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# Noninvasive pressure support ventilation (NIPSV) with face mask in patients with acute cardiogenic pulmonary edema (ACPE)

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**Abstract** *Objectives:* To assess (1) the short-term hemodynamic, respiratory and arterial blood gas effects of NIPSV in patients with ACPE who were likely to require endotracheal intubation, (2) the initial causes of failure and (3) the side effects and the difficulties of this technique.
*Design:* Uncontrolled, prospective clinical study.
*Setting:* Teaching hospital intensive care unit.
*Patients:* 26 consecutive patients with severe ACPE.
*Interventions:* Noninvasive ventilation via a face mask, using a pressure support mode ($20.5 \pm 4.7$ cm$H_2O$), with an initial fractional inspired oxygen of $93.0 \pm 16$ % and a positive end-expiratory pressure of $3.5 \pm 2.3$ cm$H_2O$. The need to intubate the patients within 48 h was considered as a criterion of failure of the procedure.
*Measurements and results:* Clinical and biological parameters were measured at 15 and 30 minutes, 1 h and 2 h and at 1 h and 2 h, respectively. There were 5 (21 %) failures and 21 (79 %) successes. In both the success and the failure groups, clinical and blood gas parameters improved at the first measure. In the success group, within 15 min of the start of NIPSV, pulse oximetry saturation ($SpO_2$) had increased from $84 \pm 12$ to $96 \pm 4$ % ($p < 0.001$), the respiratory rate (RR) had decreased from $36 \pm 5.3$ to $22.4 \pm 4.9$ breaths/min ($p < 0.0001$) and within 1 h the arterial oxygen tension and pH, respectively, had increased from $61 \pm 14$ to $270 \pm 126$ mmHg ($p < 0.0001$) and from $7.25 \pm 0.11$ to $7.34 \pm 0.07$ ($p < 0.01$) and the arterial carbon dioxide tension ($PaCO_2$) had decreased from $54.2 \pm 15$ to $43.4 \pm 6.4$ mmHg ($p < 0.01$). There were no statistical differences between the success and failure groups for the initial clinical parameters: $SpO_2$, RR, heart rate, mean arterial pressure. The only differences between the success and failure groups were in the $PaCO_2$ ($54.2 \pm 15$ vs $32 \pm 2.1$ mmHg, $p < 0.001$) and the creatine kinase (CPK) ($176 \pm 149$ vs $1282 \pm 2080$ IU/l, $p < 0.05$); this difference in CPK activity was related to the number of patients who had an acute myocardial infarction (AMI) (4/5 in the failure group vs 2/21 in the success group, $p < 0.05$). All patients with AMI in the failure group died.
*Conclusion:* Among patients in acute respiratory failure, those with severe ACPE could benefit from NIPSV if they are hypercapnic, but NIPSV should be avoided in those with AMI.

**Key words** Noninvasive ventilation · Pressure support ventilation · Cardiogenic pulmonary edema · Acute respiratory failure · Face mask

## Introduction

Noninvasive pressure support ventilation (NIPSV) has been proposed as an efficient alternative to conventional mechanical ventilation during acute exacerbations of chronic respiratory insufficiency [1–5]. The results are not as good for patients suffering from acute respiratory failure unrelated to chronic obstructive pulmonary disease (COPD) [6]. Some studies on ACPE have mostly used continuous positive airway pressure (CPAP) [7–9]. Otherwise, mechanical ventilation has been proposed as an added therapy to medical treatment because of its effects on intrathoracic pressure. Complications can result during intubation, during ventilation or after removal of the tube [10, 11]. The aim of this study was (1) to assess the short-term hemodynamic, respiratory and arterial blood gas effects of NIPSV in patients with ACPE who were likely to require endotracheal intubation, (2) to detect the initial causes of failure, and (3) to analyze the side effects and the difficulties of this technique.

## Materials and methods

### Patients

Over 6 months, 26 patients (17 men and 9 women) with ACPE and severe acute respiratory failure (ARF), admitted to the intensive care unit (ICU) for treatment with an indication for mechanical ventilation, were prospectively and consecutively included. All patients had been transported to the ICU by ambulance and had been treated conventionally with nasal $O_2$ (6 to 10 l/min) and diuretics without improvement.

