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Original Research Article

Use of rescue high frequency oscillation ventilation in neonates with acute respiratory failure after failing conventional ventilation

Ali Kumble, Abhishek K. Phadke*, Shakib Shafi

Department of Neonatology, Indiana Hospital, Mangalore, Karnataka, India

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***Correspondence:**
Dr. Abhishek K. Phadke,
E-mail: phadke18@gmail.com

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ABSTRACT

Background: High frequency oscillatory ventilation (HFOV) is a newer mode of ventilation in neonates. The objective of this study was to study the efficacy of rescue HFOV in improving the oxygenation and ventilation in neonates with acute respiratory failure after failing synchronised intermittent mandatory ventilation (SIMV).
Methods: A prospective observational study was conducted over a period of 12 months. Neonates with respiratory distress requiring ventilation on SIMV mode based upon the unit protocol were included in the study. Babies who have failed on SIMV were then switched over to HFOV. The primary outcome measures were oxygenation index (OI), ventilation: alveolar-arterial oxygen gradient ($AaDO_2$) and duration of ventilation with a secondary outcome measure of mortality and complications associated with ventilation.
Results: A total of 65 babies were ventilated out of which 11 babies required high frequency oscillatory ventilation as per the study protocol. Of 11 neonates who were oscillated eight (72.7%) improved and survived. Among the babies who survived OI<13 was seen in a total of six babies in the first three hours of oscillation and OI<10 was seen in two babies. There was no statistically significance difference in the incidence of intra-ventricular haemorrhage (IVH) and pneumothorax between HFOV and SIMV group.
Conclusions: High frequency oscillatory ventilation was found to improve short term oxygenation and ventilation in neonates who failed SIMV. HFOV is not associated with increased risk of pneumothorax or IVH.

Keywords: HFOV, High frequency oscillation, Neonates, Respiratory failure, Ventilation

INTRODUCTION

Synchronized intermittent mandatory ventilation (SIMV) has been used for many years in neonates. High frequency oscillatory ventilation (HFOV) is a new mode of ventilation using lung protective strategy.[1] It employs safer use of mean airway pressure that is higher than that generally used during SIMV.[2] In contrast to low benefits in elective use, HFOV as "rescue therapy" (rHFOV) (with early and appropriate strategy in patients with progressive respiratory distress not responding to conventional ventilation) were shown to reduce the mortality and frequency of extracorporeal membrane oxygenation (ECMO), shorten the length of hospital stay and reduce the cost of the patients.[3-5] High frequency oscillatory ventilation was associated with better early oxygenation and shorter hospital stay compared to SIMV in preterm neonates with hyaline membrane disease.[6]

Neonates who don't respond to conventional ventilation are generally switched to HFOV in many NICUs.[7] However, due to scarcity of studies in literature there is a need to document the outcomes associated with HFOV in infants with respiratory failures. We conducted this research with the hypothesis that, early use of HFOV with a lung volume recruitment strategy can provide a clinically important benefit in terms of mortality, oxygenation indices and complications like intra-ventricular haemorrhage or pneumothorax compared to conventional mechanical ventilation methods using

synchronized intermittent mandatory ventilation (SIMV). The purpose of our study was to study the efficacy of rescue HFOV in improving the oxygenation and ventilation in neonates with acute respiratory failure after failing SIMV.

METHODS

Study design and setting

A prospective observational study was conducted from November 2017 to October 2018 at a level IIIA NNF accredited 16 bedded tertiary care neonatal intensive care unit (NICU) in Mangalore, Karnataka, India. Permission to conduct the study was obtained from concerned authorities after ethical clearance was obtained from an Institutional Ethical Committee and informed consent was obtained from the parents.

Study participants

Inclusion criteria

Neonates with respiratory distress requiring ventilation on SIMV mode based upon the unit protocol were included in the study.

Exclusion criteria

Babies with severe perinatal asphyxia, complex congenital heart disease, multiple congenital anomaly or those with a confirmed metabolic disorder were excluded from the study.

