Anaesthesia for paediatric bronchoscopy requires special equipment and a sound knowledge of the anatomy, physiology and pathology of the paediatric airway, which determine key differences between paediatric and adult bronchoscopy. Whenever possible it should be performed in a tertiary referral centre. There must be excellent communication between the anaesthetist and the endoscopist to ensure that adequate oxygenation is maintained via the shared airway.

### Infant anatomy and physiology

Relative to the adult, the infant’s tongue is large and the epiglottis is longer and narrower and angled more posteriorly. Infants are obligatory nasal breathers until 5 months of age and ex-premature infants have an increased tendency to apnoea if <60 weeks post-conceptual age. The larynx is softer, higher, and more easily displaced. In contrast with adults, the narrowest part of the upper airway in paediatric patients is the cricoid ring. The cricothyroid membrane is relatively short, making needle cricothyroidotomy more difficult.

In young infants, the tidal volume is fixed and therefore the ventilatory frequency must be increased to increase minute ventilation. Ventilation is mainly diaphragmatic and there are fewer type I muscle fibres, so the infants fatigue earlier. Functional residual capacity is less than closing capacity owing to low elastic recoil of chest wall. This, and the higher metabolic requirements in infants and children create, a predisposition to hypoxia.¹

### Indications for bronchoscopy

Bronchoscopy is indicated for a wide variety of diagnostic and therapeutic procedures (Table 1). These range from the common (e.g. assessment of airway obstruction) to the rare (e.g. laser removal of tumours and the insertion of tracheal stents).

### Bronchoscopes

There are two main types of bronchoscope, flexible and rigid; the latter can be further divided into ventilating and Venturi type. It is an advantage for the anaesthetist to be skilled in the use of all these bronchoscopes. Advances in metal alloys and fibreoptic technology have facilitated the production of appropriately sized bronchoscopes for paediatric use.

#### Storz ventilating bronchoscope

The rigid instrument that is used most commonly in children is the Storz ventilating bronchoscope, which can be used for both diagnostic and therapeutic procedures (Fig. 1). The bronchoscope consists of a light metal tube within which is a removable optical telescope that seals the distal end of the instrument. Ventilation occurs via the annular space between the lumen of the bronchoscope and the outer surface of the telescope. The distal end of the instrument also has a port for attaching an anaesthetic breathing system (usually a Jackson Rees T-piece), a suction channel and a light prism.

It is important to select an instrument of suitable size for the patient’s airway; a guide to selecting bronchoscope size can be found in Table 2. The size refers to the nominal internal diameter (ID); this dictates ease of ventilation.

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**Table 1** Indications for bronchoscopy

<table>
<thead>
<tr>
<th>Diagnostic</th>
<th>Therapeutic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airway obstruction (e.g. tracheomalacia, bronchomalacia)</td>
<td>Removal of foreign body</td>
</tr>
<tr>
<td>Persistent/recurrent pneumonia</td>
<td>Suctioning mucus plugs (e.g. in cystic fibrosis)</td>
</tr>
<tr>
<td>Tracheo-oesophageal fistula</td>
<td>Facilitate endobronchial intubation for one lung anaesthesia</td>
</tr>
<tr>
<td>Brushings for cytology</td>
<td>Laser therapy</td>
</tr>
<tr>
<td>Transbronchial biopsy for histology</td>
<td>Balloon dilatation of trachea/bronchus</td>
</tr>
<tr>
<td>Failure to wean from ventilator</td>
<td>Stent insertion</td>
</tr>
</tbody>
</table>

**Key points**

- Paediatric bronchoscopy should be performed in a tertiary referral centre whenever possible.
- Special equipment and a knowledge of the anatomy, physiology, and pathology of the paediatric airway is essential.
- The correct size rigid bronchoscope allows a small leak at 20–25 cm H₂O.
- Air trapping is a potential hazard when controlled ventilation is used.
- Always assume bradycardia is secondary to hypoxia until proved otherwise.

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(spontaneous and manual) and suctioning. Note that the nominal ID is smaller than the actual diameter, for example a size 2.5 Storz has an actual ID of 3.2 mm. The outer diameter (OD) is also very important; too large a rigid scope will lead to compression of the tracheal mucosa and possible oedema. The correct size is the one that allows an audible leak at 20 cm H2O pressure.

