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Original Research Article

Outcome of different modes of non-invasive ventilation in chronic obstructive pulmonary disease patients with type II respiratory failure

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ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) is a progressive inflammatory airway disorder often leading to type II respiratory failure (RF). Non-invasive ventilation (NIV) is crucial in COPD management. This study compares T (Timed), ST (Spontaneous-Timed), and iVAPS (Intelligent volume assured pressure support) modes.
Method: A prospective, experimental, comparative study spanned two years. One hundred COPD patients with Type 2 RF were randomized into three groups: T mode (n=33), ST mode (n=33), and iVAPS mode (n=34). Outcome assessment included clinical, hematological parameters, and intubation rate.
Result: The study revealed varying degrees of success among the three modes of NIV. iVAPS mode demonstrated the highest success rate, with 79.4% of cases achieving positive outcomes. Noteworthy improvements were observed in respiratory rate (RR) and oxygen saturation (SpO_2) in the iVAPS group after 12 hours of NIV. Both the ST mode and iVAPS mode showed significant increases in pH levels, with a more pronounced improvement seen in the iVAPS group. Additionally, a substantial reduction in pCO_2 levels after BiPAP was noted in the iVAPS group. The intubation rate was lowest in the iVAPS group, though the difference did not reach statistical significance.
Conclusions: iVAPS mode demonstrated superior outcomes, including significant improvements in RR, SpO_2, pH, and pCO_2. While the intubation rate was lowest in the iVAPS group, statistical significance was not achieved. iVAPS emerges as a promising alternative, potentially averting the need for invasive ventilation. Larger, diverse studies are needed to validate these findings.

Keywords: COPD, BiPAP, iVAPS, NIV, Hypercapnic, RF

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) exacerbations are a very common reason for admission to hospital. Approximately 20% of patients hospitalized for COPD present with[1] or develop hypercapnic RF which is an indicator of increased risk of death.[1-3] Acute RF leading to acute or acute-on-chronic respiratory acidosis, develops when the respiratory muscles fail to achieve adequate alveolar ventilation despite high levels of diaphragmatic activity.[4] When faced with a load exceeding the capacity of the respiratory muscle pump, a rapid shallow breathing pattern develops characterized by an increased respiratory rate with small tidal volumes. This pattern has a complex pathophysiological mechanism and occurs at the expense of adequate alveolar ventilation. Consequently, the level of arterial carbon dioxide (CO_2) rises and respiratory acidosis ensues. Measuring respiratory rate, observing chest and abdominal wall movement, and obtaining a sample of arterial blood are therefore key in the initial assessment of the patient at risk of acute respiratory acidosis ($pH \leq 7.35$).

The utility of NIV in hypercapnic RF in COPD is well-established. Since the mid-1990's, studies have demonstrated superior outcomes in patients with hypercapnic RF during COPD exacerbation when treated with NIV compared to management without NIV.[5] It is now a standard treatment component of these patients and is included in the most recent international guidelines.[6,7] NIV can be provided via a Continuous Positive Airway Pressure (CPAP) system or a biphasic/ bilevel positive airway pressure (biPAP) system.

There are different modes of BiPAP. Spontaneous (S) mode switches between inspiratory and expiratory as the BiPAP machine senses the switch in breathing. Timed (T) mode switches between inspiratory and expiratory at a programmed rate to ensure the prescribed breaths per minute rate is maintained. Spontaneous/timed (ST) switches as it senses the change in breathing. Timed mode functions as a failsafe to ensure breathing at the required breathes per minute rate is maintained.

Some newer models have been developed recently. Average volume assured pressure support (AVAPS) is designed originally for conventional mechanical ventilation combines volume-controlled and pressure-controlled ventilation. iVAPS achieves a target alveolar ventilation by adjusting pressure support and respiratory rate automatically. In iVAPS, the target is alveolar ventilation not the tidal volume, considering a predicted dead space.

These novel modes estimate the expiratory tidal volume and respond by adjusting the inspiratory pressure (IPAP) accordingly to maintain ventilation. This is achieved by two flow sources that work in parallel, one generating constant flow to achieve desirable volume and the other generating a variable level of flow in order to maintain preset airway pressure.

Objective

Objectives of were to study the outcome of different modes of NIV in patients of COPD with type II (hypercapnic) RF in terms of success rate with each mode, mortality, intubation rate, clinical and biochemical parameters.

