Journal of Chemical Health Risks

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JCHR (2024) 14(2), 1111-1123 | ISSN:2251-6727

Outcome of Noninvasive Ventilation V/S Oxygen Therapy in Children with Congestive Heart Failure

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(Received: 14 April 2024 Revised: 1 May 2024 Accepted: 18 June 2024)

KEYWORDS
Congestive heart failure, Noninvasive ventilation, Pediatric intensive care unit, Respiratory distress, Oxygen therapy

ABSTRACT:

Background:-Children with congestive heart failure (CHF) often require significant respiratory support due to the challenging nature of treatment. The aim of this study was to investigate the differential outcomes between two respiratory support modalities for pediatric patients with CHF.

Methods:-A prospective, cross-sectional, single-masked, controlled study was conducted in the Paediatric Intensive Care Unit (PICU) in Kolkata, situated in a tertiary care center. Fifty children diagnosed with CHF were randomly assigned to receive oxygen via nasal non-invasive ventilation (NIV) or a face mask oxygen (FMO). The subjects, aged between three months and twelve years, were stratified by age. Respiratory and hemodynamic parameters were recorded at three intervals: baseline (initiation of therapy), one to two hours post-initiation, and four to six hours post-initiation. Data were analyzed using chi-square and single t-test methods.

Results:-The NIV group exhibited significantly higher pH, pCO2, pO2, and SpO2 levels during the four to six-hour period compared to the FMO group. Additionally, the NIV group demonstrated a lower heart rate (p=0.164). In instances where treatment was unsuccessful, the NIV group required intubation for an average of 57.67 hours, while the FMO group required intubation for 43.25 hours. The average duration of NIV therapy was 41.08 hours, compared to 46.87 hours for FMO therapy. Intubation was necessary in 20.0% of the NIV group and 46.7% of the FMO group (p = 0.028). Mortality rates decreased by 6.7% with NIV, compared to a 13.3% reduction with FMO.

Conclusion:-Compared to oxygen therapy with a face mask, non-invasive ventilation improved respiratory outcomes, reduced the need for intubation, and decreased mortality rates in pediatric patients with CHF. Further research is warranted to fully understand the long-term effects of these interventions.

Introduction

In heart failure (HF), the heart is unable to pump blood efficiently enough to meet the metabolic demands of the body's tissues. This condition can occur in pediatric patients due to anatomical abnormalities or weakened cardiac muscles. Left-sided congestion of the veins and arteries can lead to symptoms such as tachypnea and respiratory distress. Conversely, right-sided congestion can cause hepatomegaly, splenomegaly, peripheral edema, and ascites. Older children with uncompensated CHF often experience lethargy and decreased energy levels [1]. Congenital heart disease (CHD), affecting approximately 0.8% of live births, is the predominant

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cause of HF. Additionally, systemic diseases, chronic arrhythmias, dilated cardiomyopathy, volume overload, and pressure overload can contribute to HF. Reflecting the high prevalence of CHD as a causative factor, nearly 90% of pediatric HF cases occur within the first year of life. Acute cardiogenic pulmonary edema secondary to CHF can be effectively managed with noninvasive positive pressure ventilation (NPPV) utilizing a face mask oxygen (FMO). This approach alleviates respiratory distress, expedites the normalization of vital signs and blood gas measurements, and reduces the need for endotracheal intubation. Both bi-level positive airway pressure (BiPAP) devices and continuous positive airway pressure (CPAP) devices are classified under NPPV [2]. The use of noninvasive ventilation (NIV) for the treatment of severe CHF necessitates meticulous patient selection, continuous monitoring, appropriate technological application, and clearly defined therapeutic goals. NIV can serve as a valuable adjunct in managing patients with acute CHF who are at risk for endotracheal intubation.

Aims and Objectives

1. To evaluate the effectiveness of noninvasive ventilation in the management of pediatric congestive heart failure (CHF).

2. To compare the outcomes of conventional face mask oxygen (FMO) therapy with noninvasive ventilation in children with CHF.

Review of Literature

The application of noninvasive respiratory support techniques is increasingly prevalent in the management of respiratory failure. However, there is a paucity of data regarding the use of NPPV in children with cardiac conditions. This study is anchored in literature that demonstrates the benefits of NIV in adults with respiratory insufficiency secondary to heart failure. Respiratory failure is a significant cause of morbidity and mortality and is the leading reason for admissions to the Pediatric Intensive Care Unit (PICU). According to [3], noninvasive ventilation is now considered the gold standard for managing respiratory failure as it decreases the necessity for intubation. Despite the growing use of ventilatory support in the PICU, research in this domain remains underdeveloped. In certain conditions such as bronchiolitis, NIV is strongly recommended, while its efficacy in other scenarios is still debated.

Heart Failure, Conventional Medical Treatment, and Noninvasive Ventilation. Several guidelines advocate for the use of positive airway pressure (PAP) therapy in patients experiencing respiratory distress, signs of pulmonary edema, or persistent hypoxia despite supplemental oxygen therapy. For adult patients with acute heart failure, oxygen should be administered via nasal cannula or FMO at a rate of 2 to 6 L/min, as per [4]. Prompt initiation of NPPV is advised for patients with arterial partial pressure of carbon dioxide (PaCO2) of 50 mmHg or higher, tachypnea, labored breathing, orthopnea unresponsive to conventional treatments, or oxygen saturation (SpO2) below 95%.

