Current Paediatrics (2004) 14, 306–312

Current PAEDIATRICS

www.elsevierhealth.com/journals/cuoe

When to do a flexible bronchoscopy

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KEYWORDS
Flexible bronchoscopy;
Children

Summary Flexible bronchoscopy is an important investigation in paediatric respiratory medicine, allowing diagnostic tests to be performed in the lower airways. It is also being increasingly used for therapeutic manoeuvres and has improved our understanding of diseases such as cystic fibrosis and asthma. This article highlights the indications for performing flexible bronchoscopy in children. It also discusses techniques of lavage, brushings and biopsy, including potential complications of these procedures.

Practice point

- Essential part of paediatric respiratory medicine.
- Performed for diagnostic, therapeutic and research purposes.
- Main contraindications are removal of foreign bodies, massive haemoptysis, small airway size, and when it will not aid in patient management.
- Airway must be monitored by a separate trained individual (ideally an anaesthetist) throughout the procedure.

Introduction

In children, flexible bronchoscopy is performed primarily by respiratory paediatricians, and its use has become an essential part of paediatric respiratory medicine. Rigid bronchoscopy, on the other hand, is usually performed by thoracic or ear, nose and throat surgeons in the UK. The main indications for rigid rather than flexible bronchoscopy are shown in Table 1.

Flexible bronchoscopy can be performed for diagnostic, therapeutic or research purposes (Table 2).[1] It is indicated when the benefit outweighs the risks and when it is the best way to obtain diagnostic information. The decision to perform flexible bronchoscopy should always be made on an individual basis after consideration of the patient's history, examination, and previous diagnostic tests. Flexible bronchoscopy is generally contraindicated for the removal of endobronchial foreign bodies, in the presence of massive haemoptysis, and when the airway size is too small. Relative contraindications include bleeding diatheses, severe airway obstruction, severe hypoxia, and unstable haemodynamics, including cardiac dysrhythmias and pulmonary hypertension.

In children a normal bronchoscopic examination can be of great value; the exclusion of suspected problems may be as important as a specific finding. The diagnostic yield of flexible bronchoscopy is increased by the information obtained from

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doi:10.1016/j.cupe.2004.04.011

Table 1 Indications for rigid rather than flexible bronchoscopy.

- 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 palsy)
- Interventional bronchology (lasers, stents)

Table 2 Indications for flexible bronchoscopy in children.

Diagnostic:
Airway obstruction
Stridor
Wheeze
Chronic cough
Pulmonary infection
Radiographic abnormalities
Ventilated children
Cystic fibrosis
Immunocompromised children
Paediatric intensive care unit (excluding pulmonary infection)
Endotracheal tube/tracheostomy patency
Difficult intubation
Airway stent assessment
Stridor on extubation
Therapeutic:
Persistent atelectasis
Selective endotracheal intubation
Alveolar filling disorders
Research

bronchoalveolar lavage (BAL), mucosal biopsy and brushings.

The bronchoscopes

The wide range of bronchoscopes available allows bronchoscopy of children of all ages and sizes. In general, the larger the bronchoscope the better the image obtained, but even the smaller ones allow remarkably good views. Standard paediatric bronchoscopes are 2.7, 3.6 or 4.9 mm in external diameter; these are not suitable for preterm babies. The suction channel is 1.2 mm (for the 2.7 and 3.6 mm instruments) and 2.2 mm (for the 4.9 mm bronchoscope). Forceps for biopsy are available for all these instruments. Neonatal bronchoscopes are 2.2 mm in external diameter. However, the 2.2 mm bronchoscope does not have a suction channel and hence mucus that settles over the lens may be difficult to clear without removing the bronchoscope. Its use tends to be restricted to a ventilated neonate with an endotracheal tube too small to pass a 2.7 mm bronchoscope through, and where visualization of the airway is essential.

Bronchoalveolar lavage (BAL)

BAL is a critical part of the bronchoscopy and should always be carried out unless specifically contraindicated. The main use of BAL is in the diagnosis of infections, particularly atypical and opportunistic ones. Cytological analysis of the fluid may also be useful, for example to quantify fat-laden macrophages as evidence of aspiration.[2] Therapeutic lavage is valuable for the treatment of conditions such as collapsed lung segments and alveolar proteinosis. The European Respiratory Society has recently published guidelines on technical aspects of lavage and normal values.[3]

Technically, BAL differs from bronchial lavage. The latter refers to lavage from the large airways, either via a bronchoscope or directly down an endotracheal tube in a ventilated child. BAL refers to the wedging of a bronchoscope into a segmental or subsegmental bronchus. Samples of normal saline at room temperature or warmed are instilled and aspirated. Various formulae exist as to how much to instill (usually 1–5 ml/kg). 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 generalized on radiological imaging. For microbiological purposes, it would seem prudent to sample the area that looks most infected. If there are no specific findings, sampling from the right middle lobe or the lingula tends to be performed as these are the best places to wedge the bronchoscope and maximize the return of the BAL.

Brushings

Cytological brushings can give information, although they are not as routine in children as in adult practice where diagnosis of cancer is a regular indication. Brushings for cytological analysis are indicated for 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 known malignancy (e.g. lymphoma, acute leukaemia), to differentiate relapse from opportunistic infection, and in post bone marrow transplant patients to diagnose graft versus host disease (GVHD). 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 of the flexible bronchoscope; once the tip is seen, under direct visualisation, the brush is extruded from its casing and rubbed gently back and forth on the airway surface. It is then retracted into the casing and withdrawn from the bronchoscope.

Mucosal biopsies

Mucosal biopsies are simple to perform but currently have limited clinical applicability. They have been found to be safe and useful in the assessment of children with difficult asthma.[4] Unlike a transbronchial biopsy, there is effectively no risk of a pneumothorax, and bleeding is minimal. The cupped biopsy forceps are inserted down the suction channel in a closed position. The best site is subcarina of a segmental or sub-segmental bronchus. The biopsy is performed under direct vision and can be sent for histopathological, immunocytochemical and microbiological analysis.

Transbronchial biopsy

Transbronchial biopsies are useful following lung transplantation to help differentiate rejection from infection.[5] 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 transbronchial biopsy in these lobes. The biopsy forceps are then inserted and passed out as far as possible into the segment. Biopsies are not taken under direct vision, but an image intensifier is used to locate the forceps position. Complications include bleeding and pneumothorax.

Sedation and anaesthesia

In contrast to adult patients, children will rarely tolerate flexible bronchoscopy while alert. Techniques available to facilitate this procedure are intravenous sedation and general anaesthesia.[6] Most centres perform flexible bronchoscopy under general anaesthesia, as it is believed to be the optimum way of ensuring the safety of a child whose airway is compromised by the scope and any underlying respiratory disease. Furthermore, whilst anaesthetized, other necessary invasive tests can be performed, including venepuncture, passing a pH probe, or ciliary brushings. Whichever technique is chosen, careful consideration of issues relating to the child, the environment, the equipment and the drugs is vital to ensure patient safety. An anaesthetist, separate from the bronchoscope operator and skilled in airway management, must be responsible for this.

Diagnostic indications

Airway obstruction

Stridor

The evaluation of airway obstruction, which may involve the upper or lower airways or both, is one of the most common indications of flexible bronchoscopy in children. Stridor or noisy breathing that usually reflects an obstruction of the extrathoracic upper airways is one of the most common indications in infants. Flexible bronchoscopy allows an examination of the adenoids, larynx, and hyopopharynx in the most physiological conditions and often while stridor is audible. This gives the opportunity to study the laryngeal structure and dynamic function during inspiration and expiration. Airway endoscopy is not necessarily indicated in every infant with stridor; however, it should be performed in any child with symptoms from birth, severe or persistent symptoms, or failure to thrive, or if it is associated with hoarseness or leads to oxygen desaturation or apnoea.

Laryngomalacia is the most common congenital laryngeal anomaly and the most frequent cause of persistent stridor in children. Other congenital anomalies of the larynx and extrathoracic trachea causing stridor include tracheomalacia, laryngocoeles, laryngeal webs, and congenital neoplasms such as haemangiomas. Paralysis of the vocal cords produces stridor in infants and children and is usually the result of congenital anomalies of the nervous system. Compression of the upper airway

by a vascular ring, e.g. double aortic arch, can also cause stridor.

Stridor in older children is less common but is often an indication for endoscopy of the airways. Flexible bronchoscopy is also performed in patients with tracheostomy in order to assess the patency of the upper airway to plan decannulation.

Wheeze

Children with difficult asthma may require a bronchoscopy including endobronchial biopsy to exclude other airway pathology and to assess the type and severity of airway inflammation.[7] Persistent/unexplained wheezing that does not respond to bronchodilator and anti-inflammatory therapy is another clinical indication for flexible bronchoscopy, mainly in infants. It may be caused by vascular rings, or malacia of the bronchi or intrathoracic trachea, which can be either primary or secondary to relieved vascular compression, tracheo-oesophageal fistula, or congenital cysts. Localized monophonic wheeze may be present in a child with foreign body aspiration. It should be noted that flexible bronchoscopy is superior to rigid bronchoscopy in the assessment of airway dynamics, because less positive end expired pressure is applied during the examination.

Chronic cough

Chronic cough (atypical and persistent) in a patient with normal imaging and functional studies that does not respond to medical therapy is another indication for flexible bronchoscopy in children. Malacia, foreign body aspiration and congenital malformations should be excluded. A BAL should be performed to try to rule out conditions such as recurrent microaspiration.[8]

Pulmonary infection

The investigation of suspected pulmonary sepsis is an important application of flexible bronchoscopy. However, its capacity to alter management in children has been lacking in evidence. The situations where there is probably some evidence for use of paediatric bronchoscopy are in patients with persistently abnormal chest X-rays, ventilated patients, children with cystic fibrosis, and immunocompromised children.

Radiographic anomalies

A variety of radiographic anomalies represent important indications for flexible bronchoscopy in children. Recurrent/persistent atelectasis, recurrent pneumonia, and persistent pulmonary infiltrates are radiological indications for bronchoscopy. Abnormalities such as a narrowed bronchus or mucus plugs are commonly found. In these situations it is also very important to perform BAL for microbiological studies and to try to exclude clinical situations such as aspiration. Localized hyperinflation may be the result of partial bronchial obstruction and can be the consequence of foreign body aspiration, extrinsic bronchial compression and localized bronchomalacia.

Ventilated children

Ventilator-associated pneumonia is one of the most difficult situations in the paediatric intensive care unit. Clinical and chest X-ray signs are non-specific, and there are many other causes of infiltrates: for example, pulmonary oedema, aspiration and segmental mucous plugging.[9] Furthermore, the trachea is inevitably colonized by gram-negative rods within a few days of intubation, with a risk of contaminating cultures taken from lower down the airways. There is no agreed gold standard for diagnosis. An important recent randomized controlled trial in adults[10] compared the use of tracheal aspirates with bronchoscopy with either lavage or a protected specimen brush to diagnose ventilator-acquired pneumonia. They showed that invasive bronchoscopic diagnosis is worthwhile at least in the context of adult intensive care. It seems unlikely that a similar paediatric study will ever be mounted, and we should consider making greater use of bronchoscopy in suspected paediatric cases of ventilator-acquired pneumonia. Non-bronchoscopic BAL also has a role to play in these situations.

Cystic fibrosis

In the past there was a vogue for performing bronchoscopic washouts to remove the viscid secretions, but this was ineffective as the superficial improvement was short-lived. Recently, diagnostic indications for bronchoscopy have become more refined. The majority of children with cystic fibrosis are diagnosed under 2 years of age, when they do not produce sputum and where cough swabs are difficult to obtain. It is increasingly known that even in those diagnosed by newborn screening and who are asymptomatic there is evidence in some of bacterial infection and pulmonary inflammation.[11] Knowledge of these

organisms from the outset will alter management and therefore such bronchoscopies in newly diagnosed children are now routine in our practice.

A bronchoscopy should also be considered in children whose respiratory progress is poor and who do not produce sputum reliably to ensure appropriate targeting of antimicrobial therapy. Other indications for performing a bronchoscopy in a child with cystic fibrosis includes intractable wheezing to exclude bronchomalacia, BAL for fat-laden macrophages to exclude recurrent aspiration, and for persistent localized areas of collapse/consolidation on chest X-ray.

Immunocompromised children

In the immunocompromised, an early microbiological diagnosis is essential as opportunistic infections require specific and often toxic therapies. In post-transplant patients, the question arises as to whether the pulmonary symptoms are due to sepsis or GVHD. The computed tomography (CT) scan may suggest a diagnosis of GVHD or perhaps fungal sepsis or atypical mycobacteria. BAL is mandatory, and mucosal biopsies should be taken as this may aid cytomegalovirus and fungal diagnoses. Transbronchial biopsy is the method of choice for diagnosing GVHD.

Paediatric intensive care unit (excluding pulmonary infection)

Flexible bronchoscopy has many specific diagnostic uses in this setting, many of which have already been discussed. Children in the intensive care unit may pose particular problems since they are often ventilator-dependent and have haemodynamic instability or a coagulopathy.

Endotracheal tube/tracheostomy patency

In a ventilated child where there are concerns over sudden deterioration, even if a suction catheter passes easily, the endotracheal or tracheostomy tube may be blocked. This can be seen at bronchoscopy and remedied. If there is any doubt, it is usually simpler to change the tube, but there may be reluctance to do this if re-intubation is likely to be difficult.

Difficult intubation

This is a rare indication since conventional intubation is usually easily accomplished. If, however, the child has an unstable cervical spine, midfacial disease (for example craniofacial syndrome) or mandibular hypoplasia (Treacher Collins syndrome or Pierre Robin sequence), bronchoscopic intubation may be indicated. The bronchoscope is threaded through the endotracheal tube, passed rapidly through the nose and into the trachea. The endotracheal tube is then advanced over the bronchoscope into position. The bronchoscopist should then check the final position of the endotracheal tube.

Airway stent assessment

Stenting in children is an uncommon and relatively new procedure, although in selected cases it may offer a good alternative to prolonged ventilation. Stent placement is usually a surgical procedure using a rigid bronchoscope. After the stent has been inserted, the position and the state of any distal malacia can be checked using flexible bronchoscopy. Post-stent endobronchial washout can be performed but usually needs to be repeated; the stent interferes with the normal mucociliary clearance.

Stridor on extubation

Bronchoscopy is indicated if there has been at least one failed extubation apparently caused by upper airway obstruction and with apparently good weaning parameters and a trial of dexamethasone.[12] The differential diagnosis includes airway oedema, scarring, subglottic stenosis, and malacia (either acquired as a complication of prolonged ventilation or resulting from pre-existing disease).

Therapeutic indications

Persistent atelectasis

Where persistent atelectasis fails to improve with conventional therapies (physiotherapy and antibiotics), an airway may have become blocked with thick secretions, causing distal atelectasis. This is not uncommon in children with cystic fibrosis (Fig. 1). Bronchoscopy with repeated lavage using the largest scope possible can be effective in unblocking the airway. It is possible to instill 2.5 mg recombinant human deoxyribonuclease (rhDNase) into the affected areas at the end of the procedure.[13] Occasionally, unexpected airway pathology may be detected.

Selective endotracheal intubation

This may be indicated if there is unilateral pathology necessitating different ventilatory strategies:

for example, a unilateral uncontrolled air leak caused by a bronchopulmonary fistula or by barotrauma in a ventilated neonate.[14] This procedure is technically much easier if the long left main bronchus is to be intubated; selective right-sided intubation risks occluding the right upper lobe bronchus or leaving an unstable tube position.

Alveolar filling disorders

Patients with alveolar filling disorders, such as alveolar proteinosis or lipid aspiration, may benefit from BAL through a flexible bronchoscope.[15]

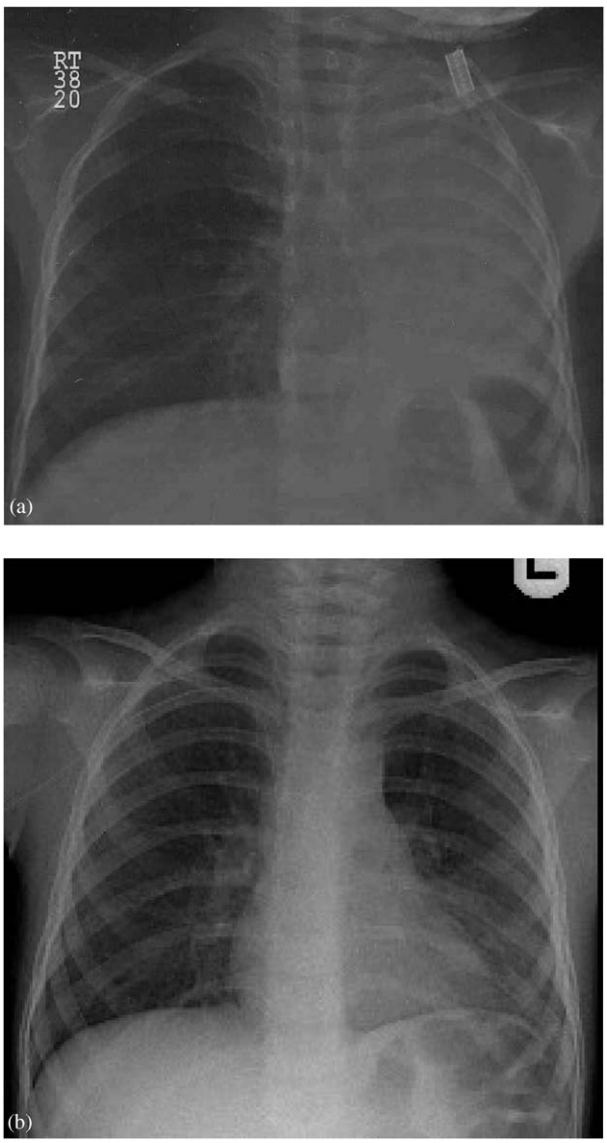

Figure 1 Chest X-ray before (a) and after (b) bronchoalveolar lavage for blocked left lower lobe with distal collapse in a 3-year-old child with cystic fibrosis.

Research

Research into the basic mechanisms of respiratory disease in children is vital in order to improve understanding of disease processes, which in turn may lead to improved clinical management. In contrast to studies in adult, invasive procedures cannot be performed in children solely for research purposes. Opportunities must therefore be taken to use clinically indicated procedures as a means of obtaining material for research. Such procedures must, however, constitute minimal risk to the child.[16] For children undergoing bronchoscopy, the performance of additional procedures such as endobronchial biopsy for research purposes is acceptable providing that the research has been approved by the appropriate ethics committee, written informed consent specifically for the research procedures is obtained from a parent (with assent from any child mature enough to understand the request), and the procedure is performed by a senior, experienced bronchoscopist. In addition, bronchoscopy can be useful in airway surface measurements, in particular airway surface liquid composition and potential difference. In diseases such as asthma[17] and cystic fibrosis[11] studies using bronchoscopy have improved understanding of pathogenesis and disease progression.

Complications

The complications of flexible bronchoscopy can be categorized as follows.

Physiological complications

These complications are part of the physiological response to blocking the child's airway. Hypoxia may be caused by a number of factors: obstruction of the airways leads to an increase in airways resistance (more pronounced on expiration than inspiration), increase in functional residual capacity, increase in positive end expiratory pressure, and reduction in tidal volume and alveolar minute volume.[18] The child's underlying lung condition may of course contribute to the situation. Other factors include lavage with large volumes of saline, overzealous suction (which removes oxygen from the airways), and mobilization of thick secretions that can block the airways higher up the bronchial tree. For similar reasons hypercapnia may ensue and this must be measured. Genuine cardiac arrythmias 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 endotracheal tube or tracheostomy) and spraying the vocal cords with local anaesthetic may be helpful. Bronchospasm can also occur, although this is rare in our experience, even with severe asthmatics.[4]

Infection

Cross-infection is a theoretical risk but should not occur with proper cleaning and disinfection of the bronchoscopes between procedures. Fever may develop in up to half the children within 24 h. Although thought to be due to bacteraemia in one series this was not detected in any of the febrile (or non-febrile) cases.[19] The transient fever does not usually present a problem and simple antipyretics are often sufficient; antibiotics are rarely indicated. However, if the child is immunocompromised there is a risk of septicaemia, so early or prophylactic use of intravenous antibiotics is indicated.[20]

Mechanical complications

Trauma to the lining of the respiratory tract is well recognized but can be kept to a minimum with careful technique. Furthermore, if there is an existing upper airway problem, such as subglottic stenosis, it only takes a small amount of oedema to compromise the airway completely. It is therefore important to have a paediatric intensive care bed available when bronchoscoping small infants with stridor. Haemoptysis secondary to a bronchoscopy is unusual even following a biopsy, but a small amount of contact bleeding may occur, especially if the airway is inflamed. Pneumothorax is one of the more serious potential complications, but is only likely to occur with transbronchial biopsy.

Conclusions

Paediatric flexible bronchoscopy is an increasingly important diagnostic investigation of the upper and lower airways. It also allows a number of therapeutic manoeuvres. Its use in research has enhanced understanding of airway pathophysiology in diseases such as asthma and cystic fibrosis. It is a safe procedure provided that the child is properly prepared and the procedure performed by skilled and trained personnel.

References

1. Midulla F, de Blic J, Barbato A, et al. Flexible endoscopy of paediatric airways. *Eur Respir J* 2003;**22**:698–708.
2. Ahrens P, Noll C, Kitz R, et al. Lipid-laden alveolar macrophages (LLAM): a useful marker of silent aspiration in children. *Pediatr Pulmonol* 1999;**28**:83–8.
3. De Blic J, Midulla F, Barbato A, et al. Bronchoalveolar lavage in children. *ERS Task force on bronchoalveolar lavage in children. European respiratory society. Eur Respir J* 2000;**15**:217–31.
4. Payne D, McKenzie SA, Stacey S, et al. Safety and ethics of bronchoscopy and endobronchial biopsy in difficult asthma. *Arch Dis Child* 2001;**84**:423–6.
5. Guilinger RA, Paradis IL, Dauber JH, et al. The importance of bronchoscopy with transbronchial biopsy and bronchoalveolar lavage in the management of lung transplant recipients. *Am J Respir Crit Care Med* 1995;**152**:2037–43.
6. Jaggar SI, Haxby E. Sedation, anaesthesia and monitoring for bronchoscopy. *Paediatr Respir Rev* 2002;**3**:321–7.
7. Payne DN, Balfour-Lynn IM. Children with difficult asthma: a practical approach. *J Asthma* 2001;**38**:189–203.
8. Fitch PS, Brown V, Schock BC, et al. Chronic cough in children: bronchoalveolar lavage findings. *Eur Respir J* 2000;**16**:1109–14.
9. Fagon JY, Chastre J, Hance AJ, et al. Evaluation of clinical judgment in the identification and treatment of nosocomial pneumonia in ventilated patients. *Chest* 1993;**103**:547–53.
10. Fagon JY, Chastre J, Wolff M, et al. Invasive and noninvasive strategies for management of suspected ventilator-associated pneumonia. *A randomized trial. Ann Intern Med* 2000;**132**:621–30.
11. Armstrong DS, Grimwood K, Carzino R, et al. Lower respiratory infection and inflammation in infants with newly diagnosed cystic fibrosis. *Br Med J* 1995;**310**:1571–2.
12. Wood RE, Postma D. Endoscopy of the airway in infants and children. *J Pediatr* 1988;**112**:1–6.
13. Slattery DM, Waltz DA, Denham B, et al. Bronchoscopically administered recombinant human DNase for lobar atelectasis in cystic fibrosis. *Pediatr Pulmonol* 2001;**31**:383–8.
14. Meyer MT, Rice TB, Glaspey JC. Selective fiberoptic left main-stem intubation for severe unilateral barotrauma in a 24-week premature infant. *Pediatr Pulmonol* 2002;**33**: 227–31.
15. Mahut B, de Blic J, Le Bourgeois M, et al. Partial and massive lung lavages in an infant with severe pulmonary alveolar proteinosis. *Pediatr Pulmonol* 1992;**13**:50–3.
16. McIntosh N, Bates P, Brykczynska G, et al. Guidelines for the ethical conduct of medical research involving children. Royal college of paediatrics, child health: ethics advisory committee. *Arch Dis Child* 2000;**82**:177–82.
17. Payne DN, Rogers AV, Adelroth E, et al. Early thickening of the reticular basement membrane in children with difficult asthma. *Am J Respir Crit Care Med* 2003;**167**:78–82.
18. Schnapf BM. Oxygen desaturation during fiberoptic bronchoscopy in pediatric patients. *Chest* 1991;**99**:591–4.
19. Picard E, Schwartz S, Goldberg S, et al. A prospective study of fever and bacteremia after flexible fiberoptic bronchoscopy in children. *Chest* 2000;**117**:573–7.
20. Picard E, Schlesinger Y, Goldberg S, et al. Fatal pneumococcal sepsis following flexible bronchoscopy in an immunocompromised infant. *Pediatr Pulmonol* 1998;**25**: 390–2.