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ORIGINAL RESEARCH

A Clinical Score for Predicting Successful Weaning from Noninvasive Positive Pressure Ventilation in Emergency Department; a Retrospective Cohort Study

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Abstract: **Introduction:** Noninvasive positive pressure ventilation (NIPPV) is recognized as an efficient treatment for patients with acute respiratory failure (ARF) in emergency department (ED). This study aimed to develop a scoring system for predicting successful weaning from NIPPV in patients with ARF. **Methods:** In this retrospective cohort study patients with ARF who received NIPPV in the ED of Ramathibodi Hospital, Thailand, between January 2020 and March 2022 were evaluated. Factors associated with weaning from NIPPV were recorded and compared between cases with and without successful weaning from NIPPV. Multivariable logistic regression analysis was used to develop a predictive model for weaning from NIPPV in ED. **Results:** A total of 494 eligible patients were treated with NIPPV of whom 203(41.1%) were successfully weaned during the study period. Based on the multivariate analysis the successful NIPPV weaning (SNOW) score was designed with six factors before discontinuation: respiratory rate, heart rate ≤ 100 bpm, systolic blood pressure ≥ 100 mmHg, arterial pH≥ 7.35, arterial PaCO2, and arterial lactate. The scores were classified into three groups: low, moderate, and high. A score of >14.5 points suggested a high probability of successful weaning from NIPPV with a positive likelihood ratio of 3.58 (95%CI: 2.56-4.99; p < 0.001). The area under the receiver operating characteristic (ROC) curve of the model in predicting successful weaning was 0.79 (95% confidence interval (CI): 0.75-0.83). **Conclusion:** It seems that the SNOW score could be considered as a helpful tool for predicting successful weaning from NIPPV in ED patients with ARF. A high predictive score, particularly one that exceeds 14.5, strongly suggests a high likelihood of successful weaning from NIPPV.

Keywords: Intermittent positive-pressure ventilation; Noninvasive ventilation; Ventilator weaning; Respiratory insufficiency; Emergency service, hospital

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1. Introduction

Patients with acute respiratory failure (ARF) frequently present to the emergency department (ED). There has been a consistent rise in hospital admissions attributed to ARF, which has subsequently led to increase in total hospital costs (1, 2). From 2002 to 2017, there was a 197% increase in incidence, from 429 to 1,275 cases per 100,000 adults per year in the United States (3). In Thailand, the incidence of ARF increased from 6.99 people per 100,000 to 8.98 people per 100,000 over a span of 3 years (2011-2014) (2, 4).

ARF can stem from various causes, including primary pulmonary pathologies or initiation by extra-pulmonary factors (5). Diagnosis of ARF requires history, physical examination, and measurement of arterial blood gases. Patients present with signs and symptoms of acute respiratory distress, tachypnea, use of accessory muscles of respiration, and paradoxical breathing (6-8). Respiratory failure is defined as a respiratory rate of at least 30 breaths per minute or oxygen saturation on room air less than 90%, using pulse oximetry (SpO2). Arterial blood gas measurements may also indicate PaO2of less than 60mmHg, PaCO2of greater than 45mmHg, or a PaO2/FiO2 ratio of less than 300mmHg (6-13).

In recent years, noninvasive positive pressure ventilation (NIPPV) has become increasingly important for managing selected cases of ARF (14, 15). NIPPV is an effective treatment for patients experiencing ARF. NIPPV has several potential advantages, particularly the avoidance of tracheal intubation and the mortality and morbidity from associated problems such as pneumonia (7, 9, 16, 17). However, NIPPV may increase the risk of complications such as barotrauma, claustrophobia, facial skin lesions, nasal/oral/airway dryness, dis-

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comfort, and gastric insufflation (15, 18), as well as costs of care if weaning from NIPPV is delayed. Therefore, the timing of withdrawal must be carefully considered once NIPPV therapy is initiated (17).

The failure rate of weaning from noninvasive ventilation exceeds 250 cases per year (19). No standard method effectively predicts successful weaning from NIPPV, and no consensus has been reached among researchers regarding the extent and nature of NIPPV discontinuation. Hence, this study aimed to develop a scoring system for predicting successful weaning from NIPPV in ED patients with ARF.

2. Methods

2.1. Study design and setting

In this retrospective cohort study, patients with ARF who received NIPPV in the ED of Ramathibodi Hospital, a super tertiary care hospital in Bangkok, Thailand, were evaluated. Data regarding the baseline characteristics, respiratory parameters and etc. were gathered from the hospital's database through the electronic medical record system, utilizing the NIPPV protocol record from January 2020 to March 2022. Finally, using multivariate regression analysis a clinical scoring system (named SNOW) was developed to predict successful weaning from NIPPV among patients with ARF who received NIPPV in the ED.

This study was approved by the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Thailand (COA. MURA2023/225). The need for informed consent was waived by the ethics committee given the retrospective study design.

2.2. Participants

We included all patients with ARF aged > 18 years who received and discontinued NIPPV within the study period. NIPPV was initiated based on the patient's respiratory status and indications, including respiratory acidosis (partial pressure of CO2≥45 mmHg; arterial pH≤7.35), tachypnea with clinical signs of respiratory muscle fatigue, or persistent hypoxemia despite supplemental oxygen therapy (20, 21). The exclusion criteria were the use of noninvasive ventilation within the previous 24 hours, those who signed do-not-resuscitate orders, the use of a tracheostomy tube, the requirement of NIPPV for post-extubation, hemodynamic instability, inability to protect the airways, excessive secretion, a lack of cooperation, inability to fit the mask, hospitalization due to trauma, or a history of surgery involving the facial, oral, tracheal, or laryngeal regions within the previous month. Additionally, individuals receiving hemodialysis or peritoneal dialysis during treatment, as well as those transitioning to high-flow nasal cannula, were also excluded from the study.

