Predictors of Successful Noninvasive Ventilation Treatment for Patients Suffering Acute Respiratory Failure

Ming-Shian Lin[1], How-Ran Guo[2,3], Ming-Hua Huang[4], Cheng-Ren Chen[1], Chen-Long Wu[2,3,5]*

Departments of [1]Chest Medicine and [4]Respiratory Therapy, Chia-Yi Christian Hospital, Chia-Yi, [2]Department of Environmental and Occupational Health, College of Medicine, National Cheng Kung University, [3]Department of Occupational and Environmental Medicine, National Cheng Kung University Hospital, and [5]Department of Occupational Medicine, Chi-Mei Foundation Medical Center, Tainan, Taiwan, R.O.C.

Background: To identify predictors of successful noninvasive ventilation (NIV) treatment for patients with acute respiratory failure.

Methods: This was a prospective intervention study of the intensive care unit of a teaching hospital in Chia-Yi, Taiwan. Patients were enrolled if they had acute respiratory failure and had been admitted to the intensive care unit of our hospital between October 1, 2004 and September 30, 2005 inclusively.

Results: All 86 patients who satisfied the study's inclusion criteria agreed to participate in the study, and each patient was followed-up until the discontinuation of NIV treatment or their death. We measured the Acute Physiology and Chronic Health Evaluation (APACHE) II score prior to their treatment and also conducted serial measurements of respiratory rate (RR), tidal volume, rapid shallow breathing index, maximal inspiratory pressure ($P_I$max), and maximal expiratory pressure ($P_E$max) prior to, and 30 minutes and 60 minutes subsequent to NIV treatment (denoted by, respectively, the subscripted numbers 0, 30 and 60). NIV treatment was determined as being successful for 55 patients (the success group, for which individuals endotracheal intubation was avoided) and as being a failure for 31 patients (the failure group). APACHE II scores prior to treatment, $P_I max_{30}$ ($P_I$max 30 minutes subsequent to NIV), RR_{30} (RR 30 minutes subsequent to NIV), and RR_{60} (RR 60 minutes subsequent to NIV) were all significantly lower for the success group than for the failure group. The success group also had significantly better values for RR during the first 30 minutes of NIV treatment and for $P_E$max during the first 60 minutes of NIV treatment compared to individuals from the failure group.

Conclusion: APACHE II scores recorded prior to NIV treatment, $P_I max_{30}$, RR_{30}, RR_{60}, as well as improvements to RR during the first 30 minutes of NIV treatment and to $P_E$max during the first 60 minutes of NIV treatment were predictors of successful NIV treatment for patients suffering from acute respiratory failure. Such parameters may be helpful in selecting patients to receive NIV treatment and also for deciding when early termination of the treatment is appropriate. [*J Chin Med Assoc* 2008;71(8):392–398]

Key Words: acute respiratory failure, APACHE II, noninvasive ventilation, rapid shallow breathing index, respiratory rate

Introduction

Appreciation of the relative benefits of noninvasive ventilation (NIV), which is the provision of mechanical respiratory assistance without the need for the insertion of an endotracheal airway for a patient, in the management of acute respiratory failure appears to be increasing not only in intensive care units (ICUs) but also in emergency departments[1–4] and general wards.[1] Given that a number of well-designed randomized controlled trials have demonstrated the relative efficacy of NIV as regards averting the need for intubation in ventilatory-support patients, NIV is now being considered more as the respiratory support of choice for acute respiratory failure.[1–4] As patient intubation can be avoided with NIV, morbidity, mortality and length of hospital

*Correspondence to: Dr Chen-Long Wu, Department of Environmental and Occupational Health, National Cheng Kung University, 138, Sheng-Li Road, Tainan 704, Taiwan, R.O.C.
E-mail: c456@cych.org.tw • Received: September 21, 2007 • Accepted: July 24, 2008

stay are consequently reduced.[1,2] NIV can also be applied to reduce the need for mechanical ventilation in selected patients.[1,2] For some patients, however, application of NIV may lead to clinicians missing the optimal time window for intubation, and thus result in a poorer patient outcome than would have been the case if appropriately timed intubation had been conducted.[1,2] Therefore, the correct identification of such patients would constitute a desirable goal. The proportion of such patients amongst the total pool of respiratory-assist patients varies from study to study.[1,2] Further, the response to NIV treatment cannot necessarily be predicted by the relative severity of the existing underlying lung disease as indicated by forced expiratory volume in the first second of forced exhalation (FEV_1), arterial blood-gas levels, or by arterial blood-gas and blood parameter values (PCO_2, pH, etc.) obtained prior to commencing NIV.[1,2] Clearly then, clinicians have, for some time, been frustrated by their inability to accurately predict the continuum of NIV.

