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ORIGINAL ARTICLE

Early postoperative prophylactic noninvasive ventilation after major lung resection in COPD patients: a randomized controlled trial

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For the POPVNI trial group.

The POPVNI trial group members are given in "Appendix".

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Electronic supplementary material
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Abstract *Objectives:* To investigate whether prophylactic postoperative NIV prevents respiratory complications following lung resection surgery in COPD patients. *Methods:* In seven thoracic surgery departments, 360 COPD patients undergoing lung resection surgery were randomly assigned to two groups: conventional postoperative treatment without ($n = 179$) or with ($n = 181$) prophylactic NIV, applied intermittently during 6 h per day for 48 h following surgery. The primary endpoint was the rate of acute respiratory events (ARE) at 30 days postoperatively (ITT analysis). Secondary endpoints were acute respiratory failure (ARF), intubation rate, mortality rate, infectious and non-infectious complications, and duration of ICU and hospital stay. *Measurements and main results:* ARE rates did not differ between the prophylactic NIV and control groups (57/181, 31.5 vs. 55/179, 30.7 %, $p = 0.93$). ARF rate was 18.8 % in the prophylactic NIV group and 24.5 % in controls ($p = 0.20$). Re-intubation rates were similar in the prophylactic NIV and control group [10/181 (5.5 %) and 13/179 (7.2 %), respectively, $p = 0.53$]. Mortality rates were 5 and 2.2 % in the control and prophylactic NIV groups, respectively ($p = 0.16$). Infectious

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and non-infectious complication rates, and duration of ICU and hospital stays were similar between groups. *Conclusions:* Prophylactic postoperative NIV did not reduce the rate of ARE in COPD patients undergoing lung resection surgery and did not influence other postoperative complications rates, mortality rates, and duration of ICU and hospital stay.

Keywords Non-invasive ventilation · COPD · Thoracic surgery · Acute respiratory failure, postoperative care

Introduction

Despite advances in surgical techniques, anesthesia, and perioperative care over the past decade, patients undergoing lung resection surgery are still at high risk of developing postoperative pulmonary complications [1], such as acute respiratory failure (ARF), pneumonia, atelectasis, or bronchopulmonary fistula, with a high mortality rate [2, 3, 4]. Postoperative ARF is observed in 2–30 % of patients [5, 6, 7]. Endotracheal invasive mechanical ventilation (ETMV) for ARF following major lung resection is associated with a mortality rate ranging from 60 to 80 %. Several observations suggest that prophylactic NIV could be useful to decrease post-operative complications rates after lung resection surgery. First, noninvasive ventilation pressure support ventilation (NIPSV) may prevent the need for intubation in patients with ARF following lung resection surgery [8, 9]. A single prospective randomized study found that, in selected patients with ARF following lung resection, NIV decreases the need for ETMV and improves clinical outcome [10]. An observational prospective cohort survey confirmed the feasibility and efficacy of NIV in both hypercapnic and hypoxic ARF following lung resection [11]. Applying NIPSV through a mask, with either bi-level positive airway pressure (BIPAP) or inspiratory pressure support and expiratory positive pressure support ventilation after lung resection surgery, could unload respiratory work of breathing, prevent diaphragmatic fatigue, induce a significant reduction in the magnitude of the postoperative pulmonary restrictive syndrome, and improve gas exchange [12].

The prophylactic use of NIV (bilevel pressure support ventilation) before and after lung surgery in COPD patients has been shown to accelerate recovery of lung function, with a trend towards reduced incidence of atelectasis and hospital length of stay [13]. In another study, the prophylactic use of NIV following thoracic surgery improved lung re-expansion, but had no significant effects on postoperative outcome [14]. These findings may be related to the small number of patients and the low rate of respiratory complications observed in this study [14]. Nevertheless, the clinical benefit of prophylactic NIV in these patients remains unclear. In addition, prophylactic NIV could be more effective in patients at higher risk for postoperative respiratory complications following lung resection. Patient-related risk factors for pulmonary complications following lung resection surgery include advanced age, altered preoperative pulmonary function tests, cardiovascular comorbidities, and smoking status [15].

