Original Article

Noninvasive mechanical ventilation: An 18-month experience of two tertiary care hospitals in north India

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ABSTRACT

Background: Noninvasive mechanical ventilation (NIMV) is the delivery of positive pressure ventilation through an interface to upper airways without using the invasive airway. Use of NIMV is becoming common with the increasing recognition of its benefits. **Objectives:** This study was done to evaluate the feasibility and outcome of NIMV in tertiary care centres. **Materials and Methods:** An observational, retrospective study conducted over a period of 18 months in two tertiary level hospitals of north India on 184 consecutive patients who were treated by NIMV, regardless of the indication. NIMV was given in accordance with the arterial blood gas (ABG) parameters defining respiratory failure (Type 1/Type 2). **Results:** The most common indication of NIMV in our hospitals was acute exacerbation of chronic obstructive pulmonary disease (AE-COPD 80.43%), and 90.54% AE-COPD patients were improved by NIMV. Application of NIMV resulted in significant improvement of pH and blood gases in COPD patients, while non-COPD patients showed significant improvement in partial pressure of oxygen (PaO_2) alone. The mean duration of NIMV was 8.35 ± 5.98 days, and patients of interstitial lung disease (ILD) were on NIMV for the maximum duration (17 ± 8.48 days). None of the patients of acute respiratory distress syndrome were cured by NIMV; 13.04% patients on NIMV required intubation and mechanical ventilation. **Conclusion:** This study demonstrates and encourages the use of NIMV as the first-line ventilatory treatment in AE-COPD patients with respiratory failure. It also supports NIMV usage in other causes of respiratory failure as a promising step toward prevention of mechanical ventilation.

KEY WORDS: Acute exacerbation, chronic obstructive pulmonary disease, noninvasive mechanical ventilation, respiratory failure

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INTRODUCTION

Noninvasive mechanical ventilation (NIMV) refers to the application of artificial ventilation without an invasive access to the airway (i.e., without using an endotracheal or tracheostomy tube). The increased popularity of NIMV among clinicians and researchers alike is justified by the fact that it spares the patient the complications associated with invasive mechanical ventilation (IMV) like nosocomial pneumonia (21%), sinusitis (5-25%),[1-4] and other airway problems. This, coupled with the availability of better and more accessible interfaces, has greatly increased the usage of NIMV over the last decade. Its success or failure is essentially determined by appropriate patient selection, correct choice of interface, its correct application, and proper patient monitoring.

NIMV has assumed a prominent role in the management of acute respiratory failure,[5-8] and its success in various conditions is supported by literature. The benefits of NIMV have been studied most extensively in hypercapnoeic respiratory failure associated with AE-COPD by means of multiple, well-designed, randomized controlled trials. It is also recommended for weaning of COPD patients from IMV. Other less extensively studied conditions of hypercapnoeic respiratory failure with weaker recommendations in favor

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Quick Response Code:

Website: www.lungindia.com

DOI: 10.4103/0970-2113.120606

of NIMV usage include neuromuscular diseases, chest-wall deformities, acute asthma, acute respiratory failure in obstructive sleep apnea/obesity-hypoventilation syndrome, and interstitial lung disease (ILD). NIMV has also been found to be beneficial in carefully selected patients of hypoxemic respiratory failure, particularly cardiogenic pulmonary edema, and less so in community acquired pneumonia (CAP), acute respiratory distress syndrome (ARDS), and chest trauma with flail chest, among others.

The variability in the success of using NIMV in different clinical conditions prompted us to conduct this study with the objective of evaluating the feasibility, efficacy, and outcome of using NIMV in tertiary care centres.

MATERIALS AND METHODS

This observational, retrospective study was conducted over an 18-month period (between November 1, 2009 and April 30, 2011) in two tertiary level referral medical institutions in north India. A total of 184 consecutive subjects who were treated with NIMV (irrespective of indication) during the study period were included. Criteria of inclusion[9] were patients of respiratory failure with (a) respiratory rate >25/min; (b) signs of increased work of breathing; (c) arterial blood gas (ABG) analysis showing pH <7.35 or partial pressure of carbon dioxide ($PaCO_2$) >45 mmHg, partial pressure of oxygen (PaO_2) <60 mmHg. The exclusion criteria were the same as the contraindications to NIMV[8] application, namely cardiac/respiratory arrest, severe encephalopathy (Glasgow Coma Scale score <10), severe upper gastrointestinal bleeding, hemodynamic instability, unstable arrhythmias, facial surgery/trauma/deformity, upper airway obstruction, inability to cooperate/protect airway/clear secretions, and high risk for aspiration.