The rapid shallow breathing index (RSBI) was introduced in 1991 by Yang and Tobin[2] and was found to be an accurate index for predicting ventilator weaning success. In contrast, however, to the best of our knowledge, few, if any, previous studies have attempted to evaluate the relative feasibility of using the RSBI to predict the outcome of NIV therapy for individuals suffering from acute respiratory failure. To evaluate the relative feasibility of using RSBI and other respiratory indices to accurately predict the outcome of NIV treatment of acute respiratory failure, we conducted a prospective study in the ICU of a teaching hospital in Chia-Yi, Taiwan.

Methods

Patients

We recruited study participants from a group of patients with acute respiratory failure who had been admitted to the adult ICU of our institution between October 1, 2004 and September 30, 2005 inclusively and who had received mechanical ventilation subsequent to their admission. If the patients met the following criteria, they were initially treated with NIV: (1) stable hemodynamic condition; (2) no need for endotracheal intubation to handle secretion; (3) no upper airway obstruction; (4) no bulbar dysfunction; (5) no life-threatening arrhythmias; and (6) no massive upper gastrointestinal bleeding. Initially, all the patients received NIV featuring a bi-level positive airway pressure (BiPAP) mode together with conventional treatment modalities, including oxygen therapy, bronchodilators, corticosteroids and antibiotics, as needed. Conventional mechanical ventilation was applied if the above medication and treatment strategy were deemed to have failed, and/or if patients exhibited unfavorable arterial blood-gas or blood parameter levels ($PaO_2 < 55$ mmHg with oxygen supplementation or blood pH < 7.30) or clinical signs of respiratory distress such as tachypnea, use of accessory muscles for respiration and/or paradoxical respiratory movement. Patients with unstable hemodynamic status (defined as the need for administration of inotropic agents to maintain systolic blood pressure > 90 mmHg), life-threatening arrhythmias, facial deformity or tracheostomy were excluded, as were those who received intubation for the removal of excessive respiratory secretions. This study was approved by the Research Committee of the hospital in which the study was conducted.

Data collection

The RSBI was measured using a hand-held spirometer (Boehringer Laboratory, Wynnewood, PA, USA) while the patient breathed through a mouthpiece, with a nasal clip on the nose to avoid air leakage. According to the suggestion of Yang and Tobin,[2] study patients were asked to breathe through the Wright respirometer for a period of 1 minute. Patient respiratory rate (RR) and tidal volume (V_T) were measured by the Wright respirometer, after which the RR value was divided by the V_T value to calculate the RSBI (RR/V_T). Measurement of the maximal inspiratory pressure ($P_I$max) and the maximal expiratory pressure ($P_E$max) were conducted using an inspiratory force meter (Ferraris Medical Ltd., Hertford, England) using the same procedures as those used for measuring the RSBI. Because all patients in the study group were suffering from acute respiratory failure, it was not feasible to occlude the airway to obtain the measurements. Therefore, patients were asked to exhale and inhale vigorously prior to the determination of $P_I$max and $P_E$max. Whilst it could be construed that this option might introduce some level of variability into the measurement accuracy for $P_I$max and $P_E$max, given that the procedure adopted for such parameter assessment was the same for all patients, the variability was deemed unlikely to introduce remarkable bias to the study results. As the Acute Physiology and Chronic Health Evaluation (APACHE) II[1] scores were recorded for the study patients at the time of their admission to the ICU, the $P_I$max, $P_E$max, RR, V_T, and RSBI measurements were repeated using the same hand-held spirometer and inspiratory force meter, prior to NIV application (denoted by a subscripted number 0), and also 30 and 60 minutes subsequent to NIV application (denoted by, respectively, a subscripted 30 and subscripted 60).