2.3. Data gathering

For all eligible patients, we recorded study variables including baseline characteristics, initial vital signs (respiratory rate, blood pressure, heart rate, body temperature, and SpO2) before initiating NIPPV and before deciding to discontinue NIPPV, urinary output during NIPPV use, diagnosis, laboratory variables, arterial blood gas analysis (pH, PaO2, PaCO2, HCO3, and lactate) before NIPPV was applied and within 120 minutes before discontinuing NIPPV, the duration of NIPPV and NIPPV setting at initiation and before discontinuation. The outcomes were NIPPV weaning success and failure.

2.4. Definitions

Weaning success was determined when: the patient wasn't decided to reinitiate NIPPV or undergo endotracheal intubation within 24 hours of discontinuing NIPPV. Weaning failure was determined when: the patient was decided to reinitiate NIPPV or undergo endotracheal intubation within 24 hours of discontinuing NIPPV.

2.5. Statistical analysis

We collected significant factors for successful weaning from NIPPV from Leela-Amornsin et al.'s study of clinical prediction score for successful weaning from NIPPV in ED (19). STATA version 16.0 analysis software was used to calculate the sample size by employing a two-sample comparison of NIPPV weaning success and failure. The assumptions were as follows: alpha=0.05 (two-sided test), power of sample size=0.8, the sample size ratio = 2:1 and the level of statistical significance < 0.05. The minimum number of patients required to determine statistical significance for each variable was calculated. A sample size of 575 was required for patients in the NIPPV weaning success group, and a sample size of 288 was required for patients in the NIPPV weaning failure group. All of the study variables were compared between the NIPPV weaning success and NIPPV weaning failure groups using the exact probability test for categorical variables and the t-test for continuous variables. The predictive power of each variable was calculated using univariable logistic regression and presented as the area under the receiver operating characteristic (AuROC) curve with 95% confidence interval (CI). The potential predictors were categorized into three levels based on multivariable logistic regression. The regression coefficients of each clinical predictor were divided by the smallest coefficient and rounded to the nearest 0 or 0.5. The discrimination of the prediction scores was presented as the AuROC curve with 95% CI for the clinical scoring of successful weaning from NIPPV in patients with ARF. The calibration of the prediction was determined using the Hosmer–Lemeshow goodness-of-fit test.

3. Results

3.1. Baseline characteristics of studied cases

During the study period, a total of 1123 eligible patients with ARF received and discontinued NIPPV in the ED. Of these, 214 patients were excluded for various reasons: 103 patients received hemodialysis or peritoneal dialysis during NIPPV, 93 patients had signed do-not-resuscitate orders, 10 patients exhibited a lack of cooperation, 5 patients had excessive secretion, and 3 patients transitioned to high-flow nasal cannula (HFNC). Eventually, data were missing significant variables in 415 patients. Consequently, a total of 494 patients with the mean age of 74.48. ± 13.78 (range:22-103) were included in the study (49.39% male). Among them, 291 (58.9%) patients had successful weaning from NIPPV, while 203 (41.1%) patients had weaning failure. As illustrated in Table 1, no significant differences were detected regarding age, sex, medical comorbidities, laboratory variables, door to NIPPV, and duration of NIPPV between NIPPV weaning success and failure groups. However, significant differences were found between the two groups in terms of body mass index < 30 (p<0.001), respiratory rate before starting NIPPV (p=0.002) and inspiratory positive airway pressure at initial setting (p=0.003).

3.2. Predictors of weaning success in univariate analysis

Table 1 compares the baseline characteristics of studied cases between those with and without successful weaning from NIPPV in ED.

Patients with a heart rate of ≤100 beats per minute, systolic blood pressure of ≥100 mmHg, and respiratory rate of <20 breaths per minute before discontinuing NIPPV demonstrated successful NIPPV weaning rates of 66.35% (p<0.001), 60.17% (p<0.001) and 74.53% (p<0.001), respectively. A diagnosis of pneumonia (p=0.001) was associated with a significantly greater incidence of weaning failure. The following levels of arterial blood gases before weaning from NIPPV were associated with higher weaning success: pH≥7.35 (p=0.007), pCO2 35-45mmHg (p<0.001), and lactate <2 mmol/L (p<0.001).

3.3. Predictors of weaning success in multivariate analysis

In the multivariable logistic regression analysis (Table 2), the statistically significant risk factors associated with weaning success were respiratory rate < 20 /min (odds ratio: 4.39, 95% CI: 1.72-11.21, p = 0.002), heart rate ≤ 100 bpm min (odds ratio: 9.49, 95% CI: 4.77-18.86, p<0.001), systolic blood pressure ≥ 100 mmHg (odds ratio: 3.34, 95% CI: 1.21-9.21, p=0.020), arterial PaCO2 35-45 mmHg (odds ratio: 4.35, 95% CI: 2.37-7.98, p<0.001), and serum lactate<2 (odds ratio: 3.02, 95% CI: 0.92-9.90, p<0.001).

Furthermore, clinically significant risk factors for the successful discontinuation of NIPPV were respiratory rate of 20-25 breaths per minute, arterial pH ≥ 7.35, PaCO2 < 35 mmHg, and lactate levels between 2-4 mmol/L before weaning from NIPPV.

