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Pediatric Fiberoptic Bronchoscopy as Adjunctive Therapy in Acute Asthma With Respiratory Failure

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Summary. Background: Status asthmaticus respiratory failure is associated with thickened mucus secretions necessitating aggressive pulmonary clearance. The role of bronchoscopy in pediatric mechanically ventilated asthmatic patients has not been published. Methods: A chart review was performed on all pediatric intensive care unit (PICU) asthmatics with respiratory failure over 13 years. Forty-four patients were identified. Patients were managed per standardized guidelines for status asthmaticus with mechanical ventilation. Ventilator management prioritized spontaneous breathing with pressure support. Extubation criteria included spontaneous tidal volumes of 5–7 cm^3/kg on low-pressure support. Standard endotracheal tube pulmonary toilet were implemented. Twenty-nine patients underwent bronchoscopy as an adjunctive therapy. Indications for bronchoscopy included: Pathogen identification via bronchoalveolar ravage, atelectasis, mucus obstruction resulting in severe air trapping, suspected aspiration, and poor response to standard therapy. Clinical outcomes of this intervention were compared to the fifteen patient cohort who did not undergo bronchoscopy. Results: Bronchoscopies revealed thick mucus plugs, secretions, and bronchial casts. The large airways were lavaged for clearance of obstructive secretions with normal saline. All patients tolerated the procedure without any complications. Demonstrable improvement in pulmonary compliance was noted. The median time of intubation for the bronchoscopy group was 10 hr compared to 20.5 hr for the control group ($P < 0.0005$). The mean intensive care unit length of stay was 3.06 days for the bronchoscopy group versus 3.4 days for the non-bronchoscopy group ($P < 0.05$). Conclusion: Flexible bronchoscopy with bronchial lavage is a safe adjunctive therapy in pediatric asthmatics with respiratory failure resulting in reduced mechanical ventilation and intensive care length of stay. Restoring lung volume in certain asthmatics during respiratory failure may be deemed beneficial. Further validated studies are necessary to recommend bronchoscopy to the present, accepted treatment regimen in pediatric asthmatic respiratory failure. **Pediatr Pulmonol. 2012; 47:1180–1184.**

Key words: status asthmaticus; respiratory failure; bronchoscopy; intubated asthma.

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INTRODUCTION

Asthma remains a prevalent pediatric condition with associated morbidity and mortality despite modern therapeutic modalities.[1,2] A subpopulation of severe asthma suffers respiratory failure with 2% mortality.[2,3] Severe air flow limitation leads to ventilation/perfusion (V/Q) imbalance, progressive alveolar hypoxia, hypoxemia, CO_2 retention, respiratory failure, and subsequent death.[4–8] The presence of infection, atelectasis, or severe mucous plugging may contribute to mechanical air flow obstruction, segmental lung collapse, lung consolidation, and increased inflammation.[9–14]

Several reports in the adult population elucidated the role of bronchoscopy in patients with severe asthma.[15–18] The safety and efficacy of flexible fiberoptic bronchoscopy in children with asthma and respiratory failure have not been established. The purpose of our study was to evaluate the safety, efficacy, and clinical outcomes of flexible fiberoptic bronchoscopy and bronchoaleolar lavage in pediatric asthmatic patients with respiratory failure.

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Conflict of interest: None.

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METHODS

Study Population

All admissions to the PICU between January 1997 and December 2009 with status asthmaticus and respiratory failure requiring intubation (endotracheal tube $\geq$ 4.0 mm) were retrospectively reviewed. Permission for data collection was approved by the Institutional Research Board (IRB) of Miller Children's Hospital, Memorial Medical Center in Long Beach. Data on patients aged 6 months to 18 years were analyzed in two arms. One arm underwent flexible fiberoptic bronchoscopy during the first 48 hr of mechanical ventilation. The comparative arm underwent intubation with mechanical ventilation without bronchoscopy. All subjects in both arms demonstrated radiographic evidence of air trapping, atelectasis, and/or pneumonia. All subjects in both arms met criteria for respiratory failure including $PaCO_2 > 50$ mmHg, end tidal $CO_2 > 55$ mmHg, and pulse oximetry < 90% on FiO_2 0.21. Excluded from the analysis were patients who sustained cardiac arrest or anoxic ischemic encephalopathy prior to admission to the PICU.

