Ro J Pediatr. 2023;72(3)
DOI: 10.37897/RJP.2023.3.3

A study of comparison of outcomes of positive pressure ventilation and face mask oxygen on arterial blood gas parameters in children with congestive heart failure

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ABSTRACT

Aims and objective. To compare the effects of Positive Pressure Ventilation (PPV) and Face Mask oxygen on arterial blood gas (ABG) parameters in children with congestive heart failure.

Materials and methods. A prospective, randomized, single-blind, cross-sectional study was undertaken in eastern India's Dr. B.C. Roy Post Graduate Institute of Pediatric Sciences PICU. From December 2014 to June 2016, single-blind randomization was used to diagnose congestive heart failure in children aged 3 months to 12 years.

Results. Patients receiving face mask oxygen had a mean pH of 7.2150, while those receiving NIV had a mean pH of 7.2740 (P value = 0.012, <0.05). After 6 hours, the pH improved more in the NIV group (mean pH = 7.3023) than the face mask oxygen group (mean pH = 7.2503), P value = 0.003 (<0.05). The group receiving face mask oxygen had a mean pCO_2 of 54.93 at the start of the study, while the NIV group had 52.83 (P value = 0.395, >0.05). The baseline pCO_2 values of the two groups were similar. After 1-2 hours of investigation, the face mask oxygen group had a mean pCO_2 of 53.50, whereas the NIV group had 47.77, with a P value of 0.008 (<0.05). After 4-6 hours, the face mask oxygen group had a mean pCO_2 of 50.90, while the NIV group had 46.77, with a P value of 0.001 (<0.05).

Conclusion. After 6 hours of therapy, NIV improved mean pH more than face mask oxygen. NIV ventilation improved pCO_2 readings more than face mask oxygen after 2 hours. The mean pCO_2 drop over 4-6 hours in the NIV group was greater than in the face mask oxygen group.

Keywords: arterial blood gas, congestive heart failure, face mask oxygen, non-invasive positive pressure ventilation, pediatric cardiology, pH, pCO_2, tertiary care center

INTRODUCTION

Heart failure (HF) is a pathophysiological state in which an abnormality of cardiac function is responsible for the failure of the heart to pump blood at a rate commensurate with the requirements of the metabolizing tissues, or does so only at elevated filling pressures. In case of children, this requirement includes growth and development [1,2]. This can be due to either a heart that pumps well but the output is insufficient (due to a structural problem), or it can be a result of a weak heart muscle that does not pump normal amount of blood to the body. Either situation will lead to pooling of blood and fluid into the lungs if the left side of the heart is the problem or pooling of blood and fluid into the liver and veins when the right side of the heart is at fault.

In children, left-sided venous congestion causes tachypnea, respiratory distress, and wheezing. Right-sided congestion may result in hepatosplenomegaly, jugular venous distention, edema, ascites [3,4]. Application of positive pressure ventilation has been suggested in association with the conventional medical treatment as an effective therapeutic

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Article History:
Received: 23 September 2023
Accepted: 30 September 2023

modality in acute cardiogenic pulmonary edema due to congestive heart failure [5]. It provides more rapid recovery of vital signs and blood gas parameters when compared with the conventional treatment with oxygen by face mask [6] However the literature available for the same is very few in pediatric population. Thus, this study was done to compare the change in clinical parameters after positive pressure ventilation and oxygen by face mask.

AIMS AND OBJECTIVE

To compare the effects of PPV and Face Mask oxygen on ABG parameters Specially pH & pCO2 in children with congestive heart failure.

Objective

- To assess the effects of PPV and ABG parameters, specifically pH and pCO_2, in congestive heart failure children.
- To evaluate the influence of PPV and face mask oxygen on pH and pCO_2 levels in children with congestive heart failure following a 1–2-hour intervention.
- To evaluate the changes in pH and pCO_2 levels after 4-6 hours of treatment with PPV and face mask oxygen in children with congestive heart failure.

Literature Review

Congestive Heart Failure in Pediatric Patients

In children, congestive heart failure (CHF) is a complicated clinical illness in which the heart fails to pump enough blood to meet the body's metabolic needs [7]. The effects of this disease extend beyond the child's immediate clinical situation and can significantly impact their development and growth [8]. Causes of congestive heart failure in children include congenital abnormalities or cardiomyopathy. Managing CHF in children is crucial to avoid further consequences such as respiratory distress and organ congestion [9].

