

Staff training influence on non-invasive ventilation outcome for acute hypercapnic respiratory failure

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ABSTRACT: *Staff training influence on non-invasive ventilation outcome for acute hypercapnic respiratory failure. J.L. Lopez-Campos, C. Garcia Polo, A. Leon Jimenez, A. Arnedillo, E. Gonzalez-Moya, J.J. Fenandez Berni.*

Background. Although non-invasive ventilation (NIV) efficacy in the treatment of acute hypercapnic respiratory failure (AHRF) have been previously demonstrated, not all the studies reveal this fact in the same degree, with some variability in the results. This study aimed to analyse variables related to NIV outcome for AHRF.

Methods. A group of consecutive patients requiring NIV due to AHRF were included in a prospective observational cohort study performed in conventional wards. Variables considered included those reported in the literature, as well as staff problems during the management of the ventilators. The study aimed to include all patients

during one year, but after the initial results, it had to be suspended.

Results. Fifteen patients were included in the study: 10 males, mean age 68 ± 12 . APACHE-II score was 17.6 ± 6.5 . pH and pCO₂ before NIV were 7.22 ± 0.11 and 110 ± 72 mmHg respectively. pH, corticosteroids use, APACHE score, and EPAP were found to influence outcome. Besides, an inadequate use of NIV due to lack of personnel training was detected in all patients with NIV failure (RR 3.5; 95% CI: 1.08-11.2; $p = 0.007$). In the light of these results, the study had to be suspended and patients were transferred to the respiratory ward.

Conclusions. NIV is a life-saving respiratory treatment influenced by several factors, of which staff training is a key one. Centres attending acute respiratory patients should have an area in which this requirement is fulfilled. *Monaldi Arch Chest Dis 2006; 65: 3, 145-151.*

Keywords: *Acute respiratory failure, medical staff, noninvasive ventilatory support, nursing staff, prognosis.*

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Introduction

Non-invasive ventilation (NIV) has demonstrated its efficacy in the treatment of acute hypercapnic respiratory failure (AHRF) due to chronic obstructive pulmonary disease (COPD) exacerbations throughout a good number of randomised controlled trials and meta-analysis [1, 2]. Likewise, NIV has a role in the treatment of AHRF resulting from other causes [3]. Although most studies present a trend towards the improvement of patients with this therapy, not all the studies demonstrate this result in the same degree, with some variability in the results. According to the different controlled trials published success rates range between 75-100% for COPD and 20-70% for non-COPD patients. During the past decades several factors have been pointed out to explain this variability in outcome [4] such as the degree of encephalopathy, several severity of disease indexes, i.e. Acute Physiology and Chronic Health Evaluation (APACHE) II score [5] or Simplified Acute Physiology Score (SAPS II) [6], arterial blood gases (pH or pCO₂ at admission and after a few hours of ventilation), or respiratory rate. Furthermore, all these variables might be influenced by patient's

tolerance to NIV, which is directly related to the staff's training and experience on NIV [7]. In this context, we undertook an observational study in order to see the influence of variables related to NIV success in our population. Nonetheless, a preliminary analysis of the results was performed after two months and in the light of the results the study had to be suspended. The results of this preliminary study and the reasons for this decision are presented here.

Methods

The study was designed as an observational prospective cohort study. It was carried out at "Puerta del Mar" University Hospital (750 beds, population: 227,141), Cadiz, Spain. In this hospital NIV is used either in the intensive care setting, the emergency department, or the conventional ward for more than 10 years, there being no specific unit for noninvasively ventilating or monitoring patients. The study population was a group of consecutive patients requiring NIV due to AHRF during one year starting October 2004. Inclusion criteria were: adult patients attending the emergency department during the period of study with AHRF

(pH < 7.35 and pCO₂ > 55 mmHg) and those with AHRF and a do-not-intubate order. Exclusion criteria were: the need of endotracheal intubation (ETI) or Intensive Care Unit (ICU) admission for treatment or monitoring (hemodynamic instability, multi-organ failure, cardiopulmonary arrest), and the inability of the patient to collaborate with NIV (severely low level of consciousness, anatomic abnormality which interferes with mask fitting, refusal of patient to receive NIV).

