ORIGINAL ARTICLE

Predictors of noninvasive mechanical ventilation weaning failure in the emergency department

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Objectives. To analyze factors related to the failure of noninvasive mechanical ventilation (NIV) weaning in a hospital emergency department (ED).

Methods. Prospective, observational cohort study with enrolled a sample of consecutive patients who required NIV during ED care. The dependent variable was NIV weaning failure, defined by the need to restart NIV in the ED after a first attempt to withdraw the respirator.

Results. Of a total of 675 candidates, we included 360 patients (53.4%). Exclusions were 100 patients (31.7%) who were on NIV at home; 58 (18.4%) in whom NIV initially failed; and 157 (49.9%) in whom weaning was attempted outside the ED. Seventy-two (17.3%) cases of weaning failure in the ED were observed. Factors independently associated with failure were the bicarbonate (HCO_3) concentrations before attempted weaning (adjusted odds ratio [aOR], 1.06; 95% CI, 1.01–1.12; $P = .014$), time on NIV in hours (aOR, 1.10; 95% CI, 1.04–1.16; $P < .001$), and a pH less than 7.35 before weaning (aOR, 2.48; 95% CI, 1.16–5.31; $P = .019$).

Conclusions. Weaning failure occurs in 17% of ED patients on NIV. Time on NIV, HCO_3 concentration, and a pH less than 7.35 before weaning are independently associated with failure to wean from the respirator.

Keywords: Respirator weaning. Prognostic factors. Noninvasive mechanical ventilation. Emergency department.

Factores predictivos de fracaso en el destete de la ventilación mecánica no invasiva en urgencias

Objetivos. Analizar los factores predictivos del fracaso del destete en los pacientes sometidos a ventilación mecánica no invasiva (VMNI) en un servicio de urgencias hospitalario (SUH).

Método. Estudio observacional de cohortes prospectivo con muestreo consecutivo de los pacientes que precisaron VMNI durante la atención en el SUH. Se estableció como variable dependiente el fracaso del destete de la VMNI, definido como la necesidad de reiniciar o instaurar la VMNI durante el mismo ingreso hospitalario tras el primer intento de destete.

Resultados. Del total de 675 pacientes elegibles, se incluyeron 360 pacientes (53,4%). Se excluyeron 100 (31,7%), 58 (18,4%) y 157 (49,9%) por VMNI domiciliaria, fracaso previo al intento de destete y por realización del intento de destete fuera del SUH, respectivamente. Sesenta y dos casos (17,3%) presentaron con fracaso del destete de la VMNI. Los factores independientes asociados al fracaso del destete fueron la concentración de bicarbonato antes del destete (ORa: 1,06; IC 95%: 1,01-1,12; p = 0,014), la duración VMNI en horas (ORa: 1,10; IC 95%: 1,04-1,16; p < 0,001) y un pH < 7,35 antes del destete (ORa: 2,48; IC: 1,16-5,31; p = 0,019).

Conclusión. El fracaso del destete de la VMNI en el SUH ocurrió en un 17% de los casos. La duración de la técnica, el valor del HCO_3^- y el pH < 7,35 antes del destete fueron factores independientes asociados al fracaso.

Palabras clave: Destete. Factores pronósticos. Ventilación mecánica no invasiva. Urgencias.

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Introduction

Noninvasive mechanical ventilation (NIV) has surpassed invasive mechanical ventilation (IMV) as the first choice of respiratory support for acute respiratory failure (ARF) in hospital emergency departments (ED)[1,2]. The level of severity measured by APACHE II, a low Glasgow Coma Scale score, a pH less than 7.25 and a high respiratory rate at the start of NIV are factors associated with NIV failure[3,4].

For clinically stabilized patients, weaning from NIV is the next critical point in the natural evolution of the patient with severe ARF. A key issue in the planning of weaning is to know how long NIV is required during the patient's hospitalization. This period involves both the planning of care and hospital care circuits[5,6] and the need for admission to a specialized respiratory care unit or an acute hospital ward[7]. In this context, the role of the ED is crucial, not only in the use of the technique, but also in deciding the ideal time to start weaning from NIV. The ED physician is uncertain about admitting these patients to the conventional ward because of the possibility of requiring the reintroduction of ventilatory support.