3.4. Designing a predictive model

The lowest coefficient obtained through multivariable logistic regression was 0.462, and the scores were categorized into increments of 0.5 points for each corresponding risk factor. The multivariable analysis showed item scores including respiratory rate (score= 0, 1.5, or 3) heart rate ≤ 100 bpm (score= 0 or 5), systolic blood pressure ≥ 100 mmHg (score= 0, or 2.5), arterial pH≥ 7.35 (score= 0 or 1), arterial PaCO2 (score= 0, 1, or 3) and serum lactate (score= 0, 1.5, or 2.5) (Table 2). As shown in Figure 2, this study indicated an AUROC curve of 78.98 (95% CI: 0.749-0.830), indicating the clinical score's capability to predict successful weaning from NIPPV.

Calibration performance for the model was also well in the Hosmer-Lemeshow test, with a X2 result of 3.29 (p=0.655). Figure 3 shows the observed risk (circle) and predicted risk (solid line) for NIPPV weaning success. The score-predicted risk increased in close association with the observed risk.

3.5. Screening performance of the model

Based on the area under the ROC curve, the risk scores were categorized into three groups: low-risk (score of <12.5), intermediate-risk (score of 12.5-14.5), and high-risk (score of >14.5) (Table 3). The low-risk group had a positive likelihood ratio of 0.23 (95% CI: 0.15-0.33, p<0.001), the moderate-risk group had a positive likelihood ratio of 0.84 (95%CI: 0.67–1.07, p=0.093), and the high-risk group had a positive likelihood ratio of 3.58 (95%CI: 2.56–4.99, p<0.001) for weaning failure (Table 3).

4. Discussion

NIPPV is now recommended as an alternative therapy to avoid the life-threatening risks of invasive mechanical ventilation (7, 16, 20, 22). In this study, multivariate analysis showed that successful weaning from NIPPV among patients with ARF was significantly associated with a respiratory rate of < 20 breaths/min, a heart rate of ≤ 100 bpm, systolic blood pressure ≥ 100 mmHg, arterial PaCO2 levels between 35-45, and arterial lactate levels < 2 before discontinuing NIPPV. Clinically significant risk factors for successful weaning from NIPPV included a respiratory rate of 20-25 breaths/min, arterial pH ≥ 7.35, PaCO2 levels < 35 mmHg, and lactate levels of 2-4 mmol/L before discontinuing NIPPV.

The study evaluated the SNOW score's ability to predict the success of weaning from NIPPV, demonstrating excellent discriminatory accuracy (AuROC: 0.79, 95% CI: 0.749-0.830) and high sensitivity according to the Hosmer-Lemeshow test. Successful weaning from NIPPV should be strongly suspected if the SNOW score is >14.5 points (positive likelihood ratio: 3.58; 95% CI: 2.56-4.99; p<0.001).

This specific patient subgroup exhibited a positive response to the therapy, warranting consideration for discontinuing NIPPV. Such an approach would reduce the risk of NIPPV-

related complications and alleviate ED overcrowding. For patients categorized as moderate-risk (score range 12.5-14.5), the likelihood of successful weaning from NIPPV was calculated at 0.84.

Although risk ratings exhibited predictive potential for successful weaning from NIPPV, the observed differences did not achieve statistical significance. Consequently, while managing individuals in this subgroup, in cases where there is no demand for resources to attend to other critically ill patients, it is advisable to sustain NIPPV until the patient's predictive score transitions to a higher category.

Nonetheless, due to resource limitations, including those arising from ED overcrowding, discontinuation of NIPPV is recommended. Patients at low risk had a 0.23 likelihood of successful weaning from NIPPV. In this situation, NIPPV treatment should be continued until the patient's overall predictive score increases to the moderate or high category.

Based on intensive care medicine and other studies, tachycardia was associated with unsuccessful weaning from NIPPV and an elevated risk of mortality in patients in the ED (23-25). In addition, our findings indicate that tachycardia (heart rate ≤ 100 bpm) was the most significant variable for predicting NIPPV weaning success, assigned a maximum score of 5 points. The recommendations of European society of cardiology (ESC) for acute heart failure and previous studies suggested that NIPPV should be initiated as soon as possible in patients experiencing respiratory distress (respiratory rate >25 breaths/min) to enhance gas exchange and reduce the rate of endotracheal intubation (11, 16). Moreover, the most important factor in determining when NIPPV may be safely withdrawn is respiratory rate of <24 breaths/min. Healthy adults typically breathe at a rate of 12 to 20 breaths/min, and a respiratory rate exceeding 20 breaths suggests abnormally rapid breathing (26). Therefore, we employed the threshold of a respiratory rate at 25 breaths/min and 20 breaths/min, assigning a maximum score of 3 points.

Blood pressure is a fundamental vital sign that necessitates systematic evaluation during the course of NIPPV treatment. Low blood pressure has been linked to an increase of in-hospital mortality in patients with acute hypoxic respiratory failure. A systolic blood pressure lower than 90 mmHg is considered a relative contraindication for NIPPV (27, 28).

Arterial blood gas is the gold standard for diagnosing respiratory failure (6). The acceptable normal ranges of arterial pH and arterial PaCO2 are 7.35-7.45 and 35-45 mmHg, respectively (29). Randomized controlled trials and meta-analyses suggest that the use of non-invasive ventilation to avoid intubation in patients with acute respiratory failure with arterial pH 7.30–7.34 is considered the first-choice ventilatory therapy due to strong evidence of efficacy and low risk of failure (10–20%) (9, 15, 21, 30, 31).