Effect of Positive Pressure Ventilation on Hemodynamics

The study "Cardiovascular Effect of Mechanical Ventilation" by [5] discusses the applications of positive end-expiratory pressure (PEEP). PEEP can enhance cardiac output in patients with left ventricular failure and pulmonary edema by reducing left ventricular afterload and limiting venous return. Improvements in oxygenation and lung volume towards functional residual capacity (FRC) can positively impact right ventricular afterload. PEEP helps maintain alveolar patency and lung volume in patients at high risk for secondary atelectasis due to edema [6]. Consequently, increasing intrathoracic pressure can improve cardiac output in patients with left ventricular dysfunction. Combined cardio-respiratory treatments incorporating noninvasive positive pressure ventilation are gaining traction for managing ventricular dysfunction. Bilevel positive airway pressure (BLAP) therapy, which can be administered via mask or nasal prongs, reduces the work of breathing and enhances left ventricular function. Additionally, it mitigates complications associated with endotracheal tubes, such as pulmonary infections and the need for sedation [7]. In pediatric patients with patent ductus arteriosus (PDA), atrial, ventricular, or atrioventricular septal defects, or left-to-right shunts, pulmonary blood flow increases as pulmonary vascular resistance (PVR) decreases. A slight increase in PVR in conjunction with PEEP can potentially reduce pulmonary blood flow, yielding additional positive effects.

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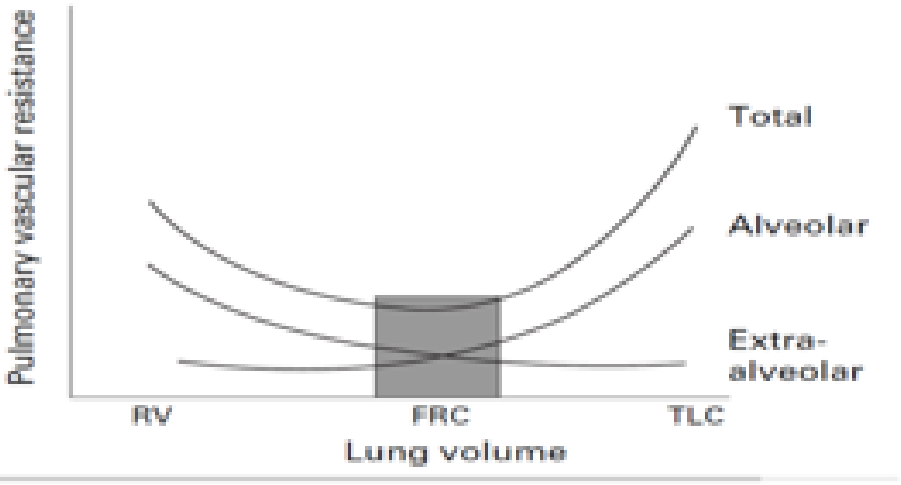
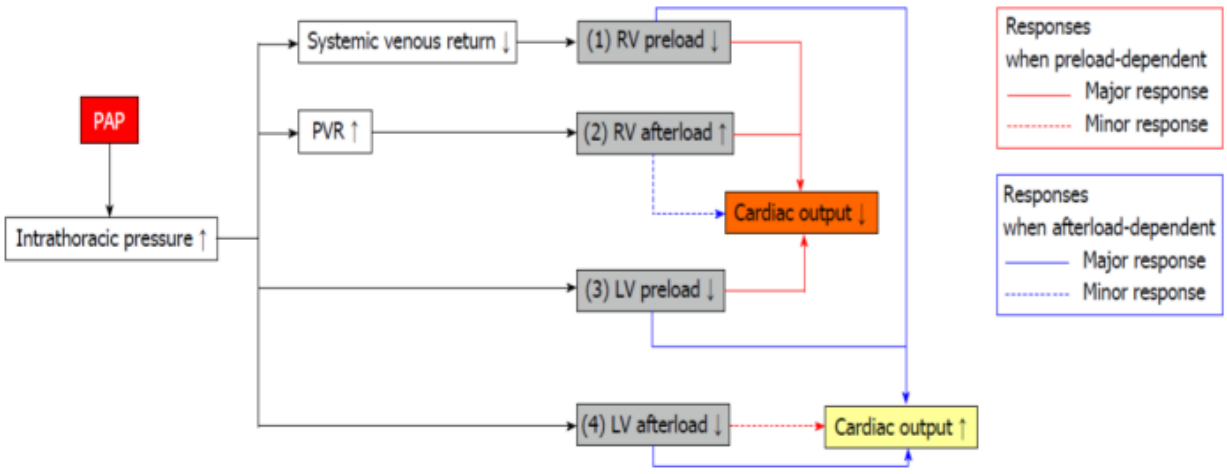
JCHR (2024) 14(2), 1111-1123 | ISSN:2251-6727



For instance, vascular capacitance rises as the volume of the lungs rises from residual volume to functional residual capacity, with the majority of the volume increase affecting the extra-alveolar arteries [8]. The result is a decline in overall PVR. As the lung volume increases beyond its functional residual capacity and reaches its total lung capacity, the effects on the intra-alveolar arteries become more pronounced, decreasing vascular capacitance and improving the whole PVR. It is conceivable for PAP to raise RV afterload, even though this would not be clinically significant without a large change in lung capacity. Limitations in left ventricular (LV) inflow and filling are caused by a decrease in systemic venous return to the RV (a drop in RV preload) and an increase in RV afterload [9]. Also, when the RV afterload is high, the RV might enlarge and move its septum towards the left ventricle. Heart output and organ perfusion are decreased, further restricting LV filling. Hence, while 10 PAP treatment decreases LV preload and afterload, it increases RV afterload and decreases RV preload. The majority of non-HF subjects rely on preload [10].