Procedure and Monitoring

Specific indications for bronchoscopy were reviewed during informed consent (Table 1). One or more indications for bronchoscopy were denoted in the informed consent. Informed consent was obtained from all parents of patients who underwent bronchoscopy understanding the risks, potential benefits, alternatives to, and reasoning for the procedure. Bronchoscopy was performed in a standard fashion as previously described.[19] Airway casts and mucus plugs were removed. Bronchial lavage specimens were sent for cell count and cultures.

Standard medical therapy for status asthmaticus was deployed for both study arms. Modalities included but were not limited to: (a) use of positive pressure or pressure support ventilation with low positive end expiratory pressure (peep = 3–4 cm H2O); (b) adjustment of effective tidal volume between 6 and 8 cm^3/kg; (c) nebulized albuterol 0.83% more frequently than every hour; (d) intravenous solumedrol (1–2 mg/kg/dose) every 6 hr; (e) intravenous aminophylline drip; (f) intravenous magnesium sulfate (50 mg/hr) every 6 hr; and (g) continuous intravenous terbutaline drip.

TABLE 1—Indications for Bronchoscopy

1	Segmental or lobar atelectasis
2	Thick mucous/mucous plugs recovered during "blind" ETT suctioning
3	Severe air trapping associated with respiratory failure
4	Evidence of lobar pneumonia
5	Suspected aspiration
6	Suspected foreign body
7	Worsening respiratory status as measured by arterial blood gases ($PaCO_2 \geq 50$), end tidal CO_2 ($ETCO_2$) $\geq$ 55 and pulse aximetry $\leq$90% or progressively worsening of lung compliance despite maximal medical therapy

Serum potassium and glucose were monitored in all patients receiving continuous albuterol and intravenous corticosteroids. Theophylline serum levels and pharmacokinetics were measured and monitored in all children that received I.V. aminophylline drip.

Clinical improvement was considered when end tidal CO_2 or $PaCO_2$ levels decreased below 50 Torr or if spontaneous tidal volume increased without change in positive pressure support.

Extubation was considered when: (a) pressure support reached a value $\leq$12 cm H2O; (b) patient was able to maintain a spontaneous tidal volume between 6 and 10 cm^3/kg; (c) $PaCO_2$ value was $\leq$50 Torr; (d) presence of gag and cough reflexes; (e) negative inspiratory force was in excess of negative 30 cm H2O; and (f) adequate response to noxious stimuli with eye opening or head lifting.

Statistical Analysis

Baseline demographic medical therapy data were presented as mean $\pm$ SD except as noted otherwise. Screening of data for differences in ventilator parameters, length of intubation, and length of stay between the two groups was performed using SAS multiple and simple linear regression analysis. A *P*-value of <0.05 was considered statistically significant.

RESULTS

Subject Characteristics

Data were collected on 44 status asthmaticus children who met the primary criteria of respiratory failure requiring intubation and mechanical ventilation. Flexible fiberoptic bronchoscopy was utilized in 29 cases. The remainder received standard medical therapy (15 patients). All 44 patients received equivalent medical therapy (Table 2).

Bronchoscopy Characteristics

All bronchoscopies and all bronchial lavage fluid was noted to contain mucus plugs or casts at the level of the tracheal, main stem, bronchial segmental, or subsegmental bronchi (Figs. 1 and 2). Eleven of the 29 patients (41%) who underwent bronchoscopy were extubated within 6 hr post procedure. Nineteen of 29 patients (65%) who underwent bronchoscopy exhibited resolution of their respiratory acidosis demonstrated by

TABLE 2—Medical Therapy Received by Patients

		NB (%)		B (%)
Albuterol MDI/aerosol	15	100	29	100
IV corticosteroid	15	100	29	100
Atrovent aerosol	12	80	27	93
Magnesium sulfate	11	73	21	72
Heliox	10	66	18	62
IV aminophylline	8	53	24	82
IV terbutaline	10	66	8	27

normalization of $PaCO_2$ within 12 hr following bronchoscopy. All intervention patients exhibited a marked improvement in alveolar–arterial gradient (A-aO_2) and shunt fraction (Qs/Qt). Improvement in oxygenation with reduction in fraction of inspired O_2 (FiO_2) were noted in all intervention patients. Subgroup analysis of 12 patients' pulmonary compliance ($\Delta V/\Delta P$) was markedly improved after the procedure.