Storz bronchoscopes are available in lengths of 20 and 30 cm. At a flow rate of 3 litre min\(^{-1}\), the resistance in a size 3.5, 30 cm scope can be three to four times greater than that in the corresponding 20 cm scope.\(^1\) During endoscopy, the bronchoscope will often be positioned endobronchially, so holes are provided in the scope wall ~5 cm from its tip to allow ventilation of the contralateral lung.

### Fibreoptic bronchoscopes

Flexible fibreoptic bronchoscopes were introduced in 1966. They consist of bundles of fibreoptic fibres with a magnifying lens system at the distal end. The tip of the bronchoscope can be angulated using a steering wheel at its distal end and on most there are suction and injection ports. Spontaneous ventilation occurs around the instrument; hence, it will be difficult for the patient to breathe if the scope is too big.

The smallest fibreoptic bronchoscope in general use is the Olympus BF N20, with an ED 1.8 mm distally and 2.2 mm proximally. The tip can be angulated 160° up and 90° down. Its main disadvantage is that it lacks a suction port. Fibreoptic scopes can be introduced nasally or orally, commonly under local anaesthesia with or without sedation. Their smaller diameter makes steerable access to the distal airway possible. The field of vision is greater with a fibreoptic than with a rigid bronchoscope; this facilitates examination of the upper lobe bronchi and apical divisions of lower lobe bronchi.

### Anaesthetic considerations

#### Preoperative assessment

Previous anaesthetic charts should be examined so that the following questions can be answered: (i) could the larynx be visualized; (ii) was there airway obstruction in any particular position at induction; (iii) size of endotracheal tube and bronchoscope used; (iv) any difficulty oxygenating during bronchoscopy; and (v) did the patient suffer postoperative stridor? Discussion with the patient and parents will help elucidate the underlying diagnosis. How do symptoms vary in relation to position, crying and feeding? A stridor present only during inspiration suggests an extrathoracic obstruction; if the stridor is expiratory then an intrathoracic cause is likely. A past medical history of lung disease of prematurity may predispose the patient to barotrauma.

Examination will focus on the airway and respiratory system. Anatomical abnormalities may dictate the type of bronchoscopy (e.g. deformities of the cervical spine or possible spinal instability may warrant a fibreoptic scope). Specific investigations may be required, for example a chest x-ray to localize an inhaled foreign body or a CT-scan to evaluate a possible cause for obstruction.

#### Premedication

Older children may benefit from an anxiolytic such as midazolam. This is given orally in a dose of 0.5 mg kg\(^{-1}\) (maximum 20 mg) 30 min before induction. However, the anaesthetist must be sure there is no evidence of airway obstruction or respiratory embarrassment. An anticholinergic should be considered, usually...
given i.v. at induction. It has the dual benefit of preventing brady-
cardia secondary to airway instrumentation, while its antisialo-
gogue effect improves the efficacy of topically applied local
anaesthesia and decreases the amount of suctioning required dur-
ing endoscopy. Where the airway is known to be narrowed, it may
be prudent to give dexamethasone (0.6 mg kg\(^{-1}\), maximum 12 mg
i.v.) to minimize airway oedema.

**Preparation**

A variety of tracheal tubes, laryngoscopes, and bronchoscopes
(including a spare light source) should be available. Most hospitals
have a specific bronchoscopy trolley, including a table of the
dimensions of all the tubes and scopes. All patients should have
standard monitoring instituted, though capnography may have
to be limited to spot checks.

**General anaesthesia techniques**

Bronchoscopy in a child almost always requires general anaesthe-
sia. The reason for the bronchoscopy usually dictates both the
method of anaesthesia and the type of bronchoscope used.

**Bronchoscopy using the ventilating bronchoscope**

The ventilating bronchoscope can be used with spontaneous or
controlled breathing. With either technique, once anaesthesia is
induced, local anaesthesia (typically 1–2% lidocaine) can be
sprayed onto the epiglottis, larynx, and between the vocal
cords. The dose is limited to 4 mg kg\(^{-1}\). The purpose of this is
to prevent laryngospasm, coughing, and decrease the general
anaesthetic requirements.