The present study [16] was performed to evaluate the feasibility and clinical outcome results of applying intermittent prophylactic NIV in a population of patients at risk, i.e. those with moderate to very severe COPD (Gold II to IV) undergoing lung resection surgery.

Methods

Study design

The study was an open, randomized, controlled, parallel-group trial with two groups: standard care without (control group) and with (study group) prophylactic NIV during the first 48 postoperative hours.

Patients selection and inclusion criteria

Patients were recruited from seven lung surgery departments in (five) university and (two) non-university hospitals in France between June 2008 and October 2010. The study was conducted in accordance with the Declaration of Helsinki. All included patients gave their informed consent to participate in the study, which was approved by the appropriate ethics committee (Comité de Protection des Personnes, Ile de France 1, 17/12/2007, approval number: 0711659). Clinical trial registration number was NCT 00428857.

Inclusion criteria were: age >18 years, scheduled pulmonary resection, and with moderate to very severe COPD (GOLD II to IV). Exclusion criteria were: sleep apnea syndrome, facial deformation, and inability to follow the study. Informed written consent was obtained from the patients and randomization was performed the day before surgery.

Treatments

Standard anesthesia surgical techniques were used in all patients [see electronic supplemental data (ESM)]. No video-assisted thoracic surgery was used. All patients

received aerosolized bronchodilators and early chest physiotherapy to assist bronchial drainage. If needed, supplemental oxygen was given through a nasal cannula to achieve an oxygen saturation level above 92 %. Patients were mobilized at day 1 following surgery. Prevention of venous thromboembolism included low molecular weight heparin and graduating compression stockings. Postoperative pain was assessed with a visual analogy scale, and patients received multimodal analgesia with free opiates analgesic drugs, systemic opiates in venous patient controlled analgesia (PCA), or local anesthetic in thoracic epidural PCA or local anesthetic in paravertebral subpleural PCA. Oral re-alimentation was started on postoperative day 2 after pneumonectomy and on postoperative day 1 for all other types of surgical procedures.

Physicians were responsible for prophylactic NIV implementation (Philips, BiPAP Vision; Respironics, Murrysville, PA, USA), which included choice and fitting of masks, adjustment of ventilator settings, and initial patient adjustment. The modalities of prophylactic NIV are described in the ESM. Prophylactic NIV was intermittently delivered to the patients for a 1-h period six times a day. Between each NIV period, the patient received supplemental oxygen through nasal cannula to achieve an oxygen saturation level above 92 %.

If a patient from either treatment group met criteria for ARF, but did not fulfill criteria for immediate reintubation, the use of NIV was permitted as rescue therapy, prior to reintubation if needed. ARF criteria are defined in the electronic supplemental material (ESM), as well as indications of rescue NIV and criteria for intubation in case of ARF. For patients in the intervention group, rescue NIV was defined as reinstitution or continuation of NIV beyond the scheduled time.

Variables collected at baseline

All the data concerning patient characteristics, surgical and anesthetic procedure, intra-operative events, treatment procedures, and 30-day postoperative outcome were prospectively collected. Collected data are provided in ESM.

Follow-up

During the first 2 days after surgery, patient heart rate (HR), pulse-oximetry, blood pressure, and respiratory rate (RR) were continuously monitored. Arterial blood pressure, HR, RR, arterial blood gas values, and chest X-ray features were recorded at admission in the ICU or intermediate care unit (before initiation of prophylactic NIV), 1 h after NIV was started, and then at least once a day. In cases of clinical change, or at least once a day, each patient was examined and screened for postoperative complications.

Doctors were asked to maintain a high level of suspicion for pulmonary complication (see ESM), NIV adverse effects (see ESM) and acquired infections according to standard definitions from the Centers for Disease Control and Prevention (Atlanta, GA, USA). Patients were followed for 30 days after surgery.

