Role of noninvasive ventilation in decreasing the length of postextubation ICU stay

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Background Respiratory failure after a planned extubation is reported to be a common event, leading to reintubation. These reintubated patients have higher morbidity, mortality, hospitalization charges, and an increased length of hospital stay.

Aim of the study The aim of this study was to assess the role of noninvasive ventilation (NIV) in decreasing the length of postextubation ICU stay.

Results Fifty-six patients with respiratory failure type II were included in our study after exclusion of four patients who had self-extubation. Twenty-six patients were allocated to the NIV group and 26 to the control group. Physiological variables of the patients 1 h after the trial were mainly significantly better in the NIV group than in the standard medical treatment (SMT) group. Trial duration was significantly shorter in the NIV group than in the SMT group.

Conclusion This supports the use of NIV early after extubation in all patients regardless of risk for respiratory failure. *Egypt J Broncho* 2016 10:173-178

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Introduction

Acute respiratory failure (ARF) in chronic obstructive pulmonary disease (COPD) generally marks a serious change in clinical state and is a frequent cause of admissions to the emergency and/or ICUs. Even more, ARF is also associated with excess mortality both during the hospital stay and in the months following discharge from the hospital [1]. The long-term prognosis of patients with COPD and ARF particularly worsens if their clinical state calls for a ventilatory support, irrespective of whether this is applied invasively or noninvasively [2].

Noninvasive ventilation (NIV) is a broad term for any ventilation therapy applied in a noninvasive manner – for example, through a mask, nasal prongs, or a helmet. This is in contrast to 'invasive ventilation', in which an endotracheal tube or a tracheal canula serves as an invasive interface between the patient and the ventilator. NIV can be used either before intubation or following extubation. Ideally, the entire spectrum of ventilation therapy (prevent, stabilize, wean, and recover) can be adequately covered using NIV [3].

NIV may be somewhat more labor-intensive compared with conventional invasive ventilation, but has benefits such as reduced length of stay on the ICU [4], shorter ventilation times, and the lower incidence of nosocomial pneumonia. Their subsequent positive effects in terms of both cost and outcome can make NIV well worth the effort [5].

All patients should be closely monitored following extubation. In many patients, early aggressive management with oxygenation and airway clearance can prevent reintubation. This may include suctioning, bronchodilator therapy, diuresis, or noninvasive positive pressure ventilation (NPPV) [6].

Patients most likely to benefit from the early application of NPPV following extubation include those with COPD, especially those who have compensated hypercapnia during their pre-extubation spontaneous breathing trial. In addition, a trial of NPPV is reasonable in patients if impending acute hypercapnic respiratory failure develops soon after extubation. Patients should be promptly intubated if they either fail the trial of NPPV or develop definitive ARF before the trial of NPPV can be initiated [7].

Aim of the work

The aim of this study was to assess whether early application of NIV, immediately after extubation, is effective in decreasing the length of postextubation ICU stay in patients with respiratory failure type II.

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Patients and methods

The study was conducted in three respiratory ICUs, Kasr Al-Ainy, El-Mehalla Chest, and El-Abbassia Chest Hospitals, during the period from December 2012 to October 2014.

Inclusion criteria

Patients with respiratory failure type II who required intubation and ventilator support for more than 48 h were screened.

Exclusion criteria

Exclusion criteria were as follows: coma, cervical spine injury, neuromuscular diseases, agitation or uncooperative state, anatomical abnormalities interfering with mask fit, uncontrolled cardiac ischemia or arrhythmias, recent facial surgery, or active upper gastrointestinal bleeding.

Data of the patients

Sociodemographic and clinical data were analyzed, which included age (years), sex (M/F), smoking (pack/year), Acute Physiology and Chronic Health Evaluation-II (APACHE-II) score on admission, APACHE-II score at entry into the study, other comorbidities (chronic heart disorders, immunosuppression, diabetes mellitus, liver cirrhosis, neoplasm, and chronic renal failure), previous use of NIV in hospital, previous intubation and mechanical ventilation (days), causes of mechanical ventilation (pneumonia, congestive heart failure, neurological disease, sepsis, postoperative respiratory failure, etc.).

Physiological variables of patients at entry into the study were recorded and analyzed: respiratory frequency (breaths/min), heart rate (beats/min), systolic blood pressure (mmHg), arterial pH, $PaCO_2$ (mmHg), and PaO_2 (mmHg).

Follow-up with ABG analysis once a day at 8 a.m. Changes either in the ventilatory settings and/or in the FiO_2 at the time of reintubation and at discharge from the ICU were assessed.

