Original Article

Neonatal Mechanical Ventilation

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Abstract. ***Objective :*** This study was undertaken to analyze indications, complications, outcome and the factors influencing neonatal mechanical ventilation. ***Methods :*** Prospective observational study conducted on 102 consecutive newborns, who required mechanical ventilation in a medical college tertiary neonatal care setting. ***Results :*** The commonest indication was birth asphyxia (37.3%), followed by hyaline membrane disease (HMD) (31.4%), meconium aspiration syndrome (MAS) (21.2%), septicemia (14.7%) and apnea of prematurity (5.9%). The overall survival rate in our study was 51%. Babies weighing less than 1.5 kg and less than 32 weeks of gestation had survival rates of 30% and 25% respectively. The best outcome among various indications was observed in babies with MAS (63.6%) followed by pneumonia (62.5%) and HMD (53.1%). Babies with birth asphyxia and septicemia had a low survival rate of only 42% and 40% respectively. The overall complication rate in the study was 58.8%. Common complications encountered were septicemia (42%), tube block (36%) and air leak (15%). ***Conclusion:*** About half (51%) of newborns requiring mechanical ventilations for various indications survived and more than half (58.8%) developed complications. The study also reconfirms that survival rate increases with birth weight and gestational age irrespective of indication. **[Indian J Pediatr 2003; 70 (7) : 537-540]**

Key words : *Neonatal ventilation; Indications; Survival; Complications.*

Mechanical ventilation is a rapidly advancing technology – intensive science. Neonatal mechanical ventilation has a definite impact on survival of sick neonates, but the investment in terms of money, time, skill and infrastructure has its limited use in developing countries. However, the judicious use of it can reduce the mortality and morbidity to a great extent. This mode of treatment started in early 90s in India, is gaining momentum in a fast pace as evidenced by increasing number of reports available in the literature.[1,2,3,4,5,6] In the present communication the authors would like to report their experience of ventilatory therapy on 102 neonates to establish the indication for ventilation, complications, survival in various disease states, gestational age and birth weight categories.

MATERIALS AND METHODS

The present study was a prospective observational study conducted on 102 neonates admitted in Neonatal Intensive Care Unit (NICU) of Child Health Institute, Department of Pediatrics, J.J.M. Medical College, Davangere, between 2000 to 2002 who required ventilatory therapy. The neonatal intensive care unit is a 20 bedded unit equipped with 3 SIEMENS servo 300 ventilators.

At admission, details of antenatal, natal and postnatal history, the birth weight, gestational age, type of delivery, Apgar score, onset of respiratory distress and other details were recorded. Diagnosis of underlying condition was made using standard clinical, laboratory and/or radiological criteria. Intermittent positive pressure ventilation (IPPV) was initiated on babies who met at least one of the inclusion criteria viz. respiratory distress with Downe's score ≥ 6, recurrent apnea, arterial blood gases (ABG) evidence of acute respiratory acidosis, neonates with respiratory distress not maintaining 87 – 93% of oxygen saturation with maximum augmented oxygen through head box.

Exclusion criteria were birth weight < 1000 gm, presence of lethal congenital malformations, clinical or laboratory evidence of severe vital organ dysfunction which has caused irreversible damage, duration of ventilation of less than 12 hrs, abrupt termination of ventilatory support for any reason and parents unwilling to give informed consent.

Time cycled, pressure limited, continuous flow ventilator was used and the initial settings varied with the underlying disease and ABG analysis. The aim was to use minimum possible fractional inspired oxygen concentration (FiO_2) to maintain normal blood gases. The parameters regulated during ventilation were

(1) FiO_2 (fraction of oxygen concentration in inspired air) : It was usually set between 0.6 and 1 i.e., (60-100%). In case of severe HMD, severe MAS and extensive pneumonia, we started with 100% FiO_2. In case of preterm babies with recurrent apnea, mild pneumonia or apnea due to hypoxic ischemic encephalopathy, we started with 60-80% of FiO_2.

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(2) PIP (Peak inspiratory pressure) : It was usually set at 18-20 cm of H_2O. During ventilating a case of severe HMD, pneumonia or severe MAS, where pulmonary resistance is more, we started with 20 cm of H_2O and went upto 24, 26, 28 etc. In case of preterms, low birth weight babies with recurrent apnea we started with 16 or 18 cm of H_2O and gradually increased.

