Noninvasive Ventilation Improves Preoxygenation before Intubation of Hypoxic Patients

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Rationale: **Critically ill patients are predisposed to oxyhemoglobin desaturation during intubation.**

Objectives: **To find out whether noninvasive ventilation (NIV), as a preoxygenation method, is more effective at reducing arterial oxyhemoglobin desaturation than usual preoxygenation during orotracheal intubation in hypoxemic, critically ill patients.**

Methods: **Prospective randomized study performed in two surgical/medical intensive care units (ICUs). Preoxygenation was performed, before a rapid sequence intubation, for a 3-min period using a nonrebreather bag-valve mask (control group) or pressure support ventilation delivered by an ICU ventilator through a face mask (NIV group) according to the randomization.**

Measurements and Main Results: **The control (n = 26) and NIV (n = 27) groups were similar in terms of age, disease severity, diagnosis at admission, and pulse oxymetry values (Sp_{O_2}) before preoxygenation. At the end of preoxygenation, Sp_{O_2} was higher in the NIV group as compared with the control group (98 ± 2 vs. 93 ± 6%, $p < 0.001$). During the intubation procedure, the lower Sp_{O_2} values were observed in the control group (81 ± 15 vs. 93 ± 8%, $p < 0.001$). Twelve (46%) patients in the control group and two (7%) in the NIV group had an Sp_{O_2} below 80% ($p < 0.01$). Five minutes after intubation, Sp_{O_2} values were still better in the NIV group as compared with the control group (98 ± 2 vs. 94 ± 6%, $p < 0.01$). Regurgitations (n = 3; 6%) and new infiltrates on post-procedure chest X ray (n = 4; 8%) were observed with no significant difference between groups.**

Conclusion: **For the intubation of hypoxemic patients, preoxygenation using NIV is more effective at reducing arterial oxyhemoglobin desaturation than the usual method.**

Keywords: continuous positive airway pressure; intubation; preoxygenation

In the intensive care unit (ICU), respiratory failure is a common problem. Airway management in critically ill patients usually requires orotracheal intubation. Complications associated with this procedure are more frequently encountered in this setting than in scheduled surgery in the operating room (1, 2). Approximately 10 to 30% of rapid sequence intubations are associated with transient oxyhemoglobin desaturation ($Sp_{O_2} < 90\%$) (3–5). Moreover, profound oxyhemoglobin desaturation ($Sp_{O_2} < 70\%$) is encountered in 2% of such procedures (4) and these desaturations have been shown to increase mortality in specific populations (5, 6).

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Usual preoxygenation (≥ 3 min of normal tidal volume ventilation with bag and mask with 100% O_2) is recommended and effective in delaying arterial desaturation during the apnea related to endotracheal intubation (ETI) procedures (7, 8). Under optimal circumstances and in healthy patients, preoxygenation, by maximizing denitrogenation, prevents arterial desaturation during ETI and reduces the need for subsequent oxygen support. However, emergency intubation in critically ill patients occurs in quite different circumstances. During apnea, the time course of oxyhemoglobin desaturation to below 85% is only 23 s in a typical critically ill postoperative patient, whereas it is 502 s in a healthy adult (9). Also, Adnet and colleagues (1) have shown that, in emergency conditions, both the difficulty and the time necessary to complete intubation are increased as compared with a scheduled procedure. More recently, it has been shown that usual preoxygenation appeared marginally effective in critically ill patients (10). As a result, there is a need to optimize the technique of preoxygenation to prolong the safe duration of apnea during the intubation procedure in critically ill patients.

Within the ICU, noninvasive ventilation (NIV) is widely used because it can reduce the need for intubation in selected populations (11–14). About 30 to 40% of patients are under NIV when the medical decision to initiate invasive ventilation is made (14–18). It has been shown that continuous positive airway pressure (CPAP) is effective in increasing the efficiency of gas exchange and in reducing the decrease in oxyhemoglobin saturation during fiberoptic bronchoscopy in hypoxemic patients (19). Some authors (8, 15, 20) have suggested the potential benefit of positive-pressure ventilation by CPAP for preoxygenating patients before intubation. To date, no study has evaluated using NIV in the pressure support mode (PSV) with positive end-expiratory pressure (PEEP) as a preoxygenation method in critically ill patients.