Patients who met the weaning criteria and passed a 2-h T-piece SBT were enrolled.

Weaning criteria [8]

(1) Improvement or resolution of the underlying cause of ARF.
(2) Correction of arterial hypoxemia [partial pressure of arterial oxygen (PaO_2)>60 mmHg at a fraction of inspired O_2 (FiO_2)<0·4 and positive end-expiratory pressure<5 cmH_2O].
(3) Absence of fever (>38°C) or hypothermia (<35°C).
(4) Blood hemoglobin concentration of 70 g/l or more.
(5) Hemodynamic stability.
(6) Alertness and ability to communicate.

Data for arterial blood gases were obtained before and at the end of the T-piece trial.

Weaning failure

Spontaneous breathing trial failure was defined as the presence and persistence of one of the following criteria:

(1) Respiratory frequency greater than 35 breaths/min.
(2) Arterial O_2 saturation using pulse-oximetry less than 90% at FiO_2 of 0.4 or more.
(3) Heart rate more than 140 beats/min or less than 50 beats/min.
(4) Systolic blood pressure greater than 200 mmHg or less than 70 mmHg.
(5) Diminished consciousness, agitation, or diaphoresis.
(6) Clinical signs suggestive of respiratory muscle fatigue, increased work of breathing, or both, such as the use of respiratory accessory muscles, paradoxical motion of the abdomen, or retraction of the intercoastal spaces [9].

Those who fulfilled the inclusion and exclusion criteria and were able to tolerate the spontaneous breathing trial with no signs of respiratory failure observed after 120 min were enrolled. The patients were randomized into either group: one group received standard medical treatment (SMT) in the form of oxygen therapy and served as the control group, and the other group received NIV and was the case group. Both groups received the same medical care according to the clinical situation. One hour after successful extubation and randomization, analysis of arterial blood gases was repeated.

(1) In the SMT group, oxygen therapy was delivered to achieve arterial oxygen saturation (SaO_2) greater than 92%. Patients also received SMT, decided by the attending physicians.
(2) In the NIV group, all patients were ventilated using either a ventilator specifically designed for NIV or an ICU ventilator using a pressure support ventilation mode with the addition of an external PEEP. Patients were given an initial external PEEP of 5 cmH_2O, which was increased until the oxygen saturation was constantly greater than 92%, and inspiratory pressure was adjusted according to tolerance. The target was a respiratory rate less than 25 breaths/min, oxygen saturations greater than 92%, and pH greater than 7.35. FiO_2 was adjusted to achieve an SaO_2 greater than 92%. A full face mask was used for all patients.

NIV or SMT was applied for at least 24 h and then withdrawn if the patient was stable; however, if the patient had respiratory distress (not reached criteria for reintubation), the treatment was continued beyond 24 h at the discretion of the clinician.

Criteria for reintubation [10]

Reintubation was performed if one major or two minor criteria were met after receiving assigned management of 1 h.

Major criteria

(1) Patients developing postextubation respiratory failure
   (a) Respiratory acidosis (pH<7.35 with PCO_2>45 mmHg and $PaCO_2$ increase of >15%).
   (b) Hypoxemia (SaO_2<90% for FiO_2>50%).
(2) Coma, cardiac or respiratory arrest, or severe hypotension.

Minor criteria

Increase in respiratory rate greater than 20% from the time of extubation and in any case more than 35/min, clinical signs of respiratory muscle fatigue (e.g. accessory muscle use and inward movements of the abdomen during inspiration), severe dyspnea, and inability to remove secretions.

Primary outcomes were length of stay, ICU stay (days), and hospital stay (days). Secondary outcomes were ICU mortality, hospital mortality, reintubation and criteria met for reintubation, and complications such as respiratory failure after extubation, cardiac failure, pneumonia, encephalopathy, etc.

Case definitions

APACHE-II: It is a severity-of-disease classification system, one of the several ICU scoring systems. It is applied within 24 h of admission of a patient to an ICU. An integer score from 0 to 71 is computed based on several measurements; higher scores correspond to more severe disease and a higher risk of death. The first APACHE model was presented by Knaus *et al.* [11] in 1981.

Standard medical treatment

Oxygen therapy was delivered to achieve an SaO_2 of 92% or greater. Patients also received SMT, decided by the attending physicians [10].

Trial duration

It is the duration that begins after a successful weaning trial in which the patients were randomized to receive NIV or SMT until the end of study (discharge from ICU, reintubation, or death) [10].