NIV

All the physicians, respiratory therapists, and nurses in the ICU who were involved with the study had been well trained on the application of NIV techniques prior to study commencement. Portable BiPAP ventilators (Respironics, Murrysville, PA, USA) were used in the *spontaneous mode*, and the interface was adapted as a full-face mask. For the management of NIV, we adopted the approach applied, in 2000, by Antón et al as part of an earlier analogous study.[5] In short, the inspiratory positive airway pressure (IPAP) level was initially set at 10 cmH_2O and then gradually increased until the respiratory rate fell to 25 breaths per minute without excessive usage of any accessory respiratory muscles. In order to facilitate comparisons between all patients, the expiratory positive airway pressure (EPAP) value was set at 4 cmH_2O without any back-up rate for all participants. The duration of the NIV session performed for our study participants was similar to that used for other studies and depended on the patient's tolerance to ventilation. We considered that treatment with NIV was successful if endotracheal intubation was avoided and if the patients were able to be subsequently discharged from hospital.

Criteria for termination of NIV

If any 1 of the following situations were detected by the physician or the respiratory therapist in charge, the NIV procedure was terminated and endotracheal intubation with invasive ventilation was immediately commenced: (1) decompensated respiratory acidosis featuring CO_2 retention and blood pH < 7.30; (2) oxygen desaturation with an SpO_2 value < 90% in spite of high oxygen supplementation (up to 15 L/min); (3) inability to tolerate the NIV mask due to discomfort or pain; (4) need for endotracheal intubation to manage secretions and/or to protect the airway; or (5) hemodynamic instability.

Statistical analysis

Results are expressed herein as mean ± standard deviation, or mean (95% confidence interval). Differences and interval changes for serial respiratory indices (RR, V_T, $P_I$max, $P_E$max, RSBI) between the success and failure groups for continuous NIV application were evaluated using Student's *t* test, whilst differences in categorical data were assessed using the χ^2 test. Interval changes with respect to indices within each study group were evaluated using paired *t* tests. The independent effects of these variables on outcome were evaluated using multivariate logistic regression analyses. All variables featuring a p value < 0.10 for the univariate analyses were included as independent variables in the initial multivariate regression model, and the final model was constructed following exclusion of the variables that featured a p value > 0.25. The area under the receiver operating characteristic curve (AUROC) for each serial respiratory index was also calculated to evaluate the capacity to predict the success of NIV treatment or otherwise. The sensitivity, specificity, positive predictive value, and negative predictive value were not reported in order to avoid dependence on a threshold value.[2]

Results

All 86 patients who satisfied the inclusion criteria agreed to participate in this study, of whom 55 (64%) were defined as being successful cases (the success group), and 31 (36%) as cases that failed NIV treatment (the failure group). The underlying diseases included pneumonia (16 patients), chronic obstructive pulmonary disease (COPD) with exacerbation (15 patients), acute cardiogenic pulmonary edema (14 patients), post-extubation stridor (11 patients), and sepsis (11 patients) (Table 1). Among the 5 most common underlying diseases for this group of 86 patients, post-extubation stridor had the highest rate of successful NIV treatment (91%), followed by sepsis (82%) and acute cardiogenic pulmonary edema (79%), with pneumonia featuring the lowest rate of NIV treatment success (38%).

Of the parameters measured prior to NIV treatment, only the APACHE II scores were significantly lower for the success group than for the failure group ($p = 0.001$), with the AUROC value here being 0.72 (Table 2). Of the serial respiratory measurements taken, $P_I max_{30}$ ($p = 0.05$), RR_{30} ($p = 0.01$), and RR_{60} ($p = 0.03$) were significantly lower for the success group than for the failure group, and the corresponding AUROC values were, respectively, 0.64, 0.65, and 0.61. When making intergroup comparison, none of the serial RSBI measurement values (taken prior to and at 30 and 60 minutes subsequent to NIV treatment) differed significantly.

Amongst the interval changes for respiratory indices, $P_I max_{0–60}$, $RR_{0–30}$, $RR_{0–60}$, $RSBI_{0–30}$, and $RSBI_{0–60}$ for the success group, and $P_E max_{0–60}$, $V_{T0–30}$, $V_{T0–60}$, and $RSBI_{0–60}$ for the failure group proved to differ statistically significantly (Table 3). When comparing the 2 study groups, only the differences in $P_E max_{0–60}$ ($p = 0.04$) and $RR_{0–30}$ ($p = 0.01$) attained what we deemed to be a statistically significant level, with the AUROC values for the success and failure groups being, respectively, 0.61 and 0.66 (Table 3). Further,