Therefore, our aim was to ascertain whether NIV, as a preoxygenation method, is more effective at reducing arterial oxyhemoglobin desaturation than usual preoxygenation in hypoxemic, critically ill patients requiring tracheal intubation for invasive ventilation in the ICU. Some of the results of these studies have been previously reported in the form of abstracts (21, 22).

METHODS

The study design was approved by the local ethics committee (Comité de Protection des Personnes dans la Recherche Biomédicale), and informed consent was obtained from the patient or from the patient's next of kin or legal representative. Because of the emergency conditions, delayed consent from patients or family was authorized. The investigators generated a random-number table on a computer, used the table to prepare envelopes for random patient allocation, and enrolled the patients. The envelopes were opaque, sealed, and numbered to ensure concealment and sequential use.

Study Population

Adults patients were recruited in two medicosurgical ICUs of two French university hospitals and considered eligible if they met two criteria: (*1*) acute respiratory failure requiring intubation and (*2*) hypoxemia, defined

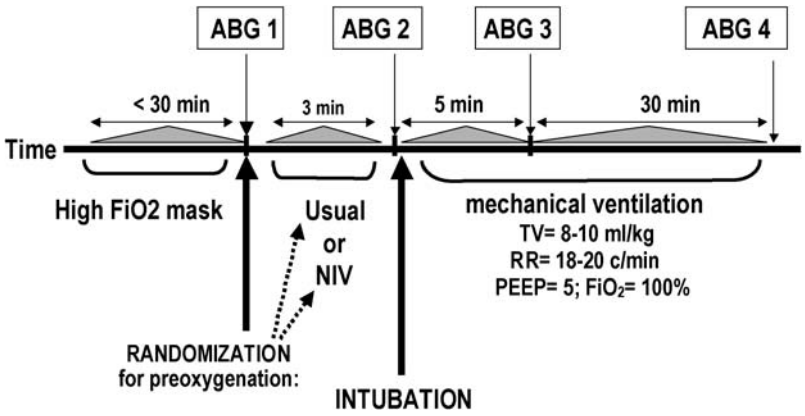

Figure 1. Design of the study. During the inclusion period, the patients were randomized to a control or noninvasive ventilation (NIV) group. Clinical parameters were recorded and arterial blood gases (ABG 1) were sampled just (1–2 min) before preoxygenation. Preoxygenation was performed for a 3-min period. A second ABG measurement was performed (ABG 2), then the anesthetic drugs were administered and the trachea was intubated immediately after 60 s. After oral intubation, the patient was mechanically ventilated with usual settings and a third and fourth ABG measurement were performed (ABG 3 and ABG 4) at 5 and 30 min, respectively, after the intubation procedure. PEEP = positive end-expiratory pressure; RR = respiratory rate; TV = tidal volume.

by a Pa_{O_2} less than 100 mm Hg under a high $F_{I_{O_2}}$ mask driven by 10 L/min oxygen. Encephalopathy or coma, cardiac resucitation, and hyperkaliemia (> 5.5 mEq/L) were the exclusion criteria. Intubation was performed after failure of either oxygen supplementation alone or noninvasive respiratory support. A patient who received an ineffective trial of NIV before enrollment into the study was removed from NIV and then again placed on face-mask oxygen before preoxygenation was again attempted.

Study Design and Measurements

The design of the study is shown in Figure 1 and is very similar to that used by Maitre and colleagues (19). During the inclusion period (at least 10 min and maximum 30 min), the patients wore a high $F_{I_{O_2}}$ mask, driven by 10 to 15 L/min oxygen, and were randomly assigned to a control or NIV group. Preoxygenation was then performed for a 3-min period before standardized rapid-sequence intubation. For the control group, preoxygenation was performed using a nonrebreather bag-valve mask driven by 15 L/min oxygen. Patients were allowed to breath spontaneously with occasional assistance (usual preoxygenation method). For the NIV group, PSV was delivered by an ICU ventilator (Evita IV ventilator; Dräger, Lübeck, Germany; or Servo 300; Siemens, Solna, Sweden) through a face mask (Airvie; Péters, Bobigny, France) adjusted to obtain an expired tidal volume of 7 to 10 ml/kg. The $F_{I_{O_2}}$ was 100% and we used a PEEP level of 5 cm H_2O.