Intubation before the bronchoscopy allows the anaesthetist to
give the endoscopist an estimate of the size of the bronchoscope,
thereby avoiding unnecessary trauma. The patient should be posi-
tioned supine with a rolled towel across the back between
the scapulae to extend the neck and push the upper trachea forward.
Sevoflurane can be used for induction and spontaneous respira-
tion maintained via a Jackson Rees T-piece attached to the side
port of the bronchoscope. Introduction of the telescope into the
bronchoscope seals its distal end. However, it also diminishes the
cross-sectional area of lumen through which the patient can
breathe, significantly increasing the work of breathing and poten-
tially causing hypercarbia. This is a particular problem in infants.

Where neuromuscular blocking agents are used, the anaesthet-
ist can ventilate the patient manually provided the telescope is in
place. Even with assisted ventilation, hypercarbia leading to res-
piratory acidosis can be a problem because the expiratory pressure
generated by passive elastic recoil of chest and lung may be insuf-
ficient to expel air through the smallest scopes. Air trapping will
occur unless a ventilation pattern with a long time constant is used;
5–10 s expirations may be required.

Premature infants 1–2 kg in weight require a size 2.5 broncho-
scope. However, the very high intrapulmonary pressure generated
when the telescope is inserted risks barotrauma and prevents
adequate gas exchange. Therefore, an apnoeic technique is
safer. This entails mild hyperventilation with oxygen 100%
before the insertion of the telescope, and ensuring that the expir-
atory limb is open to prevent hyperinflation of the lungs as oxygen
continues to be delivered at 1 litre min\(^{-1}\). Apnoea is limited by
accumulation of carbon dioxide and the presence of co-morbidity
(e.g. lung disease of prematurity). The telescope should be
removed and ventilation reinstituted before any deterioration in
the patient (e.g. bradycardia).

In infants <1 kg, even the 2.5 bronchoscope is too big, so the
telescope (OD 2.7 mm) alone can be inserted. This may be done
with an apnoeic technique as described above, or alternatively
anaesthesia can be maintained by nasopharyngeal insufflation of
sevoflurane and oxygen, the infant breathing spontaneously
around the telescope. This anaesthetic technique is also popular
for diagnostic bronchoscopy in older children when the Hopkins
rod optical telescope (OD 4.0 mm) is used.

In some hospitals total intravenous anaesthesia (TIVA) is used
to maintain anaesthesia. Propofol with or without remifentanil is
the technique of choice providing good airway reflex suppression,
rapid emergence and decreased pollution; this technique has
been used in children as young as 3 days old.\(^3\) Analgesia in the
form of paracetamol suppository is adequate. In older children
this could be given as an oral premedication. Postoperatively,
the patient should remain nil by mouth for 2 h after local anaes-
thetic spray.

**Fibreoptic bronchoscopy**

Fibreoptic bronchoscopy is used mainly for diagnosis and as an
aid to intubation in the child with a difficult airway. The simplest
technique for fibreoptic bronchoscopy is to insert a laryngeal mask
after induction of anaesthesia while maintaining spontaneous
ventilation with oxygen and sevoflurane.\(^4\) The fibreoptic scope
is passed through the laryngeal mask via an angle piece with a
sealed port and local anaesthetic is applied to the larynx via the
injection port. Once the local anaesthetic has had time to take
effect, the tip of scope is steered into the trachea. The ID of an
appropriately sized LMA allows the passage of a larger scope than
would have been possible using a tracheal tube.\(^5\) A disadvantage of
the LMA is that it can cause the vocal cords to appear immobile.

**Complications**

Complications (particularly with rigid bronchoscopes) include
trauma to lips, teeth, base of tongue (commonly injured by
inexperienced endoscopists), epiglottis and larynx. Damage to
the tracheobronchial tree is rare but includes pneumothorax,
neuromediastinum and surgical emphysema. Haemorrhage is
usually minor and settles spontaneously.

Hypoxia can occur for many reasons. If the scope is placed
in a bronchus, hypoxia may occur despite the presence of the side
ports and the scope may need to be repeatedly withdrawn.
Excessive suctioning will remove gases including oxygen and
cause increased atelectasis. Bronchospasm can be secondary to
irritation of the tracheobronchial tree. Hypercarbia can occur even when the patient seems to be adequately ventilated. The subsequent air trapping as passive expiration cannot overcome resistance can lead to barotrauma, diminished venous return and so reduced cardiac output. Pneumothorax can occur, especially if dilating a stenosis or a transbronchial biopsy is taken. A chest x-ray should be taken after such procedures before leaving the post anaesthetic area.

