Usefulness of Miniature Flexible Fiberoptic Bronchoscopy in Children*

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A miniature flexible fiberoptic bronchoscope (FFB) (Olympus BF-N20) (2.2 mm diameter) was applied to 53 children (20 female subjects) ranging in age from 3 months to 15 years (mean, 4.19 years). Most common indications for bronchoscopy included stridor or weak cry and persistent wheezing or cough unresponsive to inhaled bronchodilators, chest physiotherapy, steroids, and antimicrobial agents. There were no complications. In 38 children (71.6 percent) it was diagnostically useful, particularly for the investigations of upper airway obstruction (66 percent). In 22 children (41.5 percent) it provided guidance for surgical interventions. The instrument was particularly useful during its application in infants with severe upper airway obstruction who otherwise would require open rigid-tube bronchoscopy in the operating room. It was of limited value when excessive bronchial secretions obstructed the view of the working field for which a bronchoscope with a built-in suction channel was needed. It is concluded that this miniature FFB is a useful diagnostic tool in infants and children particularly for obstructed upper airways but has limited applications in children with peripheral airway disease. The 2.2-mm bronchoscope may have its greatest advantage in preterm neonates and intubated infants, where the small glottic or endotracheal tube size renders the 3.5-mm bronchoscope useless.

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FFB=fiberoptic bronchoscopy

Key words: children; indications; miniature fiberoptic bronchoscopy; obstruction, subglottic narrowing; upper airway

The applicability of fiberoptic bronchoscopy (FB) in infants and children as a bedside modality has gained acceptance in recent years but remained of limited value in those infants and children with significant upper airway obstruction who require instrumentation with the open rigid-tube bronchoscope under general anesthesia. Although bedside FB explores a variety of objectives that previously could be accomplished only with open rigid-tube bronchoscopy in the operating room, infants and toddlers are potentially subjected to oxygen desaturation or further obstruction during FB. To accommodate the specific needs of infants and toddlers, the development of smaller-size bronchoscopes was a welcome addition. It is the purpose of this communication to describe our experience with a specific flexible fiberoptic bronchoscope (FFB) (Olympus BF type N20) and its diagnostic usefulness in children.

METHODS

Patient Selection

Fifty-three consecutive patients underwent endoscopy with a FFB (BF type N20).

Infants or children with persistent stridor, weak cry, and those with unexplained cough and chronic wheezing unresponsive to inhaled bronchodilators, inhaled or oral steroids, constituted the majority of our candidates for FFB. Patients with severe hypoxemia (PaO2<50 mm Hg), bleeding diathesis, hemodynamic instability, or arrhythmia were excluded from bedside bronchoscopy. However, we did not exclude children with significant upper airway obstruction since we speculated that applying this miniature FFB would not compromise gas exchange. With the exception of those who were intubated, admitted to the hospital for trauma, epiglottitis, or hospitalized for other reasons, all FB procedures were performed on an outpatient basis.

Preparation for Procedure With Special Attention to Pediatric Sedation

An informed consent was obtained from all parents. Six hours with nothing by mouth was required for all infants and children prior to this procedure. An intravenous line was established in all patients at least 1/2 h before the procedure began. Fentanyl was given intravenously at 1 µg/kg, followed 10 min later by intravenous midazolam, 0.1 mg/kg, to a maximum of 2.5 mg, given slowly over 2 min. The nasopharynx, usually on the right side, was topically anesthetized by applying 1 ml of 2 percent lidocaine solution followed by local lubrication with lidocaine jelly.

