Paediatric bronchoscopy

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Bronchoscopy first saw clinical application in 1897 when Killian removed a pork bone from the right main bronchus of a German farmer. The early clinical applications of bronchoscopy were limited to the removal of foreign bodies. As illumination and optical technology improved, notably the Hopkins rod and lens system, wider applications became realised. Wood and Flink first described use of the flexible bronchoscope in children in 1978. Fibreoptic bronoscopes small enough for use in children became widely available in 1981. Since then the rise in flexible bronchoscopy has been relentless. While the experienced bronchoscopist can probably accomplish most procedures with either a flexible or a rigid bronchoscope, the two instruments have complimentary roles. What does bronchoscopy involve and what can bronchoscopy achieve in the paediatric age group?

The rigid bronchoscope

Ventilating bronchoscopes are available in a variety of sizes and lengths from 2.5 mm internal diameter upwards (Karl Storz GmbH). Safe examination of the tracheobronchial tree from the premature neonate onwards is possible. A variety of telescopes fit down the bronchoscope allowing inspection of all lobar bronchi. Ventilation through the bronchoscope alongside the telescope maintains oxygenation and, under appropriate conditions, spontaneous respiration through the bronchoscope allows assessment of the degree of airway collapse in tracheomalacia or bronchomalacia.

The principal advantage of the rigid bronchoscope is complete control of the airway. The bronchoscope functions as a rigid endotracheal tube. The clarity of vision achieved by the Hopkins rod lens telescope exceeds that of the flexible bronchoscope. The comparatively large diameter of the instrument channel and the superb array of baskets, forceps, and grabbers available enables a wide range of therapeutic procedures to be performed. In the event of significant haemorrhage or tenacious secretions, the telescope can be withdrawn and suction catheters passed directly down the bronchoscope while maintaining oxygenation and control of the airway.

Rigid bronchoscopy in children requires general anaesthesia and demands the skills of an anaesthetist with considerable paediatric expertise. Ankylosis of the jaw or neck may preclude rigid bronchoscopy and the risk of trauma to the oropharynx and airway is greater than with a flexible bronchoscope. However, the principal disadvantage of rigid bronchoscopy is limited access to the distal airways and to the upper lobes.

The flexible bronchoscope

At present, paediatric flexible bronchoscopes consist of bundles of optical fibres, rendering the instruments inherently delicate. The bronchoscope contains fibres dedicated to making the image, fibres which deliver light to the tip, and a working channel through which suction is applied and instruments passed. The picture is made of pixels, each one representing a single glass fibre. Consequently, the image is not as good as that obtained using a rigid bronchoscope. The end of the bronchoscope is steerable through an arc of 220 degrees, permitting visualisation of the entire airway. The most popular flexible paediatric bronchoscope has a 3.6 mm external diameter and a 1.2 mm working channel (Olympus BF3C20). There is a 2.2 mm external diameter flexible bronchoscope available (Olympus BF 22), although this lacks an instrument channel. The newer adult bronchoscopes have an external diameter less than 5 mm and may be used in children as young as 3 to 4 years. Larger flexible bronchoscopes (5.8–6.0 mm) can be used in adolescent patients. The instrument channel is wider in these bronchoscopes, accommodating a larger variety of instruments. The power of suction is also significantly better.

General anaesthesia is not essential for flexible bronchoscopy in children. Indeed, bronchoscopy performed under sedation, with topical anaesthesia of the airway mucosa, enables inspection of the dynamic anatomy of the airway during normal spontaneous respiration. Excellent access to the entire airway is possible, including the upper airway. It is possible to examine the airway quickly without distortion or significant damage to the airway mucosa. When general anaesthesia is employed, or bronchoscopy performed on a ventilated patient, the bronchoscope can be passed down the endotracheal tube. Use of a laryngeal mask as an alternative to endotracheal intubation
 permits inspection of the vocal cords, larynx, and upper trachea and has the additional advantage of permitting use of a larger diameter bronchoscope. Passage of a flexible bronchoscope inevitably produces some degree of airway obstruction and constant monitoring for signs of hypoxia is essential. While the 3.6 mm bronchoscope can be used in the newborn, it is not possible to ventilate the baby at the same time and therefore the examination must be very brief. The narrow instrument/suction channel of the flexible bronchoscope restricts therapeutic use, in most cases, to manipulation of biopsy forceps and cytology brushes, and delivery of saline flushes and oxygen.