In order to answer these questions, it is necessary first to know the factors associated with weaning failure in NIV. Currently, normalization of pH, $PaO_2/FiO_2 > 150$ and systolic blood pressure > 90 mm Hg without vaso-

active drugs are factors associated with success. However, these predictors have been established by experts in the recommendations of clinical practice guidelines[8,9] by extrapolation of IMV[10-12] or by few specific studies performed in intermediate respiratory care units[13]. Therefore, the aim of our work was to investigate the predictors of failure to wean from NIV initiated in the ED.

Method

A prospective observational cohort study was designed at the Hospital General Universitario Reina Sofía de Murcia (HGURS). The HGURS has 350 beds, a reference population of 250,000 people and treats an average of 93,000 emergencies per year. The study began on January 1, 2014 and ended on December 31, 2017.

Patients who required NIV during ED care were consecutively included. Patients with home NIV with 2 pressure levels, with NIV failure (patients who died without a weaning attempt, required IMV or NIV was replaced by conventional oxygen therapy (COT) due to complications) and with weaning attempts outside the ED were excluded.

Weaning failure was the dependent variable of the study and was defined as the need to restart or institute IMV during the same hospital admission after the first weaning attempt by the medical team in the ED. Short periods of disconnection from the ventilator to allow coughing, intake of small amounts of fluids or nebulizations were not considered weaning attempts. The decision to initiate weaning was made by the physician in charge. The weaning method was performed through the center's protocol, which recommends attempting weaning once the pH has been corrected, a $PaO_2/FiO_2 > 150$ and a respiratory rate lower than 30 brpm. Regarding the clinical management of the patient, both the medication used and the pressure levels and parameters programmed in the ventilator were at the discretion of the physician responsible for the patient's care, according to the aforementioned protocol.

Demographic variables (age and sex), body mass index, comorbidities (chronic obstructive pulmonary disease (COPD), obstructive sleep apnea syndrome (OSAS), arterial hypertension (AHT), diabetes mellitus (DM), chronic heart failure (CHF)) were collected, treatment with chronic home oxygen therapy (HOT) or continuous positive airway pressure (CPAP) at home, Glasgow Coma Scale score > 13, vital signs and blood gas data at the start of NIV, ED laboratory data including biomarkers (procalcitonin, NTproBNP and lactate), final diagnosis (exacerbation of COPD, acute pulmonary edema -APE-, hypoxemic respiratory failure excluding APE; hypercapnic respiratory failure excluding exacerbation of COPD and APE), gasometric data prior to the weaning attempt, time from the start of NIV to the weaning attempt, intensive care unit (ICU) admission, length of hospital stay and in-hospital mortality.

Qualitative variables were described by absolute and relative frequencies and quantitative variables by mean and standard deviation or median and interquartile range. The type of distribution was tested using the Kolmogorov-Smirnov test. Comparisons between qualitative variables were made using the chi-squared test or Fisher's test as required, and between quantitative variables the Student's t test or Mann-Whitney U test was used depending on whether the variable met the criteria for normality. To assess the association of factors with the dependent variable NIV weaning failure, logistic regression analysis was used. All significant factors were included in the univariate analysis. All analyses were 2-tailed and statistical significance was accepted if $p < 0.05$ or the 95% CI of OR excluded the value 1. Since this was an exploratory study, no sample size calculation was performed. SPSS Statistics v21 (IBM, New Castle, NY, USA) was used.

The study followed current laws and regulations and was approved by the HGURS Clinical Research Ethics Committee.

Results

During the study period, 675 patients were evaluated, and 360 cases (53.4%) were finally included. A total of 100 patients (31.7%) were excluded because they were on home treatment with NIV with 2 pressure levels, 58 (18.4%) because of initial failure of NIV and 157 (49.9%) because the weaning attempt was performed outside the ED (Figure 1).

The mean age was 78.5 (SD 11.1) years, and 145 (48.7%) were women. The most frequent comorbidities were AHT (80.6%), DM (50.6%) and CHF (45.3%). Thirty percent of the patients were being treated with HOT and 11.9% with home CPAP. The most frequent final diagnoses were APE (48.1%) followed by exacerbated COPD (35.8%). A total of 3.1% of patients required admission to the ICU and 9.2% died during admission. The mean length of stay was 9.8 (SD 6.9) days (Table 1).