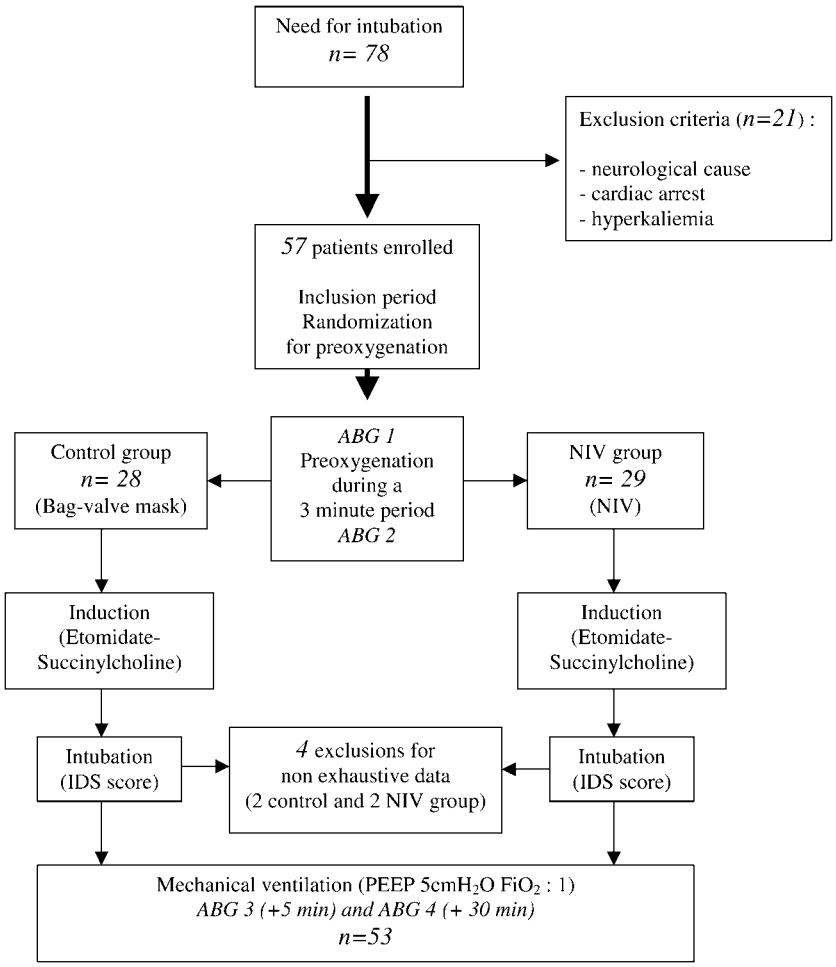

Figure 2. Between October 2004 and February 2005, 78 patients needed orotracheal intubation. Twenty-one patients were intubated for reasons other than acute respiratory failure. Consequently, 57 consecutive patients who fulfilled the study inclusion criteria were enrolled. Four patients were not included for the analysis because of the lack of exhaustive data (two patients in each group). Thus, 26 and 27 patients were evaluated in the control and NIV groups, respectively. IDS = Intubation Difficulty Scale.