Patients selected for NIPSV were those who required endotracheal intubation according to at least one of the following criteria: a respiratory rate (RR) greater than 30 breaths per minute, a pulse oximetry saturation ($SpO_2$) below 90 % despite 6–10 l/min oxygen supplementation via a nasal catheter, severe dyspnea with use of accessory respiratory muscles or paradoxical abdominal motion. The level of consciousness was assessed by the Glasgow Coma Score (GCS). Cardiogenic pulmonary edema was defined by the association of the following criteria: a past history of cardiovascular disease, predisposing factors, cardiomegaly, bilateral alveolar and interstitial opacities and presence of crepitations on auscultation. The patients who required immediate intubation for cardiac arrest, bradypnea (RR < 8/min), shock or multiple organ failure were not included, nor were patients who refused the face mask or patients with a GCS under 10. This clinical protocol was conducted in accordance with the principles established in Helsinki.

### Study design

NIPSV was administered to the patients via a face mask (Ambu, Bordeaux, France). The mask was adjusted to avoid air leaks and connected to a ventilator (CPU1, Ohmeda) set in the inspiratory pressure support (IPS) mode. The initial settings were as follow: the IPS level was set at 20 $cmH_2O$ and then adjusted for each patient in order to achieve a tidal volume between 7 and 10 ml/kg. We used a low level of positive end-expiratory pressure (PEEP) between 2 and 5 $cmH_2O$ to increase the arterial oxygen tension/fractional inspired oxygen ($PaO_2/FIO_2$) ratio and prevent atelectasis [6]. An $FIO_2$ of 100 % was initially used and then gradually decreased after 30 min if the $SpO_2$ was higher than 95 %. In the patients who developed hypoventilation under NIPSV, the ventilator mode was transiently changed to the assist-control volume mode.

NIPSV was considered a failure when intubation within the first 48 h was needed. Major criteria for intubation were standardized according to those published by Brochard et al. [2]: respiratory arrest, respiratory pauses with loss of consciousness or gasping for air, psychomotor agitation making nursing care impossible and requiring sedation, heart rate (HR) below 50 b/min with loss of alertness, and hemodynamic instability (systolic pressure < 70 mmHg). Other criteria for intubation were: the deterioration of clinical parameters (RR above the admission value, $SpO_2$ < 90 % despite NIPSV or under 6–10 l/min of oxygen) associated with a refusal of the face mask; the necessity of keeping the face mask on for more than 12 h continuously; or the clinical judgment of the physician in charge. When the patient's clinical status improved, ventilation support was used discontinuously or was stopped if clinical improvement remained stable. NIPSV weaning was started when the patients fulfilled the following conditions: $FIO_2$ of 50 % with an RR < 25/min and an $SpO_2$ > 90 %; NIPSV was resumed if the following conditions appeared within 60 min of spontaneous ventilation: RR > 25/min and $SpO_2$ < 90 %.

### Physiological measurements

The baseline assessment (before the start of NIPSV) of the patients included RR, $SpO_2$, HR, mean arterial pressure (MAP), GCS, clinical signs of increase in respiratory muscle workload, electrocardiogram (ECG) chest X-ray, blood gases [$PaO_2$, arterial carbon dioxide tension ($PaCO_2$), pH], electrolytes, creatine phosphokinase (CPK), liver function tests and blood count. The severity of illness was assessed by the Simplified Acute Physiology II Score. The same physician performed transthoracic echocardiography on all of the patients.

The diagnosis, the etiology of ACPE, and the underlying heart disease were assessed by two physicians, one from the ICU and a cardiologist. The diagnosis of myocardial infarction (AMI) was established retrospectivly on two of three of following: chest pain, increase in CPK and signs of myocardial necrosis on the ECG. Myocardial ischemia (MI) was diagnosed when there was a history of typical chest pain in combination with transient ST-segment depression or T-wave inversion. Congestive heart failure (CHF) was diagnosed if AMI or MI was absent and the patient was already receiving medication for CHF.

Clinical and biomedical parameters were monitored according to the following timing and regularly as long as necessary: clinical status at 15 and 30 min, 1 and 2 h; diuresis at 1 and 2 h; oximetry at 1 and 2 h; RR and $SpO_2$ were also measured between 1 and 3 h after NIPSV was stopped.

All the side effects, mask intolerance and reasons for changes in the ventilator settings were recorded.