Sixty-two patients (17.3%) experienced failure of the NIV weaning attempt in the ED. The clinical-analytical characteristics and destination as a function of weaning success or failure are shown in Table 1. The blood gas values are shown in Table 2. Mean baseline PaO_2/FiO_2 was 253 (SD 42.4) mm Hg, and was greater than 150 mmHg in 95.7% of the sample.

Failure to wean exacerbated COPD, APE, hypoxemic ARF and hypercapnic respiratory failure was 18.6%, 14.5%, 15.2% and 32%, respectively ($p = 0.169$). The mean duration before initiating the weaning attempt was 14.7 (SD 6.7), 12.9 (SD 6.8), 13.3 (SD 7.2) and 15.6 (SD 8.6) hours ($p = 0.113$) for exacerbated COPD, APE, hypoxemic respiratory failure and hypercapnic respiratory failure, respectively.

The mean duration before initiating the weaning attempt was 13.8 (SD 7.0) hours, and in 75% of the cases it was at least 8 hours. The mean duration in the success group was 20.5 (SD 33.6) hours and in the fail-

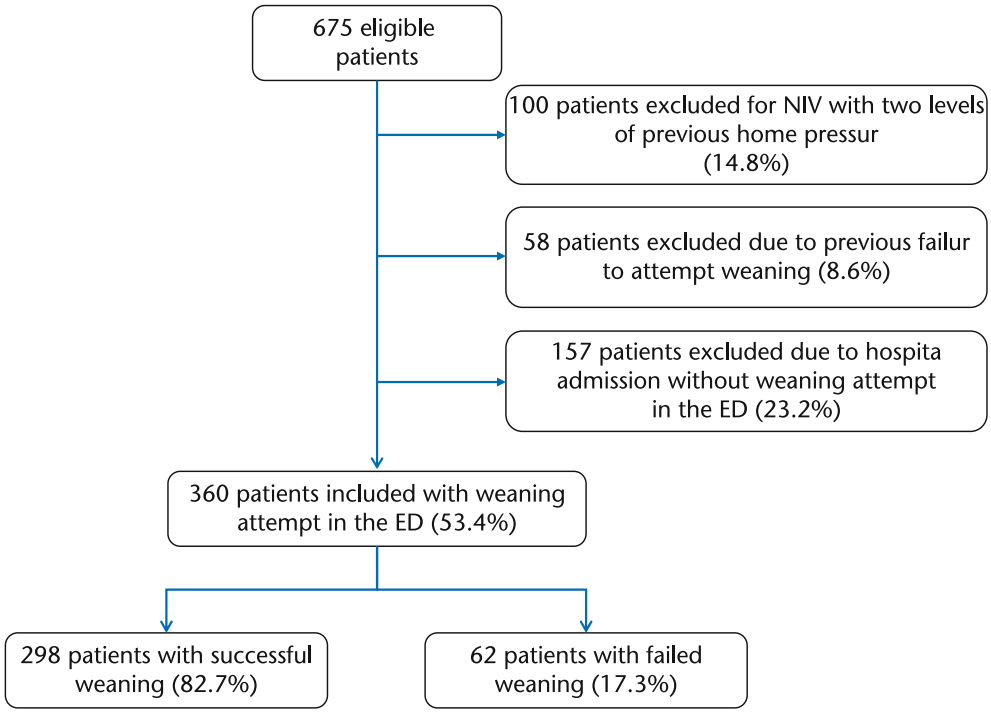

Figure 1. Flow diagram of patient inclusion.
NIV: noninvasive mechanical ventilation; ED: hospital emergency department.

ure group 48.3 (SD 76.1) hours ($p < 0.001$). When stratified by hours, attempted weaning from NIV occurred in 10% in the initial 4 hours, in 17.5% between 5 and 8 hours, in 27.5% between 9 and 12 hours, in 15.8% between 13 and 16 hours, in 15% between 17 and 20 hours and in 14.2% in more than 20 hours. The distribution of these time slots according to weaning failure and stratified by final diagnoses is shown in Figure 2.

After multivariate analysis, the variables that showed the ability to predict failure of the weaning attempt in NIV were previous bicarbonate concentration (ORa: 1.06; 95% CI: 1.011.12; $p = 0.014$), NIV duration in hours (ORa: 1.10; 95% CI: 1.041.16; $p < 0.001$) and pH < 7.35 before weaning (ORa: 2.48; CI: 1.165.31; $p = 0.019$) (Table 3).