TABLE 1. CHARACTERISTICS OF STUDY PATIENTS BEFORE PREOXYGENATION

	Control (*n* = *26*)	NIV (*n* = *27*)	p Value
Age, yr	60 ± 15	64 ± 11	0.1
Sex, F/M	7/19	10/17	0.6
Height, cm	172 ± 10	169 ± 9	0.2
Weight, kg	74 ± 14	72 ± 21	0.7
COPD, n (%)	6 (23)	7 (26)	0.9
SAPS II	51 ± 15	49 ± 14	0.8
Knauss class, A/B/C/D, n	4/9/9/4	4/9/11/3	0.8
MacCabe score, 1/2/3, n	7/12/7	7/11/9	0.7
Diagnosis			0.9
Pneumonia, n (%)	17 (65)	19 (70)	
CPE, n (%)	5 (19)	4 (15)	
Miscellaneous, n (%)	4 (15)	4 (15)	
Heart rate,* beat/min	105 (91–123)	113 (99–127)	0.3
Systolic arterial pressure, mm Hg	138 (114–155)	130 (115–159)	0.8
O_2 supply,* L/min	15 (10–15)	15 (11–15)	0.2
Blood gases*			
Pa_{O_2}, mm Hg	68 (60–79)	60 (57–89)	0.9
Pa_{CO_2}, mm Hg	53 (37–74)	49 (29–66)	0.3
BE, mmol/L	27 (22–32)	25 (19–29)	0.3
pH	7.31 (7.28–7.40)	7.31 (7.24–7.44)	0.6
Sa_{O_2}, %	92 (87–94)	91 (85–96)	0.8

Definition of abbreviations: BE = base excess; COPD = chronic obstructive pulmonary disease; CPE = cardiogenic pulmonary edema; SAPS II = Simplified Acute Physiologic Score.

The data are means ± SD, medians (interquartile range), or absolute numbers (%).

* Data were checked just before (1–2 min) the preoxygenation procedure.

Standardized rapid-sequence intubation was performed by a senior physician (etomidate, 0.3 mg/kg; succinylcholine, 1 mg/kg; laryngoscopy with a Macintosh size 3 or 4 blade, and cricoid pressure to secure the airway). After oral intubation, the patient was mechanically ventilated, with a tidal volume of 8 to 10 ml/kg, a respiratory rate of 20 breaths/min, a PEEP of 5 cm H_2O, and an $F_{I_{O_2}}$ of 100%.

Pulse oxymetry (Sp_{O_2}) was continuously monitored throughout the procedure (Oxypleth 520A; Novametrix, Wallingford, CT). Arterial blood gases were sampled just before (1–2 min) and after preoxygenation and 5 and 30 min after intubation, and analyzed using an ABL 520 analyzer (Radiometer, Copenhagen, Denmark).

The intubation conditions were reported using the intubation difficulty scale (1). Adverse events were defined as regurgitation (presence of gastric content seen during laryngoscopy), new infiltrate on post-ETI procedure chest X ray, and Sp_{O_2} less than 80% during the intubation procedure.

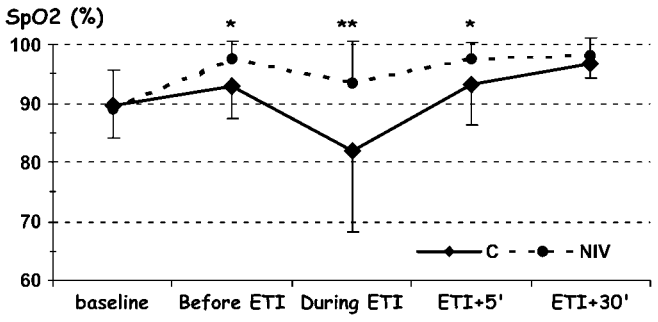

Figure 3. Variation in mean Sp_{O_2} during preoxygenation and intubation (endotracheal intubation [ETI]). Sp_{O_2} is shown for the five steps of the study: (*1*) Before preoxygenation (i.e., baseline), when the patients are breathing with a mean of 13 L/min of O_2 supply; (*2*) after 3 min of preoxygenation with either NIV or the usual method (C) according to the randomization (i.e., before ETI); (*3*) the minimal value during ETI; (*4*) 5 min after ETI; and (*5*) 30 min after ETI. *Solid line*: control (C) group; *dotted line*: NIV group. *$p < 0.05$, **$p < 0.01$, comparison between the two groups at the same point.

Endpoints and Statistical Analysis

The primary endpoint was the mean drop in Sp_{O_2} during ETI. We used data from the study performed by our group (15). In this study, in the hypoxemic patients, Sp_{O_2} during ETI was 82 ± 12%. We calculated that at least 25 patients would be required in each group to allow the detection of a 5% difference in the mean Sp_{O_2} during ETI, assuming an α risk of 0.05 and a β risk of 0.8. The secondary endpoints were Pa_{O_2} at 5 and 30 min after ETI. Nonparametric data were analyzed using Mann-Whitney U tests. For nominal data, we used χ^2 analysis or Fisher's exact test, as appropriate. Data are expressed as median values (with the interquartile range) or as means ± SD. All statistics were performed using SAS version 6.12 (SAS Institute, Cary, NC). p values of less than 0.05 were considered statistically significant.

