

Continuous Positive Airway Pressure Versus Noninvasive Pressure Support Ventilation to Treat Atelectasis After Cardiac Surgery

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Atelectasis is common after cardiac surgery and may result in impaired gas exchange. Continuous positive airway pressure (CPAP) is often used to prevent or treat postoperative atelectasis. We hypothesized that noninvasive pressure support ventilation (NIPSV) by increasing tidal volume could improve the evolution of atelectasis more than CPAP. One-hundred-fifty patients admitted to our surgical intensive care unit (SICU) with a Radiological Atelectasis Score ≥ 2 after cardiac surgery were randomly assigned to receive either CPAP or NIPSV four times a day for 30 min. Positive end-expiratory pressure was set at 5 cm H₂O in both groups. In the NIPSV group, pressure support was set to provide a tidal volume of 8–10 mL/kg.

At SICU discharge, we observed an improvement of the Radiological Atelectasis Score in 60% of the patients with NIPSV versus 40% of those receiving CPAP ($P = 0.02$). There was no difference in oxygenation (P_{aO_2} /fraction of inspired oxygen at SICU discharge: 280 ± 38 in the CPAP group versus 301 ± 40 in the NIPSV group), pulmonary function tests, or length of stay. Minor complications, such as gastric distensions, were similar in the two groups. NIPSV was superior to CPAP regarding the improvement of atelectasis based on radiological score but did not confer any additional clinical benefit, raising the question of its usefulness for altering outcome.

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The frequent incidence of atelectasis (54%–92%) is a major concern after cardiac surgery because it contributes to the deterioration of pulmonary function and oxygenation (1–3). Multiple factors, such as pleural opening, postoperative diaphragmatic dysfunction, pain, immobilization, and bed rest, in addition to possible preexisting respiratory disease, are involved in the development of atelectasis in this clinical situation (3–5). Studies have compared different regimens of chest physiotherapy, incentive spirometry, or continuous positive airway pressure (CPAP) but have not separately analyzed prophylaxis from the treatment of postoperative atelectasis. Thus, the best treatment for atelectasis after cardiac surgery remains to be determined (2,6,7). CPAP is the most commonly used intervention, with a duration of treatment ranging from 25 breaths to 3 h continuously

every day. Positive end-expiratory pressure (PEEP) levels applied range from 5 to 12 cm H₂O (2,8–10).

Noninvasive pressure support ventilation (NIPSV) is a recognized treatment for acute hypercapnic and hypoxemic acute respiratory failure (11–13). There is some evidence that NIPSV improves oxygenation in postoperative nonhypercapnic patients, but NIPSV has not been studied for treating postoperative atelectasis (10,14,15). In proportion to the level of supplemental pressure support applied, it increases tidal volume, decreases respiratory rate, and improves gas exchange and diaphragmatic activity (16,17). Pressure support is usually set to achieve a tidal volume of 8–10 mL/kg (12,18).

We hypothesized that NIPSV, by the adjunction of a pressure support to the usual CPAP, may be more effective for treating postoperative atelectasis after cardiac surgery. We tested this hypothesis in a prospective, randomized, single-blind, controlled study.

Methods

The protocol was approved by the institutional ethics committee, and written, informed consent was obtained from all patients. Between January 1999 and

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May 2000, consecutive patients admitted to our surgical intensive care unit (SICU) after cardiac surgery who had a Radiological Atelectasis Score ≥ 2 after tracheal extubation were included. The Radiological Atelectasis Score was defined according to Richter et al. (19): 0, clear lung field; 1, platelike atelectasis or slight infiltration; 2, partial atelectasis; 3, lobar atelectasis; and 4, bilateral lobar atelectasis. The exclusion criteria were pneumothorax, facial lesions, altered mental status, hemodynamic instability (defined as mean arterial blood pressure < 60 mm Hg or a need for vasopressors, electrocardiograph instability with evidence of ischemia, or significant ventricular arrhythmia), planned secondary operation or transfer to another unit within 8 h after the diagnosis of atelectasis, more respiratory physiotherapy sessions than permitted in the study protocol requested by the clinician in charge or patients needing a permanent application of positive-pressure ventilation by mask to maintain a percutaneous oxygen saturation $> 90\%$ (identified as refractory hypoxemia), or patient refusal.