Discussion

The ED's involvement in NIV is key, not only in the adequate selection of the patient and the procedure itself, but also in the planning of respiratory support which includes safe weaning of the patient. In this study, there was a high success rate (82.7%) in patients who were weaned from NIV. However, only approximately half (53.4%) of the patients treated with NIV in the ED attempted weaning in-house.

Independently associated factors with weaning failure were bicarbonate concentration and lack of pH correction before the weaning attempt and the number of hours with NIV. Of these, the most important was the presence of a lower than 7.35 pH before the attempt. In fact, when attempting weaning in this ventilatory state, the probability of failure was greater than 60%. The next factor was the number of hours of NIV prior to the weaning attempt, with a higher probability of failure before 4 hours of NIV and, progressively, from the 5th hour of NIV onwards. Finally, high bicarbonate levels increased the probability of NIV weaning failure in the ED.

Successful weaning in our study was higher than in intermediate respiratory care units (31-58%)[14,15]. This result could be due to the existence of a protocol that adequately identifies the patient as a candidate for weaning, as recommended in the clinical guidelines[8,16], patients with minimal severity criteria at the start of NIV and a satisfactory and rapid evolution that allows weaning to be initiated.

The weaning strategy used in the ED may have also played a role. In our center, in order to reduce the length of stay in the ED, we advocate a rapid weaning strategy, i.e., direct transition to conventional oxygen therapy. The use of a rapid strategy shows similar results of success compared to a progressive weaning strategy, i.e., gradual reduction of NIV time or with nocturnal NIV[15,17]. Therefore, adequate patient selection, through prognostic factors, is probably more important than the weaning strategy itself.

The traditional ventilatory gasometric parameters are pH, $PaCO_2$ and HCO_3^-. Hypoventilation causes increased $PaCO_2$ and respiratory acidosis. A pH less than 7.25 is a classic failure factor for NIV[3]. In patients with chronic hypoventilation, the kidney elevates HCO_3^- and

Table 1. Clinical-analytical, evolution and destination characteristics of the overall sample and univariate study according to successful or unsuccessful weaning

	Total N = 360 n (%)	Success N = 298 n (%)	Failure N = 62 n (%)	p value
Sex (female)	178 (49.4)	145 (48.7)	33 (53.2)	0.513
Age (years)	78.5 ± 11.1	78.6 ± 10.3	78.1 ± 14.4	0.770
Arterial hypertension	290 (80.6)	242 (81.2)	48 (77.4)	0.493
Diabetes mellitus	182 (50.6)	154 (51.7)	28 (45.2)	0.350
COPD	136 (37.8)	117 (39.3)	19 (30.6)	0.203
OSAS	53 (14.7)	41 (13.8)	12 (19.4)	0.258
CHF	163 (45.3)	140 (47.0)	23 (37.1)	0.155
HOT	108 (30)	85 (28.5)	23 (37.1)	0.180
Home CPAP	43 (11.9)	35 (11.7)	8 (12.9)	0.798
Previous NIV	133 (36.9)	107 (35.9)	26 (41.9)	0.371
Heart rate (bpm)*	95.7 (24.4)	95.6 (24.4)	96.5 (24.6)	0.797
MAP (mm Hg)*	98.5 (21.1)	98.8 (21.2)	96.9 (20.8)	0.522
Initial RR (brpm)*	24.4 (7.1)	23.8 (6.8)	26.9 (7.5)	0.016
ECG > 14 points	316 (87.8)	265 (88.9)	51 (82.3)	0.145
BMI (kg/m2)*	30.8 (6.5)	30.6 (6.3)	31.8 (7.1)	0.297
Creatinine (mg/dl)*	1.2 (0.7)	1.3 (0.8)	1.1 (0.6)	0.298
Procalcitonin (mg/dl)*	1.1 (8.2)	0.3 (1.1)	5.2 (19.7)	0.004
Lactate (mg/dl)*	2.4 (1.7)	2.5 (1.7)	1.8 (1.1)	0.008
NT- proBNP (pg/ml)**	2,538 (5,213)	5,645 (5,675)	2,453 (4,108)	0.370
Final diagnoses				0.169
COPD exacerbation	129 (35.8)	105 (35.2)	24 (38.7)	
APE	173 (48.1)	148 (49.7)	25 (40.3)	
Hypoxemic RF	33 (9.2)	28 (9.4)	5 (8.1)	
Hypercapnic RF	25 (6.9)	17 (5.7)	8 (12.9)	
ICU admission	11 (3.1)	5 (1.7)	6 (9.7)	0.001
Hospital stay (days)*	9.8 (6.9)	10.2 (7.3)	12.5 (10.1)	0.014
In-hospital mortality	33 (9.2)	15 (5.0)	18 (29.0)	< 0.001