### Statistical analysis

All values are reported as mean ± standard deviation (SD). The statistical analysis was made by a nonparametric test (Mann-Whitney U test) and a chi-square test with Yates' correction in order to compare clinical and biological parameters at baseline between the success group (S) and the failure group (F). A nonparametric paired Wilcoxon test was next used to compare the earliest para-

**Table 1** Clinical data of the patients (*HC* hypertrophic cardiopathy, *IC* ischemic cardiopathy, *VC* valvular cardiopathy, *CC* congestive cardiopathy, *AMI* acute myocardial infarction, *MI* myocardial ischemia, *CHF* congestive heart failure, *SAPS* Simplified Acute Physiology Score, *RR* respiratory rate, *$SpO_2$* pulse oximetry saturation, *MAP* mean arterial pressure, *HR* heart rate, *LVEDD* left ventricular end-diastolic diameter (echocardiography), *SF* shortening fraction (echocardiography), *S* survivor, *F* fatal outcome)

| Patient | Sex | Age (years) | Heart disease | Etiology | SAPS | RR (br/min) | $SpO_2$ (%) | MAP (mmHg) | HR (b/min) | LVEDD (mm) | SF (%) | Result of NIV | Duration of ventilation (h) | Outcome |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | F | 77 | HC | CHF | 30 | 39 | 90 | 139 | 100 | ND | ND | Success | 12 | S |
| 2 | M | 66 | IC | CHF | 35 | 40 | 88 | 79 | 85 | 70 | 23 | Success | 48 | S |
| 3 | M | 89 | IC | AMI | 34 | 40 | 100 | 95 | 107 | 68 | 23 | Success | 2 | S |
| 4 | M | 69 | IC | MI | 39 | 28 | 78 | 130 | 79 | 57 | 27 | Success | 3 | S |
| 5 | F | 74 | HC | CHF | 32 | 36 | 90 | 108 | 111 | 64 | 38 | Success | 2 | S |
| 6 | M | 76 | IC | AMI | 29 | 32 | 79 | 119 | 110 | 52 | 18 | Success | 4 | F |
| 7 | M | 82 | IC | CHF | 42 | 44 | 60 | 113 | 145 | 57 | 32 | Success | 3 | S |
| 8 | M | 72 | IC | CHF | 29 | 28 | 90 | 104 | 117 | 54 | 28 | Success | 12 | S |
| 9 | M | 47 | VC | CHF | 17 | 40 | 73 | 119 | 106 | ND | 36 | Success | 19 | S |
| 10 | M | 79 | VC | CHF | 36 | 24 | 90 | 96 | 173 | 43 | 47 | Success | 3 | S |
| 11 | M | 82 | IC | CHF | 23 | 32 | 90 | 107 | 91 | 39 | 41 | Success | 10 | S |
| 12 | M | 78 | HC | CHF | 32 | 32 | 82 | 134 | 102 | 56 | 25 | Success | 13 | S |
| 13 | F | 80 | HC | CHF | 44 | 33 | 90 | 116 | 85 | ND | ND | Success | 4 | S |
| 14 | M | 75 | HC | CHF | 28 | 44 | 97 | 107 | 80 | 49 | 30 | Success | 89 | S |
| 15 | F | 79 | IC | CHF | 48 | 40 | 91 | 86 | 123 | 50 | 26 | Success | 31 | S |
| 16 | M | 80 | HC | CHF | 29 | 36 | 87 | 99 | 150 | 48 | 28 | Success | 75 | S |
| 17 | F | 81 | HC | CHF | 23 | 36 | 84 | 88 | 65 | 52 | 41 | Success | 2 | S |
| 18 | M | 78 | HC | CHF | 21 | 38 | 90 | 102 | 86 | 63 | 21 | Success | 12 | S |
| 19 | M | 80 | HC | CHF | 29 | 40 | 81 | 108 | 128 | 48 | 28 | Success | 45 | S |
| 20 | F | 65 | HC | MI | 24 | 40 | 47 | 115 | 99 | 68 | 16 | Success | 13 | S |
| 21 | F | 68 | HC | CHF | 17 | 34 | 85 | 101 | 77 | ND | ND | Success | 4 | S |
| 22 | F | 83 | IC | CHF | 38 | 36 | 54 | 93 | 70 | 48 | 31 | Failure | 17 | S |
| 23 | M | 72 | IC | AMI | 51 | 36 | 96 | 83 | 127 | 60 | 18 | Failure | 4 | F |
| 24 | F | 86 | CC | AMI | 43 | 36 | 94 | 103 | 145 | 49 | 19 | Failure | 31 | F |
| 25 | M | 25 | | AMI | 6 | 32 | 89 | 109 | 147 | 49 | 17 | Failure | 2 | F |
| 26 | M | 81 | IC | AMI | 26 | 40 | 78 | 135 | 100 | ND | ND | Failure | 9 | F |
| Mean ± SD | | 74 ± 13 | | | 31 ± 10 | 36 ± 5 | 84 ± 13 | 107 ± 10 | 108 ± 28 | 54 ± 8 | 28 ± 9 | | 18 ± 23 | |

meters (15 min for clinical parameters, 1 h for oximetric parameters) with the baseline parameters in the success group only (the failure group was too small for this statistical analysis). The evolution of clinical and biological parameters at the following times was only descriptive.