Trial–failure interval

It is the time from extubation until the development of postextubation respiratory failure [12].

Statistical methods

The collected data were coded, tabulated, and statistically analyzed using IBM SPSS statistics (Statistical Package for Social Sciences) (V. 22.0) software version 22.0 (2013; IBM Corp., Chicago, Illinois, USA).

Descriptive statistics for quantitative data were analyzed and presented as minimum and maximum of the range as well as mean ± SD for quantitative parametric data and as median and first and third interquartile range for quantitative nonparametric data, whereas qualitative data were presented as number and percentage.

Inferential analyses were carried out for quantitative variables using the independent *t*-test in cases of two independent groups with parametric data and using the paired *t*-test in cases of two dependent groups with parametric data. The Mann–Whitney *U*-test was used in cases of two independent groups with nonparametric data. In qualitative data, inferential analyses for independent variables were carried out using the χ^2-test for differences between proportions and Fisher's exact test for variables with small expected numbers.

The level of significance was taken at *P*-value less than 0.050. The *P*-value is a statistical measure for the probability that the results observed in a study could have occurred by chance.

Results

The study groups included the NIV group (the noninvasive group) and the SMT group (the SMT).

A total of 56 patients were included in the study. They were equally divided into the NIV group and the SMT group (28 in each group). Two patients in each group had undergone self-extubation. Further analysis were carried out on the data of the 26 cases that completed the study in each group.

Tables 1 and 2 show no significant difference between the study groups as regards age, sex, special habits, and clinical respiratory condition.

Table 3 shows the comparison between the study groups as regards comorbidities. Chronic respiratory diseases other than COPD were bronchiaectasis, lobectomy, obstructive sleep apnea, and corpulmonale. No significant difference was found between the study groups with regard to comorbidities.

A comparison between the two groups 1 hour after the trial as regards physiological variables was made.

Table 1 Comparison between the study groups as regards age, sex, and special habits

Measurements	NIV (*N* = 26)	SMT (*N* = 26)	*P*
Age (years)			
Mean ± SD	60.3 ± 11.0	60.5 ± 11.0	0.960[a]
Range	43.0–83.0	45.0–87.0	
Sex [*n* (%)]			
Male	22 (84.6)	23 (88.5)	1.000[b]
Female	4 (15.4)	3 (11.5)	
Smoking [*n* (%)]			
Smoker	17 (65.4)	18 (69.2)	1.000[b]
Ex-smoker	5 (19.2)	4 (15.4)	
Nonsmoker	4 (15.4)	4 (15.4)	
Hashish [*n* (%)]	3 (11.5)	4 (15.4)	1.000[b]

NIV, noninvasive ventilation; SMT, standard medical treatment, [a]The value is calculated using the independent *t*-test, [b]The values are calculated using the Fisher exact test.

Table 2 Comparison between the study groups as regards clinical respiratory condition

Measurements	NIV (*N* = 26)	SMT (*N* = 26)	*P*
Previous MV [*n* (%)]	7 (26.9)	6 (23.1)	0.749[b]
Acute exacerbation of COPD [*n* (%)]	26 (100.0)	26 (100.0)	–
MV duration (days)			
Mean ± SD	4.1 ± 2.8	4.0 ± 2.6	0.879[a]
Range	2.0–15.0	2.0–13.0	
APACHE at admission			
Mean ± SD	21.8 ± 5.7	22.3 ± 6.4	0.749[a]
Range	11.0–35.0	10.0–35.0	
APACHE at study entry			
Mean ± SD	15.5 ± 4.1	15.3 ± 2.9	0.815[a]
Range	4.0–28.0	10.0–21.0	

APACHE, Acute Physiology and Chronic Health Evaluation; COPD, chronic obstructive pulmonary disease; NIV, noninvasive ventilation; SMT, standard medical treatment, [a]The values are calculated using the independent *t*-test, [b]The value is calculated using the χ^2-test.

Table 3 Comparison between the study groups as regards comorbidities

Measurements	NIV (*N* = 26) [*n* (%)]	SMT (*N* = 26) [*n* (%)]	*P*
Chronic heart diseases	6 (23.1)	8 (30.8)	0.532[a]
Chronic liver diseases	3 (11.5)	1 (3.8)	0.610[b]
Chronic renal diseases	1 (3.8)	0 (0.0)	1.000[b]
Chronic respiratory diseases (other than COPD)	4 (15.4)	5 (19.2)	1.000[b]
Hypertension	5 (19.2)	6 (23.1)	0.734[a]
Diabetes mellitus	3 (11.5)	3 (11.5)	1.000[b]
Morbid obesity	2 (7.7)	1 (3.8)	1.000[b]
Vascular diseases	2 (7.7)	1 (3.8)	1.000[b]
Cancer	0 (0.0)	1 (3.8)	1.000[b]

COPD, chronic obstructive pulmonary disease; NIV, noninvasive ventilation; SMT, standard medical treatment, [a]The values are calculated using the χ^2-test, [b]The values are calculated using the Fisher exact test.