METHODS

Patients

It is a prospective, experimental and comparative study, conducted in Jawaharlal Nehru medical college and hospital, Aligarh for a duration of 24 months, from November, 2019 to November, 2021 on 100 patients admitted with the diagnosis of COPD with type II (hypercapnic) RF after taking a written informed consent from the subjects. All such patients admitted in Respiratory ICU requiring NIV were recruited in the study. Patients were excluded if: not giving consent, patient requiring invasive ventilation, facial trauma, deformity and facial burns, COPD associated with carcinoma lung, agitated, uncooperative patient, recent upper airway or upper gastrointestinal surgery.

Methodology and intervention

Patients of COPD with type II RF were selected, a thorough history was taken and a detailed general and systemic examination was done and vital clinical parameters were recorded at the time of admission. Routine investigations were done at the time of admission of which an arterial blood gas (ABG) analysis was the primary investigation to be included in our study. Patients were randomly distributed into the three groups of NIV. In group 1, patients were kept on T mode, ST mode was applied in group 2 and iVAPS mode was used in group 3. Baseline clinical, biochemical and haematological parameters were recorded for each group. A proper NIV interface was chosen for each patient according to the size of their face and level of comfort. Identical NIV device (Phillips Dream station) was used to apply the three different modes in every patient. Each patient's vitals were recorded and ABG analysis was done and recorded after 2 hours, 6 hours and 12 hours of NIV. Final interpretation was done with the values achieved after 12 hours of NIV application and comparative evaluation was done. Patients of each group were followed up till the time they were admitted to analyse the success rate, intubation rate and length of ICU stay in each group. Philips dream station BiPAP was applied in all patients.

Outcome measures

Primary outcome measures: Success rate of various modes applied (Time frame- 12 hours) success is considered when the patient is able to achieve: pH >7.35, decrease in partial pressure of carbon dioxide, $PaCO_2$ (mmHg) by >15-20%, partial pressure of oxygen (PaO_2) >60 mmHg, SpO_2>90% on fraction of inspired oxygen (FiO_2) <40%, RR < 24/minute, no signs of respiratory distress like agitation, diaphoresis or anxiety.

Secondary outcome measure: It include intubation rate in each group.

Criteria for intubation: Respiratory arrest or a respiratory rate >35 breaths/min or higher than the value recorded on admission. Haemodynamic instability with systolic pressure less than 70 mmHg, and a heart rate of 60 beats/min or less. GCS- 3/15. Arterial pH of 7.30 and lower than the value recorded on admission even after the application of NIV mode. A PaO2/FiO2 less than 200 despite oxygen supplementation.

Statistical analysis

The presentation of the categorical variables was done in the form of number and percentage (%). Quantitative data

were presented as the means ± SD. The comparison of the variables which were quantitative in nature were analyzed using ANOVA. Post hoc comparison was done using Bonferroni correction for variables with p<0.05. Paired t test was used for comparison across follow up. The qualitative variables were analyzed using Chi-square test. If any cell had an expected value of less than 5, then Fisher's exact test was used. The data entry was done in the Microsoft excel spreadsheet and final analysis was done with the use of statistical package for social sciences (SPSS) software, IBM manufacturer, Chicago, USA, version 21.0. For statistical significance, p value of less than 0.05 was considered statistically significant.

RESULTS

Hundred patients were enrolled, of which 33 were treated with T-mode (group 1), 33 were treated with ST mode (group 2) and 34 were treated with iVAPS mode (group 3). The demographic data is shown in Figure 1 and 2. All the three groups were comparable on admission.

Success rate was significantly higher in group 3 i.e., 79% (27 of 34 cases) (p=0.004) which is shown in Table 1 and Figure 3.

Figure 4 and 5 show the comparison of respiratory rate and oxygen saturation among the three groups. A significant decrease was seen in respiratory rate (per minute) after BiPAP as compared to respiratory rate at admission in group 3 (mean RR at admission 20.8/minute whereas 17.9/minute after BiPAP, p=0.002) and significant increase was seen in SpO_2 (%) after BiPAP as compared to that at admission in group 3 (p=0.012). However, no such significant change was seen in respiratory rate in group 1 (p=0.115) and group 2 (p=0.072) and in SpO_2 (%) before and after biPAP in group 1 (p=0.111) and group 2 (p=0.310).

Comparison of ABG values (pH, pCO_2, pO_2) is shown in Figure 6-8. A significant increase was seen in pH after BiPAP as compared to pH at admission in group 2 (mean pH at admission 7.28 and after BiPAP mean pH 7.33) (p=0.041) and group 3 (mean pH at admission 7.27 and 7.37 after BiPAP) (p<0.0001) which was found to be more favorable and better in group 3.