Study endpoints

The primary endpoint for the comparison between prophylactic NIV and standard care was the rate of acute respiratory events (ARE) during the 30 days following surgery. ARE was defined by at least two of the following criteria: respiratory rate >30/min, PaO_2/FiO_2 <200 mmHg, $PaCO_2$ increase of more than 10 mmHg above baseline postoperative value, or a new pulmonary infiltrate on chest X-ray. Respiratory rate was assessed by reviewing the values collected through continuous monitoring. To calculate PaO_2/FiO_2 ratio when oxygen was administered through nasal cannulas, FiO_2 was determined using a correspondence table shown in the ESM. The reference value of $PaCO_2$ to define an increase of more than 10 mmHg above baseline postoperative value was the value obtained at entry in the ICU, before initiation of NIV (for patients in the prophylactic NIV group). Secondary endpoints were ARF, use of rescue NIV, pneumonia, infections of the operative site, durations of ICU, hospital stay, and mortality. These items are defined in the ESM.

An independent committee including an ICU physician, a chest physician, and a radiologist validated all ARE according to the definition. For this purpose, they reviewed all relevant data from patients' medical records including chest X-rays and/or CT-scans, and bedside flowcharts at entry and during the study.

Statistical analysis

Although ARE in the present definition were not part of our 2009 study [11], we used data from this study to estimate that a 30 % rate of ARE was expected in patients assigned to the control group and we aimed at reducing this rate to 15 % in those assigned to prophylactic NIV.

As mentioned in the protocol, calculations indicated a minimum sample size of 360 patients [confidence level $(1 - \alpha)$ 95 %, power level $(1 - \beta)$ 80 %].

All variables are reported as mean ± standard deviation (SD) or percentages as appropriate. ARE, vital status, and other binary endpoints were compared between the two groups (control and prophylactic NIV) using the Chi square test or the Fisher exact test, as appropriate.

Comparisons were performed using the Wilcoxon signed rank test for the duration of ICU and hospital stay.

All analyses were performed following an intention-to-treat approach. In patients who were not operated or whose informed consent was lost between randomization and arrival in the postoperative care setting, imputation followed a maximal penalization rule: favorable outcomes were imputed to those patients randomized to the control group, and unfavorable outcomes to those of the prophylactic NIV group. A Cox proportional hazards analysis was used to evaluate the effect of the covariates on postoperative ARE. Relative risks and their 95 % confidence interval (CI 95 %) were calculated, and the Wald test was used to test the significance of each variable. The model was built in two steps: firstly, several factors were included in a univariate model, and secondly, a stepwise modeling approach was used introducing all factors with a p value lower than 0.20 in the first step. Interactions between group treatment and center or group treatment and COPD severity (moderate/severe) were tested to account for a significant difference in ARE rates between centers or between categories of COPD severity.

Analyses were performed using SAS 9.2 (SAS Institute, NC, USA). Tests were two-sided and a p value lower than 0.05 was considered to be statistically significant.

Results

Among 419 screened patients, 360 were randomized: 181 in the prophylactic NIV group and 179 in the control group (Fig. 1). Data were incomplete in 11 patients: lack of major lung resection during surgery ($n = 2$), or loss of informed consent ($n = 9$). The preoperative characteristics, surgical procedures, and postoperative care including pain management are described in Tables 1 and 2. Patient compliance with prophylactic NIV was 83 % (5 patients withdrew prophylactic NIV during the first session and 10 patients did not complete all planned prophylactic NIV sessions). The mean time between extubation and prophylactic NIV initiation was 283 ± 277 min. No significant difference was found between prophylactic NIV and control groups regarding arterial blood gases (Table 2). The number of patients with persistent air leaks was not different between groups (17 in prophylactic NIV group vs. 14 in control group, $p = 0.70$). No severe skin breakdown (i.e., skin ulcer or necrosis) was observed. No gastric distension was reported either.

A total of 112 patients (31.1 %) experienced ARE during the 30 days after surgery, 57 in the prophylactic NIV group (31.5 %) and 55 (30.7 %) in the control group ($p = 0.93$) (Table 3). ARF occurred in 78 patients (21.7 %), including 34 (18.8 %) in the prophylactic NIV group and 44 (24.5 %) in the control group ($p = 0.20$). Nine patients required immediate intubation and invasive ventilation at the time ARF occurred (7 in the NIV group, 2 in the control group). In the others ($n = 69$), NIV was used as first-line rescue therapy. Among these 69 patients, 27 were in the prophylactic NIV group and 42 in the control group ($p = 0.04$). Rescue NIV was successful to prevent reintubation in 55/69 (79 %), with no difference between groups: 24/27 patients (89 %) in the prophylactic NIV group and 31/42 patients (73.8 %) in the control group ($p = 0.2$). Among the 23 patients reintubated, 5 in the prophylactic group and 4 in the control group were reintubated for reasons other than isolated ARF (see Fig. 2 and ESM).