Table 1. Distribution of underlying diseases amongst study participants

Underlying disease	NIV treatment			Success rate, %
	Success group, *n* (%)	Failure group, *n* (%)	Total, *n*	
Pneumonia*	6 (11)	10 (32)	16	38
COPD	9 (16)	6 (19)	15	60
Acute cardiogenic pulmonary edema	11 (20)	3 (10)	14	79
Sepsis	9 (16)	2 (6)	11	82
Extubation stridor	10 (18)	1 (3)	11	91
UTI	4 (7)	1 (3)	5	80
Malignancy	1 (2)	2 (6)	3	33
CNS diseases	1 (2)	2 (6)	3	33
Others	4 (7)	4 (13)	8	50
Total	55 (100)	31 (100)	86	64

**Defined as leukocytosis, purulent sputum, and a new infiltration patch on chest X-ray. NIV = noninvasive ventilation; COPD = chronic obstructive pulmonary disease with acute exacerbation; UTI = urinary tract infection; CNS = central nervous system.*

Table 2. Differences in demographic and respiratory indices between the success and failure groups*

Index	NIV treatment		*p* at difference	AUROC
	Success group ($n=55$)	Failure group ($n=31$)		
Male/Female ratio	1.04	0.94	0.82	
Age (yr)	70.8 ± 14.1	73.4 ± 13.9	0.40	0.56
APACHE II score	16.2 ± 6.5	20.8 ± 4.9	0.001†	0.72
P_Imax_0 (cmH_2O)	–23.0 ± 14.7	–20.3 ± 16.2	0.43	0.57
P_Imax_{30} (cmH_2O)	–25.2 ± 13.0	–19.7 ± 12.2	0.05†	0.64
P_Imax_{60} (cmH_2O)	–26.8 ± 15.3	–21.3 ± 12.8	0.11	0.61
P_Emax_0 (cmH_2O)	23.4 ± 13.8	20.2 ± 10.8	0.26	0.55
P_Emax_{30} (cmH_2O)	23.4 ± 12.0	22.2 ± 10.4	0.65	0.51
P_Emax_{60} (cmH_2O)	24.2 ± 12.6	26.9 ± 13.4	0.39	0.55
RR_0 (breaths/min)	27.8 ± 6.9	29.6 ± 7.9	0.28	0.55
RR_{30} (breaths/min)	24.9 ± 5.6	28.8 ± 7.9	0.01†	0.65
RR_{60} (breaths/min)	25.2 ± 5.9	28.6 ± 7.8	0.03†	0.61
V_{T0} (mL)	350.5 ± 154.4	316.1 ± 137.9	0.30	0.56
V_{T30} (mL)	380.4 ± 176.5	367.3 ± 175.6	0.74	0.52
V_{T60} (mL)	378.6 ± 167.5	406.2 ± 158.1	0.49	0.56
$RSBI_0$ (breaths/min/mL)	100.2 ± 58.2	113.7 ± 64.4	0.32	0.58
$RSBI_{30}$ (breaths/min/mL)	84.4 ± 50.0	101.8 ± 71.7	0.19	0.57
$RSBI_{60}$ (breaths/min/mL)	80.8 ± 41.4	82.1 ± 40.8	0.90	0.51

**Data are presented as mean ± standard deviation; †$p < 0.05$, NIV treatment success vs. failure. NIV = noninvasive ventilation; AUROC = area under the receiver operating characteristic curve; APACHE = Acute Physiology and Chronic Health Evaluation; $P_I$max = maximum inspiratory pressure; $P_E$max = maximum expiratory pressure; RR = respiratory rate; V_T = tidal volume; RSBI = rapid shallow breathing index.*

interval changes as regards RSBI did not differ statistically significantly between the 2 groups.

Six respiratory indices (APACHE II, P_Imax_{30}, RR_{30}, RR_{60}, $P_Emax_{0–60}$, $RR_{0–30}$) were found to be significant in the univariate logistic regression analyses; thus, all were included in the initial multivariate logistic regression model (Table 4). However, RR_{30} was excluded due to its significant correlation to RR_{60} (Pearson's correlation coefficient = 0.86; $p = 0.001$). Further stepwise forward and backward selection excluded P_Imax_{30}, so the final model included APACHE II, RR_{60}, $P_Emax_{0–60}$, and $RR_{0–30}$ (Table 4).

When separate analyses were performed on data relating to underlying diseases afflicting more than 10 study patients (including pneumonia, COPD, acute cardiogenic pulmonary edema, sepsis, extubation stridor), none of the indices appeared to be a significant independent predictor of treatment outcome for the study participants (data not shown), this being most likely due to the influence of a rather small sample size.