## Results

The clinical characteristics of the 26 patients on admission are shown in Table 1. On admission, there was no significant statistical difference between the two groups (S and F) concerning the clinical and biological parameters except for $PaCO_2$ and CPK (Table 2). The urinary output was higher than 100 cc/h except in 2 patients in the failure group, but there was no statistical difference between the two groups.

NIPSV was started with an $FIO_2$ of $93 \pm 16\%$, a PEEP of $3.5 \pm 2.3$ $cmH_2O$ and a pressure support of $20.5 \pm 4.7$ $cmH_2O$. A control-assisted volume mode was secondarily and transiently used in 3 patients. In the S group, total duration of mechanical ventilation was $19 \pm 24$ h and less than 4 h in 7/21 patients (33%).

Five patients (21%) were considered as failures and 21 (79%) as successes. The causes of failure were a sudden decrease of $SpO_2$ with exhaustion, an inability to stop ventilation for more than 2 min, also with exhaustion, a rapid (< 15 min) and important decrease of $SpO_2$ associated with a decrease in the GCS, a decrease of $SPO_2$ associated with shock and a decrease in the GCS, mask intolerance with deteriorating clinical parameters. All failure patients were intubated. Four patients in the F group died with AMI. The CPKs were higher in the F group than in the S group ($1282 \pm 2080$ vs $176 \pm 149$ IU/l, $p < 0.05$); this difference was related to the number of patients who had an AMI (4/5 in the F group vs 2/21 in the S group, $p < 0.05$). One patient in the S group died after 1 week from septic shock.

The patients in the F group were intubated between $1^1/_2$ and 17 h after admission. Five patients (24%) in the S group were discharged from the ICU within 12 h of admission.

**Table 2** Comparison of clinical, biological and echocardiographic parameters between failure and success groups (*SAPS* Simplified Acute Physiology Score, *RR* respiratory rate, *$SpO_2$* pulse oximetry, *HR* heart rate, *MAP* mean arterial pressure, *CPK* creatine phosphokinase, *Echo SF* shortening fraction (echocardiography), *Echo LVEDD* left ventricular end-diastolic diameter (echocardiography)

| | Success (mean ± SD) | Failure (mean ± SD) |
|---|---|---|
| Sex ratio | 6 F/15 M | 2 F/3 M |
| Age (years) | 75.1 ± 8.7 | 69.4 ± 25.3 |
| GCS | 14 ± 1.4 | 15 ± 0 |
| SAPS II | 31 ± 8 | 33 ± 18 |
| RR (breaths/min) | 36 ± 5.3 | 36 ± 2.8 |
| $SpO_2$ (%) | 84 ± 12 | 82 ± 17 |
| HR (beats/min) | 106 ± 27 | 118 ± 33 |
| MAP (mmHg) | 108 ± 15 | 105 ± 20 |
| Creatinine (μmol/l) | 140 ± 49 | 177 ± 95 |
| Urea (mmol/l) | 10 ± 5 | 14 ± 7 |
| CPK (IU/l) | 176 ± 149* | 1282 ± 2080 |
| pH | 7.25 ± 0.11 | 7.34 ± 0.09 |
| $PaCO_2$ (mmHg) | 54.2 ± 15.0** | 32 ± 2.1 |
| $PaO_2$ (mmHg) | 61 ± 14 | 60 ± 26 |
| Echo SF (%) | 29 ± 8 | 21 ± 7 |
| Echo LVEDD (mm) | 55 ± 9 | 51 ± 6 |

* $p < 0.05$; ** $p < 0.001$ (success vs failure)

Before initiating NIPSV, the $PaCO_2$ was higher in the S group than in the F group (54.2 ± 15.0 vs 32 ± 2.1 mmHg, $p < 0.001$). If we exclude from the S group 5 patients who had either a past history of chronic respiratory insufficiency, or COPD, or bicabonates higher than 26 mmol/l, the difference between the two groups was still statistically significant ($p < 0.01$) for $PaCO_2$.