*Results expressed as mean (standard deviation).
**Results expressed as median (interquartile range).
COPD: chronic obstructive pulmonary disease; OSAS: obstructive sleep apnea syndrome; CHF: chronic heart failure; HOT: chronic home oxygen therapy; NIV: noninvasive mechanical ventilation; ECG: Glasgow Coma Scale; BMI: body mass index; NT-proBNP: N-terminal portion of B-type natriuretic peptide; hypoxemic IR: patients with hypoxemic respiratory failure except for the diagnosis of acute pulmonary edema; hypercapnic IR: patients with hypoxemic respiratory failure except for the diagnoses of acute pulmonary edema and severe exacerbation of COPD; APE: acute pulmonary edema; ICU: intensive care unit; HR: heart rate; MAP: mean arterial pressure; RR: respiratory rate.

leads to pH correction (compensated respiratory acidosis). In order to initiate weaning, complete stabilization of the patient's ventilation is necessary, i.e., pH correction is required before attempting weaning[18,19]. Our results confirm this premise by showing that pH less than 7.35 before attempting weaning is an independent predictor of failure. In the univariate study, high $PaCO_2$ levels before the weaning attempt are associated with a greater probability of failure. However, this relationship disappears in the logistic regression indicating that pH is the relevant ventilatory parameter. This relationship is not new. The classic study by Confalonieri et al. in patients with severe COPD exacerbation and hypercapnic ARF documents that only pH[3] remains as an independent predictive factor[3]. Therefore, attempted weaning in the ED without pH correction should be undertaken with extreme caution.

Table 2. Blood gas values as a function of success or failure of weaning

	Total N = 360 n (%)	Success N = 298 n (%)	Failure N = 62 n (%)	p value
At the start of NIV				
pH*	7.28 (0.1)	7.28 (0.1)	7.28 (0.1)	0.790
$PaCO_2$, mm Hg*	62.5 (18.5)	61.4 (18)	68.1 (19.8)	0.017
HCO_3^- (mmol/L)*	27.9 (5.9)	27.4 (5.7)	30.7 (6.3)	< 0.001
PaO_2/FiO_2 (mm Hg)*	243 (36.6)	244.9 (36.7)	234.0 (35.3)	0.034
$PaO_2/FiO_2 \leq 250$ mm Hg	159 (44.1)	122 (40.9)	37 (59.6)	0.010
Before weaning attempt				
pH*	7.37 (0.1)	7.37 (0.1)	7.35 (0.1)	0.068
pH < 7.35	77 (21.3)	55 (18.4)	22 (35.4)	0.010
$PaCO_2$ (mm Hg)*	50.9 (10)	49.8 (9.1)	57.1 (12.3)	< 0.001
$PaCO_2 \leq 45$ mm Hg*	107 (29.7)	98 (32.8)	9 (14.5)	< 0.001
HCO_3^- (mmol/L)*	28.8 (6.1)	28.4 (5.6)	30.7 (8)	0.025
PaO_2/FiO_2 (mm Hg)*	258 (44)	262 (43)	237 (47)	0.019

*Results expressed as mean (standard deviation).

High bicarbonate levels prior to attempted weaning are an independent predictor of failure. They indicate the existence of chronic ventilatory failure, which translates into a greater likelihood of requiring a longer NIV time before attempting weaning[13,20] and, therefore, minimize the possibility of attempting weaning in the ED.