A significant decrease was seen in pCO_2 (mmHg) after BiPAP as compared to that at admission in group 3 (mean pCO_2 91.4 mmHg at admission to 73.2 mmHg after BiPAP) (p=0.0001). However, no significant change was seen in pCO_2 before and after BiPAP in group 1 (p=0.869) and group 2 (p=0.279). There was no significant improvement in pO_2 in any of the groups after NIV, on the other hand, significant decrease seen in pO_2 (mmHg) after BiPAP in group 2 (p=0.0002).

Rate of intubation was found to be lowest in group 3 (20.5%) whereas it was 36.3% and 39.3% in group 1 and group 2 respectively, however, this finding was not statistically significant. This is shown in Figure 9.

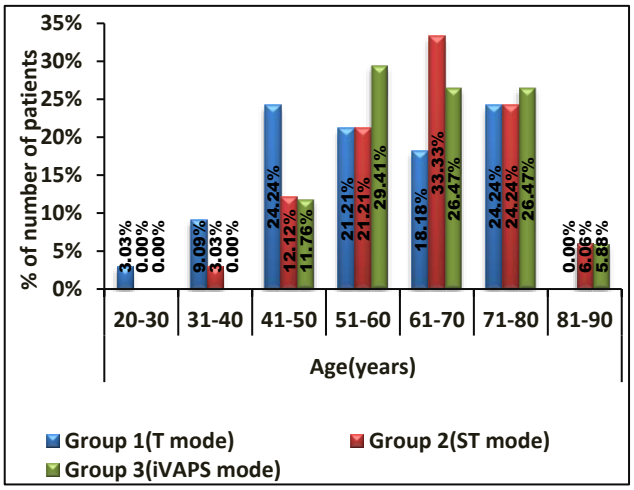

Figure 1: Comparison of age (years) between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

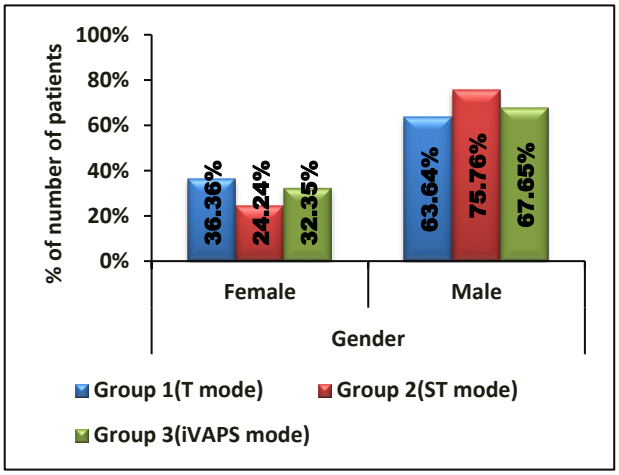

Figure 2: Comparison of gender between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

Table 1: Comparison of success between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

Success	Group 1 (T mode), (n=33) (%)	Group 2 (ST mode), (n=33) (%)	Group 3 (iVAPS mode), (n=34) (%)	Total, n (%)	P value
No	18 (54.55)	14 (42.42)	7 (20.59)	39 (39)	0.015†, 1 vs 2:0.325*
Yes	15 (45.45)	19 (57.58)	27 (79.41)	61 (61)	1 vs 3:0.004*, 2 vs
Total	33 (100)	33 (100)	34 (100)	100 (100)	3:0.054*

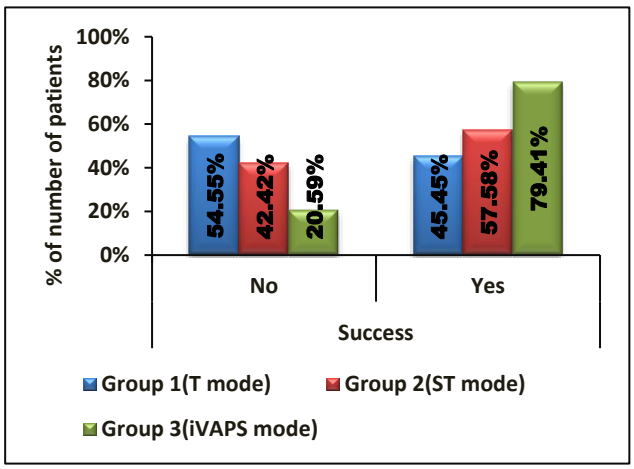

Figure 3: Comparison of success between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