(3) PEEP (Positive end expiratory pressure) : Usually it was set between 2-4 cm of H_2O. In case of respiratory illness with significant pulmonary resistance like severe HMD, MAS, pulmonary hemorrhage, we started with PEEP of 3 cm or 4 cm of H_2O. In case of respiratory failure with hypoxic ischemic encephalopathy or recurrent apnea due to central cause, PEEP was set at 2 cm H_2O.

(4) Rate : Ventilatory rate was usually set at 40/min. but in case of severe HMD, MAS, pulmonary haemorrhage, we set the rate initially at 50-60/min. and monitored oxygen saturation. In case of apnea due to central cause, rate was set at 30-40/min.

(5) Ti (Inspiratory time) : During each respiratory cycle the ratio of inspiratory time to expiratory time (i.e., Ti/Te) is very important rather than only inspiratory time. The ratio was usually maintained at 1:2. But in cases with significant respiratory distress, the ratio was kept prolonged i.e., 1:3 or1:4 to prevent air trapping. In case of respiratory failure due to encephalopathy, recurrent apnea and depression due to maternal drug intake, Ti was kept at 0.4 sec. Since rate was set at 30/min, a ratio of 1:2 was maintained.

Thus we started with the above mentioned initial settings and changes were made on the basis of periodic blood gas analysis and oxygen saturation.

Babies were nursed under servo control open care system and all were sedated with injection morphine in a dose of 0.05 to 0.2 mg/kg/dose usually one dose and occasionally 2 doses if restlessness persisted. Continuous clinical monitoring of heart rate, respiratory rate, retractions, chest expansion, air entry, capillary refill time, peripheral pulses, status of hydration and oxygen saturation was done. Continuous monitoring of oxygen saturation was done using pulse oximeter. ABG analysis was done 12^{th} hourly in stable babies and 6^{th} hourly or even more frequently in unstable babies and with changes of ventilatory settings.

Blood glucose was monitored twice daily using dextrostix. Sepsis work-up was done whenever clinically indicated. Endotracheal tube and blood culture – sensitivity were ordered whenever septicemia or pneumonia was suspected. Chest radiographs were taken as and when deemed necessary by clinical condition.

All babies were monitored for any complication like air leak, congestive cardiac failure, sepsis, patent ductus arteriosus etc. Chest physiotherapy was given during and after ventilation. Babies were weaned off the ventilator when they showed clinical, radiological improvements and normal blood gases with bare minimum ventilatory support. Dexamethasone (0.2 to 0.4 mg/kg) was given 24hrs prior to expected extubation. After extubation, the babies were placed under oxygen hood until indicated. The end point of the study was a hemodynamically stable baby accepting feeds, fit to be shifted out of NICU or when the baby succumbed during ventilatory care.

RESULTS

During the study period of 24 months, out of 2258 admissions, which included both outborn and inborn groups, 128 babies (5.6%) were given assisted ventilation. Out of these, 102 neonates who satisfied the inclusion criteria (mentioned earlier) formed our study group.

Various indications and survival rate in each of them are shown in Table 1. Two common most indications were birth asphyxia (37.3%) and HMD (31.4%). In our study it was also noted that as many as 45 babies out of 102 had more than one indication. Out of different disease states, the survival rates in MAS and pneumonia were 63.6% and 62.5% respectively. The survival rates in HMD (53.1%) and apnea of prematurity (50%), the typical diseases of prematurity, along with septicemia, which formed considerable bulk of our study group, had worse prognosis. Out of 102 neonates requiring ventilatory therapy 35 (34.2%) were inborn and 67(65.7%) were out born. The survival was better in inborn cases (22 out of 35) i.e., 62.9% and 30 out of 67 cases in outborn group (44.8%).

TABLE 1. Indications and Survival Rate

Indication	Total No. (%)	Survived No. (%)
Birth Asphyxia	38 (37.2)	16 (42.1)
HMD	32 (31.4)	17 (53.1)
MAS	22 (21.1)	14 (63.6)
AOP	6 (5.9)	3 (50.0)
Pneumonia	8 (7.9)	5 (62.5)
Septicemia	15 (14.7)	6 (40.0)
PPHN	4 (3.9)	2 (50.0)
Post resuscitative	4 (3.9)	2 (50.0)
Post operative	6 (5.9)	3 (50.0)

HMD – Hyaline membrane disease, MAS – Meconium aspiration syndrome, AOP – Apnea of prematurity, PPHN – Persistent pulmonary hypertension of the newborn.