NIV was started as soon as the inclusion criteria were met in all cases. Before initiating NIV, oral consent was obtained from the patient or the next of kin. All ventilation was carried out in conventional wards. Since it was an observational study, randomization was not required. As a first choice, patients were transferred to the respiratory ward and secondly to any internal medicine ward when there was no bed available. The main difference regarding this decision is that although all staff in our hospital was once sufficiently trained to assist ventilatory-dependent patients, only personnel on the respiratory ward are really experienced in ventilators management, since there is no continued training programme for medical and paramedical staff. The rest of the features of respiratory and medical wards in terms of number of doctors, nurses, monitoring, or operative flow charts were similar between them. Additionally, standard medical therapy consisting in corticosteroids, bronchodilators, antibiotics, subcutaneous fractionated heparin, and gastric protectors was also used in both wards as well as any medication needed to treat any existing co-morbidity. Patients were followed-up until discharge or exitus. During their stay patients were evaluated before the initiation of NIV, one hour after NIV onset and then every 24 hours. Besides, there was a physician on call in case the patient deteriorated.

Variables recorded in each evaluation were the following: previous medical records (age, sex, smoking habit, previous medical diseases, home oxygen therapy or mechanical ventilation, and number of admissions or acute ventilatory support episodes in the previous year), data upon admission (cause of exacerbation, APACHE-II, accessory muscle use, copious secretions, mental status, initial pharmacological treatment, and the ward where patient was ventilated), complementary studies (blood count and biochemistry, arterial blood gases, and condensation on chest radiography) and data regarding ventilation (time spent to establish NIV, device and masks for NIV, ventilatory parameters, presence of complications, adverse effects, total ventilation time, days of stay, inadequate use of NIV as defined below). The cause of exacerbation was classified as infection, congestive heart failure (CHF) or unknown/other. Infection was considered as the cause of admission when the sputum was purulent and white cell count was above 11,500 cells/mm³. Mental status was measured by both Brochard *et al.* [8] scale (0 normal; 1 mild asterixis; 2 marked asterixis, mild confusion, or sleepiness during the day; 3 major confusion with daytime sleepiness or agitation;

and 4 obtundation or major agitation) and Glasgow coma scale (GCS) [9]. All data were recorded by a lung physician experienced in NIV. After two months of study, a preliminary analysis of the results was performed and the study had to be suspended.

Ventilation procedure

Ventilation procedure was adopted from British Thoracic Society (BTS) guidelines [10]. Noninvasive pressure support ventilation was used in all cases. NIV was delivered by two noninvasive mechanical ventilators: Sullivan VPAP- II ST (Resmed Ltd., Abingdon, Oxfordshire, UK) and Saime VS Serena (Saime, Sanigvy le Temple, France). Oro-nasal masks (Respironics, Pittsburgh, Pa., USA) were used in all cases with three possible sizes (large, medium and small). Ventilation was then initiated in the ST mode with the following parameters: IPAP 10 cm H₂O, EPAP 4 cm H₂O, backup rate 10-15 rpm. For COPD patients IPAP was increased during the next minutes in 1 cm H₂O amounts every 5 minutes until the patient experienced discomfort or leaks appeared and EPAP was established between 4-6 cm H₂O according to the patient's tolerance. For restrictive patients IPAP was established similarly but EPAP was increased by 1 cm H₂O amounts every 5 minutes until oxygen saturation was 90% or discomfort or leaks appeared. In those cases with oxygen saturation below 90% after parameters adjustment, supplemental oxygen was administered via oro-nasal mask.

During the first 24 hours, patients were encouraged to use NIV for as long as tolerated aiming for 20 hours, with periods of relief for meals, conversation, comfort, and respiratory treatments as necessary. During relief periods oxygen was administered via nasal prongs to maintain oxygen saturation of 90%. The following days NIV use was progressively decreased according to patient's improvement. NIV was discontinued once clinical stability was achieved as defined below or if the patient refused to continue or met ETI criteria (see below).