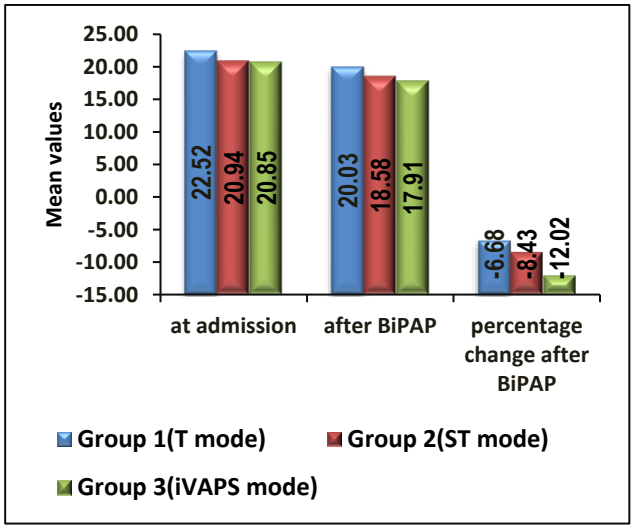

Figure 4: Comparison of respiratory rate (per minute) between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

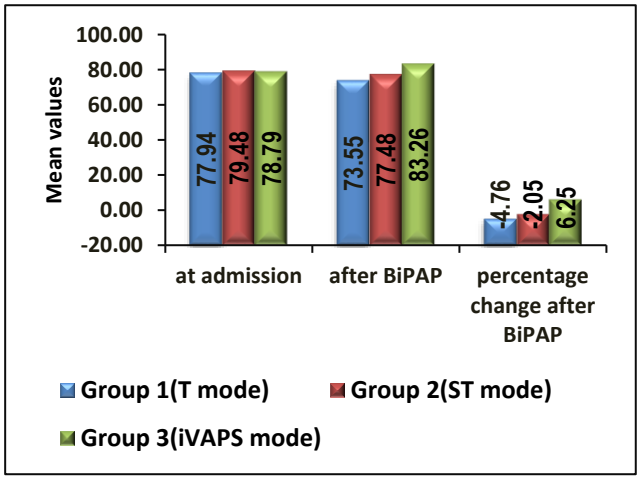

Figure 5: Comparison of SpO_2 (%) between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

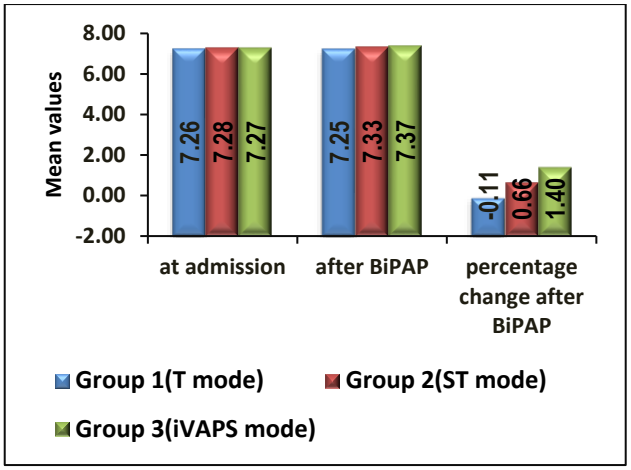

Figure 6: Comparison of pH between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

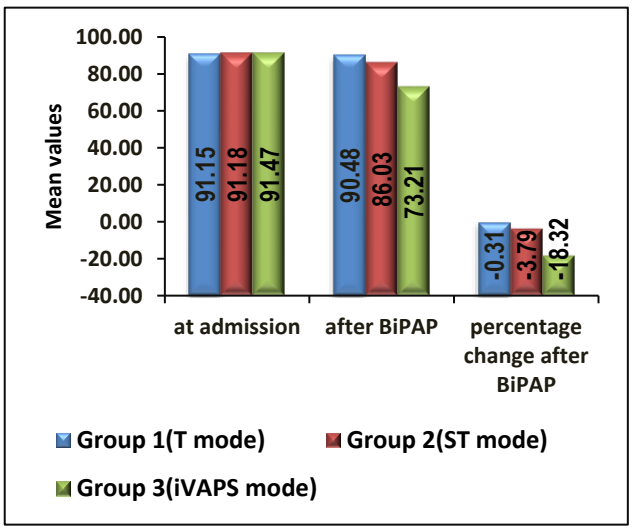

Figure 7: Comparison of pCO_2 (mmHg) between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