Before the study inclusion, all patients admitted to the SICU after cardiac surgery were tracheally intubated and received synchronized intermittent mandatory ventilation with a tidal volume of 8–10 mL/kg body weight (respiratory rate, 12 breaths/min; inspiratory/expiratory time ratio, 1:2; PEEP, 5 cm H₂O). Every ventilator was equipped with a heat and moisture exchanger. The respiratory rate and fraction of inspired oxygen (FIO₂) were adjusted according to arterial blood gas analysis. As soon as the patient showed spontaneous breathing, the pressure support was reduced to 10 cm H₂O, and the trachea was extubated according to the local protocol (percutaneous oxygen saturation $> 90\%$ at an FIO₂ of ≤ 0.4 ; pH > 7.34 ; respiratory rate ≤ 35 breaths/min with pressure support of ≤ 10 cm H₂O; PEEP ≤ 5 cm H₂O; patient awake; intact swallowing reflex; stable hemodynamics). When extubated, every patient received prophylactic respiratory physiotherapy consisting of CPAP at PEEP 5 cm H₂O four times a day for 15 min and a coughing session if necessary. Patients who developed a Radiological Atelectasis Score ≥ 2 were included in the study after informed consent and were randomly assigned to either the CPAP or the NIPSV group. Patients were blinded to randomization because an identical face mask (Vital Signs Inc., Totowa, NJ) held in place by head straps was applied for both therapeutic groups.

CPAP was provided by a gas mixer with an adjustable flow (Mov 60 O₂/Air[®]; LNI Industry, Geneva, Switzerland), which was connected to a 5-L bag and a PEEP valve (Ambu, Copenhagen, Denmark) (20). The settings were flow rate 30 L/min, PEEP 5 cm H₂O, and FIO₂ adjusted to achieve a percutaneous oxygen saturation $> 90\%$.

NIPSV was performed with Veolar FT[®] and Galileo[®] (Hamilton Inc., Reno, NV), Servo 300[®] (Siemens, Solna, Sweden), and Evita 4[®] (Dräger, Lübeck, Germany) in a spontaneous mode with a pressure support level adjusted to achieve a tidal volume of 8–10 mL/kg. Maximal pressure was delivered at 30 cm H₂O, PEEP was 5 cm H₂O, the minimal trigger flow was selected, and FIO₂ was adjusted to achieve a percutaneous oxygen saturation $> 90\%$.

In both groups, patients underwent 30-min sessions four times a day—at 5:00 AM, 10:00 AM, 4:00 PM, and 10:00 PM—in a semirecumbent position with the head at $\geq 45^\circ$ to minimize the risk of gastric distention and/or aspiration. Humidification of inspired gases was performed by a heat and moisture exchanger. Twice a day, two respiratory therapists assessed patients for airway secretions. When these were present, the therapists performed an assisted coughing session consisting of a forced inspiration and expiration repeated three times, followed by a cough. The physiotherapist held the patient's chest during the cough and performed a nasotracheal suction if there was no expectoration after three sessions. Patients were mobilized as early as possible to an arm chair for at least 1 h daily. Postoperative pain management was ensured by paracetamol (acetaminophen) by mouth 1 g every 6 h and by morphine IV to achieve a visual analog scale (VAS) score ≤ 3 . VAS ≤ 3 was required before each CPAP or NIPSV session.

The preoperative values of arterial blood gas analyses, the vital capacity (VC) and the forced expiratory volume in 1 s (FEV₁), age, sex, weight, and history of respiratory disease and smoking were recorded from the patient's chart after randomization. The type of cardiac surgery and the duration of cardiopulmonary bypass were noted. Postoperative data included the simplified acute physiologic score version II (21), the duration of mechanical ventilation and the highest PEEP used during mechanical ventilation, the day of the first postoperative mobilization, the daily duration of the mobilization to an armchair, the day of thoracic tube removal, the SICU and hospital length of stay and mortality, and the readmission to the SICU.