Ventilator Utilization

Mean duration of mechanical ventilation in the non-bronchoscopy arm was 20.5 hr. Mean duration of mechanical ventilation in the bronchoscopy arm was 10.5 hr (Fig. 3). An overall reduction in ventilator hours between groups reached statistical significance ($P < 0.0005$). Covariate analysis demonstrated an increase of one ventilator hour would result in a 1% change in the average length of stay in PICU. Associated negative correlation with days in PICU and bronchoscopy intervention predicted the average length of PICU stay would decrease by 8%. None of the extubated patients post bronchoscopy required reintubation or additional mechanical ventilatory assistance.

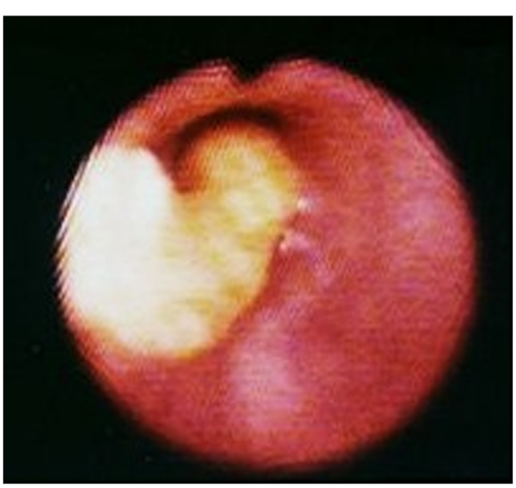

Fig. 1. Typical bronchial cast removed during bronchoscopy. [Color figure can be seen in the online version of this article, available at http://wileyonlinelibrary.com/journal/ppul]

Fig. 2. Segmental bronchial casts typically evacuated during status asthmaticus bronchoscopy. [Color figure can be seen in the online version of this article, available at http://wileyonlinelibrary.com/journal/ppul]

PICU Length of Stay

The mean length of stay in the PICU in the bronchoscopy arm was 3.06 days with a median of 2 days. The average PICU length of stay in the non-bronchoscopy arm was 3.4 days with a median of 3 days. Analysis of variance showed a statistically significant difference between the two groups when compared for length of intubation and ventilatory support with PICU length of stay ($P < 0.05$; Fig. 4). Patients who underwent bronchoscopy spent 0.63 days longer in the hospital (total length of stay, $P = 0.19$) than those who did not have bronchoscopy adjusting for other covariates. However, simple linear regression analysis demonstrated a negative slope associated with days in PICU and bronchoscopy. Patients who underwent bronchoscopy would spend 16% less days in PICU compared to no intervention.

Complications

No complications occurred during or after bronchoscopy. None of the children experienced oxygen desaturation defined as more than a 4% decrease in levels of

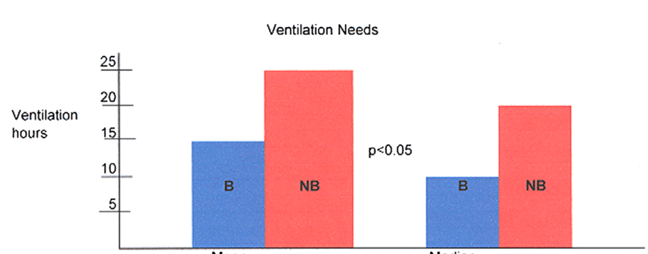

Fig. 3. Mean and median ventilator hours. (B) = Bronchoscopy arm, (NB) = No Bronchoscopy arm. [Color figure can be seen in the online version of this article, available at http://wileyonlinelibrary.com/journal/ppul]

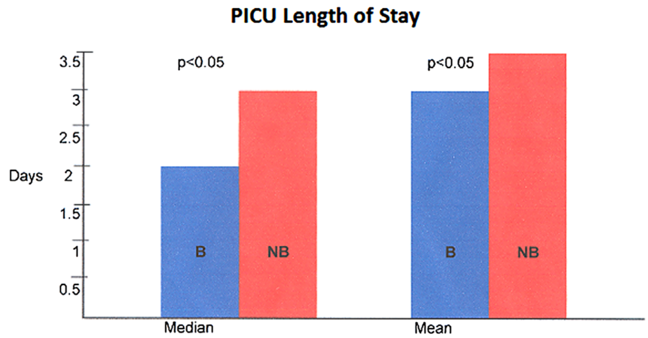

Fig. 4. PICU length of stay. [Color figure can be seen in the online version of this article, available at http://wileyonlinelibrary.com/journal/ppul]

oxygen saturation or $SaO_2 \leq 92\%$ during bronchoscopy. No episodes of bronchospasm were reported. No rise in end tidal CO_2 was noted during the procedure or thereafter. None of the patients experienced pneumothorax or pneumomediastinum during or following the procedure. Similar absence of complications was seen in the non-intervention arm.