Treatment Modalities in Pediatric CHF

Pharmacological therapies, diuretics, inotropic medications, and respiratory support are essential for treating pediatric congestive heart failure [10]. The use of respiratory assistance is essential in easing the respiratory distress typically associated with CHF in children.

NIV in Pediatric CHF

In recent years, NIV has shown great promise as an auxiliary treatment for children with congestive heart failure [11]. Noninvasive ventilation (NIV) aims to provide a patent airway without requiring endotracheal intubation. To better manage acute cardiogenic pulmonary edema [12], this method tries to improve oxygenation, lessen respiratory discomfort, and increase carbon dioxide removal.
Adult Studies on NIV in CHF

NIV is beneficial in treating acute heart failure exacerbations in multiple investigations involving adult patients. Adults with congestive heart failure have shown immediate improvements in vital signs, oxygenation, and ABG values after receiving NIV [13]. Research on the effects of NIV in children has been inspired by the promising results seen in adult trials.

Pediatric Studies on NIV in CHF

However, there is still just a small amount of promising research on using NIV for pediatric CHF. Some evidence from limited studies [14] shows that NIV may provide benefits analogous to those seen in adults. For instance, NIV has been shown to enhance oxygenation and reduce the labor of breathing in pediatric patients with acute cardiogenic pulmonary oedema, according to research by [15].

Challenges and Future Directions

Despite these encouraging results, there are still several obstacles and potential directions for future study.

- Identifying subpopulations that may benefit most from NIV is important because pediatric CHF spans a wide spectrum of etiologies and disease severity.
- Very few studies have looked at the long-term outcomes of NIV in children with CHF.
- The most effective NIV settings, such as Inspiratory Positive Airway Pressure (IPAP), Expiratory Positive Airway Pressure (EPAP), and backup rate, have yet to be determined for pediatric CHF patients so future research should investigate hospital readmission rates, quality of life, and overall survival.

MATERIALS AND METHODS

A prospective randomized single blind, cross-sectional study was conducted in the PICU of Dr. B.C. Roy Post Graduate Institute of Pediatric Sciences, Kolkata which is a tertiary care center. Children between age 3 months to 12 years admitted with diagnosis of congestive heart failure or were found to have so on subsequent clinical examination using single blind randomization. The study period extends from December 2014 to June 2016.

Methodology

After approval from the institutional ethics committee, the study was initiated. The parent of infants/children referred to our institute who were fulfilling the inclusion criteria were informed about this study. Written informed consent from the parent of admitted infants / children with congestive heart failure in PICU of Dr. B.C. Roy Post Graduate Institute of Pediatric Sciences were taken. Diagnosis of congestive heart failure was made based on history, clinical examination with finding of tachycardia, tachypnea, respiratory distress, wheezing, basal crepitation, pulsus alternans, gallop rhythm and enlarged tender liver, pulsatile engorged neck veins, positive hepatojugular reflux and findings of chest x-ray and echocardiography. Patients were assigned to receive either high flow O_2 via non-rebreathing mask or non-invasive positive pressure ventilation alternatively. Face mask oxygen (10 Litre/Minute) were given using non-rebreathing mask which prevents mixing of exhaled air and room air with that of fresh oxygen and non-invasive positive pressure ventilation were given using ventilators in NIV mode.

The starting mode of ventilation in NIV and further adjustments of the ventilator pressures and rates were made according to clinical need, patient comfort, and blood gas analysis. Positive endexpiratory pressure (PEEP) was initiated with a backup rate of 4-5 cm H_2O for all of our patients, increased as necessary up to a maximum of 10-12 cm H_2O if no improvement in oxygen saturation or arterial PaO_2 was achieved. A nasogastric tube was put in all patients. The interface was chosen according to the child's age and head size to achieve comfort and avoid significant air leaks. Colloid dressings were placed on major pressure points to minimize skin injury. All patients were continuously monitored by means of electrocardiography and pulse oximetry (Philips), and we measured respiratory rate, and central and peripheral temperature. Intermittent observations of chest movements and comfort level and auscultation of breath sounds were performed. Blood gas analysis (OPTI CCA-TS) was performed according to the protocol (at the time of initiating NIV and at 1-2 hrs, 4-6 hrs and later when clinically required).

The following data were collected prospectively before initiating NIV and face mask oxygen in respective study groups at initiation, 1-2 and 4-6hrs of intervention: blood gas analysis including pH, pCO_2. The data was entered in Microsoft excel sheet and analysis was done in spss software version 20.0. The qualitative data was presented in frequency and percentage and represented in bar diagrams. Quantitative data was presented with mean and standard deviation. Comparison between two groups was made by unpaired t-test. The association between qualitative data was done by chi-square test. P value less than 0.05 was considered significant.

