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Imaging of cavitary necrosis in complicated childhood pneumonia

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Abstract The aim of this study was to illustrate the chest radiographs (CR) and CT imaging features and sequential findings of cavitary necrosis in complicated childhood pneumonia. Among 30 children admitted in the Pediatric Intensive Care Unit for persistent or progressive pneumonia, respiratory distress or sepsis despite adequate antibiotic therapy, a study group of 9 children (5 girls and 4 boys; mean age 4 years) who had the radiographic features and CT criteria for cavitary necrosis complicated pneumonia was identified. The pathogens identified were *Streptococcus pneumoniae* ($n = 4