The following assessments were performed at inclusion in the study (Time 0; T₀) and every day (T₁, T₂, T₃, . . . T_n) until the day of discharge (time of discharge; TD). Chest radiographs, performed in a semirecumbent position in bed or in the standing position whenever possible, were evaluated by two physicians certified in intensive care independent of the study and blinded to randomization. We assessed by Cohen's κ test the intrarater and the interrater variability of the Radiological Atelectasis Score between the 2 physicians in the first 20 patients. In all chest radiographs, the differences in the Radiological Atelectasis Score rating were resolved by discussion between the physicians. Arterial blood gas tension was measured (Stat

Profile Ultra C[®]; Nova Biomedical, Waltham) with the patient breathing room air for at least 10 min (13) at 9:00 AM, 3 h 30 min after the last CPAP or NIPSV session. If the percutaneous oxygen saturation decreased to less than 88% within the 10-min interval, arterial blood gas values were measured after 10 min on an oxygen mask at an F_{iO_2} of 0.4. At TD, arterial blood gas analyses were all measured from patients breathing room air. VC and FEV₁ were measured every day at 9:00 AM by a spirometer (Micro Plus[®]; Micro Medical Ltd., Rochester, UK) when the patient was sitting in bed. The best result of two tests was recorded. The cumulative fluid balance, the type of adverse events caused by CPAP and NIPSV, and the highest level of pressure support given by NIPSV were noted. The patients were considered hypersecretive when they needed additional chest physiotherapy, such as induced cough sessions or nasotracheal suctioning. The number of sessions per patient was recorded. Daily, the maximal pain intensity and the pain intensity before each CPAP or NIPSV session were assessed by a 10-cm VAS with a range of 0 to 10, anchored by "no pain" at one end and by "worst possible pain" at the other end. At discharge, the perceived degree of comfort related to CPAP or NIPSV were evaluated by a 10-cm VAS with a range of 0-10 ("very comfortable" = 0 and "very uncomfortable" = 10) (22). Patients were discharged from the SICU if they showed a percutaneous oxygen saturation >90% with an $F_{iO_2} \leq 0.35$, were hemodynamically stable without IV vasopressors, and had no major cardiac arrhythmia for the last 24 h. Patients were discharged only after removal of the thoracic tube. The study protocol ended at the time of SICU discharge because NIPSV cannot be performed on a general ward, according to institutional regulations. The patient's SICU stay was not prolonged for study purposes. The decision to discharge the patient from the hospital was left to the discretion of the cardiovascular surgeon in charge of the patient, independent from the study team.

To achieve an expected improvement of the Radiological Atelectasis Score from 50% to 75%, the β test with an α of 0.05 and 80% power required 66 patients in each group. One-hundred-fifty patients were randomized by a computer-generated randomization table with concealed, opaque envelopes. The two groups were compared in an intention-to-treat analysis. Demographic and physiological characteristics were compared by Student's *t*-test for continuous and Fisher's exact test for categorical variables. Nonparametric or nonnormally distributed data were compared by Mann-Whitney *U*-test. Multiple comparisons were performed by one-way analysis of variance with Bonferroni's correction. We performed an analysis of covariance, with therapy (NIPSV versus CPAP) as the main predictor of interest, adjusting for Radiological Atelectasis Score at T0 treated as a continuous variable to increase precision. The Radiological Atelectasis

Score at TD was the response variable. All tests were two-tailed, and a *P* value <0.05 was considered statistically significant. Results are expressed as mean \pm SD if not specified otherwise.

Results

The flow diagram of patients in the study is summarized in Figure 1. Of 621 patients screened from January 1999 to May 2000, 225 (36%) met the radiological eligibility criteria. Seventy-five patients were excluded, and 150 were randomly assigned to receive CPAP or NIPSV. Fifteen patients discontinued the intervention: 9 patients in the CPAP group and 6 patients in the NIPSV group (see Fig. 1 for explanation). The reasons for discontinuation were comparable. Four patients in the CPAP group and three patients in the NIPSV group required more respiratory physiotherapy sessions than permitted in the study protocol for refractory hypoxemia. One patient in the CPAP group and no patient in the NIPSV group required tracheal intubation because of an acute respiratory failure. However, this was not statistically significant. The five pneumothoraces motivating the discontinuation of the study were due to an air leak during removal of the chest tube and not to the study intervention. However, all 150 patients were included in the intention-to-treat analysis.