Table 3. Interval improvement in respiratory indices prior to, and at 30 and 60 minutes subsequent to noninvasive ventilation (NIV) treatment*

	NIV treatment		*p* at difference	AUROC
	Success group	Failure group		
$P_Imax_{0–30}$ (cmH_2O)	–2.8 (–5.5 ~ 0.0)	0.6 (–5.0 ~ 6.2)	0.22	0.60
$P_Imax_{30–60}$ (cmH_2O)	–1.5 (3.8 ~ 0.9)	–0.7 (–3.0 ~ 1.6)	0.68	0.54
$P_Imax_{0–60}$ (cmH_2O)	–4.0 (–7.0 ~ –1.0)†	–2.6 (–5.9 ~ 0.6)	0.57	0.55
$P_Emax_{0–30}$ (cmH_2O)	0.6 (–1.8 ~ 3.1)	2.1 (–0.7 ~ 4.8)	0.44	0.55
$P_Emax_{30–60}$ (cmH_2O)	0.5 (–1.4 ~ 2.4)	3.4 (–0.3 ~ 7.0)	0.13	0.58
$P_Emax_{0–60}$ (cmH_2O)	1.1 (–1.9 ~ 4.2)	6.0 (2.7 ~ 9.4)†	0.04‡	0.61
$RR_{0–30}$ (breaths/min)	–2.9 (–4.1 ~ –1.8)†	–0.8 (–2.0 ~ 0.4)	0.01‡	0.66
$RR_{30–60}$ (breaths/min)	0.1 (–0.8 ~ 1.0)	–0.2 (–2.0 ~ 1.5)	0.68	0.52
$RR_{0–60}$ (breaths/min)	–2.7 (–4.2 ~ –1.1)†	–1.0 (–3.0 ~ 0.9)	0.20	0.57
$V_{T0–30}$ (mL)	31.1 (–6.3 ~ 68.6)	51.3 (18.6 ~ 83.9)†	0.46	0.56
$V_{T30–60}$ (mL)	0.0 (–33.4 ~ 33.4)	3.9 (–27.7 ~ 35.4)	0.88	0.49
$V_{T0–60}$ (mL)	23.5 (–11.9 ~ 58.8)	71.0 (33.9 ~ 108.2)†	0.10	0.65
$RSBI_{0–30}$ (breaths/min/mL)	–16.6 (–28.0 ~ –5.2)†	–12.0 (–26.9 ~ 3.0)	0.61	0.48
$RSBI_{30–60}$ (breaths/min/mL)	–4.3 (–11.2 ~ 2.5)	–3.2 (–11.7 ~ 5.3)	0.84	0.53
$RSBI_{0–60}$ (breaths/min/mL)	–16.8 (–27.3 ~ –6.4)†	–20.9 (–32.4 ~ –9.4)†	0.63	0.53

**Data are presented as mean (95% confidence interval); †$p < 0.05$ within the NIV treatment success and failure groups; ‡$p < 0.05$ between the NIV treatment success and failure groups. AUROC = area under the receiver operating characteristic curve.*

Table 4. Odds ratios (OR) and associated 95% confidence intervals (CI) for the success group as obtained from logistic regression analyses

Index	Initial model*			Final model†		
	OR‡	95% CI	*p*	OR‡	95% CI	*p*
APACHE II score	0.024	0.001–0.560	0.03§	0.024	0.001–0.546	0.02§
P_Imax_{30} (cmH_2O)	0.239	0.005–7.594	0.44	NI	NI	NI
RR_{60} (breaths/min)	0.007	0.000–8.511	0.18	0.014	0.000–0.632	0.04§
$P_Emax_{0–60}$ (cmH_2O)	0.013	0.000–0.662	0.04§	0.017	0.000–0.703	0.05§
$RR_{0–30}$ (breaths/min)	0.031	0.001–1.090	0.07	0.023	0.000–0.716	0.05§

**Included all 6 indices studied; †obtained through stepwise model construction and included only significant independent predictors; ‡odds ratio of NIV treatment success associated with each unit increase in the index; §$p < 0.05$. NI = not included in the final model.*

Discussion

The success rate for NIV treatment in our study was 64%, a figure that is similar to results from a number of previous studies, although it was apparent that there did exist a number of interstudy differences as regards underlying diseases amongst study participants.[3] Most of the major underlying diseases determined in our study, including pneumonia, COPD, acute cardiogenic pulmonary edema, and post-extubation stridor, were indicative for NIV application, as was also revealed by the authors of a number of earlier studies.[3,4,6–9]

