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Non-invasive pressure support ventilation in severe community-acquired pneumonia

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Abstract *Objective*: To explore three aspects of non-invasive pressure support ventilation (NIPSV) applied by face mask to patients with acute respiratory failure (ARF) due to severe community-acquired pneumonia (CAP): (1) the initial acute effects on respiratory rate, gas exchange and hemodynamics, (2) the clinical course and outcome during ICU and hospital stay, (3) the nursing workload as measured by the daily PRN 87 (Project Research in Nursing) score.
Setting: Medical ICU, University Hospital.
Design: Prospective, observational study.
Patients: Patients without any prior history of chronic lung disease, consecutively admitted to the ICU to receive NIPSV for ARF due to severe CAP.
Measurements and results (means ± SD): Twenty-four patients aged 49 ± 17 years, admission APACHE II 13 ± 5, were included. Admission PaO_2/FIO_2, alveolar-arterial oxygen difference ($DA-aO_2$) and $PaCO_2$ were 104 ± 48, 447 ± 120 and 40 ± 10 mmHg, respectively. All patients were normotensive. During the initial NIPSV trial respiratory rate decreased from 34 ± 8 to 28 ± 10 breaths/min ($p < 0.001$) and arterial oxygenation improved (PaO_2/FIO_2 104 ± 48 vs 153 ± 49, $DA-aO_2$ 447 ± 120 vs 370 ± 180 mmHg, $p < 0.001$) while $PaCO_2$ remained unchanged. There were no hemodynamic effects. Subsequently, a total of 133 NIPSV trials were performed (median duration 55 min, range 30–540 min) over 1–7 days. No complication occurred during NIPSV. Sixteen patients were intubated (66 %) 1.3 ± 1 days after inclusion. Upon inclusion, the patients who were subsequently intubated were older (55 ± 15 vs 37 ± 12 years) and more severely hypoxemic (63 ± 11 vs 80 ± 15 mmHg, $p < 0.05$) than those not requiring intubation. Eight patients died (33 %), all in the intubated group. Median lengths of stay in the ICU and hospital were longer in intubated patients (ICU 16 days, range 3–64 vs 6 days, range 3–7, $p < 0.05$; hospital 23 days, range 9–77 vs 9.5 days, range 4–42, $p < 0.05$). Mean daily total PRN points were stable throughout the NIPSV period and were not different between the groups. Only 14 % of PRN points resulted from respiratory therapy interventions. PRN score was higher during the first 24 h following intubation than during the first 24 h of NIPSV (278 ± 55 vs 228 ± 24 points, $p < 0.05$).
Conclusion: Despite initial improvement in arterial oxygenation with NIPSV in patients with ARF due to severe CAP, the intubation rate is high. However, the more favorable outcome and shorter ICU and hospital stays when intubation is

avoided, as well as the short delay required to assess the success or failure of NIPSV warrants a trial of NIPSV in this setting. The nursing workload remains stable during NIPSV and does not result predominantly from respiratory therapy interventions.

Introduction

In acute respiratory failure (ARF), non-invasive ventilation (NIV) has been shown to decrease the need for endotracheal intubation [1, 2, 3, 4, 5], thereby leading to a reduction in morbidity and mortality associated with mechanical ventilation (MV) [1, 4, 6, 7, 8, 9]. Furthermore, gas exchange improvement comparable to that with MV, but with fewer serious complications, has been documented [10]. However, results from most published studies demonstrate that NIV is mainly successful in avoiding intubation in patients with predominantly hypercapnic ARF, in particular those with chronic obstructive pulmonary disease (COPD) [3, 4, 5, 8, 9, 11, 12, 13]. Nonetheless, it is common practice in many ICUs (including ours) to attempt NIV in patients with hypoxemic ARF, although in the absence of firmly established evidence of its usefulness, this approach might be considered inappropriate [9].

Indeed, NIV can induce patient discomfort, complications and an increase in nursing workload and costs [14, 15], although recent data suggests that the latter might not always be true [3, 16]. Hence, further evaluation of NIV in hypoxemic ARF is clearly warranted, especially since many studies on NIV have included mixed populations of patients with both hypoxemic and hypercapnic ARF and both with and without chronic lung disease. Thus, the present study addressed the following questions in patients with ARF due to severe community-acquired pneumonia (CAP), but without associated chronic lung disease: (1) what are the acute effects of NIV on clinical, gas exchange and hemodynamic parameters? (2) What are the subsequent clinical course and outcome of these patients? (3) What is the nursing workload associated with NIV in this setting and, in patients requiring intubation, how does it compare to the initial workload of MV?

Patients and methods

All patients with severe CAP admitted to the medical ICU for NIV during a 2-year period were included in the study. The criteria for diagnosing CAP in the emergency room were: fever, cough, sputum production, dyspnea, auscultatory crackles, localized focal or multi-focal infiltrates on chest X-ray and characteristic white blood cell and plasma inflammatory parameter changes [17]. Identification of the causal infectious agent was made from positive cultures of either sputum, tracheal aspirate, bronchoalveolar fluid or blood and/or urinary antigen determination for *Legionella pneumophila*.