RESULTS

Characteristics of the Population before Preoxygenation

Between October 2004 and February 2005, 78 patients needed orotracheal intubation (Figure 2). Twenty-one patients were

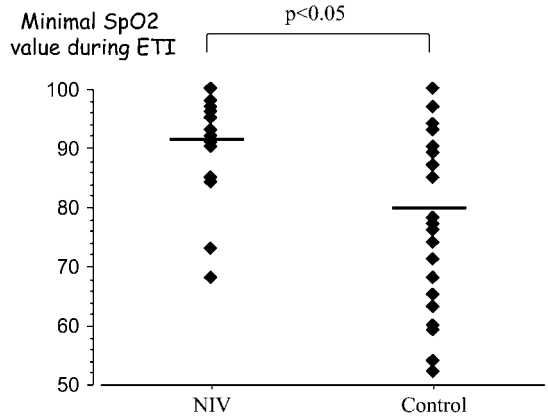

Figure 4. Minimal Sp_{O_2} values recorded during ETI. *Thick lines* represent the lowest mean Sp_{O_2} values recorded in each group of patients. NIV (n = 27) and control (n = 26).

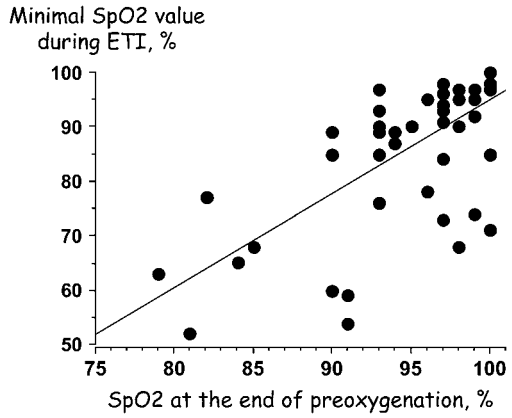

Figure 5. Correlation between the minimum Sp_{O_2} values during ETI and Sp_{O_2} values obtained at the end of preoxygenation (n = 53, $r^2 = 0.46$; $p < 0.001$).

intubated for reasons other than acute respiratory failure (e.g., neurologic causes, cardiac arrest). Consequently, 57 consecutive patients who fulfilled the study inclusion criteria were enrolled (none refused to participate). Four patients were not included for the analysis because of lack of exhaustive data (two patients in each group). Thus, 26 and 27 patients were evaluated in the control and NIV groups, respectively (Avicenne: control, n = 12; NIV, n = 12; Montpellier: control, n = 14; NIV, n = 15). The baseline characteristics of the two groups were similar in term of age, disease severity, organ failures, and diagnosis on admission (Table 1). Arterial blood gases and oxygen supply also did not differ between the two groups. Before inclusion, 15 and 16 patients in the control and NIV groups, respectively, had received at least one ineffective trial of NIV for first-line treatment of acute respiratory failure. There were no differences in patient characteristics between the Avicenne hospital (n = 24) and the Montpellier hospital (n = 29; data not shown).

TABLE 2. BLOOD GASES VALUES AFTER PREOXYGENATION, 5 AND 30 MINUTES AFTER ENDOTRACHEAL INTUBATION

Blood Gases	Control (*n = 26*)	NIV (*n = 27*)	p Value
After preoxygenation			
Pa_{O_2}, mm Hg	97 (66–163)	203 (116–276)	0.01*
Pa_{CO_2}, mm Hg	49 (39–59)	44 (34–67)	0.9
BE, mmol/L	24 (22–28)	23 (19–29)	0.35
Sa_{O_2}, %	97 (85–100)	99 (98–100)	0.031*
pH	7.29 (7.25–7.39)	7.29 (7.23–7.41)	0.97
5 min after ETI			
Pa_{O_2}, mm Hg	124 (70–183)	160 (123–299)	0.03*
Pa_{CO_2}, mm Hg	48 (44–57)	42 (38–66)	0.9
BE, mmol/L	25 (20–28)	22 (20–28)	0.38
Sa_{O_2}, %	97 (93–99)	98 (97–100)	0.04*
pH	7.30 (7.25–7.36)	7.27 (7.25–7.36)	0.76
30 min after ETI			
Pa_{O_2}, mmHg	137 (82–180)	151 (144–247)	0.01*
Pa_{CO_2}, mmHg	44 (36–48)	47 (37–52)	0.4
BE, mmol/L	22 (20–27)	24 (21–26)	0.4
Sa_{O_2}, %	97 (94–99)	99 (98–100)	0.04*
pH	7.36 (7.29–7.41)	7.32 (7.27–7.37)	0.48