At T0, the demographic and pre- and perioperative data of both groups of patients were similar (Table 1), and the two groups did not differ regarding pH, P_{aCO_2} , P_{aO_2}/F_{iO_2} (Table 2), or the Radiological Atelectasis Score (Fig. 2, Table 3). The intrarater and the interrater variability of the Radiological Atelectasis Score were respectively 0.86 and 0.82 by Cohen's κ test. At T0, an important decrease of VC and FEV₁ occurred to a similar extent in both groups compared with preoperative values and persisted at TD (Table 2).

At TD, the Radiological Atelectasis Score was similar in both groups, but the differential Radiological Atelectasis Score (Δ Radiological Atelectasis Score = Radiological Atelectasis Score at T0 - Radiological Atelectasis Score at TD) showed a statistically significant improvement in favor of the NIPSV group (*P* = 0.02) (Table 3). The Radiological Atelectasis Score decreased in 30 (40%) patients with CPAP, compared with 45 (60%) patients with NIPSV (*P* = 0.02). The Radiological Atelectasis Score even worsened in 8 (11%) patients with CPAP, compared with 1 (1%) patient with NIPSV (*P* = 0.03) (Fig. 2, Table 3). The difference in Radiological Atelectasis Score at TD comparing NIPSV with CPAP was -0.26 (95% confidence interval, -0.47 to -0.05), with a lower score among patients assigned to the NIPSV group (*P* = 0.01), adjusting for Radiological Atelectasis Score at T0. The