Our unit used the modified Nottingham Neonatal Service Clinical Guidelines for assessing need for ventilation.[8]

Respiratory support

If the baby does not improve or if deteriorates further, recruitment of the lung was done. It was done by increasing the PEEP to a higher level of 6. If the chest x ray showed under-inflation of lungs, then PEEP was increased to higher levels. Surfactant was given if PaO_2/F_IO_2 was <200 mmHg after 2 hours of ventilation in preterm babies as per the routine NICU policy.[9]

Babies who have failed on SIMV were switched over to HFOV using SLE 5000 ventilator. On HFOV these babies were started on a mean arterial pressure (MAP) of 2 cm higher than the MAP on conventional ventilator. MAP was increased until a saturation of >95% was obtained. The remaining parameters were adjusted as per routine protocol. The amplitude was adjusted based on the chest wriggle; frequency was started at 10 Hz for the preterm babies and at 8 Hz for term babies. The initial ABG analysis on HFOV was done after 2-3 hours. Recruitment of the lung was emphasized upon and reconfirmation of recruitment was done after 1-2 hours with chest radio-graph. Optimum lung expansion of 8-9 rib spaces on chest x ray was targeted. Supportive treatment was given as per the standard unit protocols.

Definition of failed SIMV and criteria for starting HFOV (any one of the below)

High pressures on SIMV: PIP>22 mmHg in all babies or MAP>10.

Inadequate oxygenation: When OI>18.

Inadequate ventilation in spite of high PEEP with adequate recruitment: PCO_2 levels of 60 mmHg or $AaDO_2$:>400

PPHN: Echocardiographic evidence of supra-systemic pulmonary pressures.

Outcome variables

The ventilator settings, ABG analysis, oxygenation index (OI), alveolar-arterial oxygen gradient ($AaDO_2$) and complications of ventilation were recorded during SIMV and subsequently when shifted over to HFOV. The primary outcome measures of the study were oxygenation index (OI), ventilation: alveolar-arterial oxygen gradient ($AaDO_2$) and duration of ventilation. The secondary outcome measures were mortality and complications of ventilation.

Statistical analysis

The data was analysed using SPSS for windows 17 (SPSS Inc., IL, USA). Descriptive statistics are summarized as means for continuous variables and percentages for categorical variables. Comparison of various parameters (OI, PCO_2, PO_2, $AaDO_2$ and pH) between SIMV and HFOV was done using unpaired t test. The level of significance was set at $p \leq 0.05$.

RESULTS

A total of 65 babies were ventilated, out of which 11 babies required HFOV as per the study protocol and were included in the study. Majority of babies who received HFOV had respiratory distress syndrome and MAS (Tables 1 and 2).

Table 1: Categorization of study participants according to gestation.

Gestation in weeks	Ventilated	HFOV	Survival in oscillated babies
Less than 30	11	1	1
30-34	15	3	2
34 -37	6	1	0
More than 37	33	6	5
Total	65	11	8 (72.7%)

HFOV-High Frequency Oscillation Ventilation

Table 2: Underlying cause for respiratory distress.

Cause of respiratory distress in babies who were oscillated	No. of cases (n=11)	Survival (n=8)	Percentage
MAS	4	3	75
RDS	5	3	60
CDH	1	1	100
Pneumonia	1	1	100

MAS-Meconium aspiration syndrome; RDS-Respiratory distress syndrome; CDH-Congenital diaphragmatic hernia

Median age of presentation was 1 day (1-13 days). Mean age at initiation of rescue HFOV was 1.9 days (range 1-3 days) and mean duration of ventilation on HFOV was 41.5 hours (range 7-124 hours).

Table 3: Comparison of outcome parameters between SIMV and three hours post rHFOV.

Parameter	SIMV Mean (SD)	3 hours after rescue HFOV mean (SD)	P value
PaO_2 (mm)	42.9 (12.2)	90 (57)	0.03*
$PaCO_2$ (mm)	55.6 (14.4)	31 (13)	0.0008**
$AaDO_2$	538 (119)	398 (96)	0.009**
FiO_2 (%)	89 (11)	71 (18)	0.02*
OI	20 (5)	14 (5.4)	0.0005**
pH	7.18 (0.13)	7.39 (0.08)	0.0007**

SIMV- Synchronised intermittent mandatory ventilation; rHFOV- Rescue high frequency oscillation ventilation; level of significance at $p \leq 0.05$; *statistically significant at $p<0.05$ and **$p<0.01$ using unpaired t test; PaO_2- Partial pressure of arterial oxygen; $PaCO_2$- Partial pressure of arterial carbon dioxide; $AaDO_2$- Alveolar-arterial oxygen gradient; FiO_2- Fraction concentration of oxygen inspired air; OI- Oxygenation index.