On the other hand, a falling heart is more responsive to reduced afterload, and hypervolemic individuals with HF are typically unresponsive to reduced preload. Individuals with HF are primarily dependent on load, and PAP treatment can boost cardiac output in those individuals. However, cardiac output reactions (increase or reduction) in HF patients will rely on their preload and afterload state [11].



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Effect of PAP on respiration

[12] outline multiple functions of PAP in breathing. By recruiting alveolar units, maintaining airway patency, and counteracting hydrostatic forces that cause pulmonary oedema, PAP increases gas exchange and oxygenation by keeping alveoli from collapsing at the end of expiration. By drawing in collapsed alveoli, reversing atelectasis, and inducing a fluid shift from the interstitial space and the alveoli to the pulmonary circulation, Second, PAP can improve lung function by maintaining functional residual capacity and reducing the strain on the respiratory muscles and the task of breathing. A third component of various PAP therapies is pressure support during inspiration to keep ventilation going. This holds extra significance for heart failure patients experiencing hypoventilation.

A meta-analysis by [13] on "noninvasive ventilation in paediatrics" found that NIV effectively treats acute pulmonary oedema in children. Rapid improvement of vital signs and reduction in the requirement for endotracheal intubation can be achieved with NIV modalities such as CPAP via facial mask. Noninvasive ventilation has many benefits, such as being easier to install, not invasive, causing less discomfort, less likely to have issues related to the endotracheal tube, and less expensive.

Material and methods

Study site

Researchers in Kolkata's Dr. B. C. Roy PICU conducted the experiments. A tertiary care facility is this. Our institute receives referrals for paediatric and neonatal patients from several districts in West Bengal.

Study population

Use single-blind randomization to admit children (ranging in age from 3 months to 12 years) who have a diagnosis of CHF or who will be diagnosed with the condition during a follow-up clinical assessment.

Study design

Prospective randomized single-masked cross-sectional. This research will take place in a healthcare facility.

Sample size

Sixty people in all, the average and standard deviation of patients on oxygen and continuous positive airway pressure plus oxygen, as reported in the paper "Treatment of severe cardiogenic pulmonary oedema with continuous positive airway pressure delivered by FMO " by Bersten, Andrew D8 et al., were 33±9 and 27±6, respectively.

Inclusion criteria

Individuals who have been diagnosed with CHF and exhibit any of the following symptoms: Having an insufficient reaction to first-line conventional treatment, being in danger of endotracheal intubation, Constantly needing more oxygen than what is provided by 4 litres per minute, and those Symptoms of respiratory muscle exhaustion and an abnormal ABG (pH < 80, PaCO2 > 45) can occur in the following situations:

Exclusion criteria

- Patients with severe hemodynamic instability
- Those with difficulty in guarding their airway
- Patients with recent facial or upper airway surgery, vomiting, or face burns
- Patients with fixed upper airway obstruction
- Patients with undrained pneumothorax
- Patients with severe hemodynamic instability
- Patients who fulfil the inclusion and exclusion criteria will be randomly assigned to the study or control groups.

Methodology

A total of twenty-six paediatric patients admitted to the PICU at the Dr B. C. Roy Postgraduate Institute of Paediatric Sciences were evaluated for CHF. Clinical examination, patient history, and imaging studies (echocardiography and chest x-ray) led to the diagnosis. Nebula cannulas or noninvasive positive pressure ventilation were used to administer high-flow oxygen to patients. A backup rate of 4–5 cm H2O was used to start positive end-expiratory pressure (PEEP), which was increased as needed. A nasogastric tube was employed nasogastric tube was employed to ensure the patient was comfortable with data collection**.**

The study utilized electrocardiography, pulse oximetry, and blood gas analysis to track patients with CHF. Age,

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sex, weight, and history of heart disease were among the variables documented. Data were taken in the beginning, one to two, and four to six hours after the intervention before administering NIV and FMO. Patients were intubated and placed on mechanical ventilation if their ABG readings did not improve after 6 hours. Even after weaning off respiratory support, the patient's medical treatment for heart failure persisted.

Statistical method

We used spss software version 20.0 to analyze the data entered into a Microsoft Excel sheet. Bar graphs showed the percentage and frequency distributions of the qualitative data. The mean and standard deviation were used to present the quantitative data. We used an unpaired t-test to compare the two sets of data. A chi-square test was used to determine the connection between the qualitative data. For statistical significance, a p-value of less than 0.05 was used.