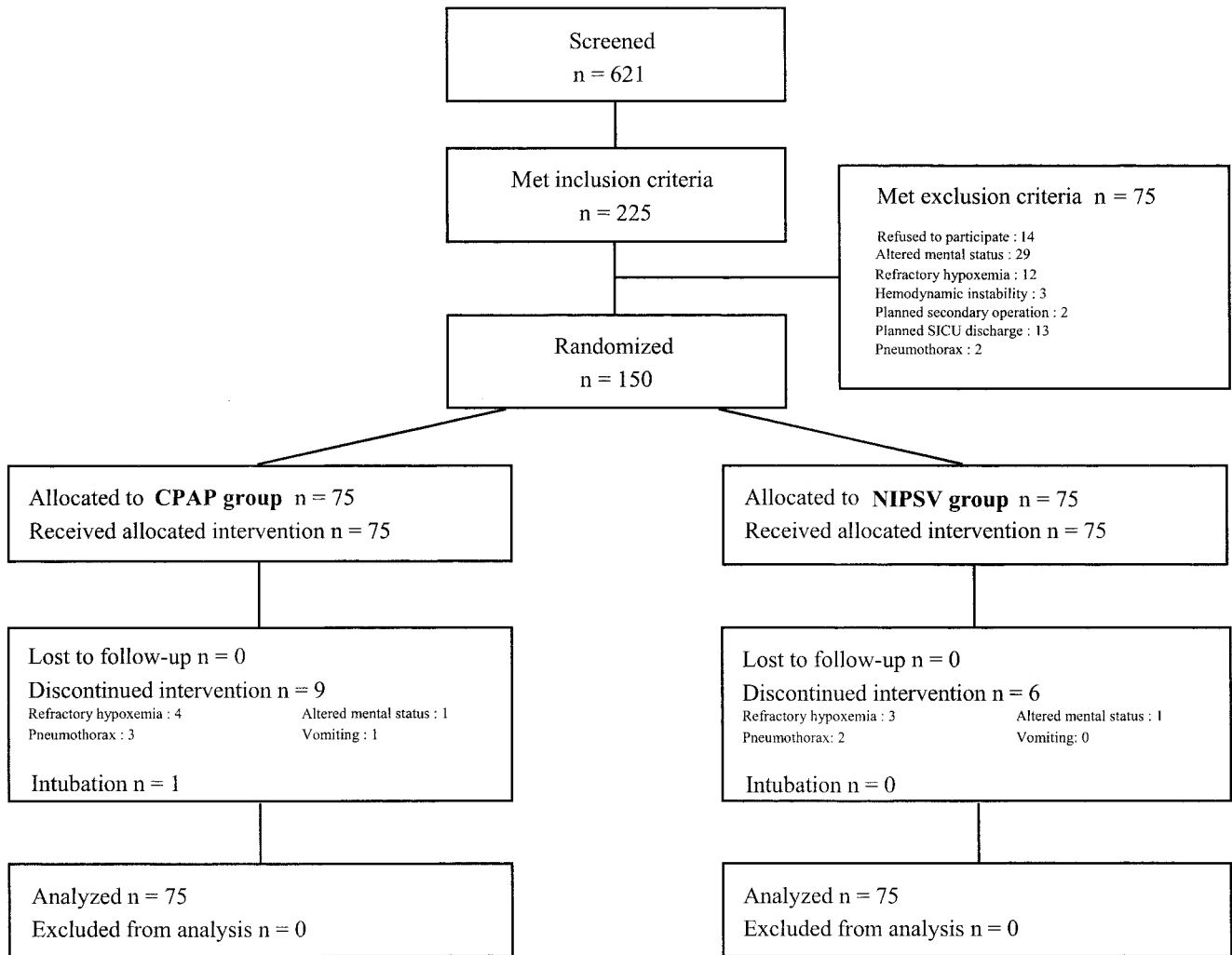


Figure 1. Flow diagram of the patients screened for the study between January 1999 and May 2000. CPAP = continuous positive airway pressure; NIPSV = noninvasive pressure support ventilation; SICU = surgical intensive care unit.

Radiological Atelectasis Score at T0 was highly predictive of the score at discharge (coefficient, 0.6; 95% confidence interval, 0.39—0.82). At TD, pH, PaCO₂, Pao₂/Fio₂, VC, and FEV₁ were similar in the two groups (Table 2).

Patients of the two groups received an equivalent number of treatment sessions (Table 4). The degree of comfort was similar in both groups (Table 4). No major complication, such as facial lesion due to the mask or pneumothorax induced by the intervention, was observed during the study. Minor complications, such as radiological gastric distention or nausea, were equally distributed between the CPAP group (19 [25%]) and the NIPSV group (12 [16%]). No bronchoscopy was performed for treatment of atelectasis in any patient.

Other confounding factors potentially related to the efficacy of the treatment, such as the presence of hypersecretion, the number of induced cough sessions or nasotracheal suctionings, the cumulative fluid balance, thoracic drainage, mobilization, and pain intensity, were

similar in the two groups (Table 4). The length of stay in the intensive care unit or in the hospital and the mortality rate during intensive care or in the hospital did not differ between the two groups (Table 2). No patient was readmitted to the SICU.

Discussion

This large study investigated the treatment of atelectasis after cardiac surgery. We showed that NIPSV increases the rate of radiological resolution of atelectasis when compared with CPAP. However, this radiological improvement was not associated with any clinical amelioration, as shown by oxygenation and pulmonary function.

In the literature, studies on postoperative atelectasis after cardiac surgery do not clearly separate the effect of the prophylactic regimen to prevent