DISCUSSION

Asthma remains the most common chronic illness of childhood characterized by variable airflow obstruction and airway hyper-responsiveness.[20] In the US, asthma affects more than 14 million people including approximately 5 million children.[1,2] Asthma maintains mortality rates at 16 per million deaths despite improved care with national clinical guidelines.[2] In several studies analyzing asthma deaths, pathologic findings revealed mucous plugging of major airways, collapse of various segments of the lungs, as well as pneumonia. Except for these findings, no other cause of death was identified.[9–14] Hence, mortality of acute severe respiratory failure related asthma episodes are associated with lung consolidation, atelectasis, or severe mechanical airway obstruction leading to severe hypoxia/hypoxemia. Several studies have shown the potential benefits of bronchoscopy and bronchial lavage with and without mucolytics in adult patients with asthma.[17–19,21,22] A singular published report on flexible bronchoscopy in children with respiratory failure due to status asthmaticus focused its emphasis on severe atelectasis.[15]

In this retrospective study, our asthmatics with respiratory failure requiring intubation who underwent bronchoscopy necessitated shorter ventilatory support (10.5 hr) compared to non-bronchoscopy cohorts (20.5 hr). Additionally, 38% of the bronchoscopy patients were extubated within 6 hr and 69% were extubated within 12 hr following the procedure. A statistically significant clinical benefit was also noted in length of time on mechanical ventilation and length of PICU stay. No overall benefit in total hospital length of stay was noted. However, the additional total length of hospital stay was statistically insignificant.

Bronchoscopy is largely considered an invasive procedure potentially associated with bronchospasm, hypoxemia, and increased CO_2 retention particularly in asthmatics. Refuting such concerns, bronchoscopy has been safely deployed in adult status asthmaticus.[23] Our study demonstrates bronchoscopy performed in critically ill asthmatic children is safe and may reduce the need for prolonged ventilatory support and its associated complications. Additionally, our bronchoscopic findings of severe mucous plugging and bronchial obstruction demonstrated clinical improvement as well as improvement in mechanical variables such as lung compliance. Restoring lung volume of atelectatic regions burdened by mucoid impaction provided the ability to wean off ventilatory support rapidly in most patients. Our study confirms previous reports which associate severe airway mechanical obstruction with respiratory failure, prolonged ventilatory time, risk of barotrauma, and increased asthma mortality.[24–28] None of our patients who underwent bronchoscopy required prolonged ventilatory support (more than 96 hr) or general anesthesia. Deep sedation was successfully accomplished while on ventilatory support and during bronchoscopy, as previously reported.[29,30] Despite limitations in study design, our study demonstrates the safety and efficacy of interventional bronchoscopy in critically ill, mechanically ventilated patients in status asthmaticus.

The limitations of our study are several. Treatment bias may be present as a potentially effective interventional bronchoscopy may have been offered to more critical status asthmaticus patients. The retrospective aspect of our analysis with inability to control for asthma phenotype, gender, age, and controller medication use did not allow for investigation into these important asthma risk variables. The overall power of the study was limited due to recruitment number. Drug utilization in treatment of status asthmaticus reflects current non-standardized guidelines as noted in both study arms. The background inability to control for standardization of intensive care management of mechanical ventilation limits the spectrum of benefit seen with bronchoscopy in this patient population.

CONCLUSION

Our study shows bronchoscopy to be a safe modality in the management of intubated patients with status asthmaticus. Clinical benefits include improvement in ventilator weaning parameters, reduced time of intubation, and decreased length of stay in the intensive care setting. This study conceptually supports bronchoscopic clearance of severe mucous plugging and mechanical obstruction associated with life threatening status asthmaticus in appropriate clinical situations. Flexible fiberoptic bronchoscopy, when performed by experienced bronchoscopists, is safe modality which may be effective in reducing intensive care morbidity in pediatric status asthmaticus with respiratory failure. If its benefits are supported by large scale, randomized, prospective studies, interventional bronchoscopy should be integrated standard guidelines for acute asthma with respiratory failure or at least considered a legitimate adjunct therapeutic modality.

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