Result analysis

The analysis of the study's outcomes includes a detailed look at the demographics and baseline features of the study's patient population and an evaluation of the initial ABG parameters in the face mask oxygen group and the non-invasive positive pressure ventilation (NIV) group.

Patient Demographics

- The trial included 60 patients, split evenly between two groups of 30.
- Patients' mean age was 8.40 months in the oxygen face mask group.
- The average patient age was 7.27 months in the NIV group.
- It's important to note that the two groups were well-matched in age, with no noticeable age gap.

According to the study results, there was likewise no discernible variation in the sex composition of the two groups.

Baseline ABG Parameters

ABG measurements were measured at the beginning of the study to establish a starting point for comparing the effects of the two treatment approaches.

In this investigation, researchers were particularly interested in the acid-base balance and respiratory status markers provided by the ABG parameters pH and pCO_2.

The ABG parameters were not significantly different between the face mask oxygen and NIV groups at baseline.

Both groups showed identical acidity (low pH) and retained carbon dioxide (high pCO_2) at the outset, suggesting no substantial difference.

The analysis of the study's results shows that the included 60 pediatric patients with congestive heart failure were evenly distributed between the face mask oxygen and NIV groups in terms of age and gender. At the outset of the trial, there were no notable variations in pH or pCO_2 levels between the two groups ABG values. For any later differences in ABG measurements to be attributable to the treatment modalities (facial mask oxygen vs. NIV), the two patient groups must begin with similar physiological characteristics.

Results

Mean age of patients in the group receiving face mask oxygen was 8.40 months while that in NIV group was 7.27 months with the P value of 0.555 which is not significant. In each group 30 patients were taken with no significant difference between the groups in age and sex (p value >0.5). The two groups had no significant difference in both the groups on ABG analysis at baseline.

Distribution of pH

Mean pH at the start of our study in the group who received face mask oxygen was 7.198 while mean pH was 7.214 in NIV group. P value being

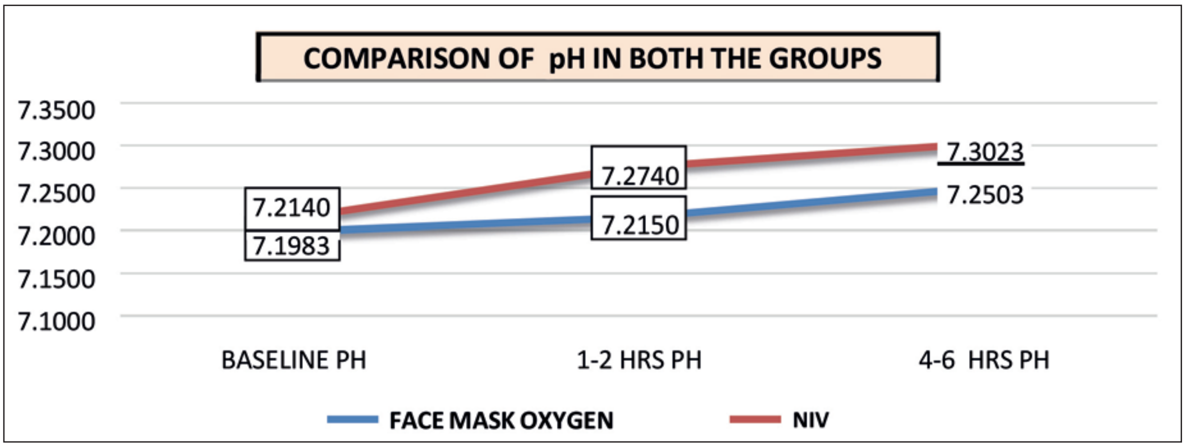

FIGURE 1. Comparison of pH in both groups

0.473 (>0.05) was not significant. The mean pH after 1-2 hours of study in both the groups was measured. The group who received face mask oxygen was 7.2150 while that of NIV pH was 7.2740 in NIV group. P value being 0.012 (<0.05) there was significant difference in both the groups after 2 hours with pH improving significantly after NIV ventilation at 2 hours. The mean pH after 4-6 hours of study the group who received face mask oxygen was 7.2503 while that of NIV pH was 7.3023 in NIV group (Figure 1). The pH compared in both the groups after 6 hours revealed mean improvement in the pH in group receiving NIV was more than the group receiving face mask oxygen. P value being 0.003 (<0.05).