Definition of abbreviations: BE = base excess; NIV = noninvasive ventilation.

Comparison between control and NIV groups. The data are medians (interquartile range).

* $p < 0.05$.

Pulse Oxymetry and Arterial Blood Gas Monitoring

Changes in mean Sp_{O_2} values during the entire procedure are shown in Figure 3. After preoxygenation, Sp_{O_2} increased in the control group from 90 ± 5% to 93 ± 6%, and in NIV group from 89 ± 6% to 98 ± 2% ($p < 0.05$). Preoxygenation did not improve Sp_{O_2} in six patients receiving the usual method, whereas Sp_{O_2} increased in all patients in the NIV group ($p = 0.03$). At the end of preoxygenation, Sp_{O_2} was statistically higher in the NIV group as compared with the control group ($p < 0.05$). During intubation, the difference between the two groups was more pronounced for minimal Sp_{O_2} values (93 ± 8% vs. 81 ± 15%, $p < 0.001$; Figure 3). Twelve patients in the control group and two in the NIV group had an Sp_{O_2} below 80% during ETI ($p < 0.01$; Figure 4). The minimal Sp_{O_2} values observed during ETI correlated with the Sp_{O_2} values obtained at the end of preoxygenation ($p < 0.001$; Figure 5). The difference in Sp_{O_2} values persisted 5 min after ETI (98 ± 2% vs. 94 ± 6%, $p < 0.01$). Thirty minutes after ETI, Sp_{O_2} was still higher in the NIV group but did not reach statistical significance (98 ± 3% vs. 97 ± 3%, $p = 0.09$).

Changes in mean Pa_{O_2} values are shown in Table 2. After preoxygenation, the increase in Pa_{O_2} was not significant in the control group (68 [60–79] vs. 97 [66–163] mm Hg, $p = 0.08$), whereas Pa_{O_2} increased significantly in the NIV group (60 [57–89] vs. 203 [116–276] mm Hg, $p < 0.001$). At the end of preoxygenation, Pa_{O_2} was statistically higher in the NIV group as compared with the control group ($p = 0.01$), and this difference persisted at 5 and 30 min after ETI (124 [70–183] vs. 160 [123–299] mm Hg, $p = 0.03$, and 137 [82–180] vs. 151 [144–247] mm Hg, respectively; $p = 0.01$).

Preoxygenation and ETI Procedure Description

The description of preoxygenation and ETI procedures is shown in Table 3. The mean level of PSV was 12 ± 2 cm H_2O in the NIV group. Eight patients (31%) in the control group and one (4%) in the NIV group were unable to maintain Sp_{O_2} of more than 92% during the preoxygenation procedure ($p = 0.02$). In 12 patients (23%), two or three ETI attempts were needed, and the intervention of another skilled operator was required in six patients (11%), with no difference between groups (Table 3). Intubation difficulty scale results are shown in Table 3. Slight to major difficulties were observed in eight (31%) and nine patients (33%) in the control and NIV groups, respectively ($p = 0.8$).

ETI-related Complications and Outcome

The incidence of ETI-related complications and outcome is reported in Table 4. Twelve patients (46%) in the control group and two (7%) in the NIV group had an Sp_{O_2} below 80% during ETI ($p < 0.01$; Figure 4). Regurgitation occurred in three patients (6%) and a new infiltrate on post-procedure chest X ray in four patients (7%), with no significant difference between groups (Table 4). Duration of mechanical ventilation, ICU length of stay, and ICU mortality were not different between groups.