NIPPV should be consider in patients who have respiratory failure with arterial PCO2 > 45 mmHg (9, 15, 21). As a result, we used the cut-offs of pH≥7.35 and PCO2 35-45 mmHg for predicting successful weaning from NIPPV. Additionally, blood lactate was regarded as a diagnostic indicator of tissue hypoxia, respiratory muscle fatigue, and the severity of chronic obstructive pulmonary disease (32). A high lactate level is strongly correlated with increased mortality in various conditions (33, 34). In this study, arterial lactate levels (<2mmol/L) predicted NIPPV weaning success and had a maximal score of 2.5 points. Nevertheless, it's important to note that the availability of arterial blood gas testing is limited in certain hospitals, particularly those situated in rural areas.

We attempted to develop a scoring system devoid of laboratory factors by evaluating clinical variables through multivariable logistic regression. The AUROC curve generated from clinical variables of 909 participants (inclusive of the missing data group) witnessed a reduction to approximately 0.65. Consequently, arterial blood gas measurements are indispensable within this scoring model.

A previous study recommended a protocol for NIPPV weaning, involving a stepwise adjustment of the ventilator mode and a reduction in positive pressure at 30-minute intervals. The study showed a median NIPPV duration of 8 hours and the interquartile range of 0. This approach notably enhanced the success rate of weaning from NIPPV (35). There was no protocol for weaning from NIPPV, and the time to start using ventilator or the ventilator mode before discontinuing from NIPPV was not associated with the incidence of successful weaning from NIPPV.

4.1. Limitations

This study possesses certain limitations. It was conducted exclusively at a single super-specialty tertiary care hospital and medical school situated in Bangkok. Therefore, the patients' baseline prognostic factors may have differed from those at other institutions.

Additionally, discontinuing NIPPV was necessary in the ED resuscitation room due to limited resources. Before applying these findings to other situations, additional hospital risk ratings (external validation) should be evaluated to determine whether predictive scores are reliable in predicting weaning from NIPPV in patients with ARF. The SNOW score consists of vital signs and arterial blood gas measurements before discontinuing NIPPV, which might not be widely used due to limitations in laboratory resources. Other clinical symptoms, such as retraction, chest discomfort, and dyspnea, should be documented and examined for the purpose of constructing a score without relying on laboratory variables in future studies.

Furthermore, this study was conducted retrospectively, which resulted in missing or incomplete data, subsequently impacting the process of analysis. Therefore, we decided to exclude enrolled patients with significant missing variables, such as arterial blood gas measurements before discontinuing NIPPV. As a result, the total number of participants was smaller than the initially estimated sample size. However,

our effort to identify factors associated with successful weaning from NIPPV among all 909 enrolled participants revealed that the significant variables remain consistent with those identified in our final study group.

5. Conclusions

Based on the model (SNOW score) designed in this study, patients who scored < 12.5 points, 12.5-14.5 points, and > 14.5 points exhibit low, moderate, and high probabilities of successful weaning, respectively. Patients with a high SNOW score should be weaned off NIPPV treatment to reduce the risk of NIPPV complications and alleviate overcrowding in the ED. The SNOW score serves as a predictive tool for successful weaning from NIPPV in ED patients with ARF.

6. Declarations

6.1. Acknowledgments

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6.2. Conflict of interest

The authors declare no conflict of interest.

6.3. Funding

Not applicable.

6.4. Authors' contribution

All authors made a significant contribution to the study, whether that is in the conception, study design, execution, acquisition of data, analysis, interpretation, or all of these areas. All authors took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; agreed on the journal to which the article has been submitted; and agreed to be accountable for all aspects of the work.

6.5. Ethical considerations

This study was approved by the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Thailand (COA. MURA2023/225). The need for informed consent was waived by the ethics committee given the retrospective study design.

6.6. Competing interests

The authors declare that they have no competing interests.

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Table 1: Comparing the baseline characteristics of participants between cases with and without successful weaning from non-invasive positive pressure ventilation (NIPPV)