**Indications for bronchoscopy**

Indications for bronchoscopy in children are summarised in table 1.

**Stridor** is a common symptom in infants and a conservative approach may be justified. However, the chances of missing significant structural pathology in the airway are high if the stridor is severe, persistent, associated with apnoea, failure to thrive, or an abnormal cry, or occurs in a child who has been ventilated previously. Endoscopic examination of the airway is indicated in this group of children. A diagnosis of laryngomalacia can be established with certainty but complete examination of the airway is essential. Flexible bronchoscopy is a useful tool to examine the upper airway during spontaneous respiration, but examination of the lower airway is safer under general anaesthesia. Unilateral or unresponsive wheeze may also indicate structural abnormality in the lower airway or even an inhaled foreign body, and bronchoscopy is a logical investigation of these symptoms.

Persistent cough is a common paediatric symptom. If it is refractory to treatment, bronchoscopy may be indicated but the diagnostic value is relatively low in the absence of other symptoms or signs, for example haemoptysis, persistently productive cough, localised wheeze, or radiological abnormalities. In a child with intractable symptoms bronchoscopy can be of great reassurance, even if normal. Children with abnormal airway dynamics (for example tracheomalacia) may have a persistent cough often precipitated by respiratory tract infection.

Bronchoscopy is an essential investigation for children with bronchiectasis. Structural abnormalities and foreign bodies can be excluded, secretions can be taken for culture, and mucosal biopsies can examined for ciliary abnormalities.

Bronchoscopy is indicated for persistent atelectasis. If radiological changes persist despite apparently adequate treatment, bronchoscopy should be considered to exclude a foreign body and obtain specimens for microbiological and cytological examination. Extensive atelectasis in young children will usually respond to selective bronchoalveolar lavage and suction.

Haemoptysis is an unusual symptom in children and if there is no clear explanation it should be investigated. Bronchoscopy during active bleeding is most likely to identify the source of bleeding, although if the haemorrhage is brisk rigid bronchoscopy is safer. The diagnosis of pulmonary haemosiderosis has been made by bronchoalveolar lavage: the lavage fluid is frankly blood stained and contains haemosiderin laden macrophages. Continuing ‘haemoptysis’ after a normal bronchoscopy is most unlikely to be of pulmonary origin.

Inhaled foreign bodies can be remarkably capricious and may present with any of the symptoms discussed above. The presence of a foreign body in the tracheobronchial tree cannot be excluded without bronchoscopy. When the history is suspicious bronchoscopy should be performed promptly. Retrieval of foreign bodies with a flexible bronchoscope is extremely difficult and this is regarded as one of the few absolute indications for rigid bronchoscopy. If the airway is normal it is prudent to examine the oesophagus because foreign bodies here may partially obstruct the airway.

Bronchoscopy has been advocated for the diagnosis of tracheo-oesophageal fistula. Diagnosis of an isolated tracheo-oesophageal fistula is notoriously difficult and this confidence is not widely shared. Tube injection oesophagoscopy is probably the most reliable method for diagnosis.

Bronchoscopy has become a valuable tool for the investigation of pulmonary infections. Bronchoalveolar lavage has a high yield in three particular groups of children: the immunosuppressed, children who fail to respond to broad spectrum antibiotics, and children who present with symptoms suggestive of an atypical pneumonia. Bronchoalveolar lavage can be directed to areas of radiological abnormality. The lavage fluid is examined for bacteria, fungi, viruses, protozoa, inflammatory cells, and malignant cells. Identification of the specific organism causing a chest infection permits precise antimicrobial therapy.

Increasingly clinicians are recognising the significance of early endobronchial infection in infants with cystic fibrosis. Broad spectrum antibiotics including antipseudomonal antibiotics used frequently or inappropriately may

