ORIGINAL ARTICLE

Respiratory Failure Requiring Ventilation in Acute Bronchiolitis

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Summary

Severe bronchiolitis requiring mechanical ventilation is uncommon and is associated with the risk of barotrauma. We report our experience with 25 (42%) of 60 infants admitted to the Paediatric Intensive Care Unit (PICU) with severe bronchiolitis who required mechanical ventilation. Eighteen patients (72%) had severe hypoxaemia (PaO_2/FiO_2< 250). The mean airway pressure required ranged from 5.8 to 15.6cmH_2O with median ventilation duration of 4.0 days (range 2.0 - 14.0 days). Oxygenation improved significantly within 12 hours of intubation. There was only one death. Mechanical ventilation is required in a subset of patients for severe bronchiolitis and is effective and generally well tolerated.

Key Words: Bronchiolitis, Oxygenation, Mechanical ventilation

Introduction

Acute bronchiolitis is commonly a mild self-limiting respiratory illness in infants. Very severe illness resulting in life threatening respiratory failure can however develop in a small group of infants namely those with well recognised risk factors like prematurity, age less than six weeks, congenital heart disease and bronchopulmonary dysplasia[1,2].

The inflammatory process that affects the small airways results in marked airway narrowing, bronchorrhoea and bronchospasm that then increase the work of breathing for the young infant. In addition, widespread atelectasis disrupts the already fragile ventilation-perfusion balance of these patients further aggravating the development of respiratory fatigue and eventually respiratory failure[3].

The difficulty in managing severe bronchiolitis in infants is the lack of effective definitive treatment namely the use of nebulised bronchodilators and steroids[4,5]. Respiratory failure although uncommon in acute bronchiolitis requires intubation and mechanical ventilation that are effective and safe in experienced hands. We report our experience in caring for patients admitted to our Paediatric Intensive Care Unit (PICU) with severe bronchiolitis that resulted in respiratory failure with regards to the indications for intubation, ventilation strategies, treatment response and complications encountered.

Materials and Methods

Patient Population

We retrospectively reviewed the medical records of all children aged less than 12 months who were admitted to the PICU between January 1993 and December 1998 with a diagnosis of acute bronchiolitis in accordance with Courts criteria[6] and who required mechanical ventilation for respiratory failure. Patients who had previous episode of wheezing or diagnosed to have acute asthma were excluded from the study.

Table I
Mechanical Ventilation for Acute Bronchiolitis

Rate	: 40 per minute
Peak inspiratory pressure (PIP)	: 18 - 25 cmH_2O
Peak expiratory pressure (PEEP)	: 2 - 4 cmH_2O
Inspiratory : Expiratory ratio	: 1:2
Fraction of inspired oxygen (FiO_2)	: Maintain saturation >93% and PO_2 > 10kPa

Intubation and Mechanical Ventilation

The indication and duration of mechanical ventilation was determined for each patient. All intubated patients received time-cycled pressure limited intermittent positive pressure ventilation with initial settings as outlined in Table I. The patients' progress, ventilatory settings and respiratory status parameters were extracted from the PICU patient flow-charts. In addition, the severity of hypoxaemia was calculated based on the ratio of the arterial oxygenation (PaO_2) to the fraction of inspired oxygen (FiO_2). The worst values within 6 hours of commencement of mechanical ventilation were noted. Severe hypoxaemia was defined as a PaO_2/FiO_2 of less than 250. Satisfactory improvement was achieved with an improvement in PaO_2/FiO_2 of more than 400. The patient's progress and development of complications namely air leaks were also studied. A favourable outcome was defined as successful extubation and discharge from the PICU.

Statistical Analysis

Analysis was done using SPSS Version 6.13 statistical programme operating on Windows 95 system. The paired samples t test was used to analyse continuous variables and proportions were compared using the Fishers exact test. A p-value of less than 0.05 was considered significant.