Many previous studies have attempted to assess the relative effectiveness of NIV treatment, but as best as we are aware, few have attempted to perform a comprehensive evaluation of the use of respiratory indices such as P_Imax, P_Emax, RR, and V_T for the purposes of predicting NIV treatment outcome. Of the baseline respiratory indices examined prior to the application of NIV, we found that only the APACHE II score at presentation, which constitutes an index of the relative severity of patient illness at the time of assessment, differed significantly between the 2 groups, with the APACHE II values being greater for the failure group, which featured AUROC values up to a figure of 0.72. A number of previous studies relating to the application of NIV for acute exacerbations of COPD had similar observations.[10–12] In contrast to such an outcome, patient gender and age did not affect the results of NIV treatment.

Subsequent to the initiation of NIV treatment, we found that only patient RR was a significant predictor of treatment success for within- and between-group analyses. Specifically, RR_{30} and RR_{60} differed significantly between the 2 groups. From a similar previous study reported in 2003, Girault et al[3] observed significant

differences 2 hours following NIV treatment commencement, and beyond 2 hours, whereas in 2001, Plant et al[13] observed significant differences 4 hours subsequent to treatment commencement. In our study, interval comparisons further demonstrated that the response to NIV treatment that occurred within the initial 30 minutes of NIV treatment (RR_{0-30}) was also significant within the success group. As such, this parameter still proved to be a significant predictor of NIV treatment success after having adjusted for APACHE II scores and other indices as presented in the final multivariate regression model.

Although RSBI would appear to be a reasonably good predictor for the weaning of a patient from invasive intubation,[14] we did not find this parameter to be a significant predictor of successful NIV treatment for either the serial or the interval changes. The fact that improvements to RSBI following NIV treatment were similar for the 2 study groups may have been due to the simultaneous interval improvements that arose within each group following NIV treatment, improvements which could be related to the "counteraction" between the improvement in RR_{0-30} for the success group and the improvement in V_{T0-30} for the failure group. The improvement in RR following NIV treatment was independent of the treatment-elicited increase in V_T (Table 3), and such an outcome could probably be explained by the NIV-elicited reduction of the extent of acidosis present prior to treatment.

The relative success of NIV treatment may be related to its impact on some of the underlying diseases, or simply to NIV application *per se*, or both. As regards the data relating to early responses, $P_E$max and V_T improved in the failure group following NIV treatment, but this was not the case for the success group. Such a result could be related to the relative progression of the pre-existing underlying diseases during NIV treatment regardless of the relative improvement in respiratory load by such treatment. Clearly, further longer-term observations of these variables as part of a future study are warranted.

Among the 5 most common underlying diseases in our study patients, post-extubation stridor had the highest rate of treatment success (91%), and pneumonia the lowest (38%). In general, study participants with post-extubation stridor featured improved/improving clinical conditions prior to extubation, this being the principal reason for which extubation was performed. Therefore, even though such individuals suffered from stridor following extubation, their general condition was relatively good, and so it is not surprising that they featured a greater success rate with NIV. On the other hand, study participants with pneumonia exhibited a downhill progression of their general condition which led to acute respiratory failure. Thus, the respiratory system was both the main and the direct target of the disease; consequently, these individuals' respiratory system was more vulnerable compared to that of non-pneumonia patients, and thus the former became less responsive to BiPAP therapy. Individuals featuring COPD with acute exacerbations are, generally, individuals who would appear to benefit the most from BiPAP therapy, but this group of patients in our study did not demonstrate a greater rate of success with NIV treatment than other groups. Such a result might be attributable to the fact that many of the COPD-afflicted study participants were of older age, and a substantial number of them were bedridden. Therefore, many of these individuals had bronchospasms and problems related to secretion from the respiratory tract, which might lead to a relatively low success rate.