CAP was diagnosed as severe if, according to published criteria, at least one of the following conditions was present [18]: respiratory rate above 30/min; PaO_2/FIO_2 below 250; bilateral or multiple lobe involvement on chest radiograph; systolic blood pressure below 90 mmHg or diastolic pressure below 60 mmHg; requirement for vasopressors. In our hospital, patients with two of the ATS criteria [18] for severe CAP are admitted to the ICU. Patients with a history of chronic obstructive or restrictive lung disease, as well as those with clinical and/or radiological signs of cardiogenic pulmonary edema were excluded. Informed consent was obtained from the patients. Patients declining intubation were not excluded from the study.

The decision to perform NIV was made by the physician in charge of the patient, based on our guidelines for NIV in CAP (at least one of the following): respiratory rate 25/min or more, $PaCO_2$ 45 mmHg or more, PaO_2/FIO_2 lower than 300. In our unit, NIPSV is usually performed in the following manner: an initial 30 min trial of pressure support (NIPSV) is applied by face mask with an Evita 2 or 4 (Drägerwerk, Lübeck, Germany) ventilator, with pressure support 15 cmH$_2$O, PEEP 5 cmH$_2$O, to test the acute physiologic effects and patient tolerance. Subsequent adjustments in settings are made by the physician in charge of the patient, based on tolerance and blood gas results, with the goal of maintaining an expired tidal volume of 6 ml/kg or higher, a respiratory rate of 25 breaths/min or less and an SaO$_2$ of 90% or more. Apart from the initial 30 min trial, NIPSV is performed continuously for the longest possible time period during the first 48 h in the ICU. NIPSV is interrupted when signs of intolerance develop and patients clearly signify their unwillingness to continue. In that case, the trial is stopped and NIPSV reinstated as soon as possible.

The decision to intubate was made according to published and commonly accepted criteria, which are those used routinely in our unit's clinical guidelines [1, 19]. *Major criteria*: respiratory arrest, loss of consciousness, psychomotor agitation and/or hemodynamic instability (systolic blood pressure < 70 mmHg or > 180 mmHg, heart rate < 50/min). *Minor criteria*: respiratory rate more than 35 breaths/min and higher than admission value, arterial pH below 7.30 and lower than admission value, PaO$_2$ less than 45 mmHg despite oxygen supplementation, neurologic deterioration and/or weak cough reflex with secretion accumulation. Intubation was performed if one major or two minor criteria were present [1, 19]. NIPSV was discontinued when patients were either intubated or had improved. In the latter case, if patients had a respiratory rate less than 30 breaths/min and a PaO$_2$ above 75 mmHg with a FIO$_2$ lower than 0.5 without ventilatory support for at least 1 h, NIPSV was tapered off by progressively reducing the number of daily trials. When respiratory rate was less than 25 breaths/min and PaO$_2$ and PaCO$_2$ were higher than 80 mmHg and lower than 45 mmHg, respectively, NIPSV was discontinued [4].

To determine the effects of the initial NIPSV trial, clinical and arterial blood gas recordings were made immediately before and during NIPSV, the latter 30 min into the trial. Subsequently, the number and duration of daily trials, intubation rate, ICU mortality and length of ICU and hospital stays were recorded.

The nursing workload associated with NIPSV was computed using the PRN 87 (Project Research in Nursing) index [20, 21] routinely used in our institution. PRN is used in various ICUs in

Canada, where it originated in the early 1970s [20], and in Europe (Belgium, France, Italy, Luxembourg, Spain and Switzerland) to measure the amount of care required by patients in acute care settings [21, 22, 23]. Briefly, PRN consists of a list of 214 direct nursing care activities, grouped in eight main categories (e.g. activity linked to respiratory therapy, diagnostic activity) to which a point value is attributed, reflecting the time required to perform a given task. Each point represents 5 min. Thus, a higher point value indicates a larger workload. In our ICU, PRN is computed prospectively at the beginning of each 8-h nursing shift, i.e. 3 times a day, by the nurse in charge of the patient. PRN collection is performed on a routine basis in our institution to analyze nursing workload in order to determine the adequacy between the latter and staffing policies. The PRN score was recorded from initiation to termination of NIPSV. If the patient was intubated, PRN was recorded for the first 24 h of MV.

The following analyses were performed:

- mean daily PRN for the period of ICU stay during which patients underwent NIPSV;
- relationship between total time on NIPSV and total PRN points during the first 24 h;
- in patients eventually requiring intubation, the individual and mean PRN values for the first 24 h of NIPSV were compared to those of the first 24 h of MV, using both total and specific category points.

Statistical analysis was performed with Statview 5.0 (SAS Institute, Cary, N. C., USA) for Macintosh. Comparisons between values obtained before and during NIPSV were made using a paired t-test. Comparisons between values in intubated and non-intubated patients and between the first 24 h of NIPSV and mechanical ventilation with intubation were made using the Mann-Whitney test. Correlations between PRN points and time spent on NIPSV were analyzed with the Pearson product-moment coefficient. A value for p of 0.05 or less was considered significant.

Results

Thirty-two patients were admitted with the diagnosis of severe CAP during the study period. Eight were excluded because of prior obstructive or restrictive lung disease. Thus, 24 patients were included in the study, whose main characteristics are outlined in Table 1. No patient declined intubation. As can be seen, all patients except two had more than one lobe involved on the initial chest radiography and all were severely hypoxemic. Positive identification of the causative agent was made in only nine (38 %) patients, *Streptococcus pneumoniae* being the most frequently identified pathogen.

