PAEDIATRIC RESPIRATORY REVIEWS (2002) **3**, 255–264
doi: 10.1016/S1526–0542(02)00195-1, available online at http://www.idealibrary.com on IDEAL®

Paediatric Respiratory Reviews

SERIES: FLEXIBLE BRONCHOSCOPY IN CHILDREN – THE BROMPTON EXPERIENCE

Bronchoscopy – how and when?

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KEYWORDS
flexible bronchoscopy, paediatric, children

Summary At the Royal Brompton Hospital, we perform over 200 flexible bronchoscopies per year in children. We will be presenting a series of five articles describing various aspects of our clinical and research practice. This first article is about the basics of how and when to perform flexible bronchoscopy. It highlights aspects of training, preparation of the patient and the equipment required. It discusses anaesthesia and gives practical details on how to actually use the bronchoscope, as well as detailing techniques of lavage, brushings and biopsy. Particular attention is paid to indications and contraindications, as well as potential complications.

INTRODUCTION

In the 20 years since paediatric flexible bronchoscopes became widely available, their use has become an essential part of paediatric respiratory medicine. This is the first of five articles in the series entitled "Flexible bronchoscopy in children – The Brompton Experience". It describes our practice at the Royal Brompton Hospital, a tertiary cardiothoracic centre in London. We will describe what we do and why but like much tertiary paediatric medicine it is not necessarily evidence-based. It simply reflects the clinical experience of our Paediatric Respiratory Unit. We perform over 200 flexible scopes each year and have run a basic training course since 1998. We recognise that other centres will have a different attitude to us over some of the issues; it is up to the reader to decide which approach to take within their own clinical practice.

TRAINING

The European Union syllabus for training in paediatric respiratory medicine, adopted by the Royal College of Paediatrics and Child Health, dictates that each trainee assists at 50 and performs 25 flexible bronchoscopies. Many trainees will have gained initial experience by attending adult bronchoscopy lists but a paediatric introductory course is useful. Most trainees will participate in one of the "hands-on" courses that are available, either in the USA (Cincinatti) or Europe (Davos, Switzerland or Lille, France). In these, experience is gained by scoping anaesthetised animals, something that is not allowed by law in the UK. Knowledge of normal anatomy (including airway size and pliability) and its variants must be gained, so that genuine abnormalities are recognised. Practice on a Bronchoscopy Training Model (for example that produced by Adam Rouilly, Sittingbourne, UK) and studying anatomical diagrams are useful, although learning names beyond the segmental bronchi is mostly unnecessary. Familiarity with the normal mucosal appearance is important so that pathological changes (for example inflammation) are recognised. After this, the next stage is scoping children under close supervision. It takes time to get the necessary experience and confidence, probably over 50 bronchoscopies. The practical aspects must become second nature so that the bronchoscopist can concentrate on the clinical findings and diagnosis.

OUR PRACTICE

Preparation

One of the most important parts of the preparation is a full explanation to the parents (and to the child if old enough) of what the procedure involves, why it is being done and what findings are expected. Signed consent is of course mandatory and we include the fact that we will do a lavage and possible mucosal biopsy as part of the procedure. Risks

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are explained in sufficient detail so that the consent is truly informed, however, for the vast majority of bronchoscopies, the only risk is of mild pyrexia and possible increased cough in the subsequent 12 hours or so. The exception to this is scoping infants with stridor, where there is a genuine risk of exacerbating the symptoms. In these cases, we will always have a Paediatric Intensive Care Unit (PICU) bed on standby in case the anaesthetist decides it is safer to keep the child ventilated for a short while (see Complications, below). Clearly this possibility must be explained in advance to the parents. We do not routinely perform investigations before the procedure itself, although obviously many of the children will have had some tests as part of the work-up of the condition/symptoms being investigated. Unless otherwise indicated (e.g. haemoptysis) a clotting screen is not performed prior to mucosal biopsy, although will be done if a transbronchial biopsy is planned. The advantage of this approach is that venepuncture can be performed during the procedure itself whilst the child is anaesthetised. Bronchoscopy is normally performed as a day case procedure, although babies and infants are usually kept in overnight as a precaution. The commonest reason for staying, however, is when the child is also having a 24-hour pH study to investigate gastro-oesophageal reflux.

Equipment

The minimum required is the bronchoscope and light source. However, all our procedures are viewed on a TV monitor which is easier to use than the eyepiece of the scope and also allows others to view the procedure. We video all procedures. This is essential, as it allows review with colleagues (useful if the findings are complex or for discussion with surgeons), review if the procedure is being repeated, use in teaching sessions and as an aid for potential medicolegal and clinical governance issues. We also have a printer for capturing images and producing instant pictures. This is particularly helpful for explaining findings to parents and is also useful for recording results in notes and for sending to referring centres. Most children also like owning a picture of the inside of their lungs to show at school.

Ancillary equipment is kept to a minimum. On the trolley we have room temperature sterile normal saline in a jug. This is used to fill the 10 or 20 ml syringes for lavage and is also used to draw through the scope at the end of the procedure to clear the suction channel prior to full cleaning. There are sterile gauze swabs and lubricant jelly for the distal end of the scope. We also use an alcohol wipe for the tip of the scope. Plenty of sputum traps are on hand for the lavage and brushes and forceps are kept nearby.

The bronchoscopes

We use Olympus scopes (Table 1) and it is important to have sufficient to ensure logistical problems are not encountered whilst servicing or repairs are being carried out. Occasionally a scope (or more usually its suction channel) malfunctions during a procedure itself, hence the need for a standby scope. Unfortunately some units may have difficulty with this due to the prohibitive price of bronchoscopes, which cost in the range of £16 000 (26 000 Euros). They are best stored hanging in a purpose-built cupboard and should not be kept in their cases as the foam fillings in the cases can harbour bacteria.

In general, the larger the scope, the better the image obtained but even the smaller ones allow remarkably good views. The image is never as clear as that obtained by rigid bronchoscopes with their Hopkins rod lens telescopes. These are invariably the images found in textbooks, which can mislead trainees who need to become accustomed to sometimes performing bronchoscopies with sub-optimal views.

We do not have a 6 mm adult scope and there is little advantage to it over the next size down. For larger children we use the 4.9 mm scope. However, although this can be used in children as young as 7–8 years, we would only use it in this age group if a biopsy was planned. Since it has the larger suction channel (2.2 mm) it allows the use of larger biopsy forceps which tend to produce better tissue samples. Another advantage of the larger suction channel is for removing thick tenacious secretions, the classic situation being in a child with cystic fibrosis.

The scope we use most often is the 3.6 mm, although this may simply reflect the ages of the children we are most often investigating. The 1.2 mm suction channel is usually adequate for suctioning secretions (and lavage) and will allow biopsies if necessary. It is less traumatic for the airways to use the smaller diameter scope. Over the last 2–3 years we have used the 2.8 mm scope and found it to be excellent. Initially produced to investigate adults with

Table 1 The Olympus range of bronchoscopes for use in children.

Olympus code	External diameter (mm)	Patients	Suction channel (mm)	Biopsy	Brushings
BF-N20	2.2	Neonate – 6 months	No	No	No
BF-XP40	2.8	Neonate – infants	1.2	Just	With caution
BF-3C40	3.6	Infants, small child	1.2	Just	With caution
BF-P40	4.9	Big child (>7–8 years)	2.2	Yes	Yes
BF-40	6.0	Adult	2.2	Yes	Yes

peripheral lesions, it is rather long but this is not a particular problem. It has a 1.2 mm suction channel and for paediatricians this has been a breakthrough. Prior to its production, the 3.6 mm scope was the smallest with a suction channel, a size too large for most neonates and small infants. Since obtaining a 2.8 mm scope, we rarely use the neonatal 2.2 mm scope, whose image is less clear and without the suction channel mucus that settles over the lens may be difficult to clear without withdrawing the whole scope. It is also prone to breaking and expensive to repair. We now restrict its use to a ventilated neonate with a 3 mm endotracheal tube in whom visualisation of the airways is essential.

Sedation and anaesthesia

Over 4 years ago our practice changed. Prior to this, other than infants under 12–18 months, bronchoscopies were performed under intravenous conscious sedation administered by the bronchoscopist or medical assistant,[1] a practice that continues in many centres. Now all our bronchoscopies are performed under general anaesthesia (GA) administered by a consultant anaesthetist in the anaesthetic room. This is so important (and contentious) that the second article in this series is devoted to sedation, anaesthesia and monitoring. We believe that a GA is the optimum way of ensuring the safety of a child whose airway is compromised by the bronchoscopy itself, let alone any underlying respiratory disease. The anaesthetist has responsibility for monitoring the patient, which allows for early recognition of any complications (see below). The bronchoscopist can then concentrate on the investigation ensuring a greater chance of a successful outcome. We also feel it is the kindest way of ensuring the child is unaware of the procedure. Whilst anaesthetised, we also perform other necessary invasive tests. This may include venepuncture, Mantoux testing, passing a pH probe or ciliary brushings. This makes the investigative stay less traumatic for children and their families. We also insert long lines in those who need intravenous antibiotics.

Personnel

Apart from the bronchoscopist, there is the anaesthetist (±trainee) and the Operating Department Assistant, the bronchoscopy nurse and paediatric respiratory trainee(s). In the PICU setting, the intensivist and PICU nurses will also be present.

TECHNIQUES

Introducing the bronchoscope

- Directly via the nose. This is the route used when scoping under intravenous sedation hence is not part of our practice.
- Through the nose via a facemask. This is the route we favour as it allows complete visualisation of the upper airways. It also means the bronchoscopy can be done with the child breathing spontaneously (anaesthetised through the facemask), allowing dynamic airway calibre information to be obtained. It is the best method for directly assessing tracheo/bronchomalacia. A larger scope can be used than if an endotracheal tube is needed. Pass the scope through the nose like a nasogastric tube (parallel to the floor of the nose) until the nasopharyngeal region is reached. Guiding it past the inferior nasal turbinates with direct vision can be quite a challenge. A useful tip is to keep your thumb off the angulation control otherwise it keeps the distal end of the scope in a rigid position rather than allowing it to curve while the scope negotiates the bends. Occasionally, and more often in babies, the scope is pushed too far initially and ends up in the oesophagus. Pull back gently and suddenly the epiglottis will flick into sight. If there is difficulty finding the larynx, ensure the child's head is in the midline and also that the anaesthetist has not inserted a Guedel airway which can distort the anatomy.
- Through the mouth via a laryngeal mask. The upper airways will be missed but the glottic region can still be viewed. It does allow a larger scope to be used than when using an endotracheal tube. This is certainly a simple technique that we use at times, particularly when principally interested in the lower airways, for example in a child in whom bronchoalveolar lavage for microbiology is the main indication.
- Through the mouth via an endotracheal tube. This method is used when we are only interested in the lower airways and the anaesthetist wishes to fully ventilate the child. It is used for a patient already ventilated in PICU. Particular care must then be taken if the endotracheal tube (ETT) is held in position by a metal Tunstall connector, which can shear the fibres on the bronchoscope. We tend to reintubate the child using standard Portex tubes unless the patient is too unstable. The limiting factor to this route is the internal diameter of the ETT (see Table 2).
- Through a tracheostomy.

Table 2 Size of bronchoscopes that fit down an endotracheal tube (ETT) during assisted ventilation.

Olympus code	External diameter (mm)	ETT internal diameter (mm)
BF-N20	2.2	3.0
BF-XP40	2.8	4.0
BF-3C40	3.6	5.0
BF-P40	4.9	6.0

Driving the bronchoscope

Most paediatricians stand at the child's head facing the child's feet, whilst most adult physicians stand at the patient's side facing towards their head. This means that for those of us at the top of the patient, what we see on the left of the monitor is truly on the patient's left side, whilst right is right – something most people find intuitively easier.

On leaving the nose, the adenoids and the other tissue of Waldeyer's ring should be identified. If obstructive sleep apnoea is a consideration, the degree of apposition of the pharyngeal structures should be noted during quiet spontaneous breathing and with mask continuous positive airways pressure (CPAP). This is best achieved with the tip of the endoscope just inside the nasopharynx. The larynx next comes into view. The shape of the epiglottis and its position during the respiratory cycle should be noted. The position and movement of the vocal cords should be evaluated. The subglottic region is carefully inspected from above the cords before attempting to progress, for fear of causing bleeding and obstruction if there is unsuspected haemangioma or subglottic stenosis. Other laryngeal structures should be inspected, including the arytenoids and the false cords, seeking an unsuspected laryngeal foreign body in particular.

The scope is passed gently through the cords with an up and down action. Orientation in the trachea is obtained from the posterior membrane, which is distinct from the cartilage rings and runs down towards the carina. When passing down standard Portex ETTs, orientation is easy as the blue line is on the posterior aspect of the tube. We scope the right side first. It is easily recognised as the right upper lobe bronchus is seen just below the carina and its three segmental bronchi (anterior, apical, posterior) can be inspected. It is sometimes difficult to manoeuvre into the right upper lobe bronchus in small infants. Moving down into the bronchus intermedius, the right middle lobe bronchus is next encountered with its narrower opening. After inspection of the medial and lateral segments, the scope is withdrawn into the bronchus intermedius. Almost diametrically opposite the right middle lobe opening lies the apical segment of the right lower lobe (known in the USA as superior, but in the UK as apical). After inspection, the remaining segments of the right lower lobe (medial, anterior, lateral, posterior) are viewed. The scope should then be withdrawn back up to the carina before moving to the left side. The left main bronchus is longer and narrower than the right, hence the further distance before encountering the left upper lobe bronchus. The latter divides into the upper division (with its two segmental bronchi – apico-posterior and anterior) and the lingula (with its two – superior and inferior). Then, back into the left main bronchus, where again the opening to the apical segment of the left lower lobe is seen close by. Finally, down to the lower lobe bronchi (anterior, lateral, posterior). Everywhere, the structure and calibre of the airway wall should be viewed and the site and nature of any compressive lesions noted (dynamic, fixed, vascular). The quality of the mucosa should be noted and also the nature (colour, thickness, viscosity) of any secretions.

Table 3 Segmental anatomy of the lower airways.

Side	Lobar bronchus	Segmental bronchi
Right	Upper lobe	Anterior, apical, posterior
	Middle lobe	Lateral, medial
	Lower lobe	Apical (superior), medial anterior, lateral, posterior
Left	Upper lobe	Apico-posterior, anterior
	Lingula	Superior, inferior
	Lower lobe	Apical (superior), anterior, lateral, posterior

The segmental anatomy of the lower airway is shown in Table 3. Diagrams can be found in several textbooks. Knowledge of nearby anatomical structures, both normal (e.g. left atrium) and pathological (e.g. right aortic arch) is essential. There are considerable variations,[2,3] mainly reduplication of upper lobe bronchi or proximal opening of segmental bronchi from the main bronchi or right bronchus intermedius; these are commoner in the right lung and in the upper lobes. Some of the different anatomical arrangements of the lower airways are given in Table 4. The anatomical characteristics differentiating right from left are that the right has a short main bronchus and a trilobed not bilobed arrangement.[4]

Some other driving tips:

- Know the anatomy.
- Decide which hand feels best holding the scope and stick to it. We prefer the left hand, since being right handed it is easier to manipulate and control the

Table 4 Possible abnormal bronchial arrangements and their significance.

Anatomical arrangement	Particular clinical significance
Mirror image arrangement	Consider primary ciliary dyskinesia
Right isomerism (two morphological right lungs)	Exclude asplenia, congenital heart disease, malrotation
Left isomerism (two morphological left lungs)	Exclude polysplenia, congenital heart disease, malrotation
Crossover segment	Exclude other lung malformation, including vascular abnormalities
Indeterminate	Exclude other lung malformation, including vascular abnormalities

scope with the right. The left simply holds the scope while the left thumb manipulates the angulation control flexing the tip of the scope. The left hand index finger operates the suction control.
- Keep a loop between the scope handle and the child as this allows more flexibility. Less movement is then required.
- When trying to pass into a bronchus in view, simply "aim" for it. Use intuitive driving rather than thinking about it too much. If you find the scope will not go where you want, simply reverse the direction of the movement and try again.
- Keep the tip of the scope off the wall with the airway centred in the field of view.
- When disorientated, straighten out the scope; the notch (a small marker) should be in the anterior position. The notch is in the plane of maximum flexion.
- Always return to the carina when lost.
- If you just see white glare, the tip may be against the airway wall. Otherwise there may be mucus stuck to the lens, so squirt 1–2 mls saline down the suction channel. You can sometimes wipe the tip against the airway wall but do this very gently. Sometimes it may be necessary to pull the scope out, clean it and start again.
- If there is a thick mucus plug that will not come up the suction channel, it may be necessary to keep the suction on with the tip of the scope wedged into the plug, then remove the whole scope and the plug may come out still attached by suction to the tip.
- Know the anatomy (yes – again).

Bronchoalveolar lavage

Bronchoalveolar lavage (BAL) is a critical part of the bronchoscopy and should almost always be carried out. Exceptions are few but would include a baby with stridor in whom an upper airway problem has been diagnosed. The main use of BAL is in the diagnosis of infections, particularly atypical ones.[5–7] It is the subject of a future article in this series. Cytological analysis of the fluid may also be useful, for example to quantify fat-laden macrophages as evidence of aspiration.[8,9] More recently, the value of therapeutic lavage has become apparent in the treatment of conditions such as alveolar proteinosis[10,11] and collapsed lung segments.[12] Recently the European Respiratory Society has published guidelines on technical aspects and normal values.[13]

Technically, BAL differs from bronchial lavage; the latter refers to lavage from the large airways, either *via* a bronchoscope or directly down an ETT in a ventilated child. BAL refers to the wedging of a bronchoscope or catheter into a segmental or sub-segmental bronchus. Samples of room temperature or warmed normal saline are instilled and aspirated. Various formulae exist as to how much to instill (usually between 1 and 5 ml/kg). In practice we use 5 ml samples for a baby, 10 mls for a small child and 15 mls for a large child. The usual return from a BAL is 40–60% increasing with subsequent samples. Choosing the area to lavage will depend on the indications, the bronchoscopic findings and whether the abnormality is focal or generalised on radiological imaging. For microbiological purposes, we sample the area that looks most infected. If there are no specific findings, we tend to sample the right middle lobe bronchus and the lingula on the left.

We use two sputum traps connected in series to the suction channel to avoid losing samples into the main wall suction catheter if there is spill over. These are not connected until the scope is through the vocal cords, to avoid sampling upper airway flora. We try to avoid any suction until the scope is in the lower airways to prevent upper airway bacteria contamination. The saline is instilled gently, under direct vision. After a brief (almost instantaneous) dwell time, it is aspirated. Failure to aspirate any saline usually means the suction channel has become blocked, a particular problem with the thick sticky secretions of cystic fibrosis. It is important not to do over-vigorous suctioning as it can damage the delicate airway mucosa. Zealous suctioning of secretions can also lead to collapse of the lung distal to it and will deplete the oxygen from that area. To increase the return, it is best to keep the opening to the suction channel centrally in the airway. Since it is not in the centre of the tip, you must effectively be looking at the airway wall rather than straight down the lumen. If the 2.2 mm scope is being used, direct lavage will not be possible as there is no suction channel. However, a suction catheter can be attached to the outside of the scope and used once it has been placed under direct vision. It is not often that this is necessary with the advent of the 2.8 mm scope and non-bronchoscopic BAL may be enough in these neonates.[14,15]

BAL is commonly used to obtain specimens for research purposes,[16] a topic that is covered in the last article of this series. Investigators have spent a long time trying to establish reproducible techniques and also to focus on the quantitative use of BAL.[17–19] Unfortunately, there is still no valid way of accounting for the dilution effect of the saline on the substance that is to be measured within the lavage fluid.

Biopsy/brushings

Cytological brushings or even mucosal (endobronchial) and transbronchial biopsy can give significant information, although they are not as routine in children as in adult practice.[20]

Brushings for cytological analysis are sometimes indicated as in the diagnosis of endobronchial pulmonary tuberculosis if plaques of granulation tissue are seen. They may also be indicated for diffuse changes seen in a child with malignancy, to differentiate relapse from opportunistic infection. They can also be used for assessing ciliary function although

upper airway samples are preferable. The technique is simple, the brush is inserted into the suction channel. Once the tip is seen, under direct visualisation the brush is extruded from its casing and rubbed gently back and forth. It is then retracted into the casing and withdrawn from the bronchoscope. The brush is then wiped onto a microscope slide to transfer the specimen onto it, fixative spray is used and a cover slip placed over the area before sending to the cytology laboratory.

Mucosal biopsies are also simple to perform but currently have limited clinical applicability. However, we have found them to be safe and useful in the assessment of difficult asthmatic children.[21] The cupped biopsy forceps are pushed down the suction channel, preferably of a 4.9 mm scope, in the closed position. The best site to biopsy is at a subcarina of a segmental bronchus. Always under direct vision, get the assistant to open the forceps, move them onto the mucosa then have the assistant close them. With an initial gentle tug, pull the forceps back and then remove them from the scope. Samples can be placed in formalin and a dry specimen kept for microbiology. Minimal localised bleeding can occur but soon stops spontaneously. In the rare cases of more prolonged bleeding, 0.1 ml of 1 in 1000 adrenaline in 5–10 mls saline can be instilled down the suction channel onto the biopsy site.

Transbronchial biopsies (TBB) are useful following lung transplantation, to help differentiate rejection from infection,[22] although are not reliable for the diagnosis of obliterative bronchiolitis.[23] The bronchoscope is passed into the segment from which the biopsy is to be taken, although the right middle lobe and lingula are avoided, as there is a greater risk of pneumothorax from TBB. The biopsy forceps are then inserted and passed out as far as possible into the segment. With inspiration, the forceps are advanced in an open position and closed at the end of the expiration. Another technique is to wiggle the open forceps backwards and forwards a few times before closing them. Biopsies can be sent for histopathological, immunocytochemical and microbiological analysis. TBB specimens that float in the formalin are more likely to contain alveoli, if they sink – blood clot or bronchial wall. Complications include bleeding and pneumothorax. Bleeding usually settles with suction supplemented by topical adrenaline. Occasionally excessive bleeding will need control by rigid bronchoscopy and local tamponade using gauze swabs soaked in adrenaline on a large biopsy forceps. Rarely it is necessary to insert the rigid bronchoscope into the opposite side and ventilate this lung alone in order to adequately oxygenate the patients. The risk of bleeding can be minimised by checking clotting parameters prior to bronchoscopy. The incidence of significant pneumothorax following biopsy is usually less than 1%, although this risk will be increased in patients who are on ventilatory support at the time of biopsy. Taking biopsies from the upper or lower lobes lessens the likelihood of pneumothorax.

INDICATIONS AND CONTRAINDICATIONS

"In case of doubt whether bronchoscopy should be done, bronchoscopy should always be done".
Chevalier Jackson, 1915.
"Not necessarily".
Ian Balfour-Lynn, 2002.

Indications

In truth, the indication for a bronchoscopy is when the information required is best obtained (safely) by a bronchoscopy. Such situations can be categorised as follows (Fig. 1).

Clinical

Diagnostic.

- Look.
  - Anatomy (upper airways, major bronchi, subsegmental bronchi).
  - Structure (mucosal quality, size of lumen).
  - Dynamics (movement of glottis, change in luminal size, malacia, pulsatility).
  - Contents (mucus plugs, secretions, blood, foreign body).
- Bronchoalveolar lavage: microbiology, cytology (including staining for lipid and haemosiderin-laden macrophages).
- Brushings: microbiology, cytology.
- Biopsy: microbiology, histology.

Therapeutic.

- Suction/lavage: mucus plugs causing localised atelectasis.

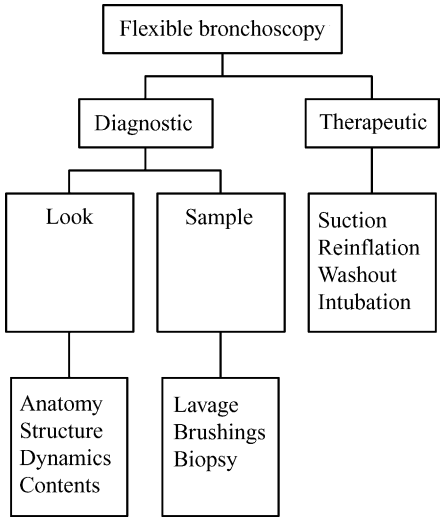

Figure 1 Flow chart of indications for a bronchoscopy.

- Reinflate atelectatic lobes/segments of lung.
- Instillation of dornase alfa (Pulmozyme) in cystic fibrosis.[24]
- Washout: alveolar proteinosis.
- Assisted endotracheal intubation/check position of ETT.

Research

- Bronchoalveolar lavage: microbiology, inflammatory markers.
- Biopsy: mucosal inflammation.

Bronchoscopy for research purposes is the subject of a future article in this series.

At the Royal Brompton Hospital, the commonest clinical scenarios that require bronchoscopy are:

- Chronic cough.
- Recurrent lower respiratory tract infections including bronchiectasis.
- Assessment of airway compression, particularly in children with congenital heart disease (including post-cardiac surgery).
- BAL for microbiology e.g. deteriorating cystic fibrosis child who does not produce sputum, child undergoing chemotherapy with non-specific chest X-ray findings or unexplained respiratory symptoms.
- Chronic stridor.
- Assessment of tracheo/bronchomalacia.
- Difficult asthma for exclusion concomitant/alternative diagnoses and mucosal biopsy.
- Unplugging atelectatic lobes/segments particularly post-cardiac surgery (Fig. 2).

Contraindications

Absolute

- Airway size too small.
- Foreign body extraction.
- Massive haemoptysis.

Clearly, if the only available bronchoscope is too large for the size of the child's airways or ETT, it would be dangerous to proceed as significant hypoxia and hypercarbia are inevitable.

A foreign body cannot be grasped through a flexible scope and it is a mistake to try and grab something with the biopsy forceps. The probable outcome is the break up of the object into smaller pieces, which then become inaccessible as they fall into more distal airways. If an object is seen, the prudent course of action is to withdraw the scope and get someone familiar with rigid bronchoscopy to retrieve the object, even if this means a second procedure and anaesthetic.

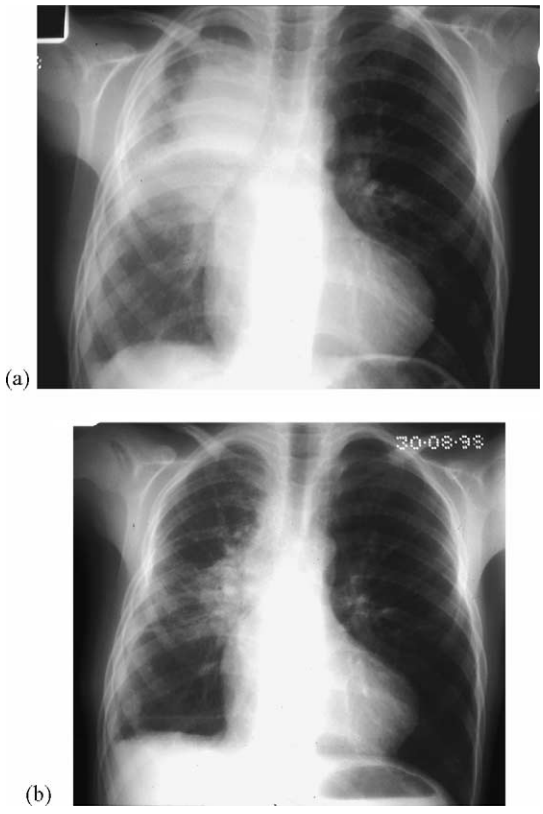

Figure 2 Right upper lobe collapse after cardiac surgery, before (a) and 2 days after (b) bronchoscopy.

Flexible bronchoscopy in the face of massive haemoptysis is contraindicated. Vision will be completely obscured by the blood within the airways, even with vigorous suction. Again, rigid bronchoscopy is the correct procedure and also may allow the operator to control the bleeding (unless generalised) with the use of adrenaline-soaked gauze swabs.

Relative

- Bleeding problems.
- Severe airway obstruction.
- Severe hypoxia.
- Unstable haemodynamics, including cardiac dysrhythmias and pulmonary hypertension.

In the above circumstances, although preferable not to proceed with a flexible bronchoscopy the clinical situation may make it necessary despite the additional risks. An experienced bronchoscopist who can perform the procedure quickly and a senior anaesthetist are essential.

COMPLICATIONS

There are many theoretical complications, some of which are so common as to be an expected part of the procedure.[25,26] For example, partially blocking an airway will inevitably lead to a transient drop in oxygen saturation

and rise in $PaCO_2$; the important thing here is to anticipate and monitor the procedure carefully, thus minimising any actual risk to the child. It is also very common, particularly in the presence of infection, for there to be a mild pyrexia for the first 24 hours after a BAL.

Complications are categorised as follows.

Physiological

- Hypoxia.
- Hypercapnia.
- Cardiac arrhythmia and bradycardia.
- Laryngo/bronchospasm.

These complications are part of the physiological response to blocking the child's airways and, although to a degree are inevitable, the effects can still be minimised to ensure they do not cause any significant problem. Hypoxia may be caused by a number of factors: obstruction to the airways leads to an increase in airways resistance (more pronounced on expiration than inspiration), increase in functional residual capacity (FRC), increase in positive end expiratory pressure (PEEP), reduction in tidal volume and alveolar minute volume. The child's underlying lung condition may of course contribute to the situation. Other factors include lavage with large volumes of saline, over-zealous suction which removes oxygen from the airways and mobilisation of thick secretions that can block the airways higher up the bronchial tree. For similar reasons hypercapnia may ensue and this can be masked, so a normal oxygen saturation must not lead to a false sense of security. Genuine cardiac arrhythmias are rare but the procedure can cause vagal stimulation and catecholamine release, so cardiac monitoring is essential. Laryngospasm is almost inevitable (unless the scope is inserted down an ETT or tracheostomy) and spraying the vocal cords with local anaesthetic may be helpful. Bronchospasm is said to be common, especially in asthmatics; however, our experience with difficult asthmatics is that this is unusual, although the patients had received oral corticosteroids for 2 weeks and nebulised bronchodilator immediately prior to the procedure.[21]

Infection

- Cross-infection.
- Transient bacteraemia.
- Septicaemia (immunocompromised).

Cross infection is a theoretical risk but should not occur with proper cleaning and disinfection of the bronchoscopes between procedures.[27] It is essential that every department is familiar with the correct cleaning methods and proper training of the staff must be given (information is available from Keymed Medical & Industrial Equipment Ltd, Southend-on-Sea, UK). Regular checks should be carried out by Hospital Infection Control teams. Fever may develop in up to half the children within 24 hours[28] and onset is usually within 4–6 hours. Although thought to be due to bacteraemia, in one series, this was not detected in any of the febrile (or non-febrile) cases.[28] This transient fever does not usually present a problem and using simple antipyretics is often sufficient; antibiotics are rarely indicated.[29] However, if the child is immunocompromised there is a risk of septicaemia,[30] so early or prophylactic use of intravenous antibiotics are indicated. Antibiotic prophylaxis against endocarditis is also indicated in children with some forms of congenital heart disease. Finally, it is also possible to cause spill over of infection from the affected lung into the other side; scoping the good side first may help reduce this possibility.

Mechanical

- Epistaxis/nasal trauma.
- Laryngeal trauma.
- Subglottic oedema.
- Airway mucosal oedema.
- Haemoptysis (biopsy).
- Pneumothorax (biopsy).

Trauma to the delicate lining of the respiratory tract is well recognised but can be kept to a minimum with careful technique. It is not uncommon for the nose to bleed a little when the scope is introduced. Further down the tract, it is particularly important to avoid laryngeal and subglottic trauma. If there is an existing upper airway problem such as laryngomalacia or even a mild subglottic stenosis, it only takes a small amount of oedema to compromise the airway completely. It is important however to view the lower airways as well, since a significant proportion (about 15%) of upper airway abnormalities are accompanied by a lower one.[31]

However, passing the scope through the narrowing airways with the risk of consequent oedema means that occasionally such a child (usually an infant) will require ventilatory support for 24 hours or so whilst corticosteroids reduce the oedema. A minor degree of airway mucosal oedema is inevitable and has little consequence, vigorous suction can contribute and care must be taken to stay "off the wall" (Professor R.E. Wood, pers. comm.).

Haemoptysis secondary to a bronchoscopy is unusual even following a biopsy but a small amount of contact bleeding may occur especially if the airways are already inflamed. Pneumothorax is one of the more serious potential complications. It is most likely with TBB, particularly if taken from the right middle lobe or lingula, so avoid these areas. Pneumothorax does not occur following endobronchial mucosal biopsy. Other possible causes are the patient coughing while the scope is wedged in a small bronchus, or if oxygen is blown down the suction channel with a view to actively reinflating a lobe or segment, something we would avoid doing.

RIGID BRONCHOSCOPY

This is usually performed by Thoracic or Ear, Nose & Throat surgeons rather than respiratory paediatricians in the UK. The main indications for rigid rather than flexible bronchoscopy are:

- Foreign body extraction.
- Haemoptysis (unless minor or chronic).
- Hypoxia (since the child can be ventilated through the scope).
- Small airway (when it may be better to ventilate through the 2.5 mm internal diameter rigid scope).
- Viewing the posterior aspect of the larynx/upper trachea (particularly when looking for H-type tracheo-oesophageal fistula, laryngeal cleft, bilateral abductor vocal cord paralysis).
- Interventional bronchology (lasers, stents).

Conflict of interest

Keymed (Medical & Industrial Equipment) Ltd. contribute towards the cost of running our bronchoscopy course by preparing programmes and registration forms. This does not present a conflict of interest for the authors.

PRACTICE POINTS

- Know the normal anatomy and common "normal variants".
- Always come back to the carina if lost.
- Bronchoscoping infants <1 year with stridor should only be done if an intensive care bed is available.
- Video all procedures for later review.
- The 2.8 mm bronchoscope has a suction channel and can be used in infants.
- An experienced anaesthetist is a vital member of the team.
- Introducing the scope through the nose *via* a facemask allows the whole respiratory tract to be viewed. With the child breathing spontaneously it also allows airway dynamics to be studied.
- Foreign body extraction requires a rigid bronchoscope.

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