Fiberoptic Bronchoscopy in Neonatal and Pediatric Intensive Care Units: A 5-Year Experience

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Key Words
Fiberoptic bronchoscopy · Intensive care unit · Respiratory disease · Neonate · Child

Abstract
Objectives: To determine the value and safety of fiberoptic bronchoscopy in neonatal and pediatric intensive care units (NICUs, PICUs). Subject and Methods: A total of 53 fiberoptic bronchoscopy procedures on 47 patients were reviewed. Bronchoalveolar lavage (BAL) was performed in 23 patients. Results: The primary diseases were pneumonia (n = 16), foreign body aspiration (n = 14), congenital airway abnormality (n = 12), trauma and/or following operations (n = 4) and Guillain-Barré syndrome (n = 1). The major bronchoscopic findings included inflammation in 26 patients, foreign body in 14, congenital airway abnormality in 12 and blood clotting in 3. Microbiology on BAL fluid was positive in 19 of 23 patients. In 23 patients with atelectasis, full and partial re-expansion was obtained in 14 and 6 patients, respectively, at 24 h after the procedures. The clinical features of 9 patients with sputum retention or blood clotting improved significantly after BAL. Positive or negative microbiologic BAL fluid results changed treatment in 11 patients, leading to marked clinical improvement in 9 patients. Moreover, 13 patients were extubated within 24 h of bronchoscopy. Conclusion: These data show that fiberoptic bronchoscopy is safe and effective in the diagnosis and therapy of pulmonary disorders in NICUs and PICUs.

Introduction
Pulmonary disorders are the predominant problem in neonatal and pediatric intensive care units (NICUs, PICUs) [1–3]. Accurate and safe diagnosis as well as therapy is needed at the bedside in this population. The diagnosis and therapeutic utility of fiberoptic bronchoscopy, coupled with its minimal morbidity and mortality, have led to its increasing use in the care of the critically ill patient. Bronchoscopy allows direct inspection of the upper and lower airways, and facilitates the diagnosis and management of a variety of pulmonary disorders. Over the years, the number of these procedures in adult ICUs has greatly increased, with both diagnostic and therapeutic objectives, such as evaluation for airway foreign body aspiration, difficult intubation, management of atelectasis and hemoptysis, diagnosis of nosocomial pneumonia in ventilated patients, and detection of airway lesions [4–8]. However, up to now, there is limited information about the safety and efficacy of bronchoscopy in NICUs and PICUs [9–11]. We reviewed 53 procedures of fiberoptic bronchoscopy in 47 pediatric patients over a period of 5 years to investigate the value and safety of fiberoptic bronchoscopy in the diagnosis and treatment of patients in NICUs and PICUs.
**Table 1.** Characteristics and primary disease of 47 patients

<table>
<thead>
<tr>
<th>Patients</th>
</tr>
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<tbody>
<tr>
<td>Male</td>
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<tr>
<td>Female</td>
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<tr>
<td>Male:female ratio</td>
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<tr>
<td>Age</td>
</tr>
<tr>
<td>&lt; 1 month</td>
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<tr>
<td>≤ 1 year</td>
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<tr>
<td>≤ 3 years</td>
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<tr>
<td>&gt; 3 years</td>
</tr>
<tr>
<td>Primary disease</td>
</tr>
<tr>
<td>Pneumonia</td>
</tr>
<tr>
<td>Airway foreign body</td>
</tr>
<tr>
<td>Congenital abnormality</td>
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<tr>
<td>Trauma and/or following operations</td>
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<tr>
<td>Guillain-Barré syndrome</td>
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**Subjects and Methods**

**Subjects**

A total of 47 patients who underwent fiberoptic bronchoscopy in our NICU and PICU during a 5-year period were enrolled in this study. In total, 53 fiberoptic bronchoscopy procedures were performed in 47 patients. Patient characteristics, including age and gender, preoperative presentations, duration of symptoms, route of bronchoscope insertion, bronchoscopic and bronchoalveolar lavage (BAL) findings, complications and prognosis were reviewed. Informed consent was obtained from the patients' parents, and the study was approved by the Ethical Committee, Zhejiang University School of Medicine, Hangzhou, China.