Acute response to non-invasive pressure support ventilation

The effects of the initial NIPSV trial are shown in Table 2. NIPSV decreased the respiratory rate and improved oxygenation, while no significant effect on $PaCO_2$ was noted. The mean rise in PaO_2/FIO_2 was 50 ± 37 (median 51, range –49 to 116), a 47 % mean in-

crease. Individual responses in respiratory rate, PaO_2/FIO_2 and $PaCO_2$ are illustrated in Fig 1. Respiratory rate decreased in 17/24 (70 %) patients, increased in 5 and remained unchanged in 2. Oxygenation was worse in only two patients, while PaO_2/FIO_2 improved by more than 20 in 19/22 others. There was no correlation between the severity of hypoxemia and respiratory rate before NIPSV, nor between the improvement in oxygenation and the decrease in respiratory rate during NIPSV. Respiratory rate and arterial oxygenation rapidly returned to their pre-NIPSV levels after discontinuation of the trial. Heart rate and mean blood pressure were uninfluenced by NIPSV.

Clinical course and outcome

A total of 133 NIPSV trials were subsequently performed. The number of trials per patient during ICU stay are illustrated in Fig 2. As can be seen, 50 % of the patients underwent eight or fewer trials. Intubation was required in 16/24 (66 %) patients. The reason for intubation was worsening of arterial blood gases with severe tachypnea in all patients, complicated by neurologic disturbances in three patients and hemodynamic instability in one. Five patients (1, 2,19, 20 and 24) were intubated after only one continuous trial of NIPSV. All other patients, intubated or not, underwent intermittent trials. The main reason for discontinuation of trials was patient intolerance (claustrophobia, panic, agitation, deliberate mask removal). Only six patients displayed no signs of intolerance, all of whom improved and were not intubated, with the exception of patient 2. Of the 16 patients requiring intubation, 14 (78 %) underwent eight or fewer trials. All five patients who were hypercapnic ($PaCO_2 > 45$ mmHg) on admission were subsequently intubated. The duration of NIPSV trials varied markedly among patients and among trials (median 55 min, range 30–540 min). The average pressure support and PEEP levels were 17 ± 4 and 4 ± 2 cmH$_2$O, respectively (mean ± SD).

The time between ICU admission (and study inclusion) and intubation was 1.3 ± 1 days (mean ± SD). The number of lobes involved and initial APACHE II score was not different between intubated and non-intubated patients (Table 3). Intubated patients were older and had a lower initial PaO_2 than non-intubated patients and the mean number of NIPSV trials was higher in non-intubated than in intubated patients (Table 3).

The outcome features of intubated and non-intubated patients are shown in Table 3. As shown, the duration of both ICU and hospital stays was longer in intubated patients. Eight patients died, all in the intubated group. Cause of death was sepsis and multiple organ failure in six patients (3, 6, 10, 15, 21, 23) and intractable heart failure in two (14, 22).

Table 1 Main characteristics of the patients (*APACHE II* APACHE II score at ICU admission, *AML* acute myelogenous leukemia, *HIV* human immunodeficiency virus, *Intub* intubation required (+) or not (-), *No. of lobes* number of lobes involved on initial chest X-ray, *s/d* survived/died)

No.	M/F	Age	Associated conditions	Causative agent[a]	No. of lobes	APACHE II	PaO$_2$/FIO$_2$[b]	PaCO$_2$[b] (mmHg)	pH[b]	Intub.	Time[c] (days)	s/d
1	F	51	–	*S. pneumoniae*	4	8	80	47	7.42	+	3	s
2	F	68	–	–	2	12	252	71	7.35	+	1	s
3	M	53	HIV	*P. carinii*	5	9	184	28	7.51	+	2	d
4	M	46	HIV	*P. carinii*	5	13	80	29	7.47	–	–	s
5	F	50	Chronic alcoholism	–	1	13	79	42	7.34	+	1	s
6	M	83	–	–	2	13	65	31	7.52	+	3	d
7	F	28	–	*S. pneumoniae*	2	5	169	38	7.31	–	–	s
8	M	49	–	–	2	18	80	42	7.45	–	–	s
9	M	32	–	*S. pneumoniae*	2	8	176	44	7.39	–	–	s
10	M	42	HIV	–	2	18	67	35	7.45	+	3	d
11	F	63	–	–	3	10	98	41	7.41	+	0	s
12	M	35	HIV	*S. pneumoniae*	3	20	105	35	7.49	–	–	s
13	M	55	Post-chemotherapy (small cell lung cancer)	–	2	18	79	38	7.4	–	–	s
14	M	78	Ischemic heart disease, atrial fibrillation	–	2	22	147	49	7.29	+	7	d
15	M	49	Post-chemotherapy (Hodgkin's disease)	–	4	13	55	37	7.46	+	2	d
16	M	46	Chronic alcoholism	–	4	10	126	35	7.41	+	2	s
17	F	18	Epilepsy	*S. pneumoniae*	3	14	94	37	7.36	–	–	s
18	M	33	Chronic hepatitis B, HIV	*P. carinii*	5	8	89	33	7.45	–	–	s
19	M	53	Chronic hepatitis B	–	3	9	96	55	7.35	+	0	s
20	M	36	Chronic hepatitis C, drug abuse	–	5	10	47	56	7.19	+	0	s
21	M	36	Post-chemotherapy (AML)	–	5	27	92	29	7.31	+	0	d
22	M	76	Ischemic heart disease	–	3	11	92	42	7.43	+	5	d
23	M	62	Post-chemotherapy (AML)	–	1	18	79	34	7.43	+	3	d
24	M	38	–	*L. pneumophila*	3	9	68	38	7.42	+	0	s
mean (SD) or total		49 (17)			3 (1)	13 (5)	104 (48)	40 (10)	7.4 (0.1)	16		16/8

[a] Identified by sputum or blood culture
[b] Values upon study inclusion
[c] Time between admission and intubation, where 0 = day of admission

In terms of complications of NIPSV, two patients experienced moderate gastric distension, one patient had mild conjunctivitis and one presented with localized redness on the bridge of the nose. None of these problems made discontinuation of NIPSV necessary.