Results

A total of 1161 patients with acute bronchiolitis were admitted during the study period, of whom 60 patients (5.2%) had severe respiratory distress requiring admission to the PICU. Forty-three of these patients (72%) were admitted directly from the Casualty unit and the rest were transferred from the general wards when their clinical condition deteriorated. Twenty-five patients or 2.2 per 100 admissions of acute bronchiolitis required mechanical ventilation. The mean age of the ventilated patients was 4.8±3.0 months with a range of 2 weeks to 11 months. There was a female preponderance of 2:1. There were 17 Malays (68%), 3 Chinese (12%) and 5 Indians (20%). Respiratory syncytial virus was identified by immunofluorescence in the nasopharyngeal secretions of 17 patients (28%).

Respiratory fatigue (10 patients) and hypoxaemia despite supplemental oxygen (10 patients) were the commonest indication for mechanical ventilation. Five required ventilatory support for cardio-respiratory arrest following prolonged apnoea. Hypercarbia ($PaCO_2$ > 8kPa) was present in 8 patients (32%). A total of 18 patients (72%) had impaired oxygenation, as their PaO_2/FiO_2 was less than 250. Induction agents used for intubation included midazolam (18 patients), fentanyl (3 patients) and ketamine (2 patients). The paralytic agent attacurium was used to facilitate intubation in 10 patients. Three patients were intubated without sedation as they had profound apnoea and impending cardiac arrest.

All patients intubated received intermittent positive pressure ventilation. The maximum mean airway pressure (MAP) required to maintain adequate oxygenation ranged from 5.8 to 15.6cmH_2O with a mean of 11.3±2.5cmH_2O and median of 12cmH_2O. The mean peak inspiratory pressure (PIP) and peak end expiratory pressure (PEEP) required to ventilate the patients were 21.7±3.9cmH_2O and 3.8±1.0cmH_2O respectively. With intubation and commencement of intermittent positive pressure ventilation, there was significant improvement in the mean PaO_2/FiO_2 ratio within 12 hours (p=0.004) and 24 hours (0.007) but not after 24 hours of ventilation (Figure 1). In the 18 patients with PaO_2/FiO_2 ratio less than 250, there was satisfactory improvement in patient oxygenation by 24 hours in 5 of them (31%) and in 12 of them (75%) by 48 hours. All patients received intravenous midazolam for sedation and only 6 patients (24%) needed continuous paralysis to facilitate ventilator-patient synchrony.

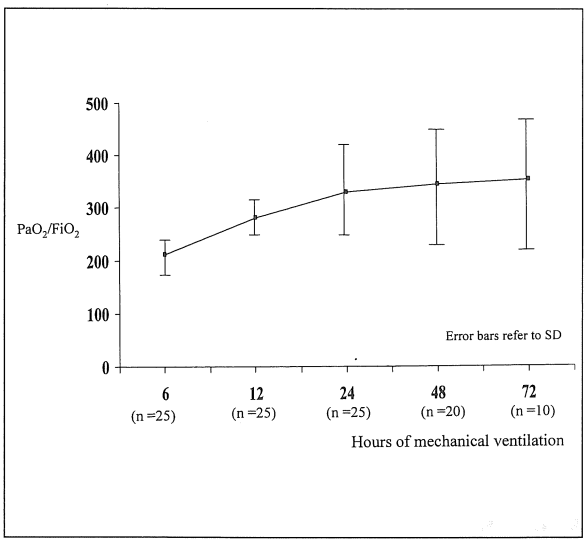

Fig. 1: Mean PaO_2/Fio_2 ratio in relation to the duration of mechanical ventilation.

The median duration of ventilation was 4.0 days (range 2.0 - 19.0 days) with 16 patients (64%) extubated within 5 days. Patients who had mechanical ventilation longer than the median duration of 4.0 days were more likely to have a PaO_2/FiO_2 ratio of less than 250 (Table II). There was only one death. This patient who had an underlying primary immunodeficiency developed refractory hypoxaemia followed by air leaks and succumbed on day 19 of mechanical ventilation.