**Bronchoscopy**

Atropine (0.03 mg/kg) and diazepam (0.1–0.3 mg/kg) were injected intravenously to 24 patients 30 min before bronchoscopy (BF-3C30, BF-XP40, BF-P40, Olympus Company) [12]. Twenty-three patients with mechanical ventilation did not receive atropine and diazepam. Topical anesthesia with 2% lidocaine was administered.

BAL with normal saline (weight 20 kg: 1 ml/kg, weight > 20 kg: 2 ml each time, 3 times) was conducted in 23 patients with –25 to about –100 mm Hg (–3.3 to –13.3 kPa) suction. Microbiological analysis of BAL fluid, including bacterial culture and smear analysis, Chlamydia and Mycoplasma pneumoniae DNA detection (real-time PCR), immunofluorescence for adenovirus, respiratory syncytial virus, influenza virus, and parainfluenza virus, was performed in 19 patients.

Oxygen was inhaled and electrocardiogram, respiration and arterial oxygen saturation (SaO₂) were continuously monitored during the procedure to keep SaO₂ over 85%. The bronchoscope was withdrawn if the SaO₂ fell below 90% and was re-inserted after SaO₂ recovery.

The staff involved in each procedure included 1 senior pediatric intensivist, 2 senior pulmonologists, the rotating pediatric resident and a registered ICU nurse. A chest radiograph was obtained routinely after all procedures.

**Results**

**Patient Characteristics**

Of the 47 patients, 33 were males and 14 females with a ratio of 2.4:1. Age ranged from 1 day to 13 years with a mean ± SD of 2.4 ± 0.7 years. The duration of primary diseases ranged from 4 h to 2 months with a median of 6 days. The primary diseases included severe pneumonia in 16 patients (34.0%), foreign body aspiration in 14 (29.8%) including 1 combined with congenital heart disease, 12 (25.5%) with congenital structural airway abnormality, 4 (8.5%) with trauma and/or prior operation and 1 (2.1%) with Guillain-Barré syndrome as shown in Table 1. Moreover, dyspnea and respiratory failure were noted in 36 patients (76.6%), including 13 (27.7%) of type I and 23 (48.9%) of type II.

**Indication of Bronchoscopy and Bronchoscope Insertion**

Of 53 procedures, 29 (54.7%) were performed on patients who were undergoing mechanical ventilation. Among these procedures, 38 (71.7%) were for diagnostic reasons (upper- and lower-airway inspection, pathogen isolation), 9 (17.0%) for therapeutic reasons (foreign body or blood clot removal, pulmonary hemorrhage, endotracheal intubation), and 6 (11.3%) for both. The fiberoptic bronchoscope was inserted through the nasopharynx in 16 (30.2%), an endotracheal tube in 33 (62.3%), and a tracheotomy tube in 4 (7.5%), as shown in Table 2.

**Bronchoscopic Findings**

The most common finding of fiberoptic bronchoscopy was inflammation, which was noted in 26 (55.3%) patients. In these 26 patients, mucous congestion and edema without sputum plugging were found in 7 (14.9%) and purulent infection with excessive secretion was noted in 19 (40.4%), of whom 9 had mucus plugging. The second most common finding was airway foreign body aspiration, which was noted in 14 (29.8%) patients: 5 (35.7%) peanut, 4 (28.6%) sunflower seeds, 2 (14.3%) fruit jelly and 1 of unknown mass. The third most common finding was congenital structural airway abnormality which was noted in 12 (25.5%) patients, including 8 with respiratory tract malacia (1 tracheomalacia, 2 bronchomalacia, 1 laryngotraceomalacia, 1 laryngobronchomalacia, and 2 tracheobronchomalacia, and 1 laryngotraceobronchomalacia); the other 4 had dysplasia (1 tracheal stenosis, 1 bronchial stenosis, 1 right main bronchial atresia, and 1 right superior lobar bronchus atresia). Additionally, a blood clot was found in 3 patients
(6.4%), including 1 with foreign body aspiration and 2 following trauma.