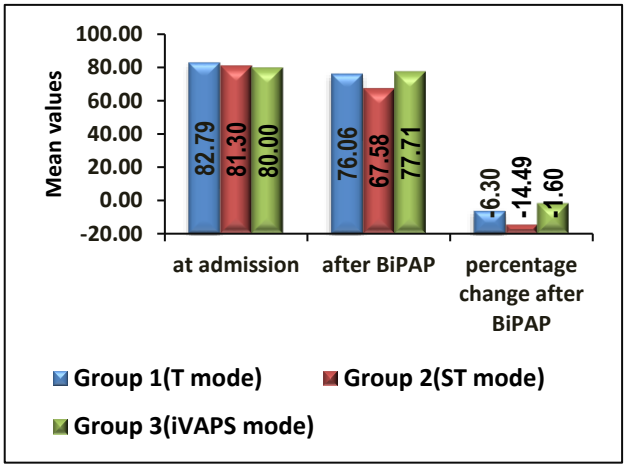

Figure 8: Comparison of pO_2 (mmHg) between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

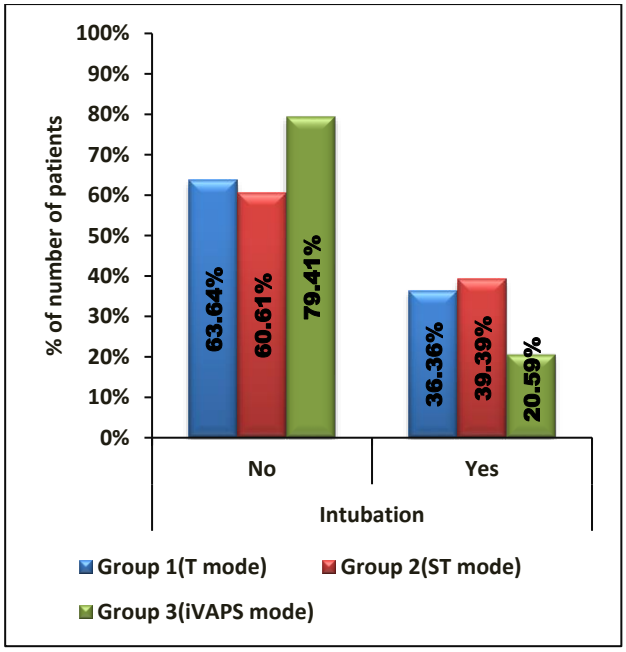

Figure 9: Comparison of intubation between group 1 (T mode), group 2 (ST mode), group 3 (iVAPS mode).

DISCUSSION

NIV in the management of hypercapnic RF in patients with COPD represents one of the major technical advances in respiratory care over the last decade.[2] A study conducted on early use of NIV for AECOPD showed that use of NIV significantly reduced the need for intubation as defined by the failure criteria.[1] Studies have provided evidence that early use of BIPAP can effectively alleviate deterioration and speed recovery of patients with type II RF due to AECOPD.[8-10] It has been observed in researches that not all modes of NIV are equally effective for RF due to COPD.[11-13] BiPAP is based on the NIPSV mode in NIV. The gas volume of BIPAP is dynamic, and its inspiratory positive airway pressure (IPAP) can overcome airway resistance and increase alveolar ventilation. Expiratory positive airway pressure (EPAP) promotes CO_2 exhalation for such patients.[14,15] Ayman et al conducted a study on patients on NIV and divided them into 3 groups i.e. CPAP group; BIPAP group and standard group.[16] They observed that there was improvement in PaO_2 in patients of group 2 (BiPAP group) during the follow up period after 1, 6, 12 h and on second day, with statistically significant improvement after 6 and 12 h and on second day with p=0.013, 0.001 and 0.012 respectively.

Our study evaluated the effect and outcome of three different modes of NIV i.e., T mode, ST mode and iVAPS mode. Our study showed significant improvement and reduction in respiratory rate (per minute) after BiPAP as compared to that at admission in group 3 (p=0.002), however no such improvement was noted in group 1 and group 2 after BiPAP. In a similar study comparing ST and iVAPS mode there was no significant difference in RR between S/T and iVAPS groups.[17]

In our study, significant increase was seen in SpO_2 (%) after BiPAP as compared to that at admission in group 3 (p=0.012). This observation can be supported by a prospective observational study of 100 adult patients with hypercapnic RF done by Chawla et al.[18] Oxygen saturation was found to be significantly higher among patients successfully managed with NIV (84.35±8.55 vs 76.87±7.33) as compared to patients who required intubation.