Results

Trend Of Respiratory Rate Over 4-6 Hours Of Study

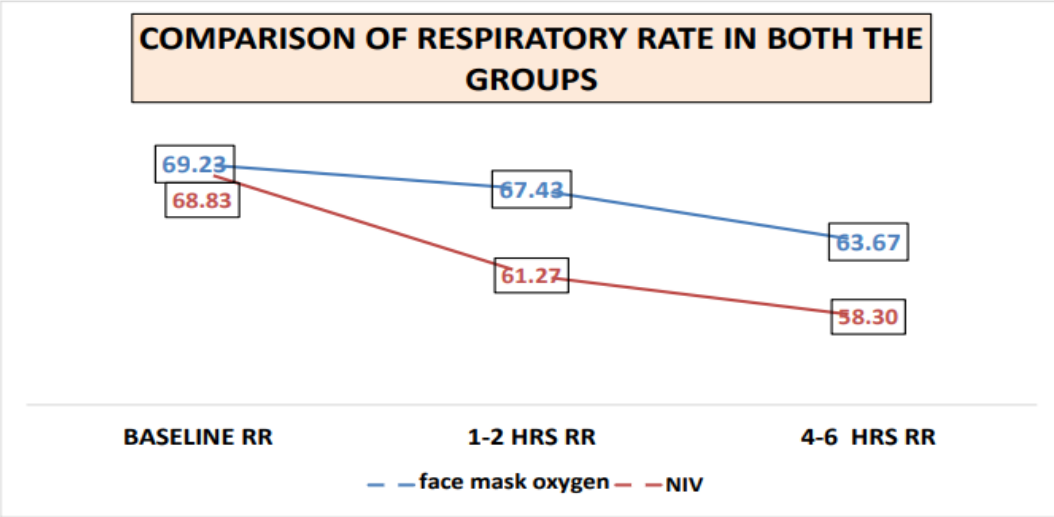

Figure -16

The group given NIV had a more significant mean reduction in respiratory rate during the research (4-6 hours) than the group given oxygen via a FMO, with a p-value of 0.02 (<0.05).

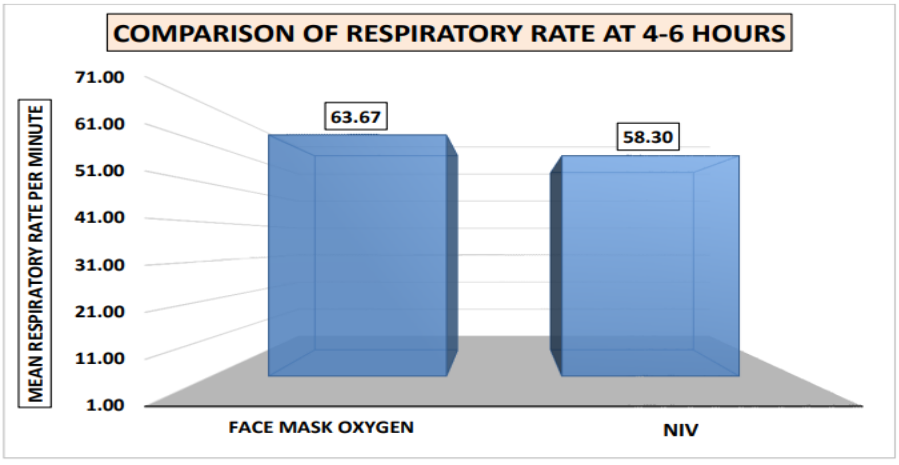

Figure -17

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Trend of Heart Rate Over 4-6 Hours Of Study

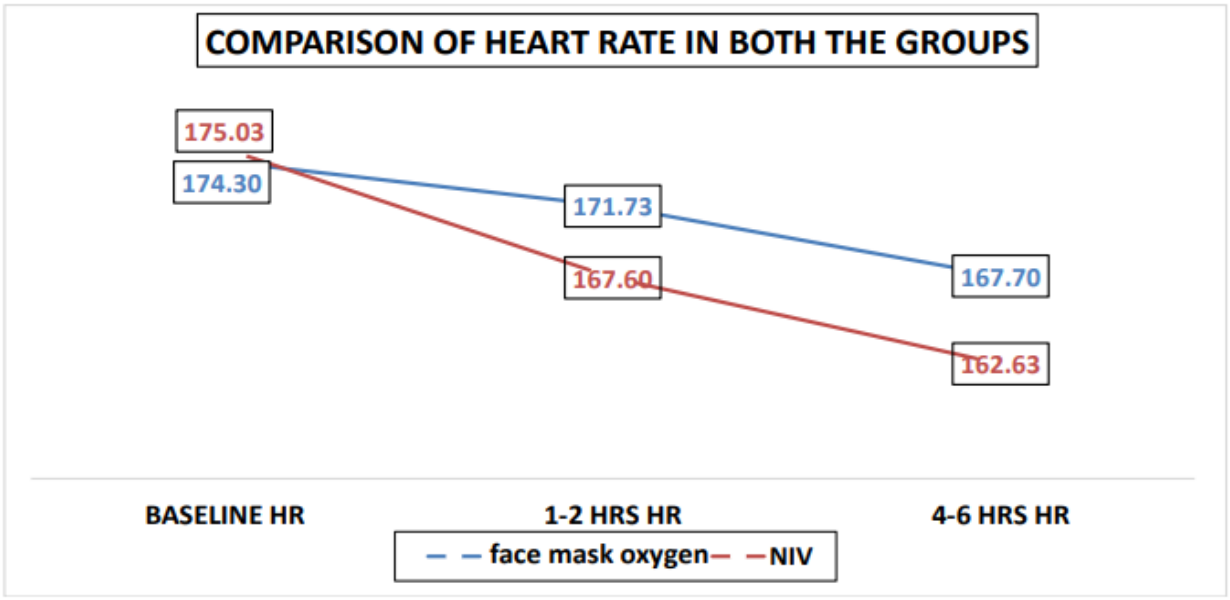

Figure -18

Over the four to six hours of the trial, the group given NIV had a more significant mean reduction in heart rate than the group given oxygen via a FMO. The p-value is 0.164, more important than the significance level of 0.05.