Postoperative infection rates, duration of ICU stay, and hospital length of stay did not differ between groups (Table 3). At day 30 after surgery, mortality rate was 3.6 % (5 % in the control group vs. 2.2 % in the prophylactic NIV group; $p = 0.16$).

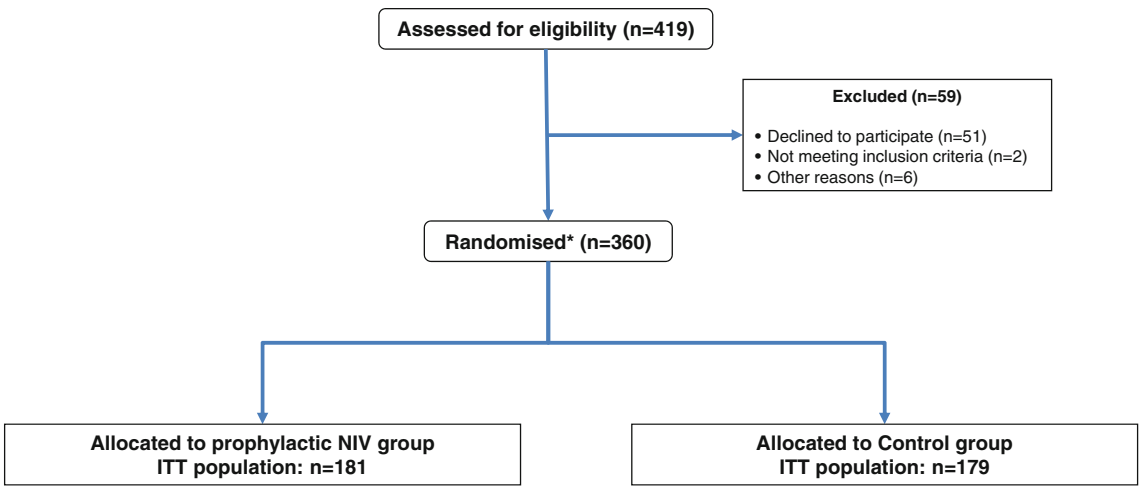

Fig. 1 Study flow chart. *Asterisk* randomization was performed the day before surgery

Table 1 Preoperative characteristics of the patients, disease and treatment before surgery

Parameters	Overall population ($n = 360$)	Prophylactic NIV group ($n = 181$)	Control group ($n = 179$)
Age, year, mean ± SD	63.6 ± 9.7	63.6 ± 10.6	63.7 ± 8.8
Male gender, *n* (%)	276 (76.6)	135 (74.5)	141 (78.7)
BMI (kg/m^2), mean ± SD	24.7 ± 4.8	24.7 ± 4.8	24.7 ± 4.9
Smokers, *n* (%)	96 (26.6)	48 (26.5)	48 (26.8)
ASA III + IV, *n* (%)	147 (40.8)	67 (37)	80 (44.6)
Charlson score, *n* (%)			
0–1	292 (81.8)	150 (82.8)	141 (79.2)
≥2	57 (15.8)	25 (13.8)	32 (17.8)
Thoracoscore, mean ± SD	9.8 (13.5)	9.4 (12.8)	10.3 (14.2)
Heart disease, *n* (%)	110 (30.5)	54 (29.8)	56 (31.2)
Ischemic Heart disease, *n* (%)	47 (13)	23 (12.7)	24 (13.4)
Peripheral vascular disease, *n* (%)	56 (15.5)	29 (16)	27 (15)
Chronic renal failure, *n* (%)	28 (7.7)	8 (4.4)	20 (11.1)
Diabetes mellitus, *n* (%)	31 (8.6)	12 (6.6)	19 (10.6)
Alcohol use, *n* (%)	40 (11.1)	19 (10.4)	21 (11.7)
FEV1/FVC (%), mean ± SD	55.2 ± 9.9	55.8 ± 9.7	57 ± 10
FEV1 (%), mean ± SD	61.9 ± 11.4	63.5 ± 10.8	60.4 ± 11.9
FEV1 <60 % pred, *n* (%)	129 (37.0)	59 (33.7)	70 (40.2)
Lung cancer, *n* (%)	283 (78.6)	143 (79)	140 (78.5)
Chemotherapy, *n* (%)	44 (12.2)	23 (12.7)	21 (11.7)
Radiotherapy, *n* (%)	14 (3.8)	8 (4.4)	6 (3.3)
Secondary lung cancer, *n* (%)	22 (6.1)	9 (4.9)	13 (7.2)
Non-malignant, *n* (%)	44 (12.2)	23 (12.7)	21 (11.7)