All patients were grouped according to the underlying clinical condition that prompted the application of NIMV. NIMV was started by pulmonologists in the emergency department and, if required, patients were shifted to intensive respiratory care unit (IRCU). Bilevel positive airway pressure (BiPAP) system (RESMED, VPAP III STA) with a full-face mask was used to apply NIMV using ST mode.

Variables collected in the study

The outcome of NIMV usage in each group was measured in terms of the number of patients cured by NIMV and those who failed on NIMV. Patients who failed on NIMV were further evaluated regarding requirement of intubation and those who subsequently survived or expired. The other variables collected in the study included ABG parameters (pH, $PaCO_2$, and PaO_2) and the mean duration of NIMV application. Paired t test and analysis of variance (ANOVA) were used for statistical analysis of data wherever required. $P < 0.05$ was considered statistically significant.

RESULTS

Out of a total of 184 patients who were included in the study, most of the patients belonged to the age group 41-59 years (78 patients, 42.39%) [Table 1]. The number of male patients (95 patients, 51.6%) slightly exceeded the number of female patients (89 patients, 48.4%). The most common indication for application of NIMV in our centers was acute exacerbation of COPD (148 patients, 80.43%). Other less common indications for NIMV were CAP (consolidation), ARDS, pulmonary edema, bronchiectasis, ILD, asthma, and kyphoscoliosis.

In COPD patients, the change in pH, $PaCO_2$, and PaO_2 from baseline to after 24 h and at the time of discharge was significant ($P < 0.0001$ by paired t test and ANOVA). However, in non-COPD patients, the change in pH and $PaCO_2$ from baseline to after 24 h and at the time of discharge was not significant, but the change in PaO_2 values from the baseline to at the time of discharge was significant ($P < 0.00001$ by paired t test and ANOVA) [Table 2].

The mean duration of NIMV usage in AE-COPD patients was 8.35 ± 5.98 days [Table 3]. Patients with underlying ILD required the maximum duration of NIMV support (17 ± 8.48 days); 134 of the 148 patients with underlying COPD (90.54%) were improved with NIMV. All patients

Table 1: Demographic characteristics of study subjects

Patient characteristics	Number of Patients (%)
Age groups (in years)	
≤20	2 (1.09)
21–40	36 (19.56)
41–59	78 (42.39)
≥60	68 (36.96)
Gender	
Male	95 (51.6)
Female	89 (48.4)
Indication of NIMV (underlying primary disease)	
AE-COPD	148 (80.43)
CAP	8 (4.34)
ARDS	6 (3.26)
Pulmonary edema	6 (3.26)
Bronchiectasis	6 (3.26)
ILD	4 (2.17)
Bronchial asthma	4 (2.17)
Kyphoscoliosis	2 (1.08)
Co-morbidities	
Hypertension (HT)	20 (10.87)
Dilated cardiomyopathy	18 (9.78)
Diabetes mellitus (DM)	14 (7.61)
DM + HT	8 (4.35)
Obstructive sleep apnea	4 (2.17)
Chronic renal failure	2 (1.09)
Acute renal failure	2 (1.09)
Ischemic heart disease	2 (1.09)
Coronary artery disease	2 (1.09)
Depression	2 (1.09)

NIMV: Noninvasive mechanical ventilation, AE-COPD: Acute exacerbation of chronic obstructive pulmonary disease, CAP: Community acquired pneumonia, ARDS: Acute respiratory distress syndrome, ILD: Interstitial lung disease