Segmental or lobar atelectasis was noted in 23 (48.9%) patients: 9 (39.1%) had mucus plugging, 8 (34.8%) foreign body aspiration, 3 (13.0%) blood clots and 3 (13.0%) congenital airway abnormalities. BAL demonstrated pathogens in 7 (36.8%) of 19 patients. Bacteria/yeasts were isolated in 5 procedures, which included 2 with *Klebsiella pneumoniae*, 1 with *Pseudomonas aeruginosa*, 1 with *Escherichia coli*, and 1 with *Candida albicans*. Cytomegalic inclusions and *Chlamydia trachomatis* were noted in 1 patient each, as shown in table 2.

**Clinical Processes**

In 14 patients with foreign body aspiration, the foreign bodies were removed successfully in 11 (78.6%) by fiberoptic bronchoscopy and the remaining 3 by rigid bronchoscopy in the Otolaryngology Department. In 23 patients with atelectasis, full re-expansion was obtained in 14 (60.9%) patients partial re-expansion in 6 (26.1%), and no change in 3 (13.0%) within 24 h after the fiberoptic bronchoscopy procedure.

The clinical symptoms and signs of the 9 patients with mucus plugging or blood clots were significantly improved after BAL. Positive or negative microbiologic BAL results led to a modification of the treatment in 11 patients, followed by a marked clinical improvement in 9. In this series, 13 (13/29, 44.8%) patients including 8 with foreign bodies and 5 with mucus plugging or blood clots, were extubated successfully within the following 24 h. However, 5 (10.6%) patients failed to improve. One remained comatose despite foreign body removal: 1 with laryngotracheobronchomalacia failed extubation, and one with pneumonia deteriorated due to pulmonary hemorrhage. Moreover, 1 patient with lower tracheal stenosis also died from pulmonary sepsis. Another patient with congenital heart disease, who had a foreign body for 2 weeks, died due to a combination of multiple organ failure and irreversible ventricular tachycardia.

**Complications**

Mild hypoxemia (SaO2 < 90%) occurred transiently during 11 (20.8%) procedures. Other complications included mild pulmonary hemorrhage in 2 (3.8%), supraventricular tachycardia in 1 (1.9%), pneumothorax in 1 (1.9%), and bronchospasms in 1 (1.9%). In patients under ventilatory support, no significant changes in ventilatory pressures were observed during the procedures. No significant airway trauma, serious hemorrhage, respiratory or cardiac arrest, or death occurred during any of these procedures.

**Table 2. Bronchoscopic procedures and findings**

<table>
<thead>
<tr>
<th>Patients</th>
<th>Indication</th>
<th>Bronchoscope insertion</th>
<th>Bronchoscopic findings</th>
<th>BAL positive for microbes</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 (71.7%)</td>
<td>Diagnostic</td>
<td>Nasopharyngeal</td>
<td>Inflammation</td>
<td>26 (55.3%)</td>
</tr>
<tr>
<td>9 (17.0%)</td>
<td>Therapeutic</td>
<td>Endotracheal tube</td>
<td>Mucus plugging</td>
<td>9 (19.1%)</td>
</tr>
<tr>
<td>6 (11.3%)</td>
<td>Both</td>
<td>Tracheotomy tube</td>
<td>Foreign body</td>
<td>14 (29.8%)</td>
</tr>
<tr>
<td>16 (30.2%)</td>
<td></td>
<td></td>
<td>Congenital abnormality</td>
<td>12 (25.5%)</td>
</tr>
<tr>
<td>33 (62.3%)</td>
<td></td>
<td></td>
<td>Blood clotting</td>
<td>3 (6.4%)</td>
</tr>
<tr>
<td>4 (7.5%)</td>
<td></td>
<td></td>
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<td>7/19 (36.8%)</td>
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</table>