Diaz et al prospectively examined patients with hypercapnic coma (GCS≤8) secondary to RF and treated with NIV.[19] At the beginning of ventilatory therapy, arterial pH was 7.13±0.06 and $PaCO_2$ was 99±19 mm Hg. Improvements in pH, GCS, $PaCO_2$, and $PaO2/FiO_2$ within the first hour of NIV correlated with NIV success.

In our study, significant change was seen in pH after BiPAP in group 2 (p=0.041) and group 3 (p<0.0001) with better and more favorable results in group 3.

Regarding pCO_2, significant decrease was seen after BiPAP as compared to that at admission in group 3 (p=0.0001). No improvement was seen in pO_2 (mmHg) after BiPAP in any of the groups, in fact, there was deterioration in pO_2 (mmHg) after BiPAP in group 2 (p=0.0002). In the study by Shaheen et al there was more significant improvement in acidosis in group treated with NIV than the conventional treatment group (p=0.014, 0.002, 0.001 and 0.006 at 1, 4, 12 and 24 hours of treatment respectively) with no significant change in pO_2 levels in both groups.[20]

A study conducted by Hussein et al on forty patients of acute hypercapnic RF due to AECOPD which aimed to compare the effectiveness of the newer iVAPS mode with S/T mode in patients showed that in the iVAPS group, there were a significantly (p<0.01) higher pH (7.34±0.02 vs 7.31±0.02 for PS group) and significantly (p<0.001) lower $PaCO_2$ (74.00±2.3 vs 79±3.7 for ST group) after 1 h NIV.[21] However, there was no statistically significant difference between the oxygenation in both groups. These findings are in accordance with our study.

There has also been certain data that do not show any difference in the various modes as in a retrospective study conducted by Soyler et al in which 82 patients with hypercapnic RF caused by AECOPD were analyzed and ABG parameters, length of hospital stay and rate of ICU admission were compared between iVAPS and BiPAP S/T.[22] The mean values of ABG parameters at the 1st and 24th hours of NIV therapy did not differ in both groups. Thus, both modes were found to be similarly effective.

In our study, success rate was significantly higher in group 3 as compared to group 1 (79.41% vs 45.45% respectively) (p=0.004) and group 2 (79.41% vs 57.54%

respectively, p=0.05) This is in accordance with the study conducted by Hussein et al in which successful outcome was achieved in 15 patients (75%) in the ST group vs 16 patients (80%) in the iVAPS group.[21] In the comparative study of ST and iVAPS mode by Salama et al, successful outcome was achieved in (82.5%) in the S/T group vs (80%) in the iVAPS group.[17]

NIV has been shown to be cost-effective in ICU setting, resulting in a better clinical outcome and decreased costs.[23,24] A study by Kolodzie et al[25] reported that the use of BiPAP in acute RF due to AECOPD has been shown to reduce the need for intubation and mechanical ventilation, the length of hospital stay, and mortality. In our study, rate of intubation was found to be lowest in group 3 (20.5%) whereas it was 36.3% and 39.3% in group 1 and group 2 respectively, however, this finding was not statistically significant.

A prospective, crossover study conducted in Germany on fourteen patients compared the effects ST mode with iVAPS mode in chronic hypercapnic COPD patients regarding the effects on alveolar ventilation, adverse patient/ventilator interactions and sleep quality.[26] The total number of respiratory events was low, and similar under ST and iVAPS conditions (p=0.064). There were also no clinically relevant differences in $PtcCO_2$ between the two groups. Respiratory rate was lower under iVAPS. Overall patient assessment scores were similar, although there was less discomfort with iVAPS. Their results showed that iVAPS NIV allows application of higher nocturnal ventilation pressures versus ST without affecting sleep quality or inducing ventilation-associated events.

Limitations

The study has potential limitations which should be considered. First, the sample size is small and not enough to ascertain the efficacy of each mode of NIV over one another. Second, owing to longer duration of hospital stay, few patients developed hospital-acquired pneumonia which might have acted as a confounding factor affecting the outcome of NIV and leading to invasive mechanical ventilation.

CONCLUSION

NIV using iVAPS is superior to other conventional NIV modes such as ST and T mode in successful management of patients presenting with hypercapnic RF due to acute exacerbation of COPD.

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