BMI body mass index, *ASA* American Society of Anesthesiologists, *FEV1* forced expiratory volume, *FVC* forced vital capacity, *pred.* predicted value, *CPAP* continuous positive airway pressure

Table 2 Surgical procedures and postoperative care

Parameters	Overall population ($n = 360$)	Prophylactic NIV group ($n = 181$)	Control group ($n = 179$)
Lobectomy, *n* (%)	208 (57.7)	107 (59.1)	101 (56.4)
Pneumonectomy, *n* (%)	45 (12.5)	24 (13.2)	21 (11.7)
Bilobectomy, *n* (%)	15 (4.1)	8 (4.4)	7 (3.9)
Wedge resection, *n* (%)	87 (24.1)	39 (21.5)	48 (26.8)
Parietal resection, *n* (%)	8 (2.2)	4 (2.2)	4 (2.2)
Bronchial anastomosis, *n* (%)	10 (2.7)	5 (2.7)	5 (2.7)
Per op Vt (ml/kg),mean ± SD			
Before simple lung ventilation, mean ± SD	7.9 ± 1.6	7.9 ± 1.6	7.9 ± 1.5
After simple lung ventilation, mean ± SD	7.5 ± 1.5	7.6 ± 1.6	7.4 ± 1.4
Pplat max (mmHg), mean ± SD			
Before simple lung ventilation, mean ± SD	21.8 ± 6.6	21.8 ± 7.3	21.9 ± 5.9
After simple lung ventilation, mean ± SD	26.9 ± 6.7	27 ± 6.6	26.9 ± 6.8
Duration of anesthesia (min), mean ± SD	225 ± 88	221 ± 85	231 ± 91
Fluid infusion volume (l), mean ± SD	2088 ± 1189	1994 ± 1187	2022 ± 1190
Blood transfusion, *n* (%)	10 (2.7)	5 (2.7)	5 (2.8)
Epinephrine (mg), mean ± SD	10.1	9.5	10.8
Epidural catheter, *n* (%)	33 (9.1)	16 (8.8)	17 (9.4)
Spinal anesthesia	6 (1.6)	2 (1.1)	4 (2.2)
Paravertebral catheter	85 (23.6)	43 (23.7)	42 (23.4)
Opiates dosage after surgery(mg/72H), mean	52	53	51
Pain level evaluation VAS <4 *n* (%) Day 0	204 (56.6)	104 (57.4)	100 (55.8)
Day 1	222 (61.6)	114 (62.9)	108 (60.3)
Day 2	257 (71.3)	130 (71.8)	127 (70.9)
PaO_2 (mmHg) Day 0	103.9	106.5	101
Day 1	90	90.5	89.6
Day 2	82.8	80.8	85.3
$PaCO_2$ (mmHg) Day 0	46.1	46.5	45.6
Day 1	44.5	44.6	44.5
Day 2	43.3	43.3	43.4