Nursing workload

The mean daily group and individual total PRN scores for the duration of NIPSV are shown in Fig. 3, as well as the number of patients still on NIPSV after study inclusion and the median time spent on NIPSV per patient each day. As can be seen, the mean daily score remained stable, even though substantial variations can be identified for some patients. No difference was noted between patients requiring intubation and those in whom the latter was avoided. There was no correlation between total PRN points and total time spent on NIPSV during the first 24 h after inclusion, as shown in Fig. 4. In patients requiring intubation, the mean total PRN score during the first 24 h of MV was significantly higher than that of the first 24 h of NIPSV (Fig. 5). However, the percentage of PRN points due to respiratory therapy was not different (NIPSV 14%, MV 13%), as shown in Fig. 6. The percentage of points associated with respiratory therapy remained fairly constant

Table 2 Respiratory and hemodynamic effects of initial non-invasive pressure support (NIPSV) trial ($n = 24$ patients) (*DA-aO₂* alveolar-arterial partial pressure of oxygen difference, *MAP* mean arterial blood pressure)

Mean (SD)	Before NIPSV[a]	NIPSV 30 min[b]	30 min after NIPSV[a] discontinuation
Respiratory rate (*n*/min)	34 (7)	28 (10)[c]	34 (8)
PH	7.4 (.08)	7.42 (.06)	7.41 (.06)
PaCO₂ (mmHg)	40 (9)	38 (7)	39 (9)
PaO₂/FIO₂	104 (48)	153 (49)[c]	100 (42)
DA-aO₂ (mmHg)	447 (120)	370 (180)[c]	455 (108)
Heart rate (*n*/min)	109 (21)	107 (20)	108 (19)
MAP (mmHg)	82 (14)	83 (2)	83 (16)

Measurements performed: [a] immediately before, [b] after 30 min of NIPSV
[c] $p < 0.001$ versus before and after NIPSV

Table 3 Baseline characteristics and outcome of intubated versus non-intubated patients

	Intubated ($n = 16$)	Non-intubated ($n = 8$)
Age	55 (15)	37 (12)[a]
No. of lobes involved	3 (1.2)	3 (1.3)
PaO₂ (mmHg)	63 (11)	80 (22)[a]
PaO₂/FIO₂	102 (53)	109 (40)
PaCO₂ (mmHg)	42 (11)	37 (5)
APACHE II	13.4 (5)	12.9 (5)
ICU stay (days)	16 (3–64)[b]	6 (3–7)[a b]
Hospital stay (days)	23 (9–77)[b]	9.5 (4–42)[a b]
ICU mortality	8	0
% of all patients	33	–
% of intubated patients	50	–

All values mean (SD), except b
a Median (min.–max) values
[b] $p < 0.05$ versus intubated patients

throughout the period of NIPSV, varying between 13–16 % of the total PRN points.

Discussion

In the present study in patients with ARF due to severe CAP, NIPSV acutely improved arterial oxygenation and reduced breathing rate in nearly all patients. However, despite this initial transient improvement, two-thirds of the patients eventually required intubation and MV, with a short mean delay (1.3 days) between admission and intubation. Subsequent outcome differed between non-intubated and intubated patients, the former having a shorter ICU and hospital stay, while ICU mortality was confined to the latter. Finally, the total and respiratory nursing workload during NIPSV was relatively stable over time, while that of the first 24 h of NIPSV was lower than during the equivalent period of MV.
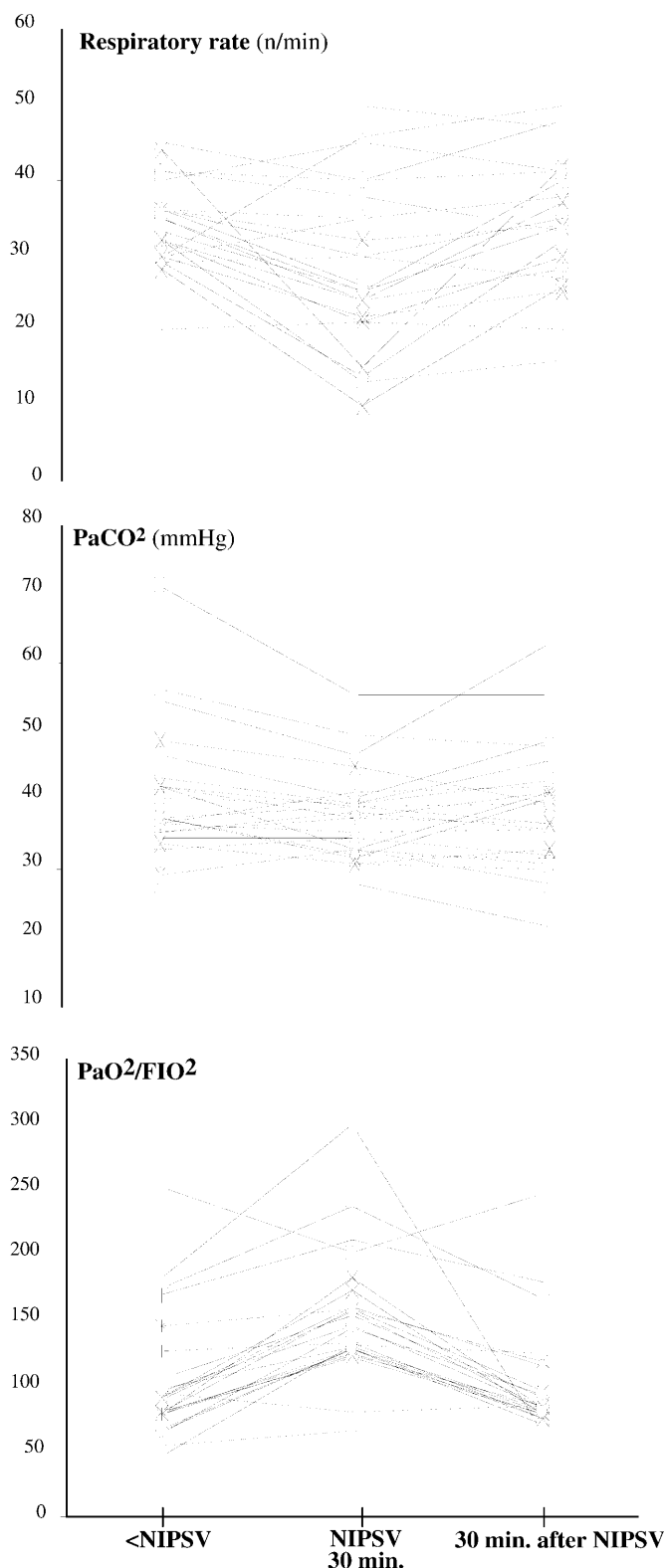