In the S group, within the first 15 min of NIPSV RR improved, decreasing from 36 ± 5.3 to 22.4 ± 4.9 breaths/min ($p < 0.0001$), $SpO_2$ increased from 84 ± 12 to 96 ± 4 % ($p < 0.001$), MAP decreased from 108 ± 15 to 99 ± 14 mmHg ($p < 0.05$) (Fig. 1). This improvement persisted at 1 and 3 h after NIPSV was stopped: RR 21.5 ± 5.1 breaths/min, $SpO_2$ 96 ± 2 %. After 1 h, pH had increased from 7.25 ± 0.11 to 7.34 ± 0.07 ($p < 0.01$) and $PaO_2$ from 61 ± 14 to 270 ± 126 mmHg ($p < 0.001$), $PaCO_2$ had decreased from 54.2 ± 15.0 to 43.4 ± 6.4 mmHg ($p < 0.01$) (Fig. 2).

NIPSV was generally well tolerated. Three patients developed side effects which did not prevent the continuation of NIPSV: nausea in 1 case, vomiting in 1 case necessitating gastric aspiration by nasogastric tube, conjunctivitis after 96 h of discontinuous ventilation in 1 case. Other complications which could not be directly related to NIPSV were observed in 6 patients: 2 developed cardiac arrhythmia which disappeared after supportive treatment, 1 had MI, 1 an infectious disease and 2 a transient cardiovascular collapse. Five of 26 patients (4 in the S group, 1 in the F group) had difficulty in tolerating the mask and required special help from the nursing staff. One patient rejected the technique after 4 h of ventilation, but he was not considered as a failure because the acute pulmonary edema had improved.

## Discussion

Most studies of NIV in acute respiratory insufficiency have been performed in an acute crisis of chronic respiratory insufficiency [1–5, 12, 13]. Some others were of ARF from various causes including COPD [4, 5]. Only a few studies concern ARF without COPD [6]. Before starting this study of patients with ACPE, the ventilation technique mostly used was CPAP [7–9]. Thus, the objective of this clinical study was to determine, in a series of consecutive patients with severe ARF due to ACPE, the benefit of NIPSV and the causes of failure before a randomized study was conducted.

In this study, we observed a rapid (15 min) and long-lasting improvement of the main respiratory parameters. In the success group, RR decreased from 36 ± 5.3 to 22.4 ± 4.9 breaths/min ($p < 0.0001$) and to 21.5 ± 5.1 breaths/min, respectively, after 15 min of NIV and 1 to 3 h after ventilation was stopped. A dyspnea score [3, 14] was not taken, but a clinical improvement in the dyspnea was observed by either the patients or the physicians. The arterial blood gas values also improved after 1 h: $PaO_2$ increased from 61 ± 14 to 270 ± 126 mmHg ($p < 0.001$), $PaCO_2$ decreased from 54.2 ± 15.0 to 43.4 ± 6.4 mmHg ($p < 0.01$) and pH increased from 7.25 ± 0.11 to 7.34 ± 0.07 ($p < 0.01$). All of these parameters returned to normal after 2 h. Since the delay between the first two blood gas measurements was 1 h, it was difficult to compare them with those reported by Metha et al. [14] or Bersten et al. [8], which improved after 30 min; however, our clinical parameters improved after 15 min. Brochard et al. [15] reported an improvement of $PaO_2$, $PaCO_2$ and pH within 45 min of pressure-support ventilation in patients with COPD in a period of failure. Wysocki et al. [6] also reported an improvement in these parameters within 30 min in patients in ARF not related to COPD. In patients with ACPE with normocapnia [7, 9] or hypercapnia [8], CPAP induced a significant and more rapid improvement (within 30 min or 1 h) of arterial blood gases and clinical parameters. It is difficult in our study to preclude the respective physiological effects of oxygen therapy, NIPSV or medical treatment on any variable, but the great difference observed between $PaO_2$ at 1 h and at baseline, and the rapid improvement of clinical parameters, with a great decrease in $PaCO_2$, suggest the primordial role of mechanical ventilation. It is also difficult to preclude the respective physiological effects of inspiratory pressure support (IPS) and PEEP in the