Table 2: ABG trends in COPD and non-COPD patients at admission, after 24 h of NIMV application, and at discharge

	pH				$PaCO_2$				PaO_2			
	B (range)	24 h (range)	D (range)	*P* value	B (range)	24 h (range)	D (range)	*P* value	B (range)	24 h (range)	D (range)	*P* value
COPD	7.334±0.08 (7.091-7.503)	7.378±0.07 (7.084-7.505)	7.421±0.062 (7.179-7.54)	*P*<0.0001	66.48±16.24 (25.7-124)	62.39±18.88 (26.4-181)	56.37±12.37 (24-131.3)	*P*<0.0001	53.43±18.73 (22.8-114)	64.42±26.13 (26.7-156)	70.6±24.1 (37.1-143)	*P*<0.0001
Non-COPD	7.373±0.111 (7.136-7.503)	7.398±0.087 (7.22-7.50)	7.428±0.069 (7.292-7.589)	*P*>0.05	54.89±23.06 (26-124)	50.01±18.20 (22.6-98.7)	51.41±17.71 (25-89.1)	*P*>0.05	52.91±18.41 (30-94)	58.97±13.99 (26.7-156)	74.02±23.54 (44-121)	*P*<0.00001

ABG: Arterial blood gas analysis, COPD: Chronic obstructive pulmonary disease, NIMV: Non-invasive mechanical ventilation, $PaCO_2$: Arterial partial pressure of carbon dioxide (mmHg), PaO_2: Arterial partial pressure of oxygen (mmHg), B: At the time of admission (baseline), 24 h: After 24 hours of application of NIMV, D: At the time of discharge

Table 3: Mean duration and outcome of NIMV usage in each group

Indication of NIMV	Mean duration of NIMV (days)	Number of patients	Cured	Failure*(*Includes intolerence to NIMV)	Intubation	Survived	Expired
AE-COPD	8.35±5.98	148	134	14	14	10	4
CAP	7.75±2.02	8	8	—	—	—	—
ARDS	10.33±15.3	6	—	6	6	2	4
Pulmonary edema	7±1	6	6	—	—	—	—
Bronchiectasis	5.66±2.08	6	6	—	—	—	—
ILD	17±8.48	4	2	2	2	—	2
Bronchial asthma	7±1.414	4	2	2	2	2	—
Kyphoscoliosis	5	2	2	—	—	—	—
Total (%)		184 (100%)	160 (86.95%)	24 (13.04%)	24 (100%)	14 (58.33%)	10 (41.66%)

NIMV: Non-invasive mechanical ventilation, AE-COPD: Acute exacerbation of chronic obstructive pulmonary disease, CAP: Community acquired pneumonia, ARDS: Acute respiratory distress syndrome, ILD: Interstitial lung disease

with underlying CAP (8 numbers), pulmonary edema (6 numbers), bronchiectasis (6 numbers), or kyphoscoliosis (2 numbers) were benefitted with NIMV, while none of the patients with ARDS (6 numbers) showed any improvement. Among ILD and asthma patients, 50% (2 out of 4) patients showed improvement with NIMV and 13.04% (24 out of 184) patients on NIMV required intubation and mechanical ventilation. Most of the complications were in the form of worsening respiratory distress despite NIMV application, which necessitated endotracheal intubation and invasive ventilation. The latter brought along associated complications like ventilator-associated pneumonia, sepsis, and cardiac arrest.

DISCUSSION

The most promising use of NIMV appears to be in patients of AE-COPD with hypercapnoeic respiratory failure who are on standard medical treatment. The results of our study strongly support and encourage the use of NIMV as the first-line ventilatory treatment in this group of patients. AE-COPD was also the commonest indication for NIMV application in our study. These patients showed significant improvement in ABG parameters at the time of discharge as compared to the baseline values. In this regard, numerous randomized controlled trials have been conducted in the past that highlight the benefits of NIMV usage in this group of patients in terms of reduced rate of endotracheal intubation and mortality,[10-20] shortened length of ICU and hospital stay,[11,12] and reduction of complications like nosocomial pneumonia. Meta-analyses[21,22] of these trials have also confirmed benefits of NIMV in AE-COPD. Studies have also found that early initiation of NIMV is associated with better outcome compared to delayed initiation.[17,21] Even in sick patients who required immediate intubation, NIMV was shown to avoid intubation in almost 50% of the patients in a prospective randomized controlled trial by Conti *et al*.[18] NIMV was not found to be beneficial in COPD patients with mild exacerbation.[22-24]

In this study, COPD patients were the ones who most commonly presented with type 2 respiratory failure (respiratory acidosis). NIMV application facilitated CO_2 wash-out in these patients and helped regain normocapnea (from 66.48 ± 16.24 at baseline to 56.37 ± 12.37 at discharge, $P < 0.0001$) [Table 2] and a normal pH (from 7.334 ± 0.08 at baseline to 7.421 ± 0.062 at discharge, $P < 0.0001$) [Table 2]. Thus, these acidotic patients responded very well to NIMV. Non-acidotic COPD patients were also benefited by NIMV as it helped decrease the respiratory rate by resting the respiratory muscles and thereby reducing the work of breathing, improving patient comfort, and possibly preventing the onset of frank respiratory failure and acidosis.