Fig. 1 Individual responses in respiratory rate, arterial partial pressure of carbon dioxide (PaCO₂) and partial pressure of oxygen/fractional inspired oxygen (PaO₂/FIO₂) to the initial trial of non-invasive pressure support ventilation in the 24 patients
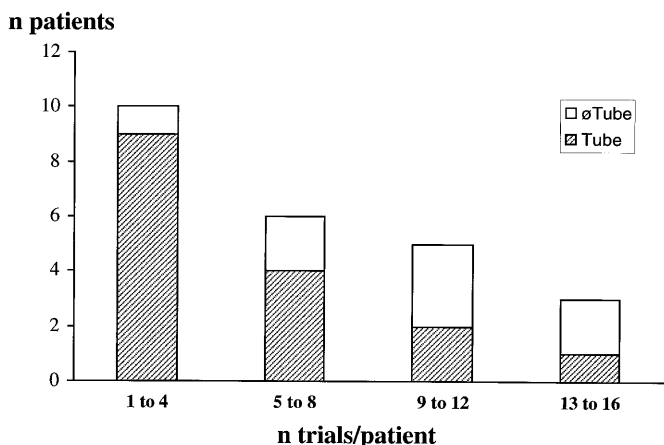
n patients

Fig. 2 Histogram chart showing the number of non-invasive pressure support ventilation trials per patient and number of patients having undergone that number of trials, with the proportion of patients requiring intubation *(shaded areas)*

Before discussing these results and comparing them to published studies, some methodological aspects should be addressed, and shortcomings and weaknesses of the study pointed out. First, since this was an observational study, no information can be derived as to the intubation rate and outcome of these patients. Second, the wisdom of choosing NIPSV rather than CPAP for primarily hypoxemic ARF might be questioned, as alveolar recruitment by PEEP is the main beneficial effect aimed for in this situation. However, the issue is probably more complex and NIPSV might exert several beneficial effects, such as reduction of severe dyspnea, respi-

ratory rate and respiratory muscle weakness [24, 25, 26], decreased work of breathing and oxygen consumption and improved gas mixing within the lungs during inspiration, all of which could explain the favorable impact on intubation rate in predominantly hypoxemic patients [10, 12, 27, 28]. Third, only five patients underwent truly continuous NIPSV, while NIPSV had to be discontinued in all the others, even if for only 1 h. In the setting of hypoxemic ARF, where the role of PEEP in maintaining alveolar recruitment is the key to improving arterial oxygenation, discontinuing NIPSV can certainly lead to worsening gas exchange, as exemplified by the results of the initial trial (Table 2 and Fig. 1). In the series already published it is not quite clear whether or not truly continuous NIPSV could indeed be carried out [4, 5, 10, 24, 29].

Acute response to non-invasive pressure support ventilation

During the initial trial of NIPSV, arterial oxygenation improved in 22/24 patients, a very high response rate (91.6 %). A comparison with published studies is difficult, since most series do not report individual responses in arterial oxygenation to NIV and do not always include a subset analysis between hypoxemic and hypercapnic, or COPD and non-COPD, patients. The response rate in most series varies between 62 and 93 % [10, 13, 29, 30, 31, 32]. Our patients' response rate was therefore at the high end of this range and was comparable to at least one study in which only patients with pneumonia were included [29]. The reduction in respi-