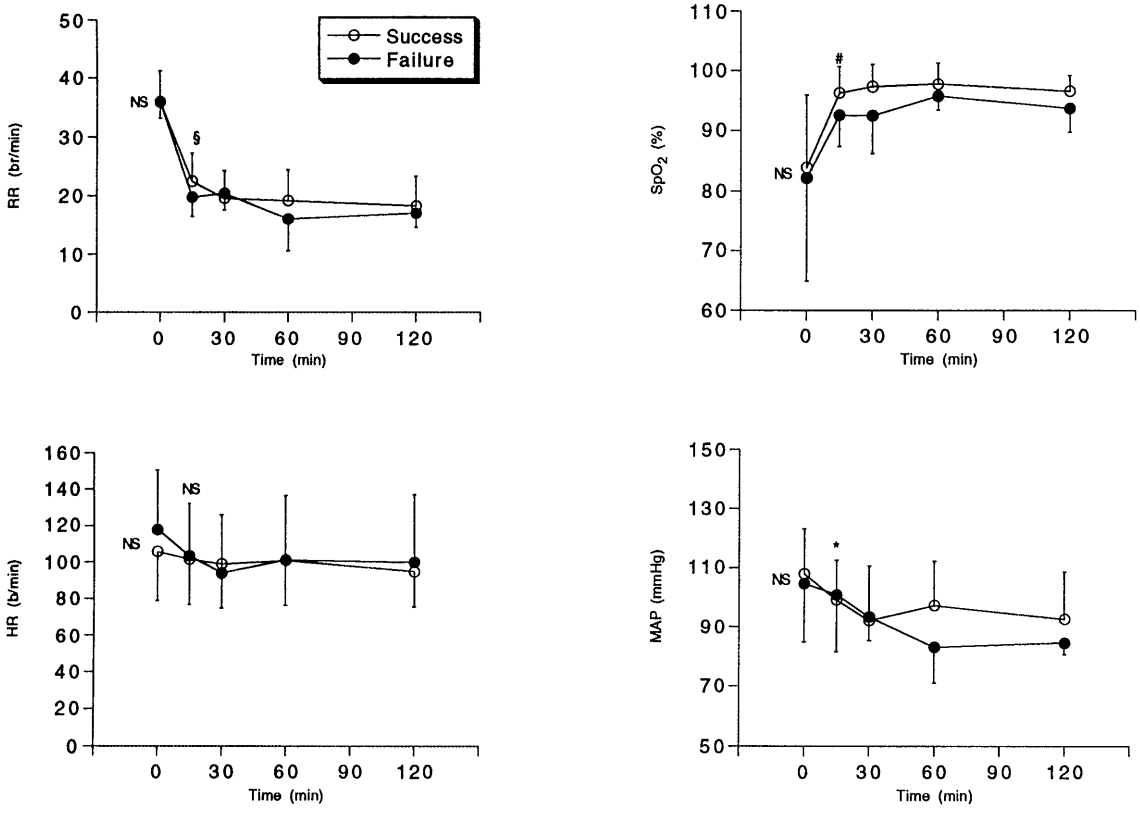


**Fig. 1** Comparison on admission (at time 0) of clinical parameters between the success and the failure groups. Evolution of clinical parameters and, for the success group, comparison between T0 and T15. * $p < 0.05$; # $p < 0.001$; § $p < 0.0001$ (*RR* respiratory rate, $SpO_2$ pulse oximetry, *HR* heart rate, *MAP* mean arterial pressure)

improvement of our patients. IPS at 20 $cmH_2O$ seemed more effective than at 12 $cmH_2O$ on gas exchange and reduced the inspiratory muscle activation, as reported by Brochard et al. [15] in COPD patients. Similarly, we chose the same level of IPS in order to obtain the same effects in ACPE patients. For CPAP, at different levels of PEEP (5, 10, 15 $cmH_2O$), PEEP was particularly efficient on the respiratory parameters [8, 9, 16, 17]. The hemodynamic effects of PEEP were more controversial and depended on preload and afterload conditions and on the cardiac output [16, 18, 19]. PEEP at 3 $cmH_2O$ improved cardiac output in patients with a pulmonary arterial occlusion pressure above 14 $cmH_2O$, as reported by Grace and Greenbaum [20]. PEEP at 10 $cmH_2O$ seems generally recommended, but, in association with IPS, the optimal level of PEEP is unknown.