Procedure and Monitoring Period

With the exception of tracheostomy evaluation or endotracheal introduction in ventilated children, all procedures were performed transnasally. Peripheral perfusion and depth of respirations were closely monitored by a registered nurse. Respirations were also monitored electronically (Hewlett-Packard, Palo Alto, Calif.). The procedure was performed in the pediatric bronchoscopy room adjacent to the pediatric intensive care unit (PICU) or at bedside in the PICU. All patients were continuously monitored by electrocardiogram, and oxygen saturation was continuously monitored by a pulse oximeter (Nelcor) to ensure oxygen saturation above 95 percent at all times. Children who experienced a fall in oxygen saturation below 95 percent during the procedure were given oxygen (5 L/min) by mask which was
of N20, Olympus diameter outer a with of tolerated was ful in usefulness complications. 3 children and presented percenting the midazolam of 2 were bronchoscope. followed by FB airway 1) plugs upper lobe Right Subglottic hemangioma 1(1.9) stenosis/edema Tracheal Tracheitis 1(1.9) Adenoidal hypertrophy Laryngomalacia Laryngomalacia + adenoidal hypertrophy Subglottic stenosis/edema Distal tracheal narrowing Tracheomalacia Tracheitis Tracheal ulceration 2° to traum Tracheal granuloma Tracheal papillomatosis Subglottic hemangioma Right mainstem bronchus narrowing and granuloma Right upper lobe bronchus take off above carina Mucus plugs or secretions in a major bronchi in children with reactive airway disease with and without atelectasis Total

<table>
<thead>
<tr>
<th>Bronchoscopic Diagnosis</th>
<th>No. of Patients (%)</th>
<th>Diagnostic Usefulness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal anatomy</td>
<td>2 (3.8)</td>
<td>Anatomic obstruction ruled out</td>
</tr>
<tr>
<td>Normal anatomy with purulent secretions</td>
<td>3 (5.6)</td>
<td>NU*</td>
</tr>
<tr>
<td>Nasopharyngeal tumor</td>
<td>1 (1.9)</td>
<td>Referral for surgery</td>
</tr>
<tr>
<td>Evaluation of epiglottis status/resolution prior to extubation</td>
<td>1 (1.9)</td>
<td>Timing of extubation</td>
</tr>
<tr>
<td>Adenoidal hypertrophy</td>
<td>5 (9.4)</td>
<td>Referral to ENT physician for surgery</td>
</tr>
<tr>
<td>Laryngomalacia</td>
<td>8 (15.1)</td>
<td>Reassuring parents and referring physicians</td>
</tr>
<tr>
<td>Laryngomalacia + adenoidal hypertrophy</td>
<td>4 (7.6)</td>
<td>Referral to ENT physician for possible surgery</td>
</tr>
<tr>
<td>Subglottic stenosis/edema</td>
<td>5 (9.4)</td>
<td>Consideration for tracheostomy tube placement or cricoid splint</td>
</tr>
<tr>
<td>Distal tracheal narrowing</td>
<td>1 (1.9)</td>
<td>Referral to ENT physician for tracheal reconstruction</td>
</tr>
<tr>
<td>Tracheomalacia</td>
<td>3 (5.6)</td>
<td>Consideration for CPAP therapy if findings persist and oxygenation remains compromised</td>
</tr>
<tr>
<td>Tracheitis</td>
<td>1 (1.9)</td>
<td>NU</td>
</tr>
<tr>
<td>Tracheal ulceration 2° to trauma</td>
<td>1 (1.9)</td>
<td>Establishes baseline status; allows follow-up</td>
</tr>
<tr>
<td>Tracheal granuloma</td>
<td>3 (5.6)</td>
<td>Referral for laser surgery</td>
</tr>
<tr>
<td>Tracheal papillomatosis</td>
<td>1 (1.9)</td>
<td>Referral for laser surgery</td>
</tr>
<tr>
<td>Subglottic hemangioma</td>
<td>1 (1.9)</td>
<td>Referral for ENT physician</td>
</tr>
<tr>
<td>Right mainstem bronchus</td>
<td>1 (1.9)</td>
<td>Referral to ENT for surgery</td>
</tr>
<tr>
<td>narrowing and granuloma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right upper lobe bronchus take off above carina</td>
<td>1 (1.9)</td>
<td>Explains radiologic and clinical findings</td>
</tr>
<tr>
<td>Mucus plugs or secretions in a major bronchi in children with reactive airway disease with and without atelectasis</td>
<td>11 (20.8)</td>
<td>NU</td>
</tr>
<tr>
<td>Total</td>
<td>53 (100)</td>
<td></td>
</tr>
</tbody>
</table>

*NU=not useful. Need for bronchoscopy with a built-in suction channel. ENT=ear, nose, and throat; CPAP=continuous positive airway pressure.

specially fenestrated to accommodate the introduction of the bronchoscope. Upon termination of bronchoscopy, the effects of fentanyl were reversed by naloxone (Narcan) and, if needed, that of midazolam by flumazenil. In order to avoid postinstrumentation airway edema, methylprednisolone sodium succinate (Solu-Medrol), 2 mg/kg, was given intravenously upon completion of FB followed by prednisone, 1 mg/kg/d, given 2 h later and during the subsequent 3 days.