Among 11 neonates who were oscillated, eight (72.7%) improved and survived. Out of the babies who survived, OI<13 was seen in a total of six babies in the first three hours of oscillation and OI<10 was seen in two babies. A statistically significant decrease in OI ($p<0.01$), $AaDO_2$ ($p<0.01$) and improvement in pH ($p<0.01$), PCO_2 ($p<0.01$), PaO_2 ($p<0.05$) with good lung recruitment was seen within three hours of rHFOV in all the babies (Table 3). There was no statistically significance difference in the incidence of intra-ventricular haemorrhage and pneumothorax between HFOV and SIMV group.

Table 4: Complications arising during SIMV and HFOV among babies.

Complication	SIMV (n=65)	HFOV (n=11)	Odd's ratio
IVH	1	1	1.52
Pneumothorax	2	1	3.12

IVH- Intra-ventricular haemorrhage; SIMV- Synchronised intermittent mandatory ventilation; HFOV- High frequency oscillation ventilation.

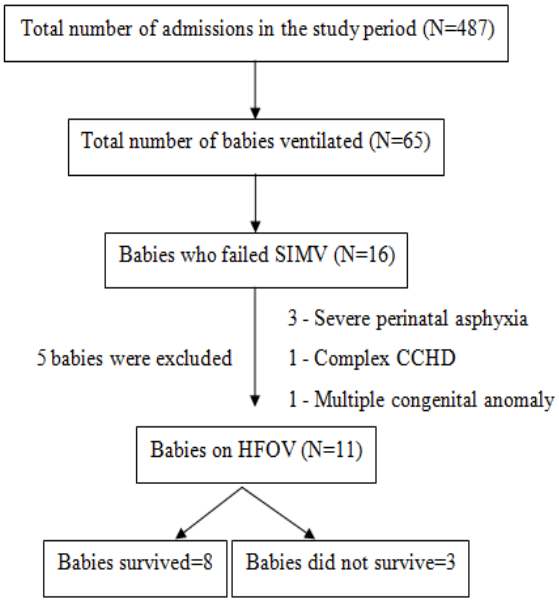

Figure 1: Flowchart of the study.

DISCUSSION

Our study showed that rescue HFOV improves oxygenation, ventilation and oxygenation indices. The HIFO trial found that in the first 24 hours after randomization, infants on HFOV required lower FiO_2 and had lower $PaCO_2$ when compared with infants on SIMV.[10] Oxygenation index of less than 13 and less than 10 was observed in six and two babies respectively and all of them survived. In addition, it was also found that there was a significant decrease in OI, $AaDO_2$ and improvement in pH, PCO_2, PO_2 with good lung recruitment within 3 hours in all the babies in the HFOV group.

The findings of our study are supported by studies that have been reported in literature. The Provos multicentric trial found an improvement in oxygenation after the babies were oscillated with a decrease in FiO_2 requirement.[11] Similarly Jaballah et al found a significant decrease in mean arterial pressure, FIO_2, OI, and $AaDO_2$ after starting HFOV in neonates who were treated for acute respiratory failure. It was also found that $PaCO_2$ decreased significantly after one hour of HFOV.[12] Similar results were also reported by Sarnaik et al, where a significant improvement was observed in arterial pH, $PaCO_2$, PaO_2 and PaO_2/FID_2 six hours after HFOV was instituted in 31 children.[13]

There was no increased incidence of IVH or air leaks in the HFOV group in the present study. Nevertheless, in the present study the odds of death among babies was more due to IVH and pneumothorax. Survival rates in our study were 72.7% which is comparable with a previous

study.[14] Debate on whether HFOV or conventional mechanical ventilation is the best ventilation strategy to support premature infants with RDS has been going on for more than 20 years. A Cochrane review that evaluated 17 studies with 3,652 infants failed to obtain conclusive evidence as to which type of mechanical ventilation is more effective.[15] Given the findings of our study that is supported by studies reported in literature, it is safe to mention that early rescue intervention with HFOV is an effective protocol for term and near-term infants with acute respiratory failure.

There are few limitations in our study. The sample size being small and given the study was conducted in one NICU, the findings of our study cannot be generalized. The absence of a control group in our study is a limitation in deriving a firm conclusions about potential benefits of rescue HFOV. The efficacy could only be demonstrated by changes in the oxygenation, pH and ventilation. There is a need for further randomized controlled trials for rescue HFOV.[16] In addition; long term neurodevelopmental outcomes were not studied in our study.

CONCLUSION

High frequency oscillatory ventilation was found to improve short term oxygenation and ventilation in neonates who failed SIMV. HFOV is not associated with increased risk of pneumothorax or intra-ventricular haemorrhage.

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