Definitions

Treatment failure. As defined by BTS consensus guideline (10): deterioration in patient's condition, failure to improve or deterioration in arterial blood gas tensions, development of new symptoms or complications that require ETI or ICU admission, or deteriorating conscious level.

Early failure. Failure of NIV before 48 hours of ventilation or without initial success.

Late failure. Failure of NIV after more than 48 hours of NIV with initial success.

Treatment success. Improvement in patient's condition and gas exchange so that mechanical ventilation can be successfully removed with clinical stability.

Clinical stability. As defined by Kramer *et al.* [11]: respiratory rate ≤ 24 rpm, heart rate ≤ 110 spm, pH ≥ 7.35 and SatO₂ > 90% with oxygen ≤ 3 lpm.

Complications. A non-expected clinical event which deteriorates the expected progression of the patient, such as nosocomial pneumonia or sepsis, pulmonary embolism, acute renal failure, shock, metabolic complications, or hepatic dysfunction.

NIV misuse event. An event regarding the ventilator use that was considered to be wrong according to the instructions of the device or the indications by the physician in charge. Every 24 hours staff was inquired about the use of NIV, such as the parameter settings, or alarms management. All events indicating an inadequate use of the ventilator were noted.

Adverse effects. Events directly related to non-invasive ventilation use, such as nasal bridge ulceration, discomfort, excessive noise of the device, or excessive leaks.

Endotracheal intubation criteria. As defined by Brochard *et al.* [8], the presence of one major criterion or two minor criteria was considered to indicate the need for ETI. Major criteria were: respiratory arrest, respiratory pauses with loss of consciousness or gasping for air, psychomotor agitation making nursing care impossible and requiring sedation, a heart rate below 50 beats per minute with loss of alertness, and hemodynamic instability with systolic arterial blood pressure below 70 mm Hg. Mi-

nor criteria were: respiratory rate above 35 breaths per minute and above the value on admission; an arterial pH value below 7.30 and below the value on admission; a value for the partial pressure of arterial oxygen below 45 mm Hg, despite oxygen therapy; and an increase in the score for encephalopathy.

Statistics

For descriptive purposes, absolute and relative frequencies were used to describe qualitative variables, and mean \pm standard deviation were used for quantitative ones. In the comparative analysis, non-parametric tests were used. Comparison between quantitative variables was assessed by Mann-Whitney U test whereas Chi-square test or Fisher's exact test were used to compare qualitative variables and to calculate relative risks with 95% confidence intervals. Due to the low number of patients included, a multivariate analysis could not be performed. Alpha error was set at 0.05.

Results

From October to December 2004 15 patients were included in the study: 10 males and 5 females, mean age 68 ± 12 years (table 1; success

Table 1. - Descriptive data of the patients

n	Sex	Age	Disease	APACHE	pH	pCO ₂	Ward events*	NIV misuse	Result
1	M	65	COPD	23	7.29	70.3	Other	No	Discharge
2	M	67	TBC	19	7.21	124	Other	Yes	Exitus
3	F	84	OHS	23	7.28	100	Other	Yes	ETI - ICU
4	M	72	COPD	21	7.21	166	Respir	No	Discharge
5	M	68	OSAS-CHF	22	7.24	65	Other	Yes	Exitus
6	F	80	TC	13	7.32	84	Other	No	Discharge
7	M	72	COPD	10	7.27	85	Respir	Yes	Discharge
8	M	70	COPD	11	7.31	95	Respir	Yes	Discharge
9	M	49	COPD	14	7.18	108.5	Respir	No	Discharge
10	M	75	COPD	11	7.29	57.4	Respir	No	Discharge
11	F	32	CAP-HIV	18	7.14	81	Other	Yes	Exitus
12	M	75	COPD	17	7.27	79	Respir	No	Discharge
13	F	74	OSAS	11	7.29	85	Respir	No	Discharge
14	M	79	COPD	18	7.26	100	Respir	No	Discharge
15	F	70	Asthma-BQ	34	6.87	354	Respir	Yes	Exitus