**Specifications of the FFB**

The instrument used was a bronchoscope (Olympus BF type N20, Olympus Corporation of America, New Hyde Park, NY) with a distal end outer diameter of 1.8 mm, and a flexible portion outer diameter of 2.2 mm. The optical system allowed a field view of 75° and depth of field 2 to 50 mm. The range of the tip-bending section provided maneuverability of 160° up and 90° down.

**RESULTS**

The procedure was well tolerated by all 53 infants and children (20 female subjects) ranging in age from 3 months to 15 years (mean, 4.19 years). There were no complications. Bronchoscopic findings and diagnostic usefulness are described in Table 1. Sixty-six percent presented with upper airway obstruction (Table 1) and the procedure was diagnostically useful in 38 (71.6 percent) of our patients. The procedure was tolerated by all infants, including 16 (30 percent) with a significant degree of upper airway obstruction, such as subglottic stenosis. Under no circumstances did the oxygen saturation fall below 93 percent. With the exception of two subjects aged 14 and 15 months, children with significant upper airway obstruction as a result of laryngomalacia, subglottic stenosis, tracheomalacia, and subglottic hemangioma ranged in age from 2 to 10 months (mean, 5.28 months). Three patients with tracheal granuloma and one patient with tracheal papillomatosis were 12, 23, 36, and 10 months of age, respectively. Bronchoscopic findings resulted in referring 22 children (41.5 percent) for surgical interventions. Upper airway obstruction was not a limiting factor for FB and did not require a referral for open rigid-tube bronchoscopy under general anesthesia. When, unexpectedly, purulent secretions were encountered, it was then necessary to withdraw the FB (BF-N20) and apply a different bronchoscope with suction capabilities (BF types 3C10/3C20: external diameter, 3.5 mm, and a built-in suction channel, 1.2 mm) in order to aspirate secretions and gain a clear view of the working field. However, the presence of subglottic narrowing precluded the use of BF types 3C10/3C20 FFB. In contrast with our extensive previous experience in children with significant upper airway obstruction, in
which flexible bronchoscopy was contraindicated for fear of obstructing the airways and inducing hypoxia/hypoxemia, the BF-N20 bronchoscope was maneuvered via subglottic stenosis or tracheal narrowing (tracheal granuloma, papillomatosis, subglottic hemangioma, etc) without any difficulty. Gas exchange was not compromised and oxygen saturation ranged between 93 percent and 99 percent. None of our patients required oxygen treatment 1 h following FB, including those who received oxygen during the procedure.

Respiratory rate, which was monitored visually and electronically, and electrocardiogram, which was continuously monitored, did not indicate hemodynamic instability or respiratory depression in any of our patients. When the larger size bronchoscope with a built-in suction channel was applied in patients who required suctioning or endobronchial aspiration, excluding those with subglottic narrowing, gas exchange was not compromised and oxygen saturation was maintained above 93 percent. Surprisingly there were instances in which patients experienced cough and wheezing with normal-looking chest radiographs, yet during endobronchial inspection retained secretions were identified.