Vt tidal volume, *pplat*, plateau pressure

Table 3 Outcomes

Variable	Population ($n = 360$)	NIV group ($n = 181$)	Control group ($n = 179$)	p value
ARE, n (%)	112 (31.1)	57 (31.5)	55 (30.7)	0.93
Acute respiratory failure, n (%)	78 (21.7)	34 (18.8)	44 (24.5)	0.20
IMV, n (%)	9 (2.5)	7 (3.9)	2 (1.1)	0.17
Pneumonia, n (%)	57 (15.8)	29 (16.0)	28 (15.6)	1
Operative site infection, n (%)	14 (3.5)	8 (4.4)	6 (3.4)	0.59
Length of hospital stay (day), mean ± SD	17.3 (35.9)	18.6 (40.7)	16.0 (30.3)	0.27
Mortality, n (%)	13 (3.6)	4 (2.2)	9 (5)	0.16

ARE acute respiratory event defined by at least two of the following criteria: respiratory rate >30/min, PaO_2/FiO_2 <200 mmHg, $PaCO_2$ increase of more than 10 mmHg above baseline postoperative value or a new pulmonary infiltrate on chest X-ray; *IMV* invasive mechanical ventilation; *NIV* non-invasive ventilation

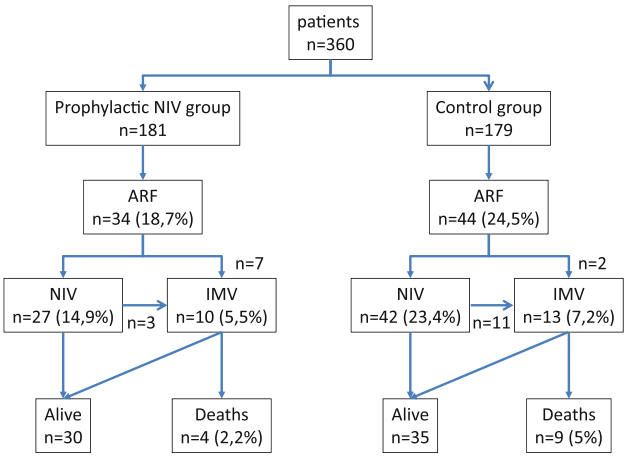

Fig. 2 Acute respiratory failure (ARF) management and outcome. *IMV* invasive mechanical ventilation, *NIV* non-invasive ventilation. Among the 10 reintubated patients in the prophylactic NIV group and he 13 in the control group, 5 and 4, respectively, were reintubated for surgical complications, i.e. 4 post-operative bleeding and 1 sepsis in the NIV group, and 1 bleeding, 1 sepsis, 1 pseudo-occlusion requiring coloscopy, and 1 stroke in the control group

Risk factors associated with ARE in univariate analyses were gender [HR = 2.02 (1.15–3.53); $p = 0.01$), COPD [HR = 1.5 (1.03–2.2); $p = 0.04$], heart disease comorbidity [HR = 1.51 (1.02–2.22); $p = 0.04$), and thoracoscore [HR = 0.01 (1.04–1.31); $p = 0.01$] (see ESM). All these factors were included in the multivariate analysis. The final multivariate Cox model showed that only thoracoscore [HR = 1.18 (1.07–1.29); $p < 0.001$] was independently associated with the occurrence of ARE. There was no significant interaction between the effect of NIV and COPD severity ($p = 0.65$).

Discussion

This randomized controlled study did not demonstrate that early prophylactic NIV after major lung resection surgery in patients with moderate-to-very severe COPD (GOLD II to IV) is able to decrease the rate of ARE. Prophylactic NIV does not decrease the overall rate of ARF, although it decreases the rate of ARF requiring rescue non-invasive ventilatory support. Prophylactic NIV does not decrease the rate of postoperative infectious complications, mortality rate, and duration of hospital stay. Several hypotheses may explain these results.

The first hypothesis relates to the main outcome chosen (somewhat arbitrarily) for the study, ARE. This composite endpoint includes clinical, biological, and radiological signs of pulmonary complications. Importantly, an independent blind committee reviewed all patients' charts and validated ARE according to a strict pre-specified definition. Other studies [17, 18, 19] investigating prophylactic NIV after extubation in at-risk patients used ARF and re-intubation rates as endpoints. In our study, prophylactic NIV significantly decreased the rate of ARF requiring rescue NIV. Intubation rates were similar between groups, and rather low. This confirms once again that, in patients with ARF after lung resection surgery, NIV is able to avoid intubation in many cases [10, 11].