The best parameter to assess the patient's oxygenation status is PaO_2/FiO_2[21]. Classically, the cut-off point for initiating weaning is a PaO_2/FiO_2 greater than 150[11]. In our study, less than 5% of the patients had an oxygenation deficit of these characteristics. This result is possibly related to the high rate of NIMV failure in patients with severe hypoxemia[22]. Although low initial and pre-weaning PaO_2/FiO_2 levels are associated with a higher probability of failure, pre-weaning PaO_2/FiO_2 does not act as an independent predictor. It is important to note that slightly more than half of the patients studied had a PaO_2/FiO_2 greater than 250. This level of oxygenation is not an indication per se to initiate NIV[23] and, therefore, the initiation of NIV was due to clinical factors or ventilatory deficit. This result indicates that the initial oxygenation status is a limiting factor for early weaning and, therefore, in the ED.

Ventilation time before the weaning attempt is key to define prolonged weaning. In our study, ventilation time was an independent predictive factor and there were two periods with a higher probability of failure: in the first 4 hours of ventilation and, after the 5th hour, a progressive increase in weaning failure was observed. The first period falls under the concept of minimum ventilation time. Classically, this cut-off point has been established by expert recommendations between 12 and 24 hours[24]. However, according to our data, in some selected cases, a minimum time of 4 hours may be sufficient. It is important to point out that in our study only 10% of patients attempted to wean within this period of time. After the 5th hour, the probability

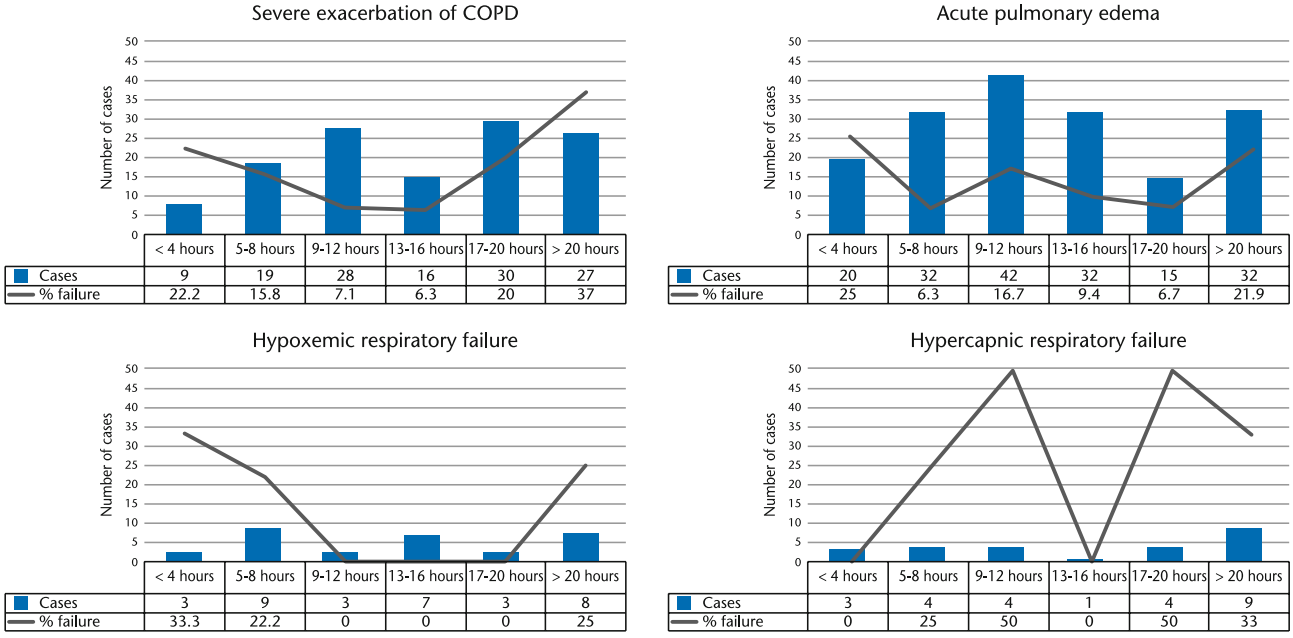

Figure 2. Stratification by hours of treatment with noninvasive mechanical ventilation (NIV) of cases (bars) and percentage of failure to wean from NIV (line) according to final diagnoses.
COPD: chronic obstructive pulmonary disease.

of failure increased progressively to 37% in patients with ventilation times of more than 20 hours. The proportion of patients in whom weaning was attempted after 20 hours was 14.2% but, as mentioned above, with a high probability of failure. Thus, in patients with no indication criteria for weaning in the first 20 hours of ventilation, we should consider including them in a multidisciplinary procedure, according to a specific protocol, to increase the probability of successful weaning[16].