**Discussion**

Inspection of the pediatric airways with the FFB has gained acceptance only during the last decade. A tracheal diameter of 4.5 mm or greater in children 3 years of age or older can easily accommodate a FB such as the BF-3C10 or BF-3C20 with external diameter of 3.5 mm and a built-in suction channel of 1.2 mm. It is practical to apply such an instrument utilizing its suction capabilities for diagnostic endobronchial aspiration, and when appropriate, applying it as a bedside modality in intubated children with acute lobar collapse in order to restore lost functional volume. It also has a role in the vast majority of patients, including neonates who require laryngoscopy for the purpose of establishing “above vocal cord diagnosis” such as laryngomalacia, adenoidal hypertrophy, vocal cord dysfunction, or nasopharyngeal tumors. However, the presence of subglottic narrowing in an infant or toddler may not accommodate a bronchoscope with a built-in suction channel and rather may subject patients to the potential risk of hypoxia/hypoxemia, traumatic injury to the airways, laryngospasm, bronchospasm, and hemodynamic instability once the FFB passes below the vocal cords. The direct inspection of the trachea or lower airways has been particularly discouraged in infants or children with upper airway obstruction, such as subglottic stenosis or tracheal stenosis, for fear of augmenting airway edema and further blocking obstructed airways as the bronchoscope is maneuvered through the narrow segment. Since severe hypoxia/hypoxemia and arrhythmia may also be the consequences of postinstrumentation airway edema, the degree of obstruction, as well as operator’s experience, must be considered even when making a decision to apply the ultrathin FB. In developing the repertoire of indications and contraindications for pediatric FB, a consensus has been reached that individuals with significant upper airway obstruction should be evaluated in the operating room, in a controlled environment and under general anesthesia. It became, therefore, attractive to develop smaller instruments that allow maneuverability through narrow or small-diameter airways, devoid of general anesthesia, and without risk of oxygen desaturation.

The application of this FFB (Olympus BF-N20) allowed inspection of the entire airway without any difficulties or complications in all 53 infants and children. Stridor and abnormal phonation were the most common indications for the procedure. Upper airway obstruction was encountered in 66 percent of our study population. Laryngomalacia and adenoidal hypertrophy were the most common conditions diagnosed in our patient population. Since laryngoscopic findings do not exclude the possibility of subglottic lesions, we recommend inspection of the lower airway, particularly in children with stridor or those suspected of having laryngomalacia. In 38 patients (71.6 percent), a medical decision was made by endoscopic findings (Table 1), and in 22 children (41.5 percent), it resulted in a referral to an ear, nose, and throat physician for surgical interventions, such as cricoid split, tracheostomy tube placement, laser surgery, and adenoidectomy. Other therapeutic interventions were guided by endoscopic findings as shown in Table 1. Children who otherwise would require open rigid-tube bronchoscopy were studied at the bedside since endoscopy with the miniature FFB was accomplished in infants with upper airway obstruction without compromising air exchange. Sixteen patients, comprising 30 percent of the study group, had significant upper airway obstruction yet were able to maintain oxygen saturation >93 percent. These patients would have otherwise been studied in the operating room. Lacking a suction channel, the miniature FFB was at a disadvantage in comparison to the standard pediatric bronchoscope (with a built-in suction channel) when purulent secretions or mucus plugs were unexpectedly encountered during inspection of the lower airways. The working field was obstructed and bronchial secretions could not be collected for diagnostic purposes. When it was determined that inspection of the peripheral airways and diagnostic bronchial lavage was essential, the miniature FFB could not be utilized.
Evaluation of infants with stridor or any abnormal phonation by the miniature FFB provided an appreciation of the dynamic state of the upper airways. The nasal introduction of the instrument and its position above the epiglottis afforded the opportunity to inspect the upper airways in their natural state devoid of disruption from general anesthetic agents or the oral approach of the rigid bronchoscope.\textsuperscript{37-40} This was particularly true with the diagnosis of laryngomalacia,\textsuperscript{37} which manifests with distinct dynamic characteristics. Owing to its small diameter and accurate maneuverability, the applications of this bronchoscope are extended into guidance during difficult intubations, confirmation of endotracheal tube position, evaluation of tracheostomies, and an objective assessment of the state of acute epiglottitis in order to determine optimal time for extubation.\textsuperscript{41-46} Its comfortable level of operation and ease of maneuverability as a bedside modality in infants renders it, in this respect, superior to the open rigid-tube bronchoscope. None of our patients experienced respiratory depression, hypoxemia, laryngospasm, or hemodynamic instability.

The miniature FFB can serve as a useful tool in evaluating upper airway obstruction in children, has a high yield of diagnostic information guiding clinical and surgical interventions, is considerably safe as a bedside modality, and may be considered an attractive alternative to open rigid-tube bronchoscopy in preterm neonates and intubated infants. While the standard FFB remains useful in the vast majority of patients from neonates to adolescents, the miniature FFB should be the tool of choice in infants and toddlers with subglottic narrowing.

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