Failures appear in grey. COPD: Chronic obstructive pulmonary disease. OSAS: Obstructive sleep apnea syndrome. CHF: Congestive heart failure. TC: Thoracic cage. CAP: Community acquired pneumonia. HIV: Human immunodeficiency virus. BQ: bronchiectasis. Respir: respiratory ward. ICU: Intensive care unit. pH: pH before NIV. ETI: endotracheal intubation. OHS: Obesity-hypoventilation syndrome. NIV: non-invasive ventilation. * As defined in the text.

group n = 10, failure group n = 5). Smoking habits included 3 current smokers, 7 ex-smokers, and 5 non-smokers. Previous medical history included systemic hypertension 7 (46,7%) patients, diabetes 3 (20%) patients, hypercholesterolemia 4 (26,7%) patients, and heart problems 10 (66,7%) patients. None of the patients had received mechanical ventilation for an acute exacerbation before, but 2 of them were receiving home pressure support mechanical ventilation, 4 of them were on a domiciliary oxygen therapy program, and 3 used home nebulizers. The number of admissions during the previous year ranged from 0 to 3 (mean 0.92 ± 1.1). The most frequent cause of the exacerbation was infection in 9 (60%) patients. APACHE-II score was 17.6 ± 6.5 with a predicted mortality of $24.1 \pm 17.4\%$. pH and pCO₂ before NIV were 7.22 ± 0.11 and 110 ± 72 mmHg respectively (table 1). Seven (46.7%) patients used accessory musculature and also seven patients had copious secretions. All patients could expectorate adequately. The most frequent mental status according to Brochard *et al.* scale [8] was mild asterixis (6 patients; 40%), followed by marked asterixis, mild confusion, or sleepiness during the day (3 patients; 20%) and major confusion with daytime sleepiness or agitation (3 patients; 20%). GCS was 12.6 ± 4 points. Severity of patients ventilated in the respiratory ward compared to those ventilated elsewhere was found not to be significantly different in terms of pH (7.2 ± 0.13 vs. 7.2 ± 0.06 ; p = 0.859) and APACHE score (16.2 ± 7.7 vs. 19.6 ± 3.8 ; p = 0.08).

Sullivan VPAP-II was used in 5 patients and Saime VS Serena in 10. Time elapsed between blood gas test result and the initiation of NIV was 113 ± 134 minutes. Time used to establish final parameters was 40 ± 14 minutes. We found no significant differences in timing between ventilators (Sullivan

VPAP-II 43 ± 13 minutes vs. Saime VS Serena 37.5 ± 15.7 minutes; p = 0.537). Ventilatory parameters were IPAP 13.5 ± 3.5 , EPAP 5.5 ± 1.2 and backup rate 12.3 ± 1.6 . There were no significant differences in ventilatory parameters according to the ventilator used (IPAP 13.4 ± 4 vs. 13.8 ± 2.5 , p = 0.797; EPAP 5.1 ± 0.9 vs. 6.2 ± 1.4 , p = 0.147; backup rate 12.5 ± 1.6 vs. 12.2 ± 1.7 , p = 0.833). However, COPD patients tended to had a lower EPAP (COPD: 4.8 ± 0.6 vs. non-COPD 6.14 ± 1.3 ; p = 0.073). Patients were ventilated for 4 ± 4.6 days, with 38 ± 44 hours of ventilation. Mean stay was 15 ± 11 days.

Adverse effects were: nasal bridge ulceration (1 patient), eye irritation (1 patient), excessive noise of the device (1 patient), and discomfort (2 patients). There were no complications during the follow-up. Significant variables and relative risks appear in table 2 and table 3. Relative risk of NIV success could not be calculated for EPAP since none of the patients with EPAP > 7 cmH₂O improved, but the relative risk to fail NIV with EPAP < 7 cmH₂O was 5.5 (95% CI: 1.5-19.2).