Table 1. Patient Characteristics

Variable	CPAP (n = 75)	NIPSV (n = 75)
Age (yr)	66±13	65±12
Male, n (%)	54 (72)	57 (76)
Body weight, kg (mean ± SD)	77±14	77±13
SAPS II (mean ± SD)	28±8	28±9
Preoperative pulmonary data		
Preexisting pulmonary disease, n (%)		
COPD	5 (7)	5 (7)
Restrictive lung disease	3 (4)	1 (1)
Asthma	1 (1)	1 (1)
History of smoking, n (%)	46 (61)	38 (51)
VC, mL (mean ± SD)	3680 ± 1240	3610 ± 1040
FEV ₁ , mL (mean ± SD)	2630 ± 970	2720 ± 800
PaO ₂ /Fio ₂ , mm Hg (mean ± SD)	338 ± 68	345 ± 78
Paco ₂ , mm Hg (mean ± SD)	39 ± 4	38 ± 4
Arterial pH (mean ± SD)	7.43 ± 0.02	7.43 ± 0.03
Surgery data		
Surgery type, n (%)		
Coronary surgery	32 (43)	33 (44)
Valvular surgery	24 (32)	26 (35)
Aortic surgery	8 (11)	4 (5)
Combination: coronary, valve, aorta	11 (14)	12 (16)
Duration of cardiopulmonary bypass, min (mean ± SD)	125 ± 53	116 ± 58
Elective operation, n (%)	71 (95)	66 (88)
Postoperative mechanical ventilation data		
Duration, min (mean ± SD)	716 ± 396	693 ± 345
PEEP, cm H ₂ O, median (range)	5 (5-10)	5 (5-10)

CPAP = continuous positive airway pressure; NIPSV = noninvasive pressure support ventilation; SAPS II = simplified acute physiologic score II (21); COPD = chronic obstructive pulmonary disease; VC = vital capacity; FEV₁ = forced expiratory volume in 1 s; PEEP = positive end-expiratory pressure; Fio₂ = fraction of inspired oxygen.

Table 2. Pulmonary Variables and Outcome

Variable	CPAP (n = 75)	NIPSV (n = 75)
pH (mean ± SD)		
T0	7.40 ± 0.04	7.40 ± 0.04
TD	7.47 ± 0.03	7.46 ± 0.03
Paco ₂ , mm Hg (mean ± SD)		
T0	37 ± 5	36 ± 5
TD	36 ± 5	35 ± 4
PaO ₂ /Fio ₂ , mm Hg (mean ± SD)		
T0	283 ± 59	289 ± 70
TD	280 ± 38	301 ± 40
VC, mL (mean ± SD) [% preoperative value]		
T0	1010 ± 370 [27]	1020 ± 370 [28]
TD	1080 ± 380 [29]	1110 ± 350 [31]
FEV ₁ , mL (mean ± SD) [% preoperative value]		
T0	820 ± 300 [31]	820 ± 280 [30]
TD	880 ± 300 [33]	900 ± 280 [33]
SICU stay, h, median (25th-75th percentiles)	65 (47-74)	60 (47-74)
Hospital stay, d, median (25th-75th percentiles)	14 (12-16)	13 (12-17)
SICU mortality, n (%)	0	0
Hospital mortality, n (%)	1 (1) ^a	0

CPAP = continuous positive airway pressure; NIPSV = noninvasive pressure support ventilation; T0 = time of inclusion in the study; TD = time of SICU discharge; VC = vital capacity; FEV₁ = forced expiratory volume in 1 s; SICU = surgical intensive care unit; Fio₂ = fraction of inspired oxygen.

^a The patient died from mesenteric ischemia.

atelectasis from the effect of the treatment of atelectasis. This difference is important in everyday clinical practice, and several authors have emphasized the need for studies analyzing separately the preventive and therapeutic regimens (8,23). This study

is the first to analyze the therapeutic effect of NIPSV on atelectasis after cardiac surgery compared with CPAP. CPAP is often used for the prevention of postoperative atelectasis after cardiac surgery (2,10), but its efficacy in atelectasis treatment was evoked