It was found that the NIV group had a significantly lower respiratory rate (22.2 ± 4.7 vs. 24.9 ± 1.9, P = 0.036), lower heart rate (98.2 ± 12.1 vs. 108.7 ± 17.2, P = 0.014), and lower systolic blood pressure (121.1 ± 11.8 vs. 131.3 ± 15.6, P = 0.01).

The SMT group had significantly higher PCO_2 (63.9 ± 11.3 vs. 55.9 ± 12.3, P = 0.019) and lower PO_2 (60.1 ± 16.8 vs. 72.3 ± 21.5, P = 0.43).

Table 4 shows that the trial duration was significantly shorter in the NIV group than in the SMT group. ICU stay was shorter in the NIV group than in the SMT group but did not reach the level of significance.

In the NIV group, five patients had respiratory distress, two patients did not reach the criteria for reintubation, and three of them had respiratory failure and were reintubated.

In the SMT group, nine patients had respiratory distress, and eight of them had respiratory failure and were reintubated.

Table 5 shows that respiratory failure and reintubation were less frequent in the NIV group than in the SMT group but did not reach the level of significance. Trial–failure interval was longer in the NIV group than in the SMT group but did not reach the level of significance.

Table 6 shows that mortality was more frequent in the SMT group than in the NIV group but did not reach the level of significance.

Discussion

The present study assessed the role of NIV in decreasing the length of postextubation ICU stay in all patients who met our inclusion criteria.

It was clear that NIV improved gas exchange and hemodynamics after extubation. The NIV group had significantly lower respiratory rate and heart rate and lower systolic blood pressure 1 h after the trial.

Arterial blood gases were mainly significantly better in the NIV group than in the SMT group, as the SMT group had significantly lower blood pH and lower PO_2 1 h after the trial. PCO_2 increased significantly in the SMT group 1 h after the trial.

This is in accordance with the results of Kilger and colleagues, who conducted a physiological study to investigate the effects of NPPV on pulmonary gas exchange in patients with persistent acute respiratory after early extubation. Blood gas indices (PaO_2, $PaCO_2$, and pH), as well as RR, changed significantly in favor of NPPV [13].

Table 4 Comparison between the study groups as regards trial duration and ICU stay (days)

Time	Measurement	NIV (*N* = 26)	SMT (*N* = 26)	*P*
Trial duration	Median (IQR)	3.0 (2.0–3.5)	4.0 (2.8–7.0)	0.041
	Range	1.0–13.0	1.0–16.0	
ICU stay	Median (IQR)	7.0 (5.0–10.0)	8.5 (6.8–15.0)	0.219[&]
	Range	4.0–28.0	5.0–30.0	

The values are calculated using the Mann–Whitney test, IQR, interquartile range; NIV, noninvasive ventilation; SMT, standard medical treatment.

Table 5 Comparison between the study groups as regards respiratory failure and trial–failure interval (h)

Measurements	NIV (*N* = 26)	SMT (*N* = 26)	*P*
Respiratory distress [*n* (%)]	5 (19.2)	9 (34.6)	0.211[a]
	N = 5	*N* = 9	
Respiratory failure and reintubation	3	8	0.205[b]
Trial–failure interval (h)			
Median (IQR)	48 (36–86)	24 (24–60)	0.197
Range	24–96	24–120	

The values are calculated using the Mann–Whitney test, IQR, interquartile range; NIV, noninvasive ventilation; SMT, standard medical treatment, [a]The value is calculated using the χ^2-test, [b]The value is calculated using the Fisher exact test.

Table 6 Comparison between the study groups as regard mortality and complications

Measurements	NIV (*N* = 26) [*n* (%)]	SMT (*N* = 26) [*n* (%)]	*P*
ICU mortality	2 (7.7)	3 (11.5)	1.000[a]
Myocardial infarction	1 (3.8)	1 (3.8)	1.000[a]
Cardiac arrest	1 (3.8)	2 (7.7)	1.000[a]
Pneumonia	0 (0.0)	1 (3.8)	1.000[a]

NIV, noninvasive ventilation; SMT, standard medical treatment, [a]The values are calculated using the Fisher exact test.