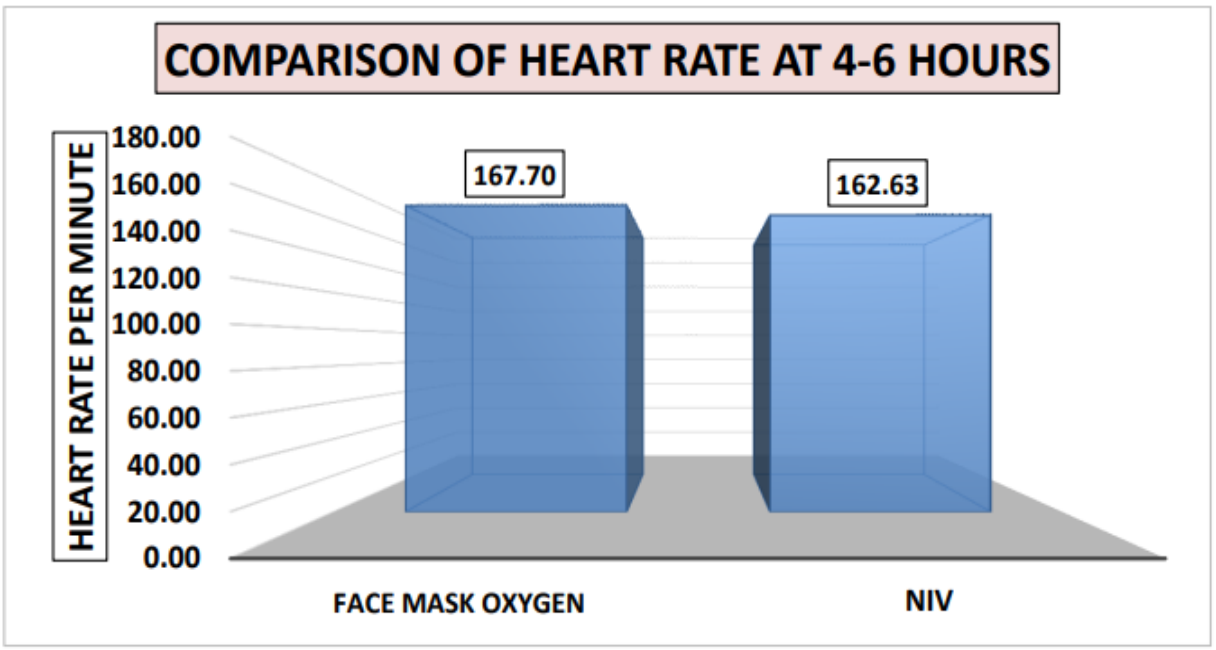

Figure -19

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TREND OF pH OVER 4-6 HOURS OF STUDY

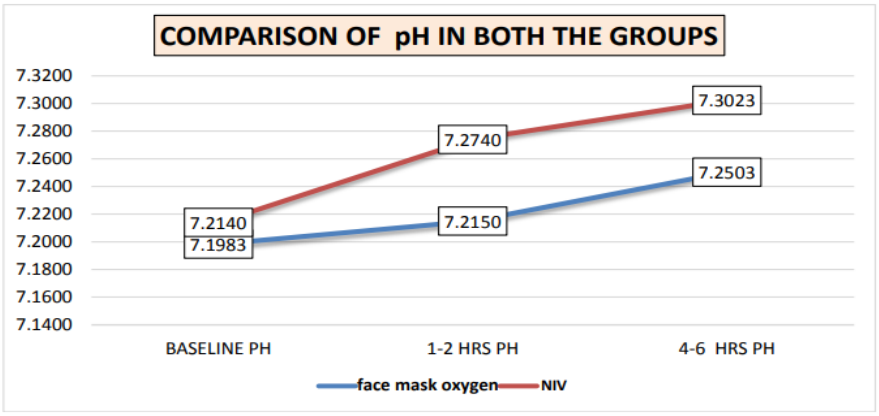


Figure -20

Results showed that after 4 to 6 hours of treatment, the pH of the NIV group improved more than that of the FMO group. Being less than 0.05, the p-value is 0.003.

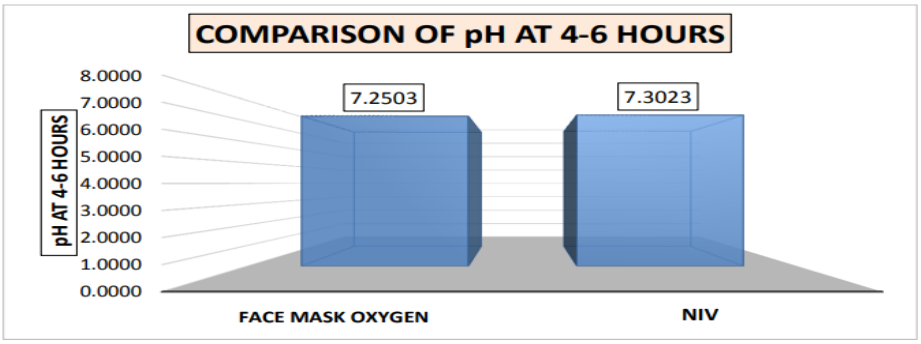
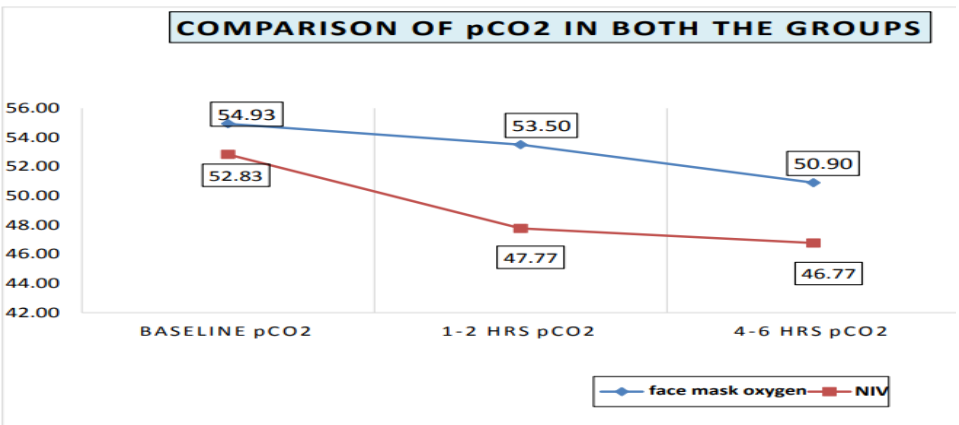