Characteristics	NIPPV weaning		odds ratio(95%Cl)	P-value	AUC
	Success (n=291)	Failure (n=203)			
Demographic factors					
Age (years)	74.59±13.41	74.32±1.01	1.00 (0.99-1.02)	0.828	0.49(0.44-0.54)
BMI < 30	250 (60.68)	162 (39.32)	1.54(0.96-2.48)	<0.001	0.53(0.50-0.57)
Sex, male	147 (60.25)	97 (39.75)	1.12(0.78-1.60)	0.550	0.51(0.47-0.56)
Medical comorbidities and prior history					
Asthma	22 (57.89)	16 (42.11)	0.96(0.49-1.87)	0.895	0.50(0.47-0.52)
COPD	67 (57.26)	50 (41.74)	0.92(0.60-1.39)	0.679	0.49(0.45-0.53)
Bronchiectasis	27 (61.36)	17 (38.64)	1.12(0.59-2.11)	0.729	0.50(0.48-0.53)
CHF	132 (62.26)	80 (37.74)	1.28(0.89-1.84)	0.189	0.53(0.49-0.57)
IHD	92 (65.71)	48 (34.29)	1.49(0.99-2.24)	0.054	0.54(0.50-0.58)
Anemia	46 (58.23)	33 (41.77)	0.97(0.59-1.58)	0.894	0.50(0.46-0.53)
Lung cancer	18 (58.06)	13 (41.94)	0.96(0.46-0.14)	0.922	0.50(0.46-0.52)
Other cancer	46 (60.53)	30 (39.47)	1.08(0.66-1.78)	0.755	0.51(0.47-0.54)
Neurologic disease	55 (54.46)	46(45.54)	0.80(0.51-1.24)	0.309	0.48(0.44-0.52)
Diabetic mellitus	130 (61.32)	82 (38.68)	1.19(0.83-1.71)	0.345	0.52(0.48-0.57)
Hypertension	217 (59.45)	148 (40.55)	1.09(0.73-1.64)	0.679	0.51(0.47-0.55)
Vital signs before starting NIPPV					
Temperature(°C)	37.06±0.95	37.14±0.89	0.91(0.75-1.10)	0.339	0.46(0.41-0.51)
Heart rate (bpm)	97.20±21.96	95.04±19.42	1.01(0.99-1.01)	0.260	0.52(0.47-0.57)
SBP (mmHg)	149.09±31.36	144.42±31.24	1.01(0.99-1.01)	0.105	0.55(0.49-0.60)
DBP (mmHg)	81.06±17.49	78.28±16.46	1.01(0.99-1.02)	0.077	0.55(0.49-0.60)
RR/min	28.55±5.79	30.14±5.38	0.95(0.92-0.98)	0.002	0.40(0.35-0.45)
O2 saturation (%)	92.44±7.16	91.86±8.85	1.01(0.96-1.03)	0.427	0.51(0.46-0.56)
Vital signs before stopping NIPPV					
Temperature (°C)	39.77±0.64	36.98±3.04	0.93(0.79-1.09)	0.364	0.49(0.44-0.55)
Heart rate (bpm)	77.83±12.22	91.67±17.41	0.94(0.92-0.95)	<0.001	0.26(0.22-0.31)
HR≤100 bpm	278 (66.35)	141 (33.65)	9.40(5.00-17.68)	<0.001	0.63(0.60-0.66)
SBP (mmHg)	134.08±20.39	134.69±24.91	1.00(0.99-1.01)	0.765	0.51(0.45-0.56)
SBP ≥100	284 (60.17)	188 (39.83)	3.24(1.30-8.09)	0.012	0.53(0.50-0.55)
DBP (mmHg)	75.92±0.82	77.51±1.14	0.99(0.98-1.01)	0.244	0.47(0.42-0.53)
RR /min	20.23±2.75	21.83±2.51	0.798(0.74-0.85)	<0.001	0.34(0.29-0.38)
RR > 25 /min	11 (28.21)	28 (71.79)	1.0(reference)	-	0.68(0.64-0.73)
RR 20-25 /min	188 (56.63)	144 (43.37)	3.32(1.60-6.90)	0.001	
RR < 20 /min	92 (74.80)	31(25.20)	7.55(3.37-16.94)	<0.001	
O2 saturation (%)	99.19±2.36	97.74±1.84	2.24(1.90-2.64)	<0.001	0.75(0.71-0.80)
Door to NIPPV (minutes)					
Median (IQR)	36 (14-100)	35 (14-136)	1.00(0.99-1.01)	0.765	0.51(0.45-0.56)
Duration of NIPPV (hour)					
Median (IQR)	5.5 (3.5-11)	6 (3-10)	1.00(0.98-1.02)	0.791	0.50(0.44-0.55)
Initial setting of NIPPV					
IPAP (cmH2O)	12.19±1.65	12.68±1.96	0.86(0.77-0.95)	0.003	0.43(0.38-0.47)
EPAP (cmH2O)	6.27±0.93	6.40±1.33	0.89(0.76-1.06)	0.192	0.48(0.43-0.53)
FiO2 (%)	0.38±0.08	0.40±0.11	0.21(0.03-1.42)	0.109	0.48(0.44-0.52)
Mode of NIPPV before weaning					
CPAP	100 (64.52)	55 (35.48)	0.71(0.48-1.05)	0.087	0.46(0.42-0.50)
BIPAP	191 (56.34)	148 (43.66)			

Table 1: Comparing the baseline characteristics of participants between cases with and without successful weaning from non-invasive positive pressure ventilation (NIPPV) (continue)