**Table 1 Indications for bronchoscopy**

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<th>Indication</th>
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<tr>
<td>Stridor</td>
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<tr>
<td>Unexplained wheeze</td>
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<td>Unexplained or persistent cough</td>
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<tr>
<td>Haemoptysis</td>
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<tr>
<td>Suspected foreign body</td>
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<td>Suspected airway trauma, chemical, or thermal injury</td>
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<td>Suspected tracheobronchial stenosis</td>
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<td>Radiological abnormalities</td>
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<td>Persistent or recurrent consolidation or atelectasis</td>
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<td>Recurrent or persistent infiltrates</td>
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<tr>
<td>Lung lesions of unknown aetiology</td>
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<tr>
<td>Immunosuppressed patients</td>
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<tr>
<td>Identify cause of pneumonia</td>
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<tr>
<td>Recurrence of disease</td>
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<tr>
<td>Cystic fibrosis</td>
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<tr>
<td>Identify cause of infection</td>
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<tr>
<td>Intensive care</td>
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<td>Examine for the position, patency, or damage related to endotracheal or tracheostomy tubes</td>
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<td>Facilitation of endotracheal intubation</td>
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<tr>
<td>Endobronchial stent placement</td>
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Encourage the development of resistant bacteria.\textsuperscript{12} Cough swabs in younger children do not necessarily identify infecting bacteria in the lower airway.\textsuperscript{9} Early identification of pseudomonas has recently become more important since it has been shown that early appropriate treatment can eradicate the infection.\textsuperscript{13,14} Early bronchoscopy in young children with cystic fibrosis may help identify the cause of persistent symptoms and enable treatment to be targeted to the infecting agent. Localised x-ray changes not responding to conventional treatment may respond to aggressive airway lavage and suction if performed early.

Endoluminal stents are widely used for palliation of inoperable obstructing tracheobronchial malignancies in adults. Tracheobronchial stenoses in the paediatric population are usually congenital. The results of surgical treatment are unsatisfactory, largely because of recurrent stenosis. Preliminary experience with the use of endoluminal stents as an adjunct to surgery is very encouraging.\textsuperscript{15} Endobronchial stents show potential for the treatment of severe bronchomalacia.\textsuperscript{16} This technique has proved useful for the management of intractable bronchomalacia in infants with congenital cardiac anomalies.

Prolonged respiratory support of the premature infant may cause significant damage to the airway.\textsuperscript{16,17} The commonest site of damage is the criocid, with ensuing subglottic stenosis. However, there is mounting evidence that ulceration and granulation tissue occurring in response to trauma from endotracheal tubes and suction catheters can progress to tracheobronchial stenoses. Recent studies have suggested that late deterioration of respiratory function may reflect the development of tracheobronchial stenosis, and balloon dilatation has been described.\textsuperscript{18} The ultrafine flexible bronchoscope allows examination of the neonatal tracheobronchial tree through the endotracheal tube and will undoubtedly have an increasing role in the assessment of infants with chronic lung disease.

Anaesthetists and physicians involved with intensive care have long recognised the value of bronchoscopy. Endotracheal intubation by passage of the tube over a flexible bronchoscope is useful when the larynx is impossible to visualise by conventional means.\textsuperscript{19} Bronchoscopy through an endotracheal tube will confirm tube position and is a useful adjunct to selective endobronchial intubation. Bronchoscopy is particularly valuable in the critically ill child with pneumonia or recalcitrant atelectasis because it involves minimal disturbance to the ventilated patient.

There is little published evidence to support the view that many bronchosopic manoeuvres, particularly in young children with cystic fibrosis and in neonates, lead to a definite improvement in outcome; however, personal practice and anecdote suggest that many of the procedures can be helpful and need further investigation.

The creation of a pneumothorax remains the commonest major complication following bronchoscopy, the reported incidence following transbronchial biopsy being up to 8%.\textsuperscript{20} The incidence can be reduced significantly by avoiding the right middle and lingual lobes. Haemorrhage can occur following bronchoscopy and significant haemorrhage is rare. Other complications are relatively minor and include pyrexia following bronchoalveolar lavage and dyspnoea.

\textbf{Conclusion}

The essential difference between bronchoscopy in adults and children is that the adult respiratory physician is usually looking for malignancy whereas the paediatric bronchoscopist is more often concerned with the management of congenital abnormalities or persistent infection. As such, it is important to be able to identify normal anatomy and recognise the significance of abnormalities. This requires close liaison between physicians and surgeons interested in the paediatric airway. The yield of clinically important information from bronchoscopy is consistently high. Flexible and rigid bronchoscopy have important and complimentary roles in the examination of the paediatric airway. Video imaging has made documentation of endoscopic findings much more satisfactory and has also simplified the teaching of bronchoscopy.

There are no absolute contraindications to bronchoscopy. Extra care, however, is required when it is performed in the presence of severe hypoxia, airway obstruction, or bleeding diatheses. Smaller more flexible bronoscopes will become available in the near future and these instruments will bring new capabilities. Particularly exciting applications are developing in the field of neonatal lung disease, cystic fibrosis, and interventional bronchoscopy.