Distribution of pCO2

Mean pCO_2 at the start of our study in the group who received face mask oxygen was 54.93 while pCO_2 was 52.83 in NIV group. P value being 0.395 (>0.05). There was no significant difference between the two groups in the pCO_2 values at baseline. Mean pCO_2 when measured after 1-2 hours of study in the group who received face mask oxygen was 53.50 while mean pCO_2 was 47.77 in NIV group (Figure 2). P value being 0.008 (<0.05). There was significant difference in the pCO_2 values with more improvement receiving NIV ventilation when compared to those who received face mask oxygen after 2 hours. Mean pCO_2 when measured after 4-6 hours of study in the group who received face mask oxygen was 50.90 while mean pCO_2 was 46.77 in NIV group. The mean decrease in the pCO_2 over 4-6 hours of study in group receiving NIV was more than the group receiving face mask oxygen. P value being 0.001 (<0.05).

So, the improvement in pCO_2 was significantly more in the patients who received NIV ventilation compared to those who received oxygen by face mask after 6 hours of commencing the treatment.

Baseline pH Levels:

In the group receiving oxygen using a face mask, the mean pH at baseline was 7.198 (95% CI: 7.170 - 7.226), while in the NIV group, it was 7.214 (95% CI: 7.186-7.242). There was no statistically significant difference in these values between the two groups.

pH Levels After 1-2 Hours:

The mean pH in the group that received face mask oxygen was 7.2150 (95% CI: 7.1901-7.2399) after 1-2 hours of intervention, while the mean pH in the NIV group was 7.2740 (95% CI: 7.2448-7.3032). The p-value for the difference being significant was 0.012.

pH Levels After 4-6 Hours:

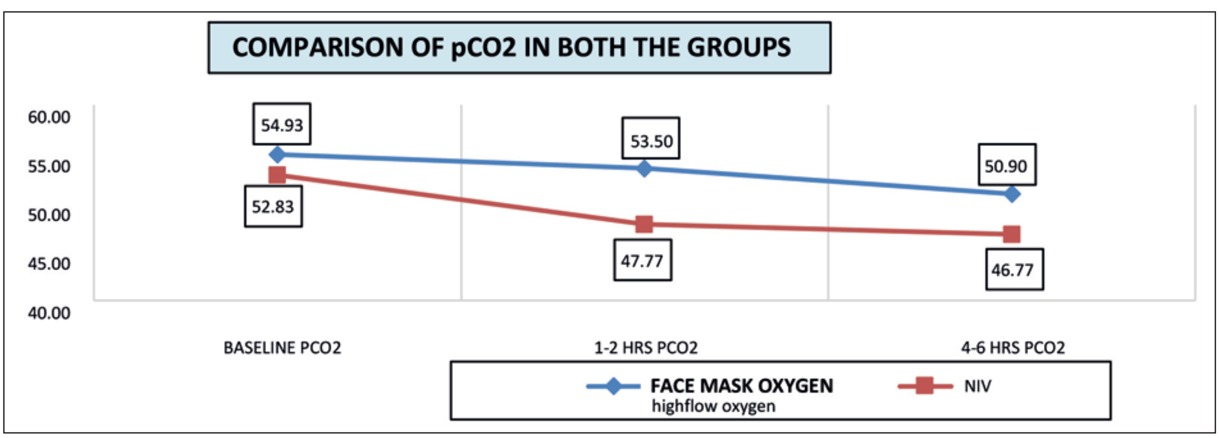

FIGURE 2. Trend of pCO_2 over 4-6 hours of study

The oxygen face mask group had a mean pH of 7.2503 (95% CI: 7.2221-7.2785) after 4 to 6 hours of treatment, while the NIV group had a pH of 7.3023 (95% CI: 7.2750-7.3296). With a p value of 0.003, the difference was still statistically significant.