Characteristics	NIPPV weaning		odds ratio(95%Cl)	P-value	AUC
	Success (n=291)	Failure (n=203)			
Diagnosis					
ACPE	159 (58.46)	113 (41.54)	0.96(0.67-1.38)	0.822	0.50(0.45-0.54)
Asthma	18 (64.29)	10 (41.09)	1.27(0.58-2.82)	0.552	0.53(0.49-0.53)
COPD	59 (55.66)	47 (44.34)	0.84(0.55-1.30)	0.444	0.49(0.45-0.52)
PE	1 (33.33)	2 (41.09)	0.35(0.03-3.85)	0.388	0.50(0.49-0.50)
Pleural effusion	29 (56.86)	22 (43.14)	0.91(0.51-1.64)	0.754	0.50(0.47-0.52)
Sepsis	88 (52.69)	79 (47.31)	0.68(0.47-0.99)	0.045	0.46(0.41-0.50)
Pneumonia	53 (45.69)	63 (54.31)	0.49(0.32-0.75)	0.001	0.44(0.40-0.48)
Neurologic disease	2 (50.00)	2 (50.00)	0.70(0.10-4.98)	0.718	0.50(0.40-0.51)
Anemia	103 (55.98)	81 (44.02)	0.83(0.57-1.19)	0.308	0.48(0.43-0.52)
Laboratory values					
Hemoglobin (g/dL)	11.24±2.41	11.24±2.65	1.00(0.93-1.07)	0.990	0.51(0.45-0.56)
Hematocrit (%)	34.37±7.24	34.53±8.08	1.00(0.97-1.02)	0.809	0.50(0.45-0.56)
WBC (cell/mm^3)	8790(6850-12010)	9650(7130-13100)	0.99(0.99-1.00)	0.040	0.44(0.39-0.50)
BUN (mg/dL)	20 (14-34)	21 (14-36)	1.00(0.99-1.01)	0.697	0.48(0.43-0.53)
Creatinine (mg/dL)	1.17(0.86-1.74)	1.09(0.79-1.86)	1.05(0.94-1.18)	0.396	0.53(0.48-0.58)
Sodium (mmol/L)	136.96±5.48	136.54±5.48	1.01(0.98-1.04)	0.447	0.51(0.46-0.57)
Potassium (mmol/L)	4.30±0.59	4.32±0.64	0.95(0.71-1.28)	0.749	0.49(0.44-0.54)
Bicarbonate (mmol/L)	21.50±4.38	22.36±5.52	0.97(0.93-1.00)	0.057	0.48(0.42-0.53)
Arterial blood gas before starting NIPPV					
pH	7.41±0.07	7.41±0.01	1.29(0.11-15.70)	0.844	0.50(0.45-0.56)
PaO2 (mmHg)	98(71-141)	107.2(68-157)	1.00(0.99-1.00)	0.462	0.50(0.44-0.55)
PaCO2 (mmHg)	36.99±14.29	39.35±14.29	0.98(0.97-1.00)	0.037	0.47(0.42-0.53)
Lactate (mmol/L)	1.30(0.8-1.79)	1.29(0.78-1.99)	0.88(0.76-1.02)	0.083	0.48(0.43-0.54)
Arterial blood gas before stopping NIPPV					
pH	7.41±0.04	7.41±0.06	0.93(0.03-3.383)	0.970	0.50(0.44-0.55)
pH≥7.35	268 (61.05)	171(38.95)	2.18(1.23-3.85)	0.007	0.54(0.51-0.57)
PaO2 (mmHg)	131.01±35.54	124.14±49.34	1.00(1.00-1.01)	0.074	0.54(0.50-0.64)
PaCO2 (mmHg)	37.63±5.89	38.49±10.95	0.99(0.97-1.01)	0.263	0.52(0.47-0.58)
PaCO2>45	31 (40.79)	45 (59.21)	1.0(reference)	-	0.66(0.61-0.70)
PaCO2=35-45	180 (73.77)	64 (26.23)	4.00(2.38-7.00)	<0.001	
PaCO2<35	80 (45.98)	94 (54.02)	1.24(0.72-2.13)	0.448	
Lactate (mmol/L)	0.8 (0.6-1.3)	1.1(0.69-1.8)	0.68(0.56-0.83)	p<0.001	0.40(0.35-0.45)
Lactate>4	5 (31.25)	11 (68.75)	1.0(reference)	-	0.56(0.53-0.60)
Lactate=2-4	21 (38.89)	33 (61.11)	1.40(0.43-4.60)	0.580	
Lactate<2	265 (62.5)	159 (37.5)	3.67(1.25-10.75)	<0.001	

Data are presented as mean ± standard deviation, frequency (%), and median (inter quartile range).
Area under the receiver operating characteristic (ROC) curve (AUC) and odds ratio are presented with 95% confidence interval.
SD: standard deviation; IQR: interquartile range; BMI: body mass index; COPD: chronic obstructive pulmonary disease;
bpm: beats per minute; HR: heart rate; RR: respiratory rate; h: hours; BIPAP: bi-level positive airway pressure;
CPAP: continuous positive airway pressure; PaCO2: partial pressure of carbon dioxide; PaO2: partial pressure of oxygen;
FiO2: fraction of inspired oxygen; IPAP: inspiratory positive airway pressure; EPAP: expiratory positive airway pressure;
CHF: Chronic heart failure; IHD: ischemic heart disease; SBP: Systolic blood pressure; DBP: diastolic blood pressure;
ACPE: Acute cardiogenic pulmonary edema; WBC: White blood cell; BUN: Blood urea nitrogen; PE: Pulmonary embolism.

Table 2: Multivariable logistic regression analysis of risk factors associated with the successful weaning from non-invasive positive pressure ventilation (NIPPV)

Predictors	Adjusted OR	p-value	Coefficient	Score
RR before discontinuing NIPPV				
RR>25 /min	Reference	-	-	0
RR 20-25 /min	1.91 (0.81-4.50)	0.14	0.65	1.5
RR < 20 /min	4.39 (1.72-11.21)	0.002	1.48	3
HR≤100 before discontinuing NIPPV				
No	Reference	-	-	0
Yes	9.49 (4.77-18.86)	<0.001	2.25	5
SBP≥100 mmHg before discontinuing NIPPV				
No	Reference	-	-	0
Yes	3.34 (1.21-9.21)	0.020	1.21	2.5
Arterial pH ≥7.35 before discontinuing NIPPV				
No	Reference	-	-	0
Yes	1.61 (0.83-3.12)	0.158	0.48	1
PaCO2 before discontinuing NIPPV				
PaCO2 >45 (mmHg)	Reference	-	-	0
PaCO2 35-45 (mmHg)	4.35 (2.37-7.98)	<0.001	1.47	3
PaCO2 <35 (mmHg)	1.59 (0.86-2.93)	0.138	0.46	1
Lactate(mmol/L) before discontinuing NIPPV				
>4	Reference	-	-	0
2-4	1.97 (0.52-7.56)	0.321	0.69	1.5
<2	3.02 (0.92-9.90)	<0.001	1.11	2.5

Data are presented with 95% confidence interval. Coefficients were obtained from multivariable binary logistic regression. The lowest coefficient obtained using multivariable logistic regression was 0.462, and the scores were split into groups of 0.5 points for each risk factor. OR: odds ratio; CI: confidence interval; RR: Respiratory rate, HR: Heart rate, SBP: systolic blood pressure, PaCO2: partial pressure of carbon dioxide. "Reference" refers to the reference category.