As detailed in Table 2 survival rate varied considerably with birth weight and gestational age, showing improvement with increase in either of them. The survival rate was 30% in babies weighing less than 1.5 kg compared to 60% in babies weighing more than 2.5kg. Similarly the survival rate was 25% and 50.8% in those with gestational age of less than 32 weeks and more than 37 weeks respectively. Further, it was also observed that female babies who formed only 30.4% of the study group had a better survival rate of 58.1% compared to 47.9% in males.

Table 2. Frequency Distribution of Sex, Weight and Gestational Age in Relation to Outcome.

Character		No. of cases	Survived No.(%)
Sex	Male	71	34 (47.9)
	Female	31	18 (58.1)
Weight	1–1.5 kg	10	3 (30)
	1.5–2 kg	24	10 (41.7)
	2–2.5 kg	18	9 (50)
	> 2.5 kg	50	30 (60)
Gest. Age	< 32 weeks	12	3 (25)
	32–34 weeks	15	10 (66.7)
	34–37 weeks	16	9 (56.2)
	> 37 weeks	59	30 (50.8)

Ventilatory settings and mean duration of ventilation varied in different disease states as depicted in Table 3. Maximum mean peak inspiratory pressure (PIP) was used in HMD (24.3 ± 4.7 of H_2O). Maximum rates and FiO_2 used were almost similar in all groups. Duration of ventilation required was comparatively more in MAS (74.1 ± 33.2 hrs) and pneumonia (70.1 ± 24.8 hrs) as against HMD (66.4 ± 26.1 hrs). During the present study, one or the other complication occurred in 58.8 % of cases. More than one complication occurred in many cases. Septicemia (38.2%) and tube block (32.3%) were the two most common complications. The other complications are listed in table 4, along with survival rates.

DISCUSSION

Mechanical ventilation has dramatically improved the survival rates of sick neonates. In the 24 months study, out of 2258 admissions in the NICU 128 babies (5.6%) were given assisted ventilation. Nangia *et al*[2] and Mathur *et al*[4] reported that 8.9% and 13% of the babies admitted in their nursery required mechanical ventilation. This probably depends on several factors like admission policy of NICU, draining area, level of services available and the infrastructure of the NICU.

Current survival rates reported from well developed NICUs in USA are 95 to 97% in babies more than 1000 gm with almost 80 to 90% intact survivals.[7] The present Indian scenario is comparable with reports of 1980s[8] from the developed countries. The delay in the availability of technical advancement probably contributes to this poor performance.

The overall survival rate in our study was 51% where as other Indian studies reported a survival rate varying from 46.5%[2] to 55.8%[4]. In the present study female babies had a better survival rate – 58.1% compared to 47.9% in males. Most other Indian studies also show a similar trend. Irrespective of the indications for ventilation, survival rate improved with increasing birth weight and gestational age (Table 4). Similar trend is also observed by other Indian studies. In the present study survival rate varied with different indications with a better outcome in MAS (63.6%) as compared to 42.1% in birth asphyxia. Further it was observed that inborn babies had a better survival rate of 62.9% when compared to 44.8% in outborn babies. It is possible that early intervention would have been responsible for better outcome in inborn babies.

The commonest indication for mechanical ventilation in our study was birth asphyxia (37.3%) followed by HMD (31.4%), whereas in other studies reported by Nangia *et al*,[2] Singh *et al*,[3] Mathur *et al*,[4] and Maiyya *et al*[5] HMD was the commonest indication. Krishnan *et al* reported septicemia as the commonest indication.[1] In the study many of the cases had more than one indication (45/102) which is also reported by few others. Further in our study, tracheoesophageal fistula was an indication for assisted ventilation in 5 cases, out of which 3 survived, comparable with report of Nangia *et al.*[2]

Ventilatory settings varied in all the studies. This may be because the ventilatory settings used are individualized to the need of the baby considering

Table 3. Mean Ventilatory Settings in Different Disease States.

Indication	Mean PIP cm of H_2O	PEEP* cm of H_2O (n)	Max. FiO_2 (Range)	Max. Rate/ min	Mean duration of ventilation (Hrs.)
Birth asphyxia	21.8 ± 4.1	3 (1) 4 (37)	1.0 (0.6 – 1)	56.8± 8.4	64.4 ± 31.8
HMD	24.3 ± 4.7	3 (0) 4 (32)	1.0 (0.8–0)	56.4± 9.0	66.4 ± 26.1
MAS	21.5 ± 4.0	3 (2) 4 (4)	1.0 (0.7–1)	56.7 ± 15.1	74.5 ± 33.2
Apnea	22.7 ± 5.9	3 (0) 4 (8)	1.0 (0.6–1)	55.0 ± 10.7	62.3 ± 27.9
Pneumonia	22.3± 3.8	3 (0) 4 (15)	1.0 (0.6–1)	54.0 ± 12.4	70.1 ± 24.8
Septicemia	23.9 ± 3.2	3 (1) 4 (3)	1.0 (0.6–1)	50.0 ± 11.5	57.5 ± 31.4

HMD – Hyaline membrane disease, MAS – Meconium aspiration syndrome.
PIP – Peak inspiratory pressure, PEEP – positive end expiratory pressure.
*Babies received PEEP of either 3 or 4 cm of H_2O, (n) – No. of cases receiving the corresponding PEEP.