**Discussion**

The present report analyzes the application and value of fiberoptic bronchoscopy in a group of neonates and children admitted to our NICU and PICU. Previously, fiberoptic bronchoscopy was not encouraged in severe respiratory disorders due to concerns regarding an associated decrease in PaO2, which might cause respiratory or cardiac arrest [13, 14]. In this work, some of our patients were in critical conditions that made them more susceptible to complications (e.g. trauma, airway foreign body, or congenital structural airway abnormality); however, their complications as well as transient lower SaO2 rates were similar to those observed in other pediatric pulmonary services [15, 16] where rigid or fiberoptic bronchoscopy was performed. Moreover, these complications subsided rapidly, no one died directly due to the procedure or from a complication of these procedures, although 5 cases were unimproved due to their primary disease. This suggests that fiberoptic bronchoscopy in the NICU and PICU is safe if performed by expert operators, life monitors and emergency equipment.

In this study, we noted that most of the children who underwent fiberoptic bronchoscopy were under 3 years of age. In this population (infants and toddlers), there is a higher risk for aspiration of foreign bodies, congenital airway structural abnormalities [12, 17–19] as well as weakness of cough that might predispose them to mucus plugging. Moreover, congenital airway structural abnormalities and foreign body aspiration are more prevalent.

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in males [12, 17, 18] and this correlates with our data. In this work, most procedures (71.7%) were performed for diagnostic reasons although therapeutic management was undertaken in most patients with foreign body aspiration and airway plugging. The etiologies of 38 patients were identified by fiber-optic bronchoscopy, which is consistent with previous reports [10, 20, 21]. Moreover, therapy by fiberoptic bronchoscopy was performed after evolution by flexible bronchoscopy.

We found that mucus plugging, airway foreign body aspiration and congenital airway abnormality were the most common indications for bronchoscopy in the NICU and PICU. Of them, mucus plugging was the most common cause requiring bronchoscopy in our ICU, which might be associated with weakness of cough, serious pulmonary infection with excessive secretion, nervous system and/or muscle disorder, muscle relaxant, sedatives or anesthetic use in postoperative or mechanical ventilation. Foreign body aspiration was the second most common cause in these series. Unlike foreign body aspiration in adults, the diagnosis of foreign body aspiration in a pediatric patient is more difficult since they most commonly occur in infants and toddlers who are unable to readily communicate the circumstances leading to the aspiration event [12]. In this study, only 5 patients had an accurate history of foreign body aspiration, and most of them were unable to provide a detailed history. Congenital abnormality was another common cause that was very difficult to diagnose by history, physical examination and imaging. Bronchoscopy may be the only method for diagnosis. Furthermore, bronchoscopy can also differentiate the type and identify the severity of the abnormality [22–24]. Of 47 patients, only 2 were considered to have an airway abnormality by imaging (right pulmonary hypoplasia and narrowing of the distal trachea) that was later confirmed by bronchoscopy. It should be emphasized that general anesthesia might depress spontaneous breathing and cough which might alter the collapse of the respiratory tract wall. So, if respiratory tract malacia cannot be excluded, topical anesthesia, but not general anesthesia, should be applied in fiberoptic bronchoscopy. From these observations, we conclude that bronchoscopic suction is easy, quick, and highly effective and does not provoke any epithelial changes [25, 26]. In children with airway inflammation, especially with mucus plugging, removal of mucus plugging can relieve the obstruction and the toxic symptoms. In this work, we also found that 5 out of 12 patients with mucus plugging and blood clotting significantly improved after bronchoscopy. Microbiological detection by BAL was very helpful for therapy, i.e. selection of the antibiotic and duration of administration. Negative microbiologic BAL findings were also important as they accelerated the search for other sites of infection and led to cessation or to downgrading of antibiotic treatment. The 44.8% rate of successful extubation within 24 h following fiberoptic bronchoscopy and BAL in patients with atelectasis highlights the importance of targeted, direct-vision removal of airway plugging in critically ill infants and children.

**Conclusion**

Our data showed that fiberoptic bronchoscopy is safe and effective in the diagnosis and therapy of serious pulmonary disorders in the NICU and PICU. We suggest that bronchoscopy should be recommended promptly, especially in patients receiving ventilation.

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References