Table 3: Probability categories of SNOW score in the NIPPV weaning success

Categories	Score	NIPPV weaning		PLR (95% CI)	P-value
		Success (n=291)	Failure (n=203)		
Low	<12.5	29 (24.37)	90 (75.63)	0.23 (0.15-0.33)	<0.001
Moderate	12.5-14.5	98 (54.75)	81 (45.25)	0.84 (0.67-1.07)	0.093
High	>14.5	164 (83.67)	32 (16.33)	3.58 (2.56-4.99)	<0.001

PLR: positive likelihood ratio; CI: confidence Interval; NIPPV: non-invasive positive pressure ventilation; SNOW: successful NIPPV weaning.

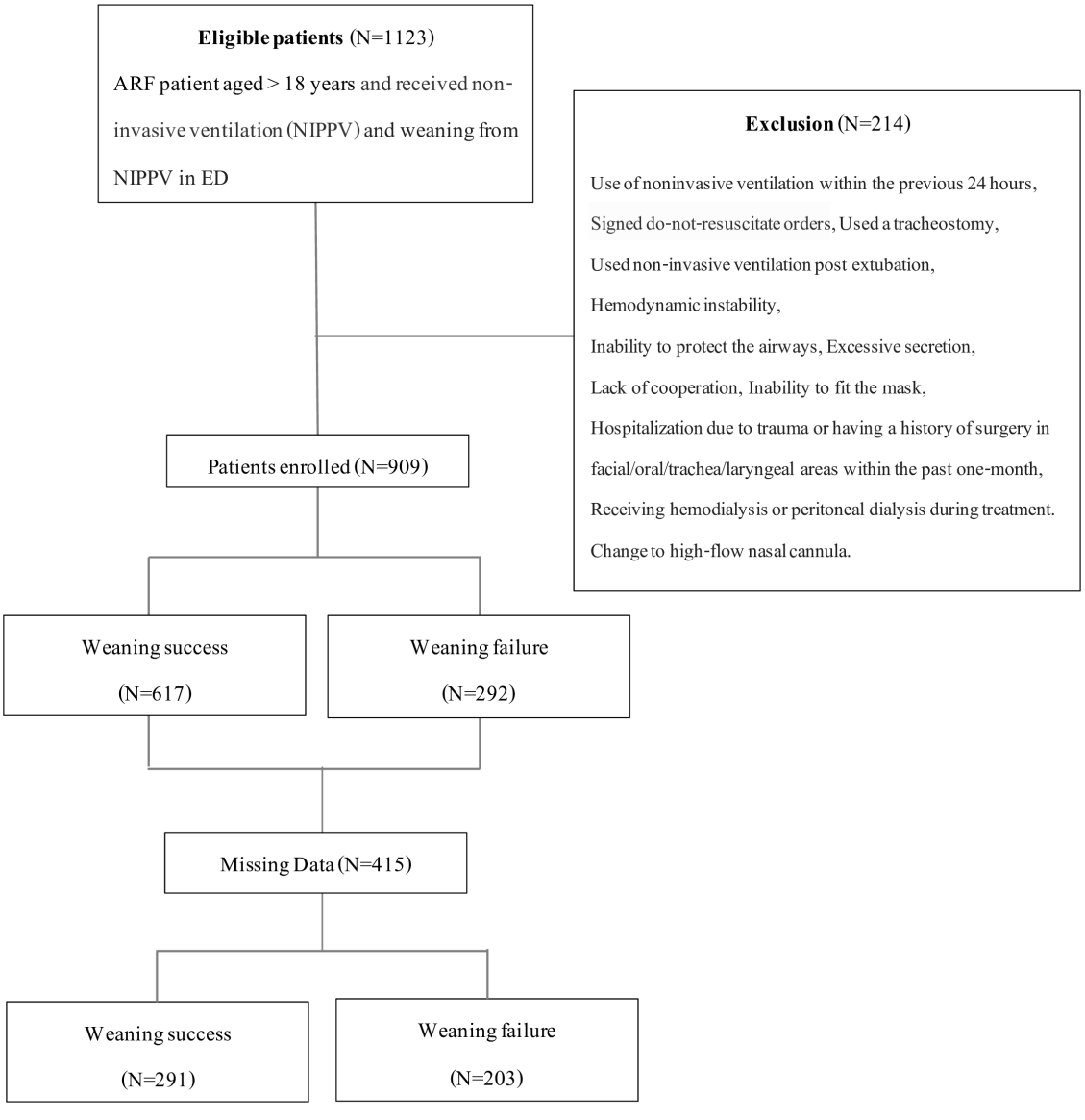

Figure 1: Flow of patients through the study. NIPPV: noninvasive positive pressure ventilation; ARF: acute respiratory failure; ED: emergency department.