Bradycardia is uncommon but should be assumed to be secondary to hypoxia until proven otherwise. In recovery, staff should look for signs of stridor secondary to subglottic oedema. In this event, nebulized epinephrine 1:1000 should be administered in a dose of 0.5 ml kg⁻¹, maximum 5 ml per administration.⁶ As the vasoconstricting effect of nebulized epinephrine is transient, this dose may have to be repeated frequently. I.V. dexamethasone produces more sustained relief of stridor, but may take 1–2 h to act. Re-intubation may be required. Rarer problems include epistaxis when a fibreoptic scope is inserted nasally, and the potential transmission of infection as sterilization of these scopes can prove difficult.

**Removal of inhaled foreign body**

Presentation of inhaled foreign body can vary from complete obstruction of the upper airway with hypoxia and cardiac arrest to partial obstruction with coughing, wheezing, stridor and dyspnoea. The history is commonly immediate but up to 30% of cases can present more than a week later as they are initially asymptomatic. Of those presenting with a clear history, it is important to appreciate that, though they may appear undistressed, they can subsequently obstruct completely. Hence they should be admitted for observation before early bronchoscopy.

Most foreign bodies are radiolucent and the chest x-ray will often be normal. Therefore, a positive history and clinical signs of aspiration alone may be enough evidence for endoscopy. A chest x-ray in inspiration and expiration may aid location of the foreign body and show any atelectasis, or pneumonia. Most importantly the presence of air trapping must be sought. If the latter is present, nitrous oxide should not be used. As well as anticholinergic medication, it may be prudent to also consider prescribing anti-aspiration premedication. Management of these cases requires the presence of two anaesthetists.

Usually a Storz bronchoscope is used, although in some hospitals a fibreoptic bronchoscope is used to pass a Dormia basket to snare the foreign body.⁷ Once the patient is deeply anaesthetized, the rigid bronchoscope should be introduced into the trachea to control the airway as opposed to immediate intubation. This allows the subglottic and upper tracheal regions to be seen as the scope enters, so reducing the possibility of moving a proximal foreign body distally and obstructing the airway.⁸

A major problem of operating through a Storz bronchoscope is the loss of magnification following removal of the telescope. This can be overcome by using special grasping forceps with a collar to hold the Hopkins rod optical telescope. Once fixed together, the forceps and the rod are passed through a 3.5 or larger Storz bronchoscope. This technique results in excellent visual conditions for removal of the foreign body in children aged 1 yr and above.

Whatever technique is used, spontaneous respiration is best preserved, although inhalation induction may be prolonged in the presence of hypoventilation (especially if a main bronchus is obstructed). Sevoflurane in oxygen 100% and topical anaesthesia to the airway is the technique of choice. Care must be taken to maintain spontaneous breathing or gentle assisted ventilation as positive pressure may drive the foreign body distally. However, the true incidence of this rare complication is unknown, and hypoxia and hypoventilation are more common and dangerous complications. Assisted ventilation is usually necessary. The stomach can be emptied to decrease the possibility of aspiration. I.V. induction and neuromuscular blocking agents are only appropriate if the anaesthetist is sure there is no air trapping attributable to the risk of barotrauma.

Just before removing the foreign body, it will aid extraction through the cords if a small dose of neuromuscular blocking agent or propofol is given. After extraction, the endoscopist should re-examine the tracheobronchial tree for a second foreign body. A large foreign body may occlude the trachea as it is withdrawn and, unless it can be done quickly, the foreign body may have to be pushed back into the main bronchus from whence it came. Rarely, it may not be possible to carry out the extraction via the larynx and a tracheotomy has to be performed to facilitate removal.⁹ Once the procedure is finished a tracheal tube can be inserted if a full stomach is considered a problem, and the patient woken up and extubated once protective reflexes have returned.

**References**

3. Thaung MK, Balakrishnan A. A modified technique of tubeless anaesthesia for microlaryngoscopy and bronchoscopy in young children with stridor. Paediatr Anaesth 1998; 8: 201–4

See multiple choice questions 30–33.