DISCUSSION

The present study proposes for the first time preoxygenation using the NIV technique. The results have shown that this approach is safe and more effective in providing oxygenation and preventing arterial oxyhemoglobin desaturation than the usual method of preoxygenation during ETI in critically ill patients. We found that, despite similar baseline characteristics and oxygenation, NIV was more effective than the usual method in reducing the decrease in Sp_{O_2} and allowed enhancement of Pa_{O_2} up to 30 min after ETI.

TABLE 3. PREOXYGENATION AND ENDOTRACHEAL INTUBATION PROCEDURE DESCRIPTION

	Control (*n* = 26)	NIV (*n* = 27)	p Value
Preoxygenation			
Inability to maintain $Sp_{O_2} \geq 92\%$	8 (31)	1 (4)	0.02†
Intubation			
Number of attempts			0.3
One	19 (70)	22 (81)	
Two	6 (23)	5 (19)	
Three	1 (4)	0	
Intervention of another skilled operator	4 (15)	2 (7)	0.2
Cormack and Lehane classification			0.8
1	18 (69)	18 (67)	
2	4 (15)	3 (11)	
3	2 (8)	5 (19)	
4	2 (8)	1 (4)	
IDS*			0.8
Easy (0)	18 (69)	18 (67)	
Slight difficulty (IDS ≤ 5)	6 (23)	7 (26)	
Moderate to major difficulty (IDS > 5)	2 (8)	2 (8)	

Definition of abbreviations: IDS = Intubation Difficulty Scale; NIV = noninvasive ventilation.

The data are absolute numbers (%).

* Score taking into account the number of attempts, operator, alternative technique, the Cormack grade, the lifting force required, the need for laryngeal pressure, and the vocal cord mobility (1).

† $p < 0.05$.

Preoxygenation in Critically Ill Patients

Preoxygenation before intubation increases the maximum amount of time that a patient can tolerate the related apnea. In critically ill patients with oxygen transport limitations (2, 8, 19) and suspected time-consuming airway management, maximal preoxygenation is strongly indicated (2, 8, 20). In addition, when invasive ventilation is initiated to manage acute respiratory failure, the underlying lung disease (i.e., limited alveolar volume and enhanced shunt fraction) limits *per se* the efficiency of preoxygenation. As a result, hemoglobin desaturation is a well-known complication in this population (2, 4, 8, 20, 23, 24). In our study, the incidence of oxyhemoglobin desaturation below 80% was observed in 14 among 53 studied patients (Figure 4). In contrast with the NIV group, preoxygenation was ineffective in improving Sp_{O_2} in 6 of 26 patients receiving the usual method. This study confirms that preoxygenation does not always protect critically ill patients against hemoglobin desaturation during intubation.

NIV Technique

NIV has been proposed for several applications in the ICU, such as for avoiding endotracheal intubation and facilitation of weaning and extubation. To our knowledge, the use of NIV in the preoxygenation procedure has never been described. There is no delay that would limit the use of NIV for the purpose of preoxygenation because the need for ventilator equipment is usually anticipated in hypoxemic patients. Interruption of preoxygenation with NIV due to intolerance of the technique was not required in this study. These results argue against a limitation of NIV, used as a preoxygenation method, in this population of patients.

Critically ill patients are usually considered to have a full stomach. Positive-pressure ventilation may increase gastric air content and hence may promote pulmonary aspiration during an ETI procedure. The risk exists with an insufflation pressure of greater than 20 cm H_2O, which can be easily obtained using manual ventilation (25, 26). In our present study, NIV was used in a pressure-limited mode, which allowed for precise control of the insufflation pressure (PSV + PEEP levels). None of the NIV group of patients received an insufflation pressure of more than 20 cm H_2O.

In addition, pulmonary aspiration of gastric contents during ETI is frequently encountered in this clinical setting (2). In our study, regurgitation was observed in three patients and new infiltrate was present on the chest radiograph obtained after intubation in four patients. NIV did not increase regurgitation or new infiltrates.