In the present study, the trial duration was significantly shorter in the NIV group than in the SMT group, and ICU stay was shorter in the NIV group than in the SMT group.

Respiratory failure and reintubation (three in the NIV group vs. eight in the SMT, $P = 0.205$) were nonsignificantly less frequent in the NIV group than in the SMT group.

The time from extubation to respiratory failure and reintubation was nonsignificantly longer in the NIV group than in the SMT group and did not influence mortality, which was nonsignificantly more frequent in the SMT group than in the NIV group.

Randomized controlled studies assessed the efficacy of the early application of NIV after a planned extubation in selected patients at increased risk of developing respiratory failure after extubation.

An Italian multicenter trial enrolled 97 consecutive patients mechanically ventilated for more than 48 h who were considered at risk of developing respiratory failure after extubation. After a successful weaning trial, 48 patients were randomized to receive NIV for at least 8 h a day for the first 48 h, and 49 patients received SMT. Patients who received NIV had a lower rate of reintubation, compared with those who received SMT ($P = 0.027$). The need for reintubation was associated with a higher risk of mortality, and the use of NIV resulted in a reduction in the risk for ICU mortality (–10%, $P = 0.01$). The authors concluded that NIV was more effective compared with SMT in preventing postextubation respiratory failure in a population considered at risk for this complication [10].

Another randomized clinical trial was conducted on 162 patients mechanically ventilated for at least 48 h who tolerated SBT through a T-piece. Patients were at risk for respiratory failure after extubation. Seventy-nine patients were randomly allocated after extubation to receive NIV continuously for 24 h, and 83 patients received conventional management; 51% of patients had underlying chronic respiratory disorders, mainly COPD or chronic bronchitis. Respiratory failure after extubation was less frequent in the NIV group ($P = 0.029$). The ICU mortality (two patients (3%) versus 12 patients (14%); $P = 0.015$) was lower in the NIV group, but the hospital and 90-day survival was similar among patients from the two groups [8].

However, the results of the present study are in accordance with the previously discussed studies as regards the decreased incidence of respiratory failure, mortality, and length of ICU stay. The small sample size of the present study in comparison of the other studies may explain the absence of statistically significant results.

Moreover, the previously discussed studies included only patients at risk of developing postextubation respiratory failure.

Different risk factors were proposed according to different study designs, such as the presence of hypercapnia, congestive heart failure, ineffective cough and excessive tracheobronchial secretions, more than one failure of a weaning trial, more than one comorbid condition, upper airway obstruction [10], age more than 65 years, cardiac failure as the cause of intubation, APACHE-II score greater than 12 on the day of extubation [8], and a BMI of 35 kg/m^2 or greater [14].

However, in the present study we did not specify certain groups at risk to be included and NIV was

indiscriminately applied to prevent the development of postextubation respiratory failure.

This may have influenced the results as specifying patients at risk expectedly will show more obvious benefit.

This explanation is supported by a recent study that included more than 400 unselected ICU patients extubated after a successful 2-h SBT; reintubation rates were similar in patients treated with prophylactic NIV or oxygen therapy [15].

In contrast to the previous results, Jiang and colleagues conducted a randomized trial to assess the role of the early application of bi-level positive airway pressure on the outcome of extubation in ventilator weaning. Ninety-three extubated patients, 56 with planned and 37 with unplanned extubation, were randomly allocated to be extubated with early use of NIV just after extubation or with conventional management. There were 24 COPD patients in the NIV group and 19 in the conventional therapy group. This study did not show any significant benefit of NIV in averting reintubation [16].

A possible reason for this lack of benefit of NIV could be that there was not a good criteria selection of patients due to the high proportion of unplanned extubation, which was the main determinant of poor outcome.

These results, in context with a wealth of physiological data and clearly demonstrated utility in other settings, suggest that 'prophylactic' postextubation NIV, when properly applied, might prove to be a valuable adjunctive measure in patients. Further studies and confirmation are warranted.

Conclusion

The early use of NIV after extubation decreased ICU stay, diminished the risk for respiratory failure after extubation, and reduced mortality in patients with respiratory failure type II.

Acknowledgements

The findings of this study support the judicious use of NIV in patients who met our inclusion criteria, and suggest a potential benefit to patient morbidity, patient safety, and the economic burden of ICU care.

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Conflicts of interest

There are no conflicts of interest.

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