TABLE 4. **Complications and Survival Rate**

Complications	Total No.	Improved (%)
Air leak	14	5 (35.7)
Septicemia	39	25 (64.1)
Tube block	33	20 (60.6)
Weaning failure	3	2 (66.7)
IVH	3	1 (33.3)
Pul. Hemorrhage	1	0

various factors. Therefore every baby requires different settings and should be taken as an individual case. But it is noted that PIP needed in HMD is higher in all studies.[1,2,3,4,5] In the study, HMD needed maximum PIP of 24.3 + /–4.7 cm of H_2O followed by septicemia (23.9+/–3.3 cm of H_2O). Apnea of prematurity needed the least PIP (18.7+/–1.3 cm of H_2O). The mean duration needed in birth asphyxia was 56.8 ± 33.2 hrs, pneumonia 70.1± 24.8 hr which is comparable with series of Mathur *et al.*[4] HMD needed a mean duration of 96.4 hr in the study done by Mathur *et al.*[4] in contrast with our study (66.4 ± 26.1hr). Similarly the mean duration of ventilation given in cases of septicemia in their study is 94.3 hr as compared to 67.5 ± 31.4 hr in our study. Duration of ventilation needed was maximum in MAS (74.5 +/–33.2 hr) and pneumonia (70.1+/–24.8 hr) compared to other indications.

During the present study one or the other complication occurred in 58.8% of the cases. Major complications were septicemia (38.2%), tube block (32.3%) followed by air leak. More than one complication occurred in many cases. The incidence of septicemia reported by Singh *et al*[3] and Mathur *et al*[4] are 37%, 36.7% respectively. Singh *et al*[6] in their subsequent study showed an incidence of septicemia of 50.6%. Krishnan *et al*[1] report only 4.4% of septicemia and they attribute it to the use of minimum pressure, shortest possible duration of ventilation, endotracheal toilet and vigorous postextubation chest physiotherapy[1]. Septicemia remains a major problem due to repeated interventions and prolonged ventilation. Adequate precautions should be taken to prevent septicemia, as it may prove fatal in many cases. Minimum interventions, minimum possible pressures and duration of ventilation, along with judicious use of antibiotics may prevent high incidence of septicemia.

The occurrence of pneumonia as a complication was nil in our study but reports from Mathur *et al*[4] and Maiyya *et al*[5] show pneumonia in 28.8% and 25% cases respectively. Careful attention to endotracheal toilet and chest physiotherapy would have contributed to the less incidence of pneumonia in our study.

Pneumothorax occurred in 13.7% of cases in our study, which is comparable with series of Singh *et al*[3] (13%). The incidence of pneumothorax reported by Mathur *et al*[4] is 6.7% and Krishnan *et al*[1] is 8.8%. The survival rate in babies who developed pneumothorax was only 35.9%. Singh *et al*[3] also report this trend with a survival rate of 33.3% in babies who developed pneumothorax. Careful monitoring and early intervention may prove life saving.

Tube block was encountered in 32.3% of cases in our study in contrast to only 5.8% reported by Krishnan *et al.*[1] Other reported studies have not mentioned this complication. In our study, 3 cases had intra ventricular hemorrhage (IVH) and pulmonary hemorrhage occurred in one case. Singh *et al*[3] have reported IVH as a leading cause of death in their study (52%).

Mechanical ventilation in neonates has improved the survival rate of sick neonates especially in the term appropriate for gestational age babies. But the incidence of complications cannot be overlooked as it influences the outcome and may prove fatal in many cases. Timely intervention along with energetic monitoring is the corner stone for the success of assisted ventilation. Consensus in relation to time of intervention, various strategies adopted in different indications has to be made. Care is to be taken not to underventilate or overventilate the babies and to prevent complications like barotraumas and oxygen toxicity, especially in preterm babies. With the availability of different newer modes and advanced monitoring equipments, more can be expected in the near future.

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