Baseline pCO_2 Levels:

At baseline, the oxygen face mask group had a mean pCO_2 of 54.93 (95% CI, 54.17–55.69), while the non-invasive ventilation group had a mean pCO_2 of 52.83 (95% CI, 52.08–53.58). There was no statistically significant difference in these values between the two groups.

pCO2 Levels After 1-2 Hours:

The mean partial pressure of carbon dioxide (pCO_2) in the face mask oxygen group was 53.50 (95% CI: 52.48-54.52) after 1 to 2 hours of intervention, while the mean pCO_2 in the NIV group was 47.77 (95% CI: 46.56-48.98). The p-value for the difference being significant was 0.008.

pCO2 Levels After 4-6 Hours:

Compared to the NIV group, who's mean pCO_2 was 46.77 (95% CI: 45.60-47.94) after 4 to 6 hours of treatment, the face mask oxygen group's pCO_2 was 50.90 (95% CI: 49.98-51.82). The p-value for the difference remained significant at 0.001.

Findings

This study compared the effects of two therapy methods, NIV and ABG parameters, pH and pCO2 in children with congestive heart failure.

The children in the research who were given NIV had much higher pH levels than those given oxygen through face masks. This is a more in-depth explanation of:

- pH levels were similar in both groups at the beginning of the research.
- Still, the NIV group demonstrated a substantial increase in pH compared to the face mask oxygen group after only 1–2 hours of treatment. This development suggests that NIV was more effective in resolving acid-base imbalance in these people early in treatment.
- Over the course of 4–6 hours, the pH disparity between the NIV and oxygen mask groups widened, with the NIV group showing significantly higher pH. That NIV's positive effects on pH levels continued for so long throughout treatment is more evidence of that fact.

Another crucial result was the effect on pCO_2 levels, which stands for relative pressure of carbon dioxide in the blood. The data showed that NIV was superior to oxygen masks in promoting the exhalation of carbon dioxide from the body.

- There was no initial difference in pCO_2 readings between the two groups, indicating that both could retain a similar amount of carbon dioxide.
- The pCO_2 values of the NIV group dropped much more than those of the face mask oxygen group after 1-2 hours of intervention. This drop suggests that early on in therapy, NIV helped facilitate the excretion of additional CO_2 from the body.
- After 4 to 6 hours, the disparity between the pCO_2 levels of the NIV and face mask oxygen groups was very pronounced.
- This indicates that NIV maintained its ability to improve CO_2 removal over the prolonged time of treatment.

The results of this study indicate that NIV is superior to conventional mechanical ventilation for treating congestive heart failure in children. These enhancements are crucial for patients with congestive heart failure because they assist in managing the respiratory discomfort and acid-base imbalances that frequently accompany this condition. However, more research and larger-scale investigations are required to validate these results and investigate other pertinent characteristics and long-term consequences linked with NIV treatment in this pediatric population.

DISCUSSION

The study results are analyzed and interpreted in light of the prior literature in the discussion section. Here, we explore how this study's findings match the existing literature and highlight the need for more research into NIV as a therapy option for pediatric patients with congestive heart failure.

Managing acute cardiogenic pulmonary oedema due to congestive heart failure in children may benefit from NIV, as suggested by the study results, which are consistent with the literature. Existing studies have shown the favorable effects of NIV in improving oxygenation, decreasing respiratory distress, and promoting carbon dioxide elimination during acute exacerbations of heart failure, albeit these trials have mostly been undertaken in adult populations. The study's inclusion of children further supports NIV's potential value in treating the respiratory problems often seen in kids with heart failure.

Many questions remain unanswered even though this trial provides important new information about the short-term effects of NIV versus face mask oxygen in children with congestive heart failure. Beyond pH and pCO2, more clinical factors may be the focus of future research. It may be possible to gain a more complete picture of the clinical response to NIV in children with congestive heart failure by measuring oxygen saturation, heart rate, and respiratory rate. The long-term effects of NIV therapy in this group need to be assessed urgently. The long-term benefits of NIV for managing children with congestive heart failure can be evaluated by looking at hospital length of stay, readmission rates, and overall survival. More study is needed to determine whether or not NIV has a varied effect on various subsets of pediatric patients with congestive heart failure (such as those with different etiologies, ages, or severity levels). Care is most effective when individualized per the patient's unique qualities.

It is critical to study how NIV affects the well-being of children and their carers. An all-encompassing view of therapy results can be gained by evaluating physical functionality, mental well-being, and carer load. Studies comparing NIV to other therapy methods, including invasive mechanical ventilation or a high-flow nasal cannula, can further be the most useful method in specific clinical settings.

CONCLUSION

Although very few studies are available regarding use of NIV as a modality of treatment in CCF compared to face mask Oxygen in children but in this small study we have seen significant improvement in maintaining pH and CO_2 washout from body by NIV modality. We need further study to see improvement of another parameter of ABG also.

Conflict of interest: none declared
Financial support: none declared

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