Figure -21

TREND OF pCO2 OVER 4-6 HOURS OF STUDY



Over the four to six hours of the trial, the group given NIV had a more significant mean reduction in pCO2 than the group given oxygen through a FMO since the p-value is 0.001 (<0.05).

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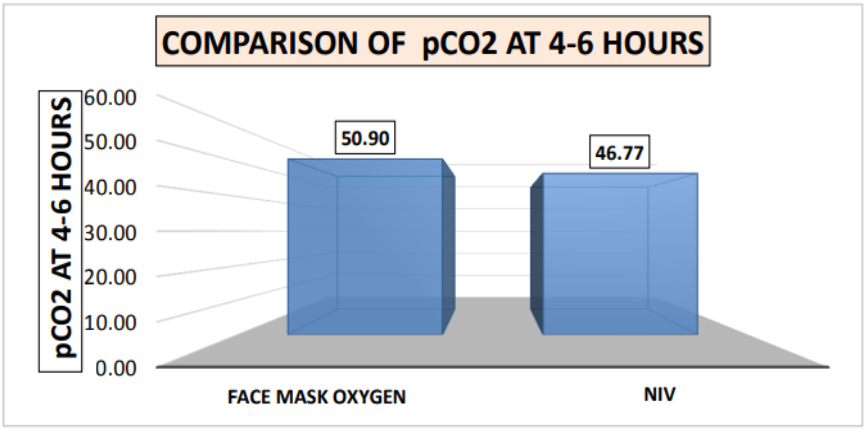

Figure -23

Trend of PO2 Over 4-6 Hours Of Study

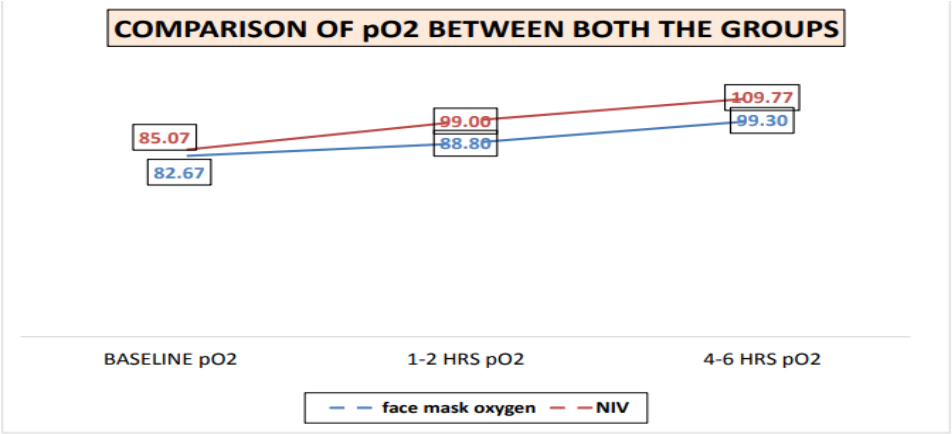

Figure -24

The NIV group showed a more extraordinary mean rise in pO2 during the research (4-6 hours) than the FMO group. As the p-value is 0.008,

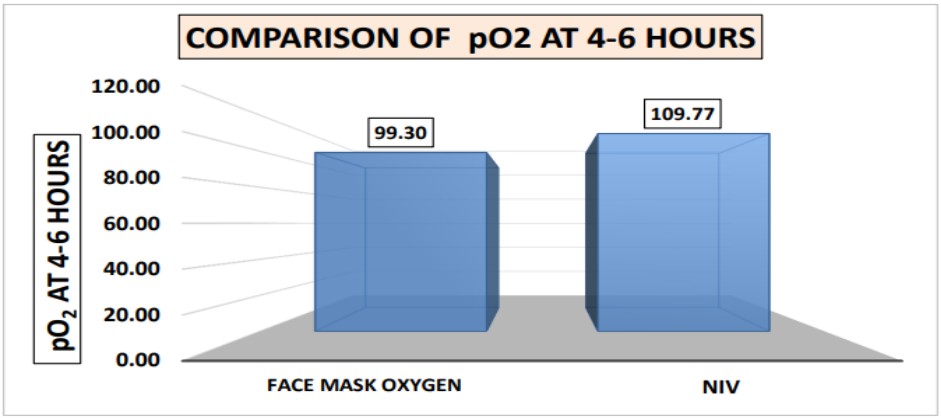

Figure -25

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trend of Spo2 over 4-6 hours of study