In our study, the final diagnosis of the patients was a predictor. Although the time before attempted weaning was shorter in patients with APE, no statistically significant differences were observed between the final diagnoses. Probably, each type of pathology conditions, in a specific patient, a different initial clinical situation, evolution and ventilation time. Therefore, more important than the pathology triggering ARF are the clinical repercussions, mainly on oxygenation and ventilation status, and the patient's previous respiratory clinical situation.

Table 3. Variables associated in logistic regression with failure to wean from noninvasive mechanical ventilation in the emergency department

	aOR (IC 95%)	P value
HCO_3^- before weaning	1.06 (1.01-1.12)	0.014
NIV time, hours	1.10 (1.04-1.16)	< 0.001
pH < 7.35 before weaning	2.48 (1.16-5.31)	0.019

Adjustment variables: pCO_2 before weaning, pO_2/FiO_2 before weaning, final diagnoses, HCO_3^- and pH < 7.35 before weaning and NIV time and hours. NIV: noninvasive mechanical ventilation; ED: hospital emergency department; aOR: adjusted odds ratio. pO_2: arterial oxygen pressure; pCO_2: arterial carbon dioxide pressure; FiO_2: inspired oxygen fraction; HCO_3^-: bicarbonate.

The main limitation of the study was the absence of assessment of ventilator parameters. The second limitation was that, although the predominant pathology was APE and severe exacerbation of COPD, a significant percentage of patients had other diagnoses. This heterogeneity made it difficult to extrapolate results from the sample to each of the respiratory pathologies in particular. Third, our ED has extensive experience in the treatment of ARF by means of this ventilatory support and the results may not be extrapolable to other services with less experience. Fourth, although the institutional protocol advocates prompt weaning, the time of the weaning itself was not recorded. Finally, the possibility of rotating therapies and, therefore, their possible role in the weaning of these patients was not taken into account. In this sense, new studies are needed that take into account these limitations and include ventilator parameters. Despite these limitations, we believe that the study provides interesting data, taking into account that it shows certain strengths, such as the large sample analyzed and the analysis of multiple sociodemographic, clinical and analytical variables.

In conclusion, half of the patients who underwent NIV were susceptible to weaning in the ED. Proper patient selection could be key to these results. Therefore, the emergency physician should avoid attempting NIV weaning in a patient with high bicarbonate, no pH correction before the weaning attempt, and a NIV time of less than 4 or greater than 20 hours.

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References

1 Kelly AM, Holdgate A, Keijzers G, Klim S, Graham CA, Craig S, et al. Epidemiology, treatment, disposition and outcome of patients with acute exacerbation of COPD presenting to emergency departments in Australia and South East Asia: An AANZDEM study. Respirology. 2018;23:681-6.

2 Kelly AM, Keijzers G, Klim S, Graham CA, Craig S, Kuan WS, et al. An Observational Study of Dyspnea in Emergency Departments: The Asia, Australia, and New Zealand Dyspnea in Emergency Departments Study (AANZDEM). Mark Courtney D, Mark Courtney D, editores. Acad Emerg Med. 2017;24:328-36.

3 Confalonieri M, Garuti G, Cattaruzza MS, Osborn JF, Antonelli M, Conti G, et al. A chart of failure risk for noninvasive ventilation in patients with COPD exacerbation. Eur Respir J. 2005;25:348-55.

4 Martín-González F, González-Robledo J, Sánchez-Hernández F, Moreno-García MN, Barreda-Mellado I. Efectividad y predictores de fracaso de la ventilación mecánica no invasiva en la insuficiencia respiratoria aguda. Med Intensiva. 2016;40:9-17.

5 Tudela P, Mòdol JM. On hospital emergency department crowding. Emergencias. 2015;27:113-20.

6 Ward MJ, Ferrand YB, Laker LF, Froehle CM, Vogus TJ, Dittus RS, et al. The nature and necessity of operational flexibility in the emergency department. Ann Emerg Med. 2015;65:156-61.

7 Cabrini L, Landoni G, Bocchino S, Lembo R, Monti G, Greco M, et al. Long-Term Survival Rate in Patients With Acute Respiratory Failure Treated With Noninvasive Ventilation in Ordinary Wards. Crit Care Med. 2016;44:2139-44.