Regarding patients of CAP, our results differ from those of previous studies in that all our 8 patients of CAP were benefitted by NIMV. This could possibly be attributed to the fewer number of CAP patients in our study. Previous published studies on the use of NIMV in hypoxemic respiratory failure in CAP have shown conflicting results.[25-27] Some of these[28-32] have shown no major benefit of NIMV in this group of patients. On the other hand, a randomized controlled trial done on patients with severe CAP and hypoxemic respiratory failure in a subgroup of COPD patients has demonstrated major benefit of NIMV.[25] However, these studies largely lead to the conclusion that

NIMV may be useful in carefully selected CAP patients, particularly those with concomitant COPD. Whatever may be the reason, a trial of NIMV may not prove harmful, if not useful, in this group of patients.

In our study, none of the patients having ARDS could be benefitted by NIMV and mortality rate following intubation was nearly 67%. Usefulness of NIMV in ARDS is questionable, as suggested by the limited studies available. In a study by Rocker *et al*.,[33] endotracheal intubation could be avoided in 67% patients of ARDS by applying NIMV. Two other studies[34,35] that included ARDS patients in comparing NIMV with a conventional approach found that the rate of endotracheal intubation in ARDS patients randomized to NIMV was 40% and the mortality rate in these patients was 35%. It may be concluded that NIMV should be very carefully applied to ARDS patients who are preferably hemodynamically stable, in an intensive care setting.

A beneficial outcome was seen in all 6 patients of pulmonary edema in whom NIMV was applied in the present study. Among the causes of hypoxemic respiratory failure, NIMV has been found to be very effective in patients of cardiogenic pulmonary edema in previous studies.[36-39] A study by Nava *et al*.,[40] revealed that, in these patients, NIMV, in comparison to medical therapy plus oxygen, resulted in an improvement of PaO_2/FiO_2 ratio, respiratory rate, and dyspnea, but had no beneficial effect on intubation rate, hospital mortality, and duration of hospital stay. Thus, in addition to standard medical therapy, NIMV appears to be a feasible supplementary treatment in acutely decompensated patients of cardiogenic pulmonary edema.

Among asthmatics, 2 out of 4 patients showed improvement by NIMV usage in our study. As far as the use of NIMV in bronchial asthma is concerned, the evidence is inconclusive.[41] A retrospective analysis[42] shows rapid improvement of blood gases and less hypercapnea in asthmatics treated with NIMV. A randomized controlled trial[43] showed beneficial effect of NIMV in selected patients of asthma in terms of improved lung function, faster alleviation of symptoms, and reduced need of hospitalization. However, another randomized controlled trial[44] did not demonstrate any benefit. Thus, NIMV may be tried in those asthmatics that respond inadequately to medical therapy and have no contraindication for NIMV usage, preferably in the ICU.

No randomized controlled trials have examined the effect of NIMV in patients of chest wall deformity like kyphoscoliosis and neuromuscular diseases. Only some retrospective case series suggest that NIMV alleviates gas exchange abnormalities and avoids intubation in this group of patients who present with respiratory failure.[45] Our study showed improvement in both the patients of kyphoscoliosis when put on NIMV. Thus, NIMV may be beneficial in these patients when they present with acute-on-chronic respiratory failure.

To conclude, this study demonstrates the feasibility and efficacy of NIMV applied in regular clinical practice. The results strongly support and encourage the use of NIMV as a first-line ventilatory treatment in AE-COPD patients with respiratory failure. NIMV should also be considered in other causes of respiratory failure as a promising step toward prevention of mechanical ventilation.

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How to cite this article: Verma AK, Mishra M, Kant S, Kumar A, Verma SK, Chaudhri S, Prabhuram J. Noninvasive mechanical ventilation: An 18-month experience of two tertiary care hospitals in north India. Lung India 2013;30:307-11.

Source of Support: Nil, **Conflict of Interest:** None declared.