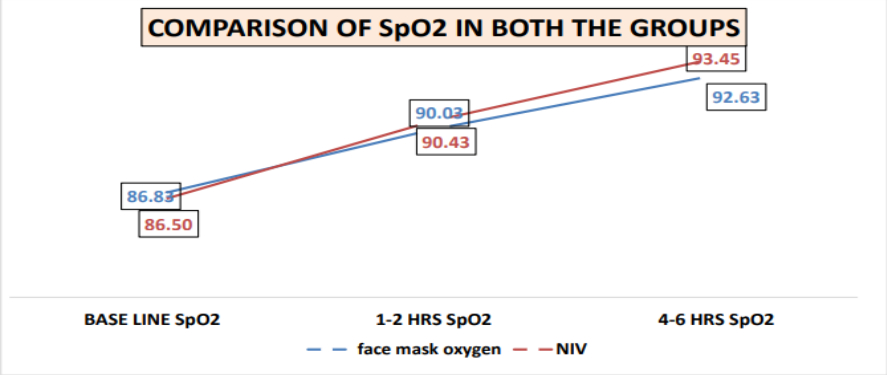

Figure -26

Over the study's four to six hours, the group given NIV had a higher mean increase in SpO2 than those given oxygen through a FMO. Being 0.245 (>0.05), the p-value

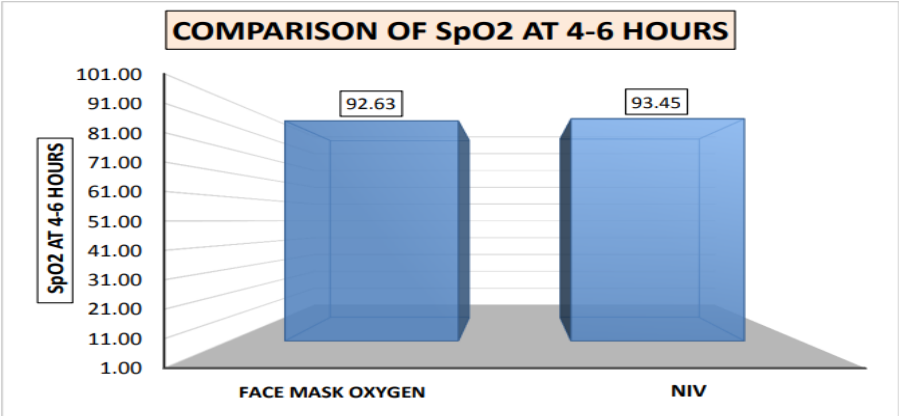

Figure -27

Mean Duration Fmo Niv In Respective Group

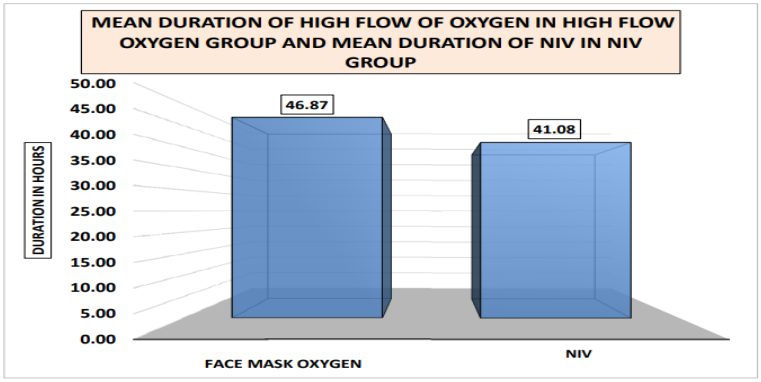

Figure -28

Patients in the FMO group had a mean length of 46.87 hours, whereas those in the noninvasive ventilation group had a mean duration of 41.08 hours.

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Duration Of Intubaton In Two Groups After Failure Of Niv And Fmo In Respective Groups

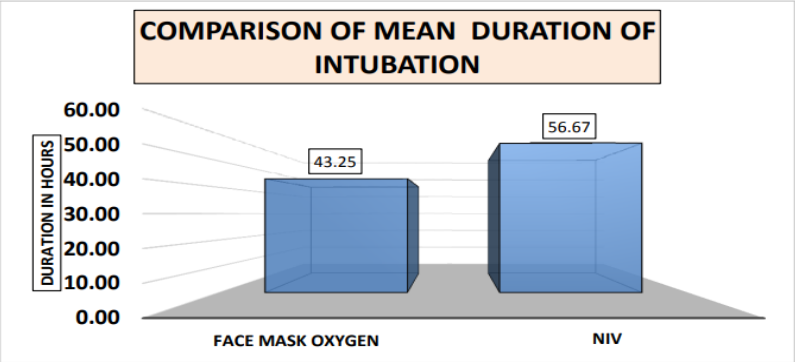

Figure -29

After FMO therapy failed, the average number of hours spent intubated in the group that received the mask was 43.25, compared to 57.67 in the group that received noninvasive ventilation.