From our study, the highest AUROC value from amongst all the respiratory indices was observed for the APACHE II scores (0.72). Although the AUROC values for some of the respiratory indices did exhibit significant differences during comparison between the success and failure groups, no single index alone was able to be applied to explain the relative success of NIV treatment outcome. Some previous studies have shown that a good level of patient consciousness and a lower APACHE II score at the outset of NIV treatment, and the extent of the initial improvement in pH, Pa_{CO2}, and RR are significant predictors of NIV treatment outcome.[15,16] In 2000, Antón et al[5] reported a multivariate predictive model that featured an adequate power of discrimination that could correctly classify more than 95% of the patients in a subsequent sample of new patients. Some of these above-mentioned studies combined both clinical and laboratory data, the combination of which may, on occasion, be too complex for clinical application. Moreover, for application in the emergency department of a hospital, as well as for general wards, clinical parameters relating to initial patient responses to NIV treatment should be explored by researchers as a part of further studies. This would be appropriate since it may not always be possible at the outset of NIV treatment for clinicians to predict which individuals will benefit from treatment.

In conclusion, we evaluated the application of various respiratory indices in the prediction of NIV treatment outcome in patients with acute respiratory failure. None of the respiratory indices addressed prior to the commencement of NIV treatment appeared to be predictive of treatment outcome, although individuals who had a lower APACHE II score initially were more likely to be associated with a poorer prognosis

following treatment. Subsequent to the commencement of NIV treatment, whilst we noted that RSBI was not a significant predictor of successful NIV application, improvements in RR, especially those arising during the first 30 minutes subsequent to the application of NIV treatment, were associated with a better patient outcome.

Acknowledgments

This research was supported, in part, by grant number R90-11 from Chia-Yi Christian Hospital, Chia-Yi, Taiwan, R.O.C.

References

1. Knaus WA, Draper EA, Wagner DP. APACHE II: a severity of disease classification system. *Crit Care Med* 1985;13:818–29.
2. Yang KL, Tobin MJ. A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. *N Engl J Med* 1991;324:1445–50.
3. Girault C, Briel A, Hellot MF. Noninvasive mechanical ventilation in clinical practice: a 2-year experience in a medical intensive care unit. *Crit Care Med* 2003;31:552–9.
4. Confalonieri M, Potena A, Carbone G, Porta RD, Tolley EA, Umberto Meduri G. Acute respiratory failure in patients with severe community-acquired pneumonia. A prospective randomized evaluation of noninvasive ventilation. *Am J Respir Crit Care Med* 1999;160:1585–91.
5. Antón A, Guell R, Gomez J. Predicting the result of noninvasive ventilation in severe acute exacerbations of patients with chronic airflow limitation. *Chest* 2000;117:828–33.
6. Hill NS. Noninvasive ventilation in chronic obstructive pulmonary disease. *Clin Chest Med* 2000;21:783–97.
7. Plant PK, Owen JL, Parrott S. Cost effectiveness of ward based non-invasive ventilation for acute exacerbations of chronic obstructive pulmonary disease: economic analysis of randomised controlled trial. *Br Med J* 2003;326:956.
8. Pang D, Keenan SP, Cook DJ. The effect of positive pressure airway support on mortality and the need for intubation in cardiogenic pulmonary edema: a systematic review. *Chest* 1998;114:1185–92.
9. Ferrer M, Esquinas A, Arancibia F. Noninvasive ventilation during persistent weaning failure: a randomized controlled trial. *Am J Respir Crit Care Med* 2003;168:70–6.
10. Soo Hoo GW, Santiago S, Williams AJ. Nasal mechanical ventilation for hypercapnic respiratory failure in chronic obstructive pulmonary disease: determinants of success and failure. *Crit Care Med* 1994;22:1253–61.
11. Ambrosino N, Foglio K, Rubini F. Non-invasive mechanical ventilation in acute respiratory failure due to chronic obstructive pulmonary disease: correlates for success. *Thorax* 1995;50:755–7.
12. Putinati S, Ballerin L, Piattella M. Is it possible to predict the success of non-invasive positive pressure ventilation in acute respiratory failure due to COPD? *Respir Med* 2000;94:997–1001.
13. Plant PK, Owen JL, Elliott MW. Non-invasive ventilation in acute exacerbations of chronic obstructive pulmonary disease: long term survival and predictors of in-hospital outcome. *Thorax* 2001;56:708–12.
14. Krieger BP, Isber J, Breitenbucher A. Serial measurements of the rapid-shallow-breathing index as a predictor of weaning outcome in elderly medical patients. *Chest* 1997;112:1029–34.
15. British Thoracic Society Standards of Care Committee. Noninvasive ventilation in acute respiratory failure. *Thorax* 2002;57:192–211.
16. Liesching T, Kwok H, Hill NS. Acute applications of noninvasive positive pressure ventilation. *Chest* 2003;124:699–713.