Fig. 3 Evolution of individual mean total daily Project Research in Nursing (PRN) points until intubation or discontinuation of non-invasive pressure support ventilation (NIPSV), in non-intubated *(open circles)* and intubated *(black circles)* patients. *Upper panel* indicates number of patients still on NIPSV each day, mean PRN points for the group and median and range of time spent on NIPSV per patient
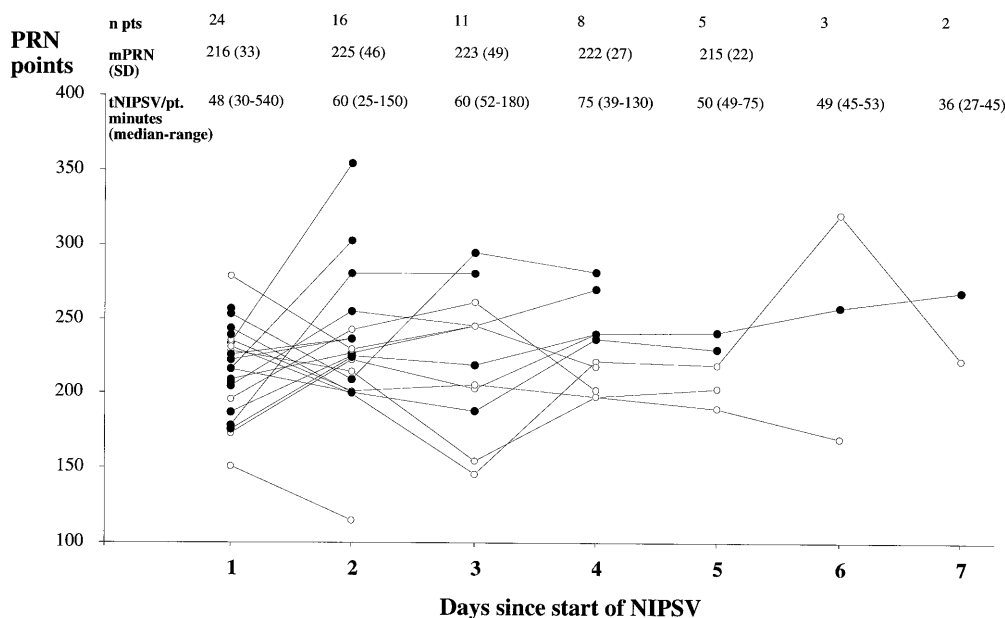
Fig. 4 Plot showing absence of correlation between individual mean total Project Research in Nursing (PRN) points and total time spent on non-invasive pressure support ventilation (NIPSV) during the first 24 h
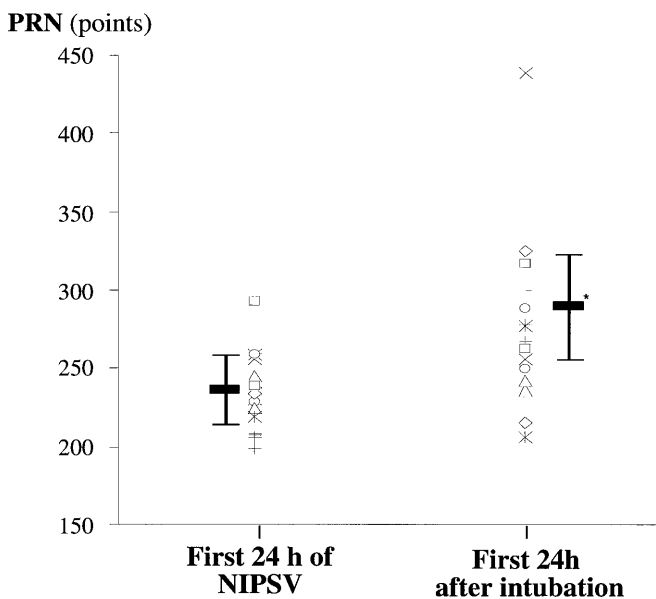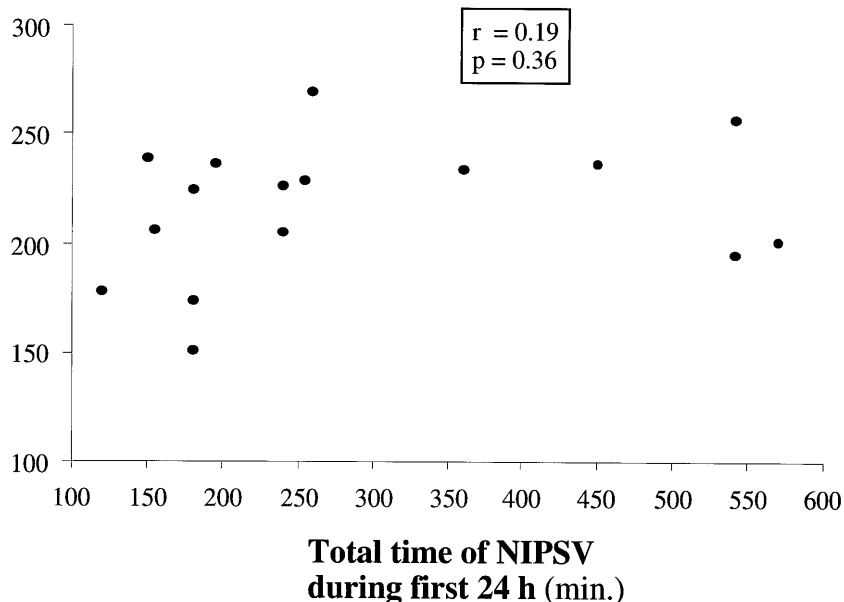
PRN points during first 24 h

$r = 0.19$
$p = 0.36$

Total time of NIPSV during first 24 h (min.)