Distribution of Requirement Of Intubaton In Both Groups

TABLE 6

Crosstab

			Group name		
			Face mask oxygen	NIV	Total
Requirement of intubation	No	Count	16	24	40
		% within group name	53.3%	80.0%	66.7%
	Yes	Count	14	6	20
		% within group name	46.7%	20.0%	33.3%
Total		Count	30	30	60
		% within group name	100.0%	100.0%	100.0%

Intubation was necessary for 46.7% of patients in the FMO group and 20.0% in the noninvasive ventilation group. As the p-value is 0.028

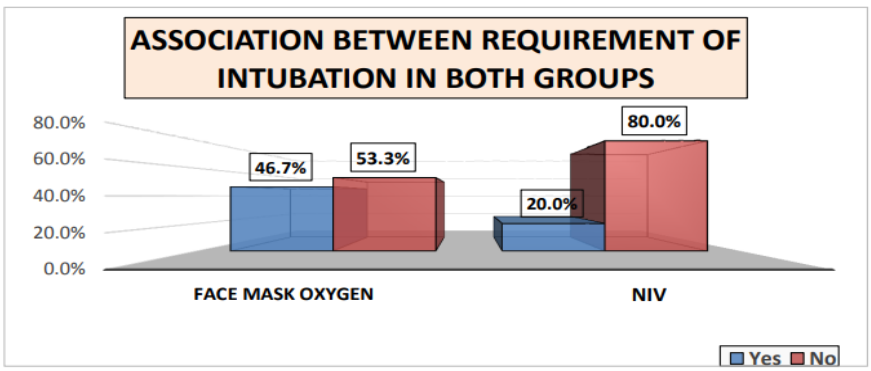

Figure -30

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Final Outcome in the Two Group

TABLE 7

Crosstab					
			Group name		
			Face mask oxygen	NIV	Total
Final outcome	Discharged	Count	26	28	54
		% within group name	86.7%	93.3%	90.0%
	Death	Count	4	2	6
		% within group name	13.3%	6.7%	10.0%
Total		Count	30	30	60
		% within group name	100.0%	100.0%	100.0%

Chi-Square Tests					
	Value	df	Asymp. Sig. (2-sided)	p value	Exact Sig. (1-sided)
Pearson Chi-Square	.741[a]	1	.389		
Fisher's Exact Test				.671	.335
a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.00.					
b. Computed only for a 2x2 table					

86.7% patients in face mask oxygen group while 93.3% in NIV group improved to discharge.

P value 0.671

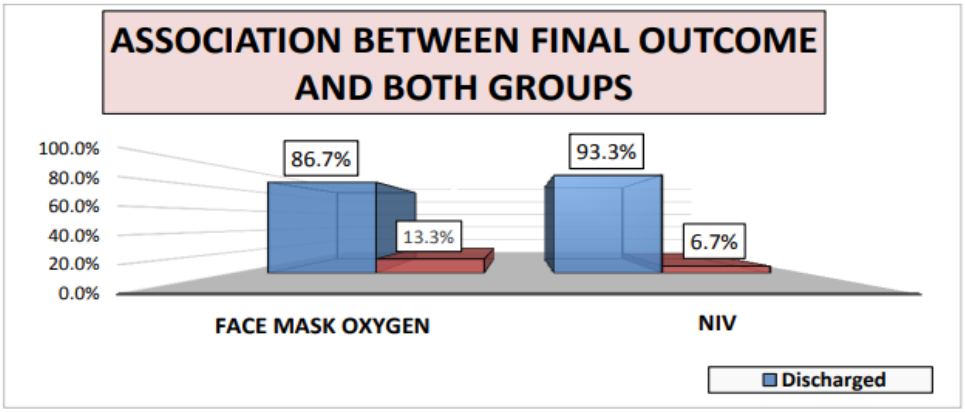

Figure -31

Discussion

Patients with CHF who were not responding to medicinal therapy alone were shown to be effectively treated with FMO and noninvasive ventilation in a prospective cross-sectional research. After the 6 hours, there was a notable difference in the respiratory and cardiac rates of the NIV group despite the patients' mean ages being similar. After 24 hours, however, respiratory indices did not differ significantly between the two groups. According to the

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study, patients who were given continuous positive airway pressure for 30 minutes had a more pronounced reduction in respiratory rate and arterial carbon dioxide tension. Patients with CHF may benefit from using a FMO concentrator in addition to their current medical treatment, according to the study.

One hour following therapy, patients reporting dyspnea, heart rate, acidity, and hypercapnia tend to have better outcomes when treated with noninvasive ventilation (NIV). According to studies, significant respiratory rate, heart rate, pH, and pCO2 improvements were observed at 2, 6, 12, and 24 hours following the start of NIV. After one hour of CPAP, the group experienced less dyspnea, acidosis, heart rate, and respiratory rate. Within the first hour of administering NIV, paediatric patients' respiratory and heart rates improved significantly, and they continued to stabilize over the next 8-10 hours. NIV had an 80% success rate, and the total success rate was 57%. At discharge, 86.7% of patients in the group that used FMO did better than the 93.3% who received noninvasive ventilation (NIV).

Summary

The research aimed to determine whether noninvasive ventilation could be an effective alternative to conventional medical treatment for CHF in children. There was a marked improvement in respiratory rate, heart rate, pH, pCO2, pO2, and SpO2 when oxygen was administered to the face through a non-rebreathing mask. In contrast to the NIV group, where 80% of patients improved without intubation, 46.7% of patients in the FMO group had to be intubated.

Conclusion

When noninvasive ventilation treats CHF, the patient's respiratory indices and heart rate quickly improve. Respiratory rate, pH, pO2, and pCO2 all showed significant improvement. The SpO2 and heart rate improved from the baseline, although there was no statistical significance. Compared to patients who received oxygen through a FMO, those in the NIV group required fewer endotracheal intubations. The group that got NIV had a reduced mortality rate. Because this study did not find a statistically significant relationship between mortality and the other indicators (SpO2, heart rate), additional research is required to draw firm conclusions.

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JCHR (2024) 14(2), 1111-1123 | ISSN:2251-6727

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