8 Davidson C, Banham S, Elliott M, Kennedy D, Gelder C, Glossop A, et al. British Thoracic Society/Intensive Care Society Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults. BMJ Open Respiratory Research. 2016;3:e000133.

9 BTS Guideline. Non invasive ventilation in acute respiratory failure. British Thoracic Society Standards of Care Committee. Thorax. 2002;57:192-211.

10 Burns KEA, Raptis S, Nisenbaum R, Rizvi L, Jones A, Bakshi J, et al. International Practice Variation in Weaning Critically Ill Adults from Invasive Mechanical Ventilation. Ann Am Thorac Soc. 2018;15:494-502.

11 Schmidt GA, Girard TD, Kress JP, Morris PE, Ouellette DR, Alhazzani W, et al. Liberation From Mechanical Ventilation in Critically Ill Adults: Executive Summary of an Official American College of Chest Physicians/American Thoracic Society Clinical Practice Guideline. Chest. 2017;151:160-5.

12 Subirà C, Hernández G, Vázquez A, Rodríguez-García R, González-Castro A, García C, et al. Effect of Pressure Support vs T-Piece Ventilation Strategies During Spontaneous Breathing Trials on Successful Extubation Among Patients Receiving Mechanical Ventilation: A Randomized Clinical Trial. JAMA. 2019;321:2175-82.

13 Cuvelier A. Dependency on mask ventilation after acute respiratory failure in the intermediate care unit. Eur Resp J. 2005;26:289-97.

14 Confalonieri M, Gorini M, Ambrosino N, Mollica C, Corrado A. Respiratory intensive care units in Italy: a national census and prospective cohort study. Thorax. 2001;56:373-8.

15 Sellares J, Ferrer M, Anton A, Loureiro H, Bencosme C, Alonso R, et al. Discontinuing noninvasive ventilation in severe chronic obstructive pulmonary disease exacerbations: a randomised controlled trial. Eur Respir J. 2017;50:1601448.

16 Borges LGA, Savi A, Teixeira C, de Oliveira RP, De Camillis MLF, Wickert R, et al. Mechanical ventilation weaning protocol improves medical adherence and results. J Crit Care. 2017;41:296-302.

17 Lun C-T, Chan VL, Leung W-S, Cheung APS, Cheng S-L, Tsui MSN, et al. A pilot randomized study comparing two methods of non-invasive ventilation withdrawal after acute respiratory failure in chronic obstructive pulmonary disease: RCT versus NIV withdrawal in acute COPD. Respirology. 2013;18:814-9.

18 MacIntyre NR, Cook DJ, Ely EW, Epstein SK, Fink JB, Heffner JE, et al. Evidence-based guidelines for weaning and discontinuing ventilatory support: a collective task force facilitated by the American College of Chest Physicians; the American Association for Respiratory Care; and the American College of Critical Care Medicine. Chest. 2001;120:375S-95S.

19 Esteban A, Alía I, Ibañez J, Benito S, Tobin MJ. Modes of mechanical ventilation and weaning. A national survey of Spanish hospitals. The Spanish Lung Failure Collaborative Group. Chest. 1994;106:1188-93.

20 Faverio P, Stainer A, De Giacomi F, Messinesi G, Paolini V, Monzani A, et al. Noninvasive Ventilation Weaning in Acute Hypercapnic Respiratory Failure due to COPD Exacerbation: A Real-Life Observational Study. Can Respir J. 2019;2019:3478968.

21 ARDS Definition Task Force, Ranieri VM, Rubenfeld GD, Thompson BT, Ferguson ND, Caldwell E, et al. Acute respiratory distress syndrome: the Berlin Definition. JAMA. 2012;307:2526-33.

22 Rochwerg B, Brochard L, Elliott MW, Hess D, Hill NS, Nava S, et al. Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. Eur Respir J. 2017;50:1602426.

23 Carrillo A, Gonzalez-Diaz G, Ferrer M, Martinez-Quintana ME, Lopez-Martínez A, Llamas N, et al. Non-invasive ventilation in community-acquired pneumonia and severe acute respiratory failure. Intensive Care Med. 2012;38:458-66.

24 Mehta S, Hill NS. Non invasive ventilation. State of the Art. Am J Respir Crit Care Med. 2001;163:540-77.