The second hypothesis involves the selection of our study population. We aimed at including mild to very severe COPD patients according to the GOLD classification of severity of airflow obstruction [20], yet anticipated very small numbers of patients with very severe and even severe COPD. Actually, 63 % of the enrolled patients had moderate preoperative airflow obstruction (FEV_1 >60 % predicted value). An observational study [21] found that, besides age, cardiovascular diseases, and the extent of lung resection, a preoperative FEV_1 below 60 % is a major predictor of perioperative mortality and respiratory morbidity. Perrin et al. [13] showed that perioperative NIV reduced postoperative lung function impairment and the duration of hospital stay in 39 COPD patients undergoing lung resection. In this study, the severity of airway obstruction was more pronounced (mean FEV_1: 54 % predicted value) than in our study (mean FEV_1: 62 % predicted value). Indeed,

univariate analysis found an association between COPD severity and occurrence of ARE [RR 1.50 (1.03–2.20), $p = 0.04$]. However, there was no significant interaction between COPD severity and NIV effect, which might in part relate to a lack of power, due to the low number of patients with severe COPD.

The third hypothesis relates to NIV application methods. Prophylactic NIV was not applied immediately after extubation, as the mean time between extubation and NIV initiation was more than 4 h; this could have decreased its efficacy. Zoremba et al. [22], in a randomized study, found that early initiation of short-term NIV in the recovery room promotes more rapid recovery of postoperative lung function (measured by inspiratory and expiratory spirometry, four times during the first 24 h) and oxygenation in obese patients. In this study, the effect lasted 24 h after discontinuation of NIV.

The intermittent application of NIV, only six 1-h periods a day, may be insufficiently effective in preventing respiratory complications. Continuous application of NIV might have been more efficient. In the randomized controlled study by Ferrer et al. [23], continuous application of NIV immediately after extubation reduced the risk of respiratory failure and lowered 90-day mortality in patients with hypercapnia during a spontaneous breathing, weaning trial.

Prophylatic NIV settings may also have been suboptimal in some cases. In our study, since we were applying preventive NIV (to patients without respiratory failure), the initial inspiratory pressure was set at 8 cm of H_2O, i.e. only 4 cm of H_2O above PEP level. This initial setting was chosen to avoid deleterious effects of high volume or high pressure [24]. In COPD patients, the use of higher levels of inspiratory pressure may lead to a greater clinical and arterial blood gases improvement [13, 25].

Strengths and limitations of the study

The main strengths of this study are its multicenter prospective randomized controlled nature and the 30-day clinical follow-up after surgery. It must be mentioned that the choice of ARE as a primary endpoint was somehow arbitrary, and was guided by the need for a sufficiently frequent event with clinical relevance. One limitation could be an insufficient power, related to a too small number of enrolled subjects: the target used for calculation of the number of patients needed to be randomized was a 50 % reduction of event rate in the prophylactic NIV versus the control group. This may have been over-optimistic, in part explaining the lack of significance of the results. In addition, some statistical power was likely lost due to the 24 % of patients from the control group who received rescue NIV. An imbalance in the occurrence of complications other than isolated ARF requiring IMV could also have influenced the results. Among the 10 reintubated patients in the prophylactic NIV group and the 13 in the control group, 5 and 4, respectively, were reintubated for reasons other than isolated ARF. Exploratory analyses with mechanical ventilation as an outcome were performed after exclusion of these cases and found results similar to the original analyses (data not shown).

Finally, none of the analyzed population received all the planned prophylactic NIV sessions (5 patients did not receive NIV at all and prophylactic NIV was stopped at 48 h in 10 others). However, per protocol analysis provide the same results as the ITT analysis (data not shown).

Conclusion

This study does not support the use of prophylactic NIV in all COPD patients undergoing lung resection surgery. However, prophylactic use of optimized NIV following lung resection may be beneficial in a subset of COPD patients with more severe airflow obstruction.

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Conflicts of interest None of the authors has any conflict of interest relevant to this study.

Appendix: POPVNI trial group

Participating centers

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