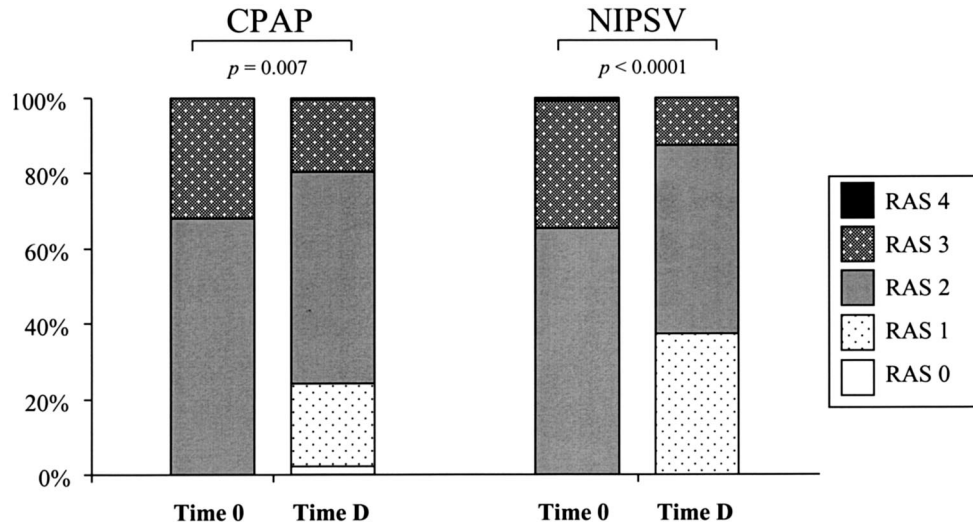


Figure 2. Distribution of the Radiological Atelectasis Score (RAS) for the continuous positive airway pressure (CPAP) and the noninvasive pressure support ventilation (NIPSV) groups at Time 0 and time of discharge (Time D). RAS (19): 0, clear lung fields; 1, platelike atelectasis or slight infiltration; 2, partial atelectasis; 3, lobar atelectasis; 4, bilateral lobar atelectasis. Statistical analysis was performed by Mann-Whitney *U*-test.

Table 3. Radiological Evaluation

Variable	CPAP (n = 75)	NIPSV (n = 75)	P value ^a
Radiological Atelectasis Score at T0, median (range)	2 (2-3)	2 (2-4)	0.53
Radiological Atelectasis Score at TD, median (range)	2 (0-4)	2 (1-3)	0.07
Δ Radiological Atelectasis Score, ^b median (range)	0 (-1-2)	1 (-1-2)	0.02
Radiological evolution between T0 and TD, ^c n (%)			
Worse	8 (11)	1 (1)	0.03
No change	37 (49)	29 (39)	0.25
Improvement	30 (40)	45 (60)	0.02

CPAP = continuous positive airway pressure; NIPSV = noninvasive pressure support ventilation; T0 = time of inclusion in the study; TD = time of surgical intensive care unit discharge.

^a Calculated with Fisher's exact test or the Mann-Whitney *U*-test as appropriate.

^b Δ Radiological Atelectasis Score = Radiological Atelectasis Score T0 - Radiological Atelectasis Score TD.

^c Worse = patient with a Radiological Atelectasis Score that increased from T0 to TD; No change = patient with the same Radiological Atelectasis Score at T0 and TD; Improvement = patient with a Radiological Atelectasis Score that decreased from T0 to TD.

only after abdominal surgery: in 10 (83%) of 12 patients, Andersen et al. (9) showed a partial resolution of atelectasis after CPAP (PEEP, 15 cm H₂O for ≈2 min every hour). In our study, the CPAP group showed improvement in only 30 (40%) of the 75 patients. This difference is not surprising because of the different patient populations: the risk factors for the development and evolution of postoperative atelectasis are linked with the site and type of surgery (24,25).

Despite the radiological improvement of atelectasis, 149 patients left our SICU with persistent atelectasis. Furthermore, we could not find a difference between groups regarding oxygenation and pulmonary function that remained below normal limits in both groups at SICU discharge. This is consistent

with the study of Ricksten et al. (26), who demonstrated that only the resolution and not the reduction of the radiological size of atelectasis can induce significant changes of oxygenation and pulmonary functions.

NIPSV was as safe and comfortable as CPAP. These results on the safety and comfort of NIPSV are also consistent with other publications regarding NIPSV and acute respiratory failure (11,12). No major complication was noted, and few minor side effects were observed in both groups.

The SICU or hospital length of stay and mortality did not differ between groups. However, our study was not designed or powered to address questions about the clinical outcome of the two therapeutic approaches.