In our study, we had 5 failures (21%) and 21 successes (79%). Because of the lack of a control group, we can only presume the role of NIPSV and not drawn any conclusions on the efficiency of this mode of ventilation in comparison with conventional treatment or other modes of ventilation. However, we can observe that all the patients admitted to the ICU for severe cardiogenic pulmonary edema were, at entry, candidates for intubation but that NIPSV allowed us to avoid intubation. It is an inhomogeneous series, but it was probably in the interest of the study to include all patients having ACPE. In a review of studies (seven of nine uncontrolled series) [12] of ARF (including mostly exacerbation of obstructive airway disease), some have reported success rates ranging from 60 to 80%. In the randomized study including patients with ARF from various causes, Wysocki et al. [6] found no statistical difference in the rate of endotracheal intubation between the patients treated with NIPSV (62%) and those treated conventionally (70%) ($p = 0.88$). In the study of Väisanen et al. [7] in patients with ACPE treated with CPAP, 83% recovered: PEEP was 10 $cmH_2O$ and $FIO_2$ 39%. In the randomized study, CPAP versus conventional therapy, reported by Bersten et al. [8], none of the patients treated with $O_2$, CPAP and conventional therapy was intubated compared to 35% of the patients treated with $O_2$ and conventional therapy; the ventilation parameters were: PEEP 10 $cmH_2O$ and $FIO_2$ between 60 and 100%; the mean total duration of ventilation was $9.3 \pm 4.9$ h. In another study [21] using a historical control group, NIPSV avoided the need for intubation in 13/15 (87%) patients as compared to only 2/15 (13%)

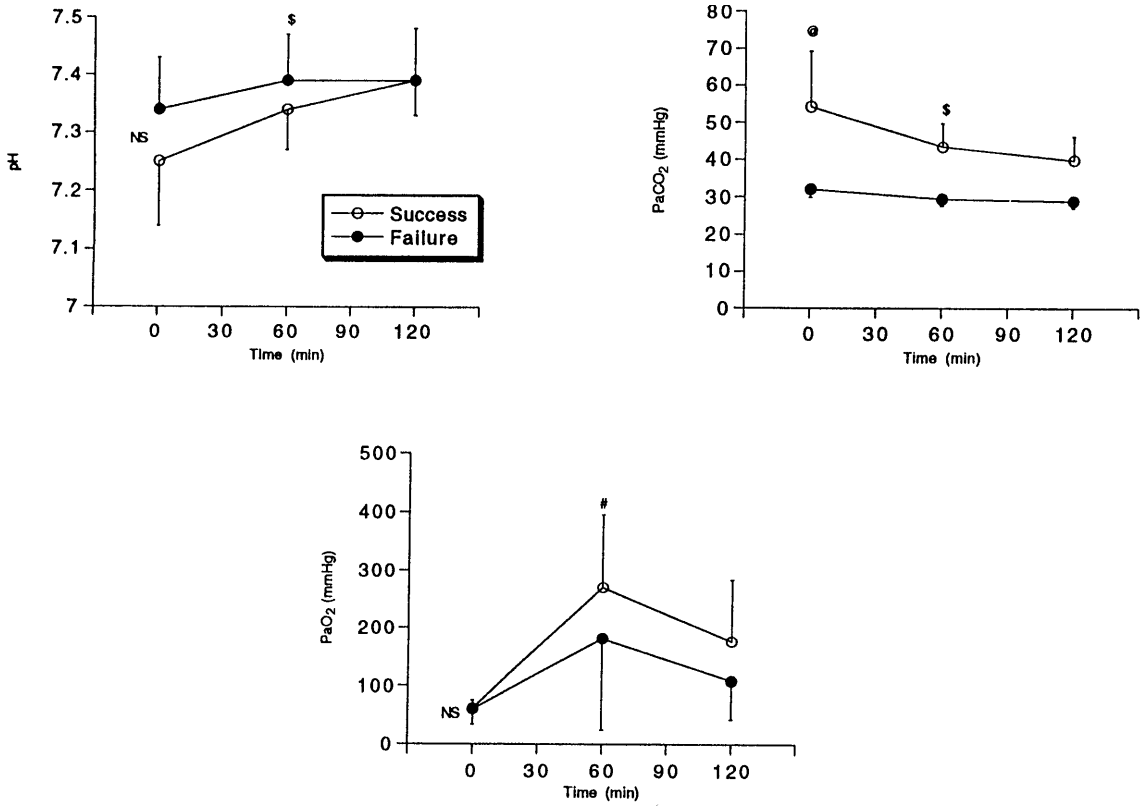


**Fig. 2** Comparison on admission (at time 0) of blood gas parameters between the success and the failure groups. @ $p < 0.001$. Evolution of parameters and, for the success group, comparison between T0 and T60: \$ $p < 0.01$; # $p < 0.001$

patients with matching criteria receiving conventional therapy. More recently, a prospective, controlled, randomized study [14] showed that bi-level positive airway pressure (BiPAP) more rapidly improved hemodynamic and physiological respiratory parameters than CPAP. In these studies [8, 14, 21], it is not clear if all patients had hypercapnia. In our series, if we considered only hypercapnic patients, we had no failure of NIPSV.