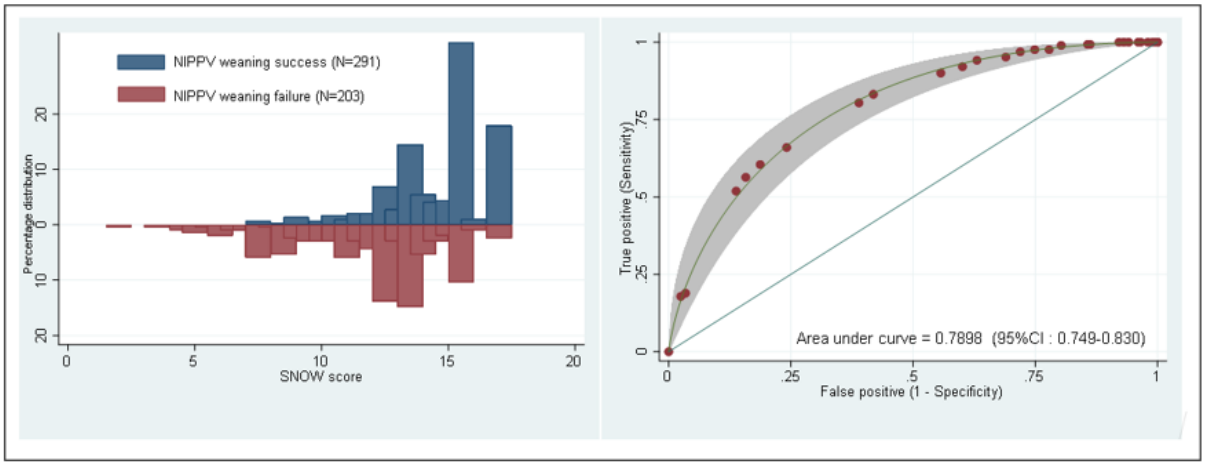

Figure 2: Left: A comparison of the risk scores between patients who were successfully weaned and those who failed to be weaned from non-invasive positive pressure ventilation (NIPPV). Right: Area under the receiver operating characteristic curve and 95% confidence interval (CI) of the predictive power of the successful NIPPV weaning (SNOW) score.

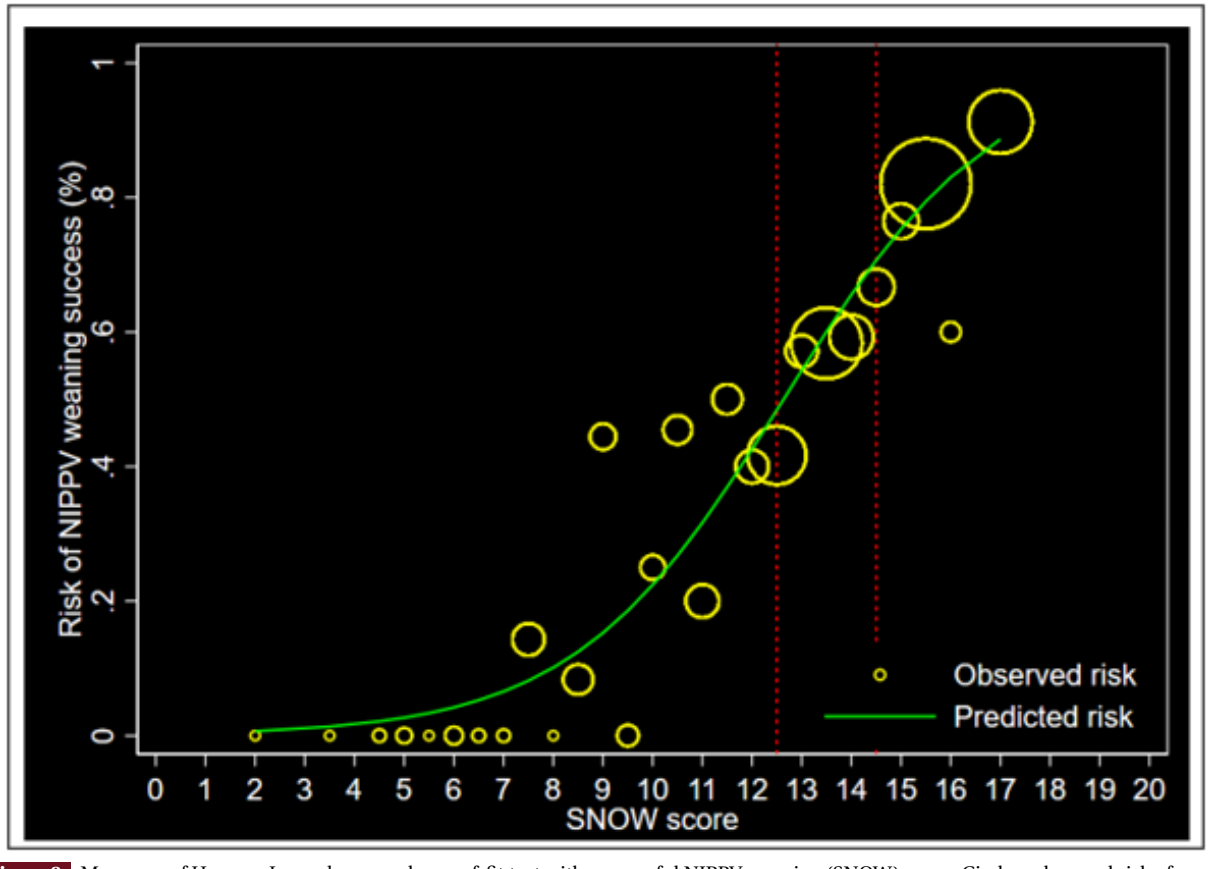

Figure 3: Measures of Hosmer-Lemeshow goodness-of-fit test with successful NIPPV weaning (SNOW) score. Circles: observed risk of weaning success; Solid line: Score-predicted risk of weaning success.