PRN (points)

First 24 h of NIPSV

First 24h after intubation

Fig. 5 Comparison of individual and mean ± SD of Project Research in Nursing (PRN) points during the first 24 h of non-invasive pressure support ventilation (NIPSV) and the first 24 h of mechanical ventilation. * $p < 0.05$
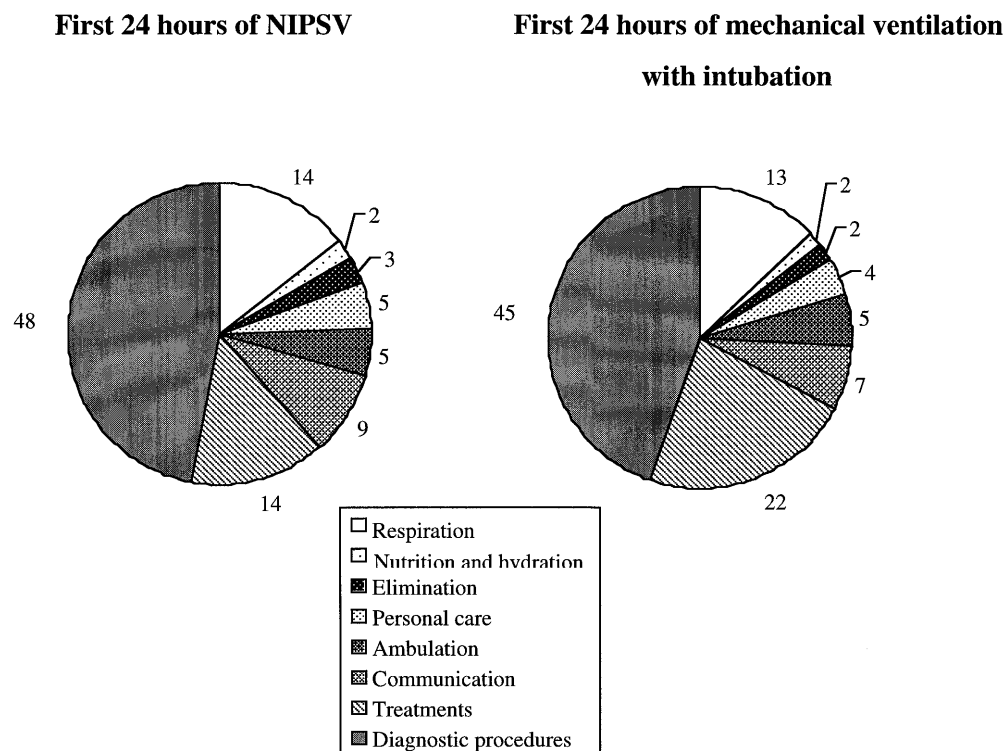
ratory rate in 70 % of our patients is in accordance with the results of the studies cited above, and a classical effect of NIPSV in ARF [33]. Finally, the absence of hemodynamic repercussions of NIPSV is also a common finding in studies on NIPSV in ARF not resulting from acute cardiogenic pulmonary edema [33].

Clinical course and outcome

The intubation rates published vary according to whether ARF is hypercapnic or hypoxemic and whether COPD is present or not [8, 33]; they range between 9 and 26 % in COPD patients with acute decompensation [1, 3, 13, 34, 35]. In studies including both hypoxemic and hypercapnic patients, intubation rates vary between 21 and 63 % [4, 5, 10, 11, 12]. The intubation rate in our series is thus higher than in most series, although in line with the rate observed in hypoxemic ARF by some authors [4, 12]. The discrepancy between ours and the lower rate documented in the subgroup of patients with CAP but without COPD in the series by Confalonieri et al. (38 vs 66 %) seems surprising, especially since fairly similar NIPSV techniques and intubation criteria were used [5]. However, even though admission APACHE II scores were comparable, our patients had lower PaO_2/FIO_2 values and a higher mean number of lobes involved on admission chest X-ray, suggesting more severe ARF and, in some cases, early ARDS. Nonetheless, our patients can be considered as representative of those admitted to the ICU with severe CAP, judging from the comparable intubation rates of 61 and 68 % and mortality of 24 and 42 % documented in two recent series [36, 37].

In any case, despite the fact that our five hypercapnic patients needed intubation, overall our results confirm those of other authors which indicate that the application of NIPSV is less likely to avoid intubation in patients without hypercapnic or COPD-associated ARF than when these conditions are met. Various explana-

Fig. 6 Pie-chart indicating the percentage *(numbers next to areas of chart)* of total Project Research in Nursing (PRN) points associated with the various nursing activities during the first 24 h of non-invasive pressure support ventilation (NIPSV) *(left)* and mechanical ventilation *(right)*. Examples of nursing activities include: respiration: administering oxygen, performing physiotherapy, administering NIPSV, suctioning; nutrition and hydration: helping patient drink or eat, enteral feeding; elimination: helping patient use urinal, bedpan, incontinence care; personal care: helping patient in performing personal care gestures (washing, grooming hair); ambulation: moving patient, assisting patient in movements, passive or active movements; communication: giving support, information, teaching of techniques, discussion with family; treatments: administering drugs, changing dressings, performing technical acts such as inserting a peripheral i.v. catheter; diagnostic procedures: drawing and processing biological fluid samples, arterial blood gases, X-ray