Discussion

The pathological hallmark of air trapping and increased airway resistance in acute bronchiolitis is due to airway narrowing as a result of luminal plugging, mucosal oedema and bronchospasm. These changes lead to increased work of breathing. Patients who cannot cope with this demand eventually develop respiratory exhaustion and hypercarbia[7,8]. Nonetheless, disturbance in airway dynamics is not the only pathological process that contributes to respiratory failure; as inadequate alveoli ventilation despite adequate lung perfusion results in intra-pulmonary shunting and impairment of oxygenation[9,10]. This impairment of oxygenation is caused by a combination of widespread atelectasis and small airway obstruction that reduces the availability of air-flow into the alveoli for gas exchange. The majority of our patients who required mechanical ventilation had significant impairment of oxygenation (PaO_2/FiO_2 ratio < 250) and 10 patients were cyanosed despite supplemental oxygen prior to intubation. PaO_2/FiO_2 ratio has been shown to be a useful and reliable indicator of the degree of oxygenation impairment in the critically ill and more importantly is clinically useful in assessing response to treatment[11,12].

We found that the impaired oxygenation was easily reversed following institution of mechanical ventilation as treatment response was seen within hours and satisfactory oxygenation was achieved in the majority within 48 hours. Respiratory fatigue was most likely the predominant cause of respiratory failure in our patients and the presence of intra-pulmonary shunting although

Table II
Comparison between Patients Requiring Mechanical Ventilation More Than 4 Days and Those Less Than 4 Days

Clinical Parameter	Mechanical Ventilation > 4 days (n = 16)	Mechanical Ventilation < 4 days (n = 9)	p value
PaO_2/FiO_2 less than 250	15 (94%)	3 (33%)	0.003*
Hypoxaemia	9 (56%)	4 (44%)	0.20
Hypercarbia	5 (31%)	3 (33%)	0.67
Mean airway pressure (cmH_2O)	11.0 ± 2.7	11.6 ± 2.4	0.57
Pneumonic infiltration on chest x-ray	14 (88%)	6 (67%)	0.31

** significant p value*

not severe and persistent increased the demand for respiratory work thus aggravating the already tiring infant. Interestingly, we did not require high positive airway pressures to achieve adequate ventilation as expected in infants with obstructive airway disease[13,14,15] but our ventilation strategy was comparable with several studies that used lower airway pressures to ventilate infants with bronchiolitis[16,17]. We postulate that the increased secretions and mucosal oedema in the small airways had a greater contribution to the increased work of breathing and airway resistance in our patients but were easily overcome with the application of positive airway pressure. The need for mechanical ventilation in respiratory failure due to acute bronchiolitis is relatively short and usually less than 96 hours[13,14,16].

The ventilatory strategy practised in our PICU (Table II) appeared to be effective and well tolerated as only one patient developing air leaks. Mechanical ventilation was also well tolerated with the majority only requiring sedation to minimise ventilator-patient asynchrony. Ventilator-patient synchrony is exceptionally important in patients with air trapping as they are at increased risk of pneumothorax and pneumomediastinum. The preferred sedative in our PICU was midazolam which was both safe and efficacious although intravenous ketamine has been shown to have an additional therapeutic effect of relieving bronchospasm[18,19]. The potential risks of bronchorrhoea and its associated cardiovascular side-effects limited its use in our PICU.

The overall mortality in severe bronchiolitis remains low with proper care and management in the PICU[20,21]. However, the patient population described here appears to be less severe than those reported in temperate countries where refractory hypoxaemia occurs and requires rescue treatment modalities like extra-corporeal membrane oxygenation, high frequency oscillatory ventilation and heliox administration[22,23,24]. The only non-survivor in our study had refractory hypoxaemia that fulfilled the criteria that may have benefited from such rescue treatment.

Conclusion

Respiratory failure and hypoxaemia seen in the majority of patients with severe bronchiolitis admitted to our PICU were effectively treated with the institution of mechanical ventilation. Our patients with bronchiolitis requiring intensive care appear to be less severe, tolerated mechanical ventilation well and most importantly had a favourable outcome. Close monitoring and early appropriate intervention with conventional mechanical ventilation remains the cornerstone of treatment for these patients.

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