In our study, a low $PaCO_2$ on admission ($32 \pm 2.1$ mmHg) was a discriminating and significant factor of failure of NIPSV. In an open study reported by Wysocki et al. [5], none of the patients with ARF and an initial $PaCO_2$ of 35 mmHg or less was successfully treated with NIPSV; these results suggest that $CO_2$ retention without hypoxemia is a better indication of NIPSV than severe hypoxemia alone. In the randomized study of Wysocki et al. [6], only the patients with an initial $PaCO_2$ higher than 45 mmHg showed some benefit from NIV. In our study, after excluding the patients with chronic respiratory insufficiency and those with a bicarbonate level greater than 26 mmol/l, we also observed a significant difference in the initial $PaCO_2$ values between the success and failure groups. The patients successfully ventilated had a higher $PaCO_2$ than those in whom ventilation failed; this suggests that patients with pulmonary pump failure with ACPE are candidates for NIPSV. Nevertheless, we have no physiopathologic explanation which could explain why a low $PaCO_2$ was a factor of failure. However, the improvement of respiratory parameters and the brief description of the events at failure may suggest inadequate cerebral perfusion secondary to low cardiac output.

We observed that 4/5 patients who died were in the failure group, with a low $PaCO_2$; thus, the comparison with previous reports [8] without knowing if all patients were hypercapnic is difficult. Moreover, there is no statistical difference between the observed mortality and the expected [22] according to the SAPS II score (5 vs 3.9; NS).

In our study, 80 % of the patients in the failure group (intubated patients) died and had an AMI. The presence of AMI, confirmed by the level of CPK on admission, was a factor of failure of NIV (4/5 patients had an AMI in the failure group vs 2/21 in the success group). For some authors [12], the presence of MI is a contraindication for NIV. However, the study of Metha et al. [14] was stopped because of a high proportion of AMIs in the BiPAP group (71 %) compared to the CPAP group (31 %), but there was no clear explanation of whether

AMI was present at admission or occurred during NIPSV. More (10/14) patients had chest pain in the BiPAP group at study entry than in the CPAP group (4/13), even if this difference was not significant ($p = 0.06$). It is difficult to establish exactly (before or under NIPSV), as in our study, when the AMI occurred, because CPK increased with delay. Thus it was not possible to find a cut-off value for the CPK that could predict success or failure. Moreover, we do not know if NIPSV extended an infarction in progress or aggravated ischemic conditions [14]. In Bersten et al.'s study [8], the presence of an AMI was not considered as a discriminant factor between success and failure groups and between survivors and nonsurvivors (the rate of CPK was the same in each group). For instance, these studies and present experience gives reason to believe that AMI is not a good indication for NIPSV.

The respective efficacy of a face or nasal mask is still subject of debate [23–25]. However, in emergency situations as in the case of our patients, the face mask is mandatory in order to avoid leaks. Some patients had difficulty in tolerating the face mask, especially at the beginning of NIPSV, but with psychological assistance from physicians and nurses they quickly learned to tolerate the mask, especially when their condition improved. Patients' requests to stop the ventilation was mostly a criteria of success. In our study, the frequency and the types of side effects were the same, as in most studies. Consciousness disturbances are usually considered as a major contraindication of NIPSV [12, 13, 26]. In our study, all patients with moderate disturbances of consciousness (GCS between 10 and 14) were successfully ventilated. Therefore, in our opinion, consciousness disturbances related to an increased $PaCO_2$ are not a contraindication for NIPSV.

We cannot draw firm conclusions on the efficacy of NIPSV in our series, we can only presume the role of this mode of ventilation in the outcome in patients with severe ACPE. Among patients in ARF, patients with severe ACPE could draw some benefit from NIPSV, particularly when they are hypercapnic. However, before the results of further clinical and physiopathologic studies are reported, NIPSV should be avoided in patients with myocardial infarction.

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