First 24 hours of NIPSV

First 24 hours of mechanical ventilation with intubation

☐ Respiration
☐ Nutrition and hydration
▨ Elimination
☒ Personal care
▨ Ambulation
▨ Communication
◩ Treatments
▨ Diagnostic procedures

tions have been put forward to explain these differences, which have been extensively reviewed elsewhere and will not be detailed here [5, 33, 38, 39, 40]. Suffice it to say that one of the main effects of NIV in ARF is its ability to decrease respiratory muscle workload [41, 42], thereby reducing fatigue and increasing alveolar ventilation [39]. Indeed, in the study by Confalonieri et al., even though the intubation rate was lower in the NIPSV group, subset analysis shows that only in those patients with COPD, particularly prone to respiratory muscle fatigue, was the difference significant [5]. In hypoxemic ARF, respiratory muscle fatigue is seldom a prominent feature [43], implying that any effect of NIV should result from other mechanisms, such as alveolar recruitment and left ventricular unloading in cardiogenic pulmonary edema [40, 44, 45, 46]. However, cardiogenic pulmonary edema is often a rapidly evolving mechanism, in which alveolar flooding and instability can reverse quickly, whereas the situation of alveolar damage in CAP is quite different and more prolonged. Furthermore, all five hypercapnic patients in our study were intubated, which suggests that, in the setting of CAP, hypercapnia might not have the same favorable prognostic implication regarding the success of NIPSV as in other disease states.

Nonetheless, intubation was required within 36 h after ICU admission, and most of the patients who were intubated had undergone only a small number of NIPSV trials (Fig. 2). Thus, the risk of needlessly increasing patient discomfort and nursing workload

through a protracted and futile course of NIPSV seems small. Another factor which should encourage attempting NIPSV is the shorter duration of ICU and hospital stays in non-intubated patients, although it is difficult to attribute this solely to the effects of NIPSV in the absence of a control group.

Finally, the patients requiring intubation were older and had a lower admission PaO_2, suggesting the feasibility of searching for criteria to identify those patients most likely to benefit from NIPSV through large prospective trials.

Nursing workload

As shown in Fig. 3, the mean daily total PRN score while patients underwent NIPSV trials varied little over time, even though marked variations occurred in a few individual patients, while the median time of NIPSV per patient increased steadily during that same period. No major difference in pattern or total PRN score can be identified between patients who were eventually intubated and those who were not (Fig. 3). This finding indicates that the overall nursing workload in patients receiving NIPSV is fairly stable and seems very little influenced by the NIPSV itself. Supporting this view is the fact that, during the first 24 h of NIPSV, there was no relationship between the total time spent on NIPSV and the number of PRN points (Fig. 4).

These findings are not surprising if one considers that the proportion of PRN points associated with respiratory treatment (including NIPSV) represented only 14 % of the total points (Fig. 5).

Analyzing nursing workload is a complex and very difficult task, and a highly objective and reproducible workload measurement tool is almost impossible to obtain in the acute care setting [22, 23]. PRN is an important step in that direction, even though it was initially not developed for the ICU, one of its main drawbacks being that it probably underestimates the absolute value of respiratory/ventilatory therapy-associated workload. However, even if the absolute amount of workload was underestimated in our study, day-to-day relative variations still provide some valuable information.

In a study on a small group of patients with either obstructive or restrictive lung disease undergoing volume-controlled NIV by nasal mask, we outlined the highly time-consuming nature of NIV, while its benefit in avoiding intubation was limited to restrictive patients [14]. However the study was performed in the early days of the systematic use of NIV in ARF in our unit. In addition, we used nasal NIV, which can prove more difficult in the acute setting, in part because of the extra attention needed to ensure the patient keeps his mouth closed at all times [47]. Nava et al., comparing two groups of COPD patients, one undergoing NIPSV, the other MV, found that the time spent at the bedside by nurses during the first 6 h did not differ between techniques, whereas a significant difference was present after this initial phase, the workload being lower in the NIPSV group [16]. We also found that the nursing workload was lower during the first 24 h of NIPSV than during the first 24 h of MV (Fig 5). However, our study did not compare the two groups, hence patients who were intubated were also those in whom increasing severity of disease rather than MV *per se* could have led to a rise in nursing workload. Interestingly, the proportion of the nurses' time devoted to respiratory-related activity in the study by Nava et al. was 21 % with NIPSV, and 20 % with MV [16]. These figures are close to ours (14 % and 13 % for NIPSV and MV, respectively), even though different indices of nursing workload were used (Fig.6). Finally, two studies showed that nursing workload was not different between COPD patients treated with nasal volume-controlled NIV and those receiving standard treatment [3, 48]. Hence, our data concurs with that of others in demonstrating that, in an ICU team experienced in the practice of NIV, nursing workload is not substantially increased by NIPSV, even in patients with severe ARF.

In conclusion, NIPSV can improve oxygenation and reduce respiratory rate in most patients with ARF due to severe CAP, but the subsequent course of these patients is marked by a high intubation rate. However, intubation is required very early after ICU admission, after a small number of NIPSV trials have been performed. Furthermore, patients avoiding intubation have a shorter stay in the ICU and hospital. Nursing workload is stable over time in patients receiving NIPSV, and only a small percentage of total workload seems to be due to the NIPSV itself. Hence, a trial of NIPSV is warranted in these patients, since this technique can have a favorable impact on outcome and, in experienced hands, appears not to increase nursing workload significantly.

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