second, patients analyzed in this study were collected over a period of 7 years, which might lead to significant heterogeneity among the study population. Nevertheless, the management of myasthenic crisis did not change in this time period in this medical center. Third, measuring Pemax is effort-dependent and failure to generate a strong expiration may reflect a simple lack of patient cooperation rather than insufficient muscle strength. Finally, different medical centers may have different treatment protocols for myasthenic crisis, and conclusions from this one-institutional study may not be applicable to other centers. Additional prospective, large-scale, and randomized studies are needed to evaluate the optimal timing and weaning parameters for myasthenic crisis, and the role NIV plays in the future health of these patients.

In summary, this study has demonstrated that NIV may initially be applied in those patients with fewer comorbidities and a lesser degree of renal compensation for respiratory acidosis. Furthermore, poor cough strength with sputum impaction is a common cause of extubation failure in myasthenic crisis, which is associated with significant in-hospital morbidity in these patients. Our data also suggest that an adequate level of Pemax may provide clinicians with an objective and inexpensive predictor for extubation success. The optimal management of these patients may depend on tailoring the treatments on an individual basis using one's best clinical judgment.

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