Table 4. Intervention and Postoperative Characteristics

Variable	CPAP (n = 75)	NIPSV (n = 75)
Intervention		
Total session of CPAP or NIPSV, <i>n</i> , median (25th–75th percentiles)	6 (5–9)	5 (5–9)
Pressure support sovra-PEEP, ^a cm H ₂ O (mean ± SD)		9.9 ± 3.7
Degree of comfort, VAS score (mean ± SD)	4.7 ± 2.6	4.6 ± 2.7
Additional chest physiotherapy		
Hypersecretive patients, <i>n</i> (%)	21 (28)	27 (36)
Requiring induced cough session, <i>n</i> (%)	18 (24)	26 (35)
Requiring nasotracheal suctioning, <i>n</i> (%)	3 (4)	3 (4)
Induced cough sessions per patient (mean ± SD)	3 ± 3.8	2.2 ± 1.4
Nasotracheal suctioning per patient (mean ± SD)	0.8 ± 2.6	0.5 ± 1.4
Other data		
Cumulative fluid balance, mL (mean ± SD)		
T0	710 ± 1595	925 ± 1455
TD	20 ± 1925	460 ± 1670
Postoperative day of thoracic tube removal, median (range)	2 (2–3)	2 (1–5)
Postoperative day of first mobilization, median (range)	2 (1–11)	2 (1–3)
Duration of mobilization, min (mean ± SD) [<i>n</i>]		
T0	86 ± 50 [8]	222 ± 126 [5]
T1	122 ± 88 [68]	129 ± 108 [58]
T2	170 ± 97 [32]	190 ± 142 [29]
Pain control		
Pain intensity before session, VAS score (mean ± SD)		
T0	3 ± 1.3	3 ± 1.2
T1	1.8 ± 1.4	1.5 ± 1.4
T2	1 ± 1.3	1.3 ± 1.5
Maximal pain intensity during the day, VAS score (mean ± SD)		
T0	4.9 ± 2.1	4.6 ± 2.2
T1	3.1 ± 2.2	2.8 ± 2.2
T2	2 ± 2.2	1.7 ± 1.9

CPAP = continuous positive airway pressure; NIPSV = noninvasive pressure support ventilation; *n* = number of patients; PEEP = positive end-expiratory pressure; T0 = time of inclusion in the study; T1 = Day 1 of the study; T2 = Day 2 of the study; TD = time of SICU discharge; VAS = visual analog scale; SICU = surgical intensive care unit.

^a Pressure support sovra-PEEP: total pressure support minus extrinsic PEEP.

Our study has some limitations. The first regards the large number of patients who met exclusion criteria. Although this created a more homogeneous study group, some excluded patients, particularly those with refractory hypoxemia, could have benefited more from NIPSV. The second limitation was the short duration of the treatment of both groups because of the transfer of patients to the wards. Because of the restricted availability of SICU beds and for ethical reasons, the SICU stay was not to be prolonged because of the study. This could explain the persistence of radiological atelectasis in most of our patients, as in other studies (27). We cannot exclude that the pursuit of treatment by NIPSV after three days could have caused a further increase in resolution of atelectasis associated with an improvement of oxygenation or pulmonary function. Third, referring to previous studies, we chose only 5 cm H₂O of PEEP (4,10), because our study sought to analyze the effect of the additional pressure support at the same level of PEEP in both groups. Therefore, our study cannot exclude that higher levels of PEEP

may have improved the results in the CPAP or NIPSV group.

Finally, the application of NIPSV is considered time consuming for nurses and may require more resources (12,28). This aspect of the comparison of the two methods was not addressed in our study. However, present preoccupations about cost effectiveness and costs of health care suggest that strong evidence of benefit for patients should be present whenever a new therapeutical approach is proposed.

In conclusion, we showed in this large, prospective, randomized, single-blind, controlled study that NIPSV is superior to CPAP regarding the improvement of the Radiological Atelectasis Score after cardiac surgery. The persistence of atelectasis at SICU discharge and the lack of other clinical benefits (oxygenation, pulmonary function, and length of stay) raise the questions of the clinical usefulness and the duration of any treatment. Furthermore, NIPSV does not appear to be less resource consuming. Thus, we cannot encourage the use of NIPSV for the treatment of atelectasis after cardiac surgery.

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