NIV effect on oxygenation and outcome. In acute respiratory failure, similarly to invasive ventilation, NIV improves oxygenation by delivering high oxygen concentration, by unloading respiratory muscle, by recruiting alveoli, and by increasing lung volumes (10). Few data are available regarding the time necessary to improve oxygenation. In the study of Rasanen and

TABLE 4. ENDOTRACHEAL INTUBATION–RELATED COMPLICATIONS AND OUTCOME

	Control (*n* = 26)	NIV (*n* = 27)	p Value
$Sp_{O_2} < 80\%$	12 (46)	2 (7)	< 0.01
Regurgitation, n (%)	2 (8)	1 (4)	1
New infiltrate on post-ETI procedure chest X ray, n (%)	3 (12)	1 (4)	0.55
Duration of mechanical ventilation, d	10 (7–16)	9 (6–17)	0.89
ICU length of stay, d	17 (12–23)	18 (11–26)	0.92
ICU mortality, n	13 (50)	8 (30)	0.21

Definition of abbreviations: ETI = endotracheal intubation; ICU = intensive care unit; NIV = noninvasive ventilation.

The data are medians (interquartile range), or absolute numbers (%).

$p < 0.05$.

colleagues (27) and in others (28, 29), CPAP rapidly (10 min) improved oxygenation in patients with cardiogenic pulmonary edema. In the present study, 3 min of NIV significantly increased Pa_{O_2} and Sp_{O_2} as compared with usual preoxygenation. This clinical study did not allow for monitoring end-tidal oxygen concentration (FE_{O_2}). Nevertheless, we postulate that the significant improvement in oxygenation observed after 3 min of preoxygenation using NIV was mainly attributable to the high delivered oxygen concentration and to the recruitment of collapsed alveoli. Thus, in hypoxemic patients in a supine position, NIV probably increased FRC by recruiting collapsed alveoli, thereby allowing for an increase in the reserves of oxygen held within the body. This hypothesis is supported by the fact that only two patients in the NIV group had an Sp_{O_2} lower than 80% during ETI compared with 12 patients in the control group (Figure 4).

The beneficial effect on Pa_{O_2} was still observed 30 min after ETI in patients who received NIV during preoxygenation. One explanation could be the residual effect of NIV in recruiting alveoli and increasing lung volume before ETI (30).

The design of this study did not allow us to determine whether the minimal alteration on Sp_{O_2} and gas exchange in the patients in the NIV group improves outcome. Further studies are needed to clarify the potential benefits of NIV as a preoxygenation method on morbidity/mortality.

Monitoring Preoxygenation

In this study, Sp_{O_2} values obtained after preoxygenation were correlated with the minimal Sp_{O_2} value during the ETI procedure. However, a high Sp_{O_2} value (i.e., above 98%) before ETI did not predict safe airway management (Figure 5). This implies that Sp_{O_2}, as a preoxygenation monitoring, is required but is not totally sufficient to ensure adequate oxygenation during subsequent ETI. During preoxygenation, arterial hemoglobin saturation increases without relationship to total body oxygen stores (31). The limitations of pulse oxymetry monitoring in this setting have been reported previously (9, 31, 32).

Study limitations. Because our study could not be blinded, we chose instead to minimize bias by distancing the investigators from making clinical decisions about the included patients. However, there were unavoidable circumstances in which study investigators were part of the primary clinician teams caring for study participants. Although characteristics were similar between the subgroup of patients receiving (n = 31) and not receiving (n = 22) at least one NIV trial before the inclusion period, this may have influenced the results. Also, the number of patients is small and the results are limited to the spectrum of causes of acute respiratory failure presented in this study. The study presents a novel approach to preoxygenation that has not been previously reported. However, it is uncertain that this approach will improve clinical outcomes, and additional studies are warranted to determine its role, technique for application, and impact on important clinical outcomes.

Conclusions

In critically ill patients, NIV applied during 3 min before ETI ensured better Sp_{O_2} and Pa_{O_2} values during tracheal intubation as compared with the usual preoxygenation method. In contrast to NIV, usual preoxygenation was unable to improve Sp_{O_2} in all the patients. Further studies are needed to confirm the benefits of NIV use for preoxygenation in selected patients as a new indication of NIV.

Conflict of Interest Statement: None of the authors has a financial relationship with a commercial entity that has an interest in the subject of this manuscript.

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