There was one late failure (patient number 5) and 4 early ones. Only one patient underwent ETI, since the other failures had a do-not-intubate order. Failure rate was 33.3%. Failure rate rose up to 71.4% (table 1, table 2) in the subgroup of patients with an inadequate use of NIV, whereas in the rest of the sample all patients improved with NIV. Similarly, failure rate was 11.1% in the subgroup of patients ventilated in the respiratory ward versus 66.7% for those ventilated elsewhere (table 1, table 2). Problems detected regarding the use of NIV are summarized in table 4. These results suggested that personnel lack of skill significantly influenced prognosis, so the study was suspended to transfer patients to the respiratory ward where a trained staff is in charge of noninvasively ventilated patients.

Table 2. -Comparison of most important variables between groups. Qualitative variables are expressed in absolute an relative frequencies. Quantitative variables are expressed in mean \pm standard deviation

Variable	Success group N = 10	Failure group N = 5	p
NIV misuse	2 (20%)	5 (100%)	0.007
Respiratory ward	8 (80%)	1 (20%)	0.089
COPD	8 (80%)	0 (0%)	0.007
Open eyes spontaneously	10 (100%)	3 (60%)	0.095
Glasgow	14 ± 2.3	9.8 ± 5.4	0.055
pH before NIV	7.26 ± 0.04	7.14 ± 0.16	0.042
pH after 1 h ventilation	7.36 ± 0.07	7.17 ± 0.08	0.004
Corticosteroids	9 (90%)	2 (40%)	0.039
APACHE	14.8 ± 4.7	23.2 ± 6.3	0.019
EPAP	4.89 ± 0.7	6.6 ± 1.1	0.019

Table 3. - Relative risks of NIV success for significant variables

Variable		Relative risk	95% confidence interval	p
NIV inadequate use	Yes	1		0.007
	No	3.5	1.08-11.2	
COPD	Yes	3.5	1.08-11.2	0.007
	No	1		
pH before NIV	> 7.29	2	1.07-3.7	0.042
	< 7.29	1		
pH after 1 h ventilation	> 7.30	6	1-35.9	0.023
	< 7.30	1		
Corticosteroids use	Yes	4.1	1.04-16.3	0.039
	No	1		
APACHE	> 17	1		0.026
	< 17	2.6	1.09-6.5	

Table 4. - Main problems encountered during follow-up. Percentages are referred to total number of patients

Problems	Number of patients: n (%)
The ventilator was not used during that shift because the staff didn't know how to operate the ventilator	6 (40%)
Bad mask fitting with excessive leaks	3 (20%)
Personnel didn't know how to control oxygen therapy. High flow rates	1 (6.6%)
The ventilator was not connected because oxygen saturation was $\geq 90\%$ while receiving oxygen	1 (6.6%)
Ventilator was reconnected after a resting period without expiratory valve	1 (6.6%)
Personnel didn't know how to deal with ventilator alarms	1 (6.6%)
The patient was not under close observation. The ventilator disconnected and no one noticed	1 (6.6%)

Discussion

The aim of this study was to determine variables related to NIV outcome. Success rates are influenced by many factors, among which the clinician team's training and experience is a key one [7]. Our findings suggest that the use of NIV by an inexperienced personnel leads to a high failure rate, which led to the suspension of the study. The use of NIV outside the ICU permits clinicians perform an early intervention to prevent further respiratory deterioration, it gives access to respiratory support for patients who would not otherwise be admitted to the ICU, and supply ventilatory support in a less intimidating environment [12]. Nonetheless, the location chosen for patients receiving NIV should include factors such as adequate monitoring, and staff skill and experience in the procedure, the equipment and the potential complications [12].

Although all staff was once trained to assist patients, in our hospital there is no continued training programme for medical and paramedical staff, and only personnel on the respiratory ward is used to work with ventilated patients whereas the rest of the staff work with ventilators only occasionally. This makes a considerable difference in experience between both settings. Medical and paramedical staff expertise is a variable difficult to measure which directly influences outcome and which has been poorly studied so far. The most recent study by Carlucci *et al.* [13] showed that, over time, a better staff training allows the treatment of more severe and a greater number of patients without significantly changing the rate of success. These authors suggested that with greater staff training and experience, more severely ill patients may be treated with a lower risk of failure. Soo Hoo *et al.* [14] in a small study (14 episodes in 12 patients, success rate 50%), found that there were no differ-

ences in age, prior pulmonary function, baseline arterial blood gas tensions, admission arterial blood gas tensions, or respiratory rate between those patients successfully treated and those who failed NIV. Nonetheless, the authors found that those patients unable to coordinate with the ventilator or to minimize leaks failed NIV.

Success rate in our study was similar to those published in previous studies with various forms of AHRF [15, 16, 17]. Nonetheless, in our series pH upon admission was lower than that reported in the largest study performed in ward [15]. In this study it was found that COPD subgroup with pH below 7.30 might not benefit from NIV. Although pH before NIV is related to the severity of the patient's condition and thus influences prognosis [18], in our experience it is pH after a few hours of ventilation, one hour in our case, rather than pH before ventilation what really influences prognosis (table 2, table 3). So we believe that in clinical practice if patients meet NIV criteria, a first trial with NIV should be started with a prompt evaluation after one hour of NIV in order to decide whether to continue NIV or not. Similar results can be drawn from a recent study by Confalonieri *et al.* [4]. These authors demonstrated that pH < 7.25 after two hours of NIV increased failure risk > 90% with an odds ratio of 21.02 (10.07-43.87), whereas pH upon admission represented a less striking increase in failure risk with an odds ratio of 1.97 (1.23-3.15) in the logistic regression model.

Timing is an additional factor which was considered in this study. We recorded three timing periods: time elapsed before admission, time between the result of the blood gas analysis and the initiation of NIV, and time employed in establishing ventilatory parameters. In our case, none of these periods turned out to be a factor influencing prognosis, but larger studies might show different results.

Optimal inspiratory pressures have not been established for NIV, there being studies with both similar and higher IPAP than ours [17, 19]. Lower pressures ensure a better tolerability with fewer adverse effects. Nonetheless, since this study was not designed to assess this matter, further studies should be carried out to establish possible pressures cut-off points. Expiratory pressure was found to be different between groups and close to the level of significance, probably because titration in restrictive patients included a higher EPAP than in COPD. Similarly, differences encountered in corticosteroids treatment are probably associated with COPD subgroup which is related to a better prognosis. It would have been desirable to have a multivariate analysis to assess these differences. However, due to the low number of patients, this type of analysis could not be performed.

Variables related to level of consciousness (open eyes spontaneously, and GCS; table 2) and the ward where NIV was carried out were close to statistical significance, which probably denotes a problem with the number of patients included in this study. In Confalonieri *et al.* study [4] GCS was

significantly associated with outcome with an odds ratio of 2.29 (95% confidence interval: 1.41-3.72) for GCS between 12-14 and an odds ratio of 4.40 (95% confidence interval: 2.59-7.49) for GCS ≤ 11 points.

Of the 5 patients who failed, 4 were early failures and 1 was a late one. Most of the studies report an incidence of late failure of about 10-20%. The recognition of this subset of patients with a late failure is critical because prolonged application of NIV may delay the time of intubation [20]. This group of late failures have been described to have significantly lower activities of daily living scores, lower blood pressure, more tachycardia and are more likely to have associated complications, such as hyperglycaemia. But the key point is that this is a subgroup of patients particularly associated with poor outcomes, and patients should be rapidly considered for intubation since their mortality rate is 92% if NIV is continued, whereas mortality decreases to 53% if they are intubated. In our case, the patient deteriorated rapidly and died in the next few hours.

In conclusion, NIV is a life-saving respiratory treatment for AHRF which is influenced by several factors that should be controlled to guarantee the success of the therapy. One decisive factor is the control of ventilatory support by personnel with sufficient time and experience. Centres attending acute respiratory patients should have an area in which this requirement is fulfilled.

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