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CME ARTICLE

Lung abscess in children

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EDUCATIONAL AIMS

- To appreciate the presenting features of lung abscess in children.
- To distinguish between a primary and a secondary lung abscess in terms of management and outcome.
- To consider antibiotic therapy choices for children with a lung abscess.
- To appreciate the role of interventional radiology in the management of lung abscess.

KEYWORDS
lung abscess;
children;
interventional radiology;
management;
prognosis

Summary Lung abscess is an uncommon paediatric problem, with a paucity of quality data on the subject in the medical literature. Although the condition has for many years been managed successfully with prolonged courses of intravenous antibiotics, the evolution of interventional radiology has seen the use of percutaneously placed 'pigtail catheters' inserted under ultrasound and computed tomography guidance become the mainstay of therapy where such resources are available. This has been suggested to result in a more rapid defervescence of fever and symptoms, shorter periods of intravenous antibiotics and a decreased length of inpatient care. More invasive procedures, aspiration and drainage, together with improved microbiological diagnostic techniques, including polymerase chain reaction testing, has increased the yield of pathogens identified from abscess fluid samples. Culture results will guide treatment, especially for immunocompromised subjects who may develop a lung abscess as a complication of their underlying condition. The predominant pathogens isolated from primary lung abscesses in children include streptococcal species, *Staphylococcus aureus* and *Klebsiella pneumoniae*. Children with a lung abscess, both primary and secondary, have a significantly better prognosis than adults with the same condition.

A lung abscess is a thick-walled cavity that contains purulent material resulting from a pulmonary infection. It is an uncommon condition that can occur at any age. It is believed to be less common in children than adults, and the literature is accordingly relatively sparse. The pathogenesis of lung abscess involves an area of initial pneumonitis that leads to necrosis, cavitation and abscess formation.[1] It is initiated or complicated by infectious organisms such as streptococcal and staphylococcal species.[1,2] Some series impose a minimum size of 2 cm as a diagnostic criterion.[1,2]

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KEY POINTS

- Pulmonary aspiration may be a central factor in the development of lung abscess.
- The evolution of a lung abscess may be surprisingly indolent, occurring over several weeks. The predominant symptoms are cough and fever.
- The early use of interventional radiology for the placement of drainage catheters is increasingly being recognised as a way of hastening recovery, decreasing the length of hospitalisation and improving the yield of cultures.
- For primary lung abscesses, antibiotic choices should cover the likely organisms, including *Staphylococcus aureus*, streptococcal species and Gram-negative bacilli, that are normally found in the upper respiratory tract.
- For patients at risk of secondary lung abscess through aspiration, it is important to cover anaerobes normally found in the upper airway. For immunocompromised hosts, antibiotic coverage is broader and likely to include a consideration of fungal pathogens.
- The prognosis for a full recovery in children with primary or secondary lung abscess is excellent.

The size criteria may, however, relate more to historical criteria related to chest radiographs that preceded the excellent resolution of computed tomography (CT) and magnetic resonance imaging (MRI) scans. Nonetheless, if left untreated for over a week, the abscess may be complicated by significant morbidity, including empyema and fistula formation.[1]

DEFINITION

There are two types of lung abscess, which may be arbitrarily divided into primary and secondary based upon the existence of pre-existing conditions. A primary lung abscess occurs in a previously well child with normal lungs.[1–3] A secondary lung abscess occurs in children with an underlying lung abnormality, which may be congenital (cystic fibrosis, immunodeficiency or structural as in a congenital cyst adenomatoid malformation) or acquired (achalasia or a neurodevelopmental abnormality such as cerebral palsy with repeated pulmonary aspiration and suppurative lung disease).[1–3] The presence of a factor predisposing to lung abscess will influence the likelihood of certain pathogens being isolated.[3]

PATHOPHYSIOLOGY

Pulmonary aspiration may be a central factor in the evolution of a lung abscess. Of course, people of any age probably aspirate to some extent on a daily basis ('micro-aspiration'), but it is likely that the number of episodes of aspiration, the volume of aspirated material and any impairment of mucociliary clearance mechanisms contribute to the development of a lung abscess.[4] Supporting this concept is the fact that lung abscesses occur more commonly in the most dependant parts of the lung for the supine patient, namely the upper lobes and the apical segments of the lower lobes.[4] Interestingly, it takes days before the symptoms and signs develop even after a known aspiration event has occurred, because the body's host defence mechanisms may decrease perfusion to an area of aspiration and thereby reduce the influx of defence mediators and the egress of infective material.[5]

A lung abscess may arise from embolic phenomena such as may be seen in right-sided bacterial endocarditis, more likely in children with right-sided heart valve abnormalities and those who have previously had right-sided cardiac surgery or the placement of a central venous line.[6] Rarely, children with septicaemia may have foci in the lungs from haematogenous spread or from thrombophlebitis with septic emboli.[5] In addition, local extension from pharyngeal abscesses or abdominal collections is also seen.[5]

FACTORS PREDISPOSING TO LUNG ABSCESS

Secondary lung abscesses may be seen in children at increased risk of pulmonary aspiration, immunocompromised hosts and those with underlying localised structural lung abnormalities or generalised suppurative lung disease.[7,8] Broadly speaking, pulmonary aspiration is more likely in children with neurodevelopmental abnormalities, especially those with poorly coordinated swallowing, neuromuscular conditions such as myotonic dystrophy and Duchenne muscular dystrophy, children with oesophageal motility problems (post-tracheo-oesophageal atresia repair, oesophageal strictures, achalasia) and rarely those with tracheo-oesophageal connections ('H'-type tracheo-oesophageal fistula).[7–9] Immunocompromised conditions may include various congenital immunodeficiencies, those children on chemotherapy or immunosuppressive treatment (e.g. corticosteroids) and, less commonly in the developed world, those children with nutritional deficiencies.[7–9] Localised structural lung abnormalities, such as congenital cyst adenomatoid malformations and bronchogenic cysts may predispose to secondary infection. Less commonly today with newborn screening in some countries and the liberal use of oral, nebulised and intravenous antibiotics, children with suppurative lung disease such as cystic fibrosis may develop lung abscesses.[10,11]

MICROBIOLOGY

Organisms responsible for causing lung abscess are increasingly being sought at or near the time of presentation using

Table 1 Pathogens isolated in lung abscess

Classification	Pathogen	Primary lung abscess	Secondary lung abscess
Aerobic Gram-positive cocci	*Streptococcus pneumoniae*	++++	++
	Staphylococcus aureus	+++	++
	Streptococcus pyogenes	++	
	Streptococcus milleri	+	
	Streptococcus viridans		+
Aerobic Gram-negative bacilli	*Pseudomonas aeruginosa*	++	+++
	Klebsiella pneumoniae	+	+
	Moraxella catarrhalis		+
	Acinetobacter species		
	Escherichia coli	+	
	Salmonella species		+
Anaerobic	*Bacteroides*		++
	Prevotella species		+
	Actinomyces species	+	
Fungus	*Candida albicans*		+
	Aspergillus species		+

techniques of interventional radiology.[12,13] The pathogens may be classified into aerobic, anaerobic and fungal.[1,2,6–8] More commonly isolated pathogens are listed in Table 1.[1,6,8] The increasingly interventional approach has seen the proportion of pathogens responsible for lung abscesses increase from less than 30% to around 60% currently.[2,7] It is worth noting that lung abscess is rare in neonates and also may be associated with predisposing factors such as lung cysts, pneumonia or the presence of central venous lines.[2,9,12] In addition to *Staphylococcus aureus*, one should also consider group B *Streptococcus*, *Escherichia coli* and *Klebsiella pneumoniae*.[2,7,9]

PRESENTING SYMPTOMS AND SIGNS

The distinction of a lung abscess from pneumonia on history or clinical findings is seldom possible. Consequently, the diagnosis is usually made on the chest radiograph, supported by more definitive imaging initiated as part of interventional therapy. The use of CT scanning may facilitate the distinction between a lung abscess and necrotising pneumonia, as well as being part of the interventional procedure to guide the interventional radiologist as he or she drains the abscess.[14] This has been our experience at The Children's Hospital at Westmead in Sydney with 23 lung abscesses (9 primary, 14 secondary) over 16 years and is consistent with previously reported series.[1–5]

Common symptoms and signs reported in children with lung abscess from our own institution and recent studies are summarised in Table 2. Fever and cough consistently predominate but are not universal. Unlike the situation with adults, haemoptysis is uncommon as a presenting feature in children with lung abscess. Overriding these symptoms is the fact that the evolution of a lung abscess may be surprisingly indolent, lasting for up to several weeks.[4]

The physical signs elicited in a child with lung abscess most commonly include tachypnoea, a dull percussion note or reduced air entry locally, fever and localised crepitations and did not differ whether the abscess was assessed to be a primary lung abscess or a secondary lung abscess (Table 3).

IMAGING THE LUNG ABSCESS

The basic diagnostic test for a lung abscess is the chest radiograph (Fig. 1). However, in order to distinguish a lung

Table 2 Symptoms reported in several series for children with a lung abscess

	Children's Hospital at Westmead, Sydney* (1985–2001) (n = 23)	Tan *et al.*[7] (n = 45)	Chan *et al.*[2] (n = 27)	Yen *et al.*[8] (n = 23)
Fever	83%	84%	100%	91%
Cough	65%	53%	67%	87%
Dyspnoea	36%	35%	19%	35%
Chest pain	31%	24%	22%	9%
Anorexia/nausea and vomiting	24%	20%	4%	26%
Malaise and lethargy	31%	11%	Not reported	22%

* Prior to 1995, the Children's Hospital at Westmead was known as The Royal Alexandra Hospital for Children.

Table 3 Clinical signs elicited in children with primary and secondary lung abscess from The Children's Hospital at Westmead (1985–2001)

	Primary lung abscess (n = 9)	Secondary lung abscess (n = 14)
Tachypnoea	100%	71%
Dull percussion note or reduced air entry	44%	79%
Fever	44%	50%
Localised crepitations	33%	36%

abscess from an empyema, necrotising pneumonia, sequestration, pneumatocoele or underlying congenital abnormality such as a bronchogenic cyst, a contrast-enhanced CT scan is usually considered to be the investigation of choice.[12–14] In many centres, the CT scan will enable the interventional radiologist to undertake diagnostic aspiration of the abscess and often therapeutic drainage with a small temporary catheter.[12–14]

The characteristic appearance of a lung abscess on a CT image is shown in Fig. 2. In particular, the thick-walled cavity contains mobile, central fluid occurring in the midst of an area of consolidated lung. An air–fluid level is often apparent on the CT scan, even when it is not evident on the plain chest radiograph.[12–14] MRI scans, although they do not involve irradiation, offer no diagnostic advantage over CT scans and are not routinely used in most centres for the investigation and treatment of lung abscess.

Conversely, ultrasound as a tool is useful in defining a lung abscess.[9,15] Its utility includes the lack of sedation needed to conduct the test in infants and preschool-aged children, the lack of irradiation, the ease with which it can be obtained in most paediatric centres and the relatively low cost. The optimal roles of ultrasound may be in the initial evaluation of a critically unwell child at the bedside (or in the radiology suite) and the ability to differentiate an abscess that abuts onto the hemidiaphragm or pleura.[15] Doppler ultrasonography will assist in the delineation of pleural fluid and large blood vessels and the circulation from which they originate, particularly when the possibility of a pulmonary sequestration is being entertained.[16] Furthermore, a lung abscess may, in its early stages, appear as an avascular, hypoechoic mass prior to it containing air. Notwithstanding the limitations of ultrasound, some interventional radiologists prefer to use ultrasound guidance under general anaesthesia in order to aspirate or place a drain into a lung abscess that is peripherally placed.[15]

If, however, intervention is required, general anaesthesia will be required for the insertion of a needle or drain to the abscess cavity. Thus, where the abscess is appreciated on the plain chest radiograph, the ultrasound may be an unnecessary test as a CT scan will be preferred to guide the invasive drainage procedure.[13] In the setting where CT scanning and interventional radiology are not available, ultrasound is a safe non-invasive test that may monitor recovery.[15]

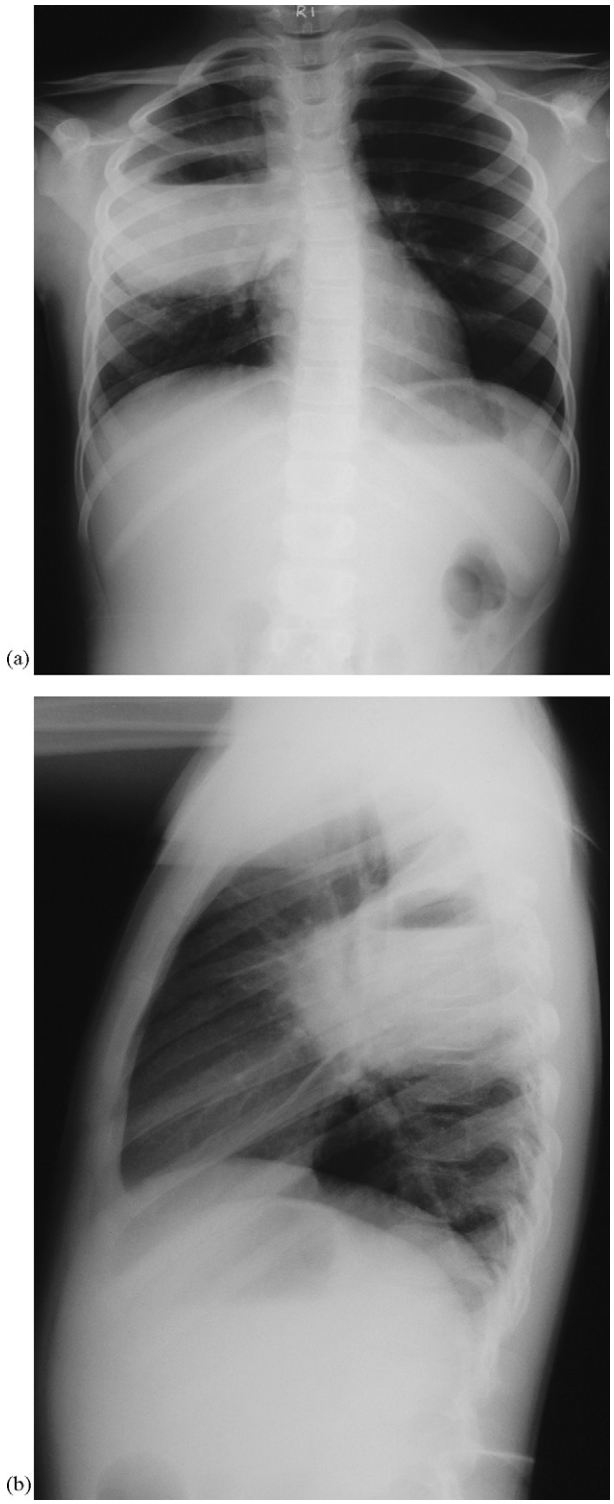

Figure 1 (a, b) Posteroanterior and lateral chest radiographs showing an 8 cm diameter lung abscess with an air–fluid level in the right mid-zone.

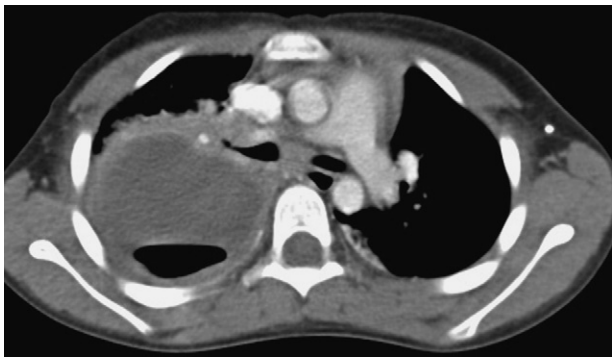

Figure 2 A computed tomography scan showing a lung abscess with a pigtail catheter inserted.

ASSESSMENT AND MANAGEMENT

The assessment and management of lung abscesses in children varies with the degree of experience of the clinician and the access to interventional radiologists and surgeons. For a primary lung abscess, the prognosis following a variety of treatment strategies is usually favourable. The mortality in paediatric lung abscess almost always relates to the conditions predisposing to a secondary lung abscess.[1,2,4] From the more conservative approaches of lengthy courses of intravenous antibiotics to short courses of intravenous antibiotics after drainage of the abscess, much of the current emphasis is on minimising symptoms, facilitating faster recovery with the use of interventional radiologists and thereby minimising the length of hospitalisation.

Antibiotics

The mainstay of management of a lung abscess is hospital admission and systemic antibiotics, which adequately treat

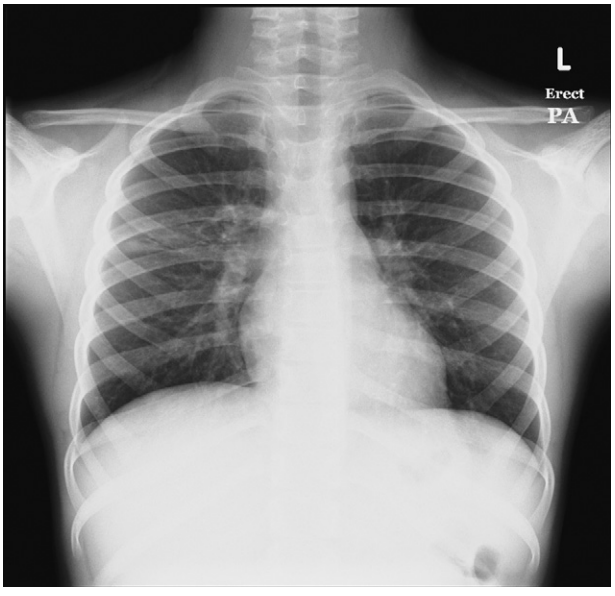

Figure 3 The chest radiograph 6 weeks after presentation for the patient with a right upper lobe abscess seen in Figure 1.

90% of patients of all ages.[3,17,18]. Written up 25 years ago, the retrospective case series of Asher *et al.*[3] provided insight into the course of 14 children with a lung abscess treated with intravenous antibiotics alone. Specifically, the average length of stay was 13 days (range 6–26 days), and there was no mortality with a follow-up period of between 16 months and 5 years. However, the length of intravenous antibiotic therapy does vary with local experience. In a review article by Tan *et al.*,[7] it was recommended that parental antibiotics be given for 2–3 weeks followed by oral therapy for 4–8 weeks, the authors going on to suggest that neonates should receive the whole course parenterally.[7] Our local experience, aided by the presence of interventional radiologists, has suggested good outcomes with intravenous therapy for as little as 5 days followed by 4 weeks of oral antibiotics (see the case study below).

Penicillin has traditionally been viewed as the first antibiotic of choice.[3,9,19]. It is inexpensive and readily available, and has proved reliably effective based on the premise that one wishes to treat pharyngeal flora that may be introduced into the lung through pulmonary aspiration.[3,19,20] Specifically, this is useful for many species of streptococci and anaerobic bacteria.[19,20] The rise of penicillin resistance, primarily through the liberal use of antibiotics, mediated via beta-lactamase-producing anaerobic organisms, has led many centres to add metronidazole or clindamycin to penicillin as first-line therapy, especially to cover *Staph. aureus* in those who are debilitated or extremely unwell.[9,21]

The use of clindamycin has the added benefit of covering *Staph. aureus* and anaerobes, as well as providing a tablet formulation to permit continuity of one antibiotic alone for oral therapy after hospital discharge. Other institutions, including our own, initially prefer to use a third-generation cephalosporin and flucloxacillin until the aspirated lung abscess fluid culture results are available to rationalise therapy. However, the choice of antibiotics varies somewhat between institutions and is guided by a number of factors, including the ability to isolate organisms through aspiration and drainage of the abscess, whether the abscess is believed to be a primary or secondary phenomenon, the likelihood of penicillin resistance, cost and local practices.

For primary lung abscesses, antibiotic choices should cover likely organisms including *Staph. aureus*, *Streptococcus pneumoniae* and other streptococcal species, and Gram-negative bacilli that are normally found in the upper respiratory tract.[19] For patients at risk of secondary lung abscess through aspiration, it is important to cover anaerobes normally found in the upper airway. For immunocompromised hosts, antibiotic coverage is broader and likely to include a consideration of fungal pathogens.[8]

Role of surgery

Surgery for lung abscess in adult and paediatric patients has been associated with significant morbidity, such as

empyema, bronchoalveolar air leak and a mortality rate of 5–10%.[6,18] In children, however, a number of papers have compared surgical management with medical therapy alone or medical therapy coupled with interventional radiology.[6–8,12] Consistently over the years, surgery was seen as an intervention for failed medical therapy whether the lung abscess was considered primary or secondary to an underlying lung condition.[21] Surgery was described in mainly retrospective case series with inconsistent outcomes, often not reporting on the length of hospital stay. In the view of the authors and others,[13] the uncommon need for surgery for lung abscess has been further reduced by the use of interventional radiology techniques early in the course of management, particularly for children who are extremely unwell at presentation.

Role of interventional radiology

The rediscovery of interventional radiology has dramatically altered the management of lung abscess over the past 20 years in many paediatric teaching hospitals. This has been facilitated by the evolution of better imaging equipment. Fifty years ago, Monaldi[22] first described the percutaneous insertion of a tube under fluoroscopic control to drain a lung abscess. However, with limited antibiotics by modern standards and a high mortality rate, the technique did not gain popularity for 2–3 decades. Vainrub *et al.*[23] reported the use of fluoroscopically guided aspiration for lung abscesses in three adults considered too unstable for surgery and unresponsive to antibiotic therapy alone. The aspiration of lung abscesses with or without an external drain under CT guidance for large, peripherally located abscesses has been used in the paediatric population since the 1980s, with reports of improved success rates, reduced morbidity and mortality.[24–26]

The concept has emerged of CT-guided drainage and the insertion of a pigtail catheter when medical therapy has 'failed' or for rapid diagnostic and therapeutic benefit.[7,27] Outcome data regarding the use of interventional radiology in paediatric lung abscess are, however, limited. At The Children's Hospital at Westmead, the rise in interventional radiology over the past 20 years has resulted in the routine use of CT-guided aspiration for abscesses and, in more recent years, in the use of CT-guided pigtail drainage catheters at the time of presentation. This has translated into a higher proportion of positive cultures overall, with a higher prevalence of anaerobes, a reduced proportion of *Staph. aureus* and *Haemophilus influenzae* type B (since the introduction of routine immunisation in 1992) and a shorter length of hospital stay than reported in previous series. Mirroring a report in adults[17] and children,[8] proportionately fewer cases of secondary lung abscess were seen, although this still remained the predominant type (3:2 versus 5:2 in older series).[2,7,20] This may reflect more aggressive and effective therapy for the more common predisposing conditions, including immunodeficiencies, neurodevelopmental abnormalities and cystic fibrosis. Most interestingly, for the 19 patients managed exclusively in our institution (mean age 8.3 years; range 20 days to 19.5 years) between 1985 and 2000 with a primary lung abscess ($n = 9$), the average length of stay in our institution was 12.4 days (95% CI 8.4, 16.5) and for those with secondary lung abscess ($n = 10$) it was 25.1 days [95% CI 14.6, 35.6], giving an overall average of 19.1 days [95% CI 13.0, 25.2].

In comparison, over the past 5 years, the length of hospital stay has decreased in our institution. Current practice at The Children's Hospital at Westmead in Sydney sees children presenting with a primary lung abscess managed routinely undergoing placement of a CT-guided pigtail catheter at presentation, with 2–3 days of drainage, intravenous antibiotics and discharge within 7 days on a course of oral antibiotic therapy to complete a month of total antimicrobial therapy guided by culture results (see the case history below).

COMPLICATIONS

Complications of lung abscess may arise by progression of the condition or occur as a result of treatment. The lung abscess may spontaneously rupture into adjacent compartments, rupture into the pleural space leading to empyema, pyothorax or pneumothorax.[9,18] The connection between the abscess cavity and the pleural space may persist, leading to the formation of a bronchopleural fistula.[27] Alternatively, if the lung abscess has occurred as a result of haematogenous spread, multiple abscesses may be seen.[9]

With the increasingly invasive approach, complications of anaesthesia and interventional radiology procedures have to be considered. Many children will undergo the CT-guided placement of pigtail catheters and will therefore have some radiation exposure. The procedures will be generally performed under general anaesthesia so the risks of aspiration, reactions to the anaesthetic agents, postoperative nausea and fever should also be considered. The drains will be left in situ for 2–3 days, and some analgesia will be required. Limited mobility will be available while the drain is in position. A small entry site scar will result from placement of the drain.

The choice of antibiotics may be associated with a reaction, commonly in the form of a fever or a rash, but anaphylaxis may occasionally be seen. The risks can be minimised by asking about allergies prior to prescribing antibiotics and regularly reviewing the patient's clinical course and fever charts.

The timing of a repeat chest radiograph is a frequently raised conundrum. Once therapy has been initiated and the patient is demonstrating an expected recovery pattern, there is merit is deferring the chest radiograph until after the course of oral antibiotics has been completed. Although it is appropriate to document the recovery, radiological improvement may take longer than the clinical resolution.[9]

LONG-TERM OUTCOME

The prognosis for children with primary lung abscess is overwhelmingly favourable. In adults, the morbidity with lung abscess is reported as being 15–20%,[28] whereas in children the mortality is significantly lower, probably of the order of less than 5%, and occurs predominantly in those with a secondary lung abscess.[8,9] In adults with a lung abscess, factors such as the presence of pneumonia, cancer, a reduced level of consciousness, anaemia and the isolation of *Pseudomonas aeruginosa*, *Staph. aureus* and *K. pneumoniae* were poor prognostic factors.[28]

It is the co-morbidity of the predisposing conditions in both adults and children that contributes to the mortality rate. Consequently, almost all immunologically competent children with a primary lung abscess would be expected to recover, whereas those with predisposing conditions, predominantly immunocompromised states, would expect to fare worse. Very few long-term follow-up data are, however, available for children, although Asher and colleagues[3] reported 9 of 11 patients with primary lung abscess, when seen on average 9 years after presentation, who had normal lung function. Children, like adults, with secondary lung abscesses are a heterogeneous group, and their prognosis, both from a respiratory viewpoint and generally, will be more directly influenced by the predisposing condition.[7,28,29] Furthermore, Nonoyama *et al.*[30] found normal spirometry at follow-up in children aged less than 10 years who underwent surgical management of their lung abscesses.

FURTHER EVIDENCE NEEDED TO IMPROVE MANAGEMENT

Once again, there is a clear need for a collaborative database to monitor the prevalence and progress of children with a lung abscess. In particular, with the increasing use of antibiotics both in the community and in the hospital setting for complex cases, monitoring pathogens and antibiotic resistance patterns will be important. Clinical guidelines based upon pooled experience, encompassing interventional radiology and a less invasive approach, will assist clinicians to care better for patients.

Case history

A previously well 8-year-old girl presented in June 2006 with a 3-week history of cough, fever, chest pain and weight loss of 2 kg. Her illness had begun with a coryzal illness, her cough becoming moist after a week. She was reviewed by a number of general practitioners but was not offered antibiotics until the 18th day of her illness, and she presented on the 22nd day of illness with a chest radiograph showing a lung abscess in her right lung (see Fig. 1 above).

The girl was admitted and taken to the interventional radiology suite four hours later, where, under general anaesthesia, she underwent the CT-guided insertion of a pigtail catheter; 100 ml creamy purulent material was aspirated and sent for culture (see Fig. 2 above). Intravenous cefotaxime and flucloxacillin were commenced via a percutaneously inserted 'long line' in the cubital fossa. The fevers settled within 48 hours. A further 70 ml was drained via the pigtail catheter over the subsequent 72 hours before its removal. The culture grew a fully sensitive *Strep. pyogenes*, and the patient was discharged on 4 weeks of amoxicillin/clavulinic acid in a twice-daily regime.

The girl was back to her normal activity levels within 3 days of discharge and returned to school 5 days after discharge. She remained well with no recurrence of her symptoms when she was reviewed a week after finishing her oral antibiotics, when she had a near normal chest radiograph (see Fig. 3 above).

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Educational questions

Answer true or false to the following questions:

1. For children with lung abscess in comparison to adults with the same condition:
   a. Haemoptysis is a less common presenting feature.
   b. Anaerobic bacteria are rarely implicated.
   c. The size and location of the abscess are important prognostic factors.
   d. Lobectomy is considered more often.
   e. The mortality is significantly higher than in adults.
2. For children with lung abscesses in general:
   a. The presenting symptoms have usually lasted for less than a week.
   b. The most common presenting features are cough and fever.
   c. The right middle lobe is the most common site.
   d. A chest radiograph is usually the best initial investigation.
   e. A lung abscess is rare in neonates.
3. For children with primary lung abscesses:
   a. Anaerobes are the predominant species.
   b. Fungal infections are common.
   c. Streptococcal species are frequently cultured.
   d. Antibiotic cover should include the treatment of both streptococcal and staphylococcal species.
   e. Penicillin resistance is a consideration in certain populations.
4. In children with secondary lung abscess:
   a. Pulmonary aspiration is seen as a likely route of infection.
   b. Lobectomy is the preferred therapy.
   c. For immunocompromised hosts, antimicrobial therapy to cover fungal infection is recommended.
   d. The recovery time is longer than with a primary lung abscess.
   e. *Pseudomonas aeruginosa* is more likely to be isolated from the abscess fluid.
5. Imaging lung abscesses:
   a. On ultrasound, a lung abscess in the early stages may appear as an avascular, hypoechoic mass prior to its containing air.
   b. An air–fluid level is often apparent on the CT scan, even when it is not evident on the plain chest radiograph.
   c. Ultrasound is a useful investigation for monitoring the resolution of a lung abscess.
   d. An MRI scan is considered to be a routine test in the management of lung abscess.
   e. It may take more than 4 weeks for the chest radiograph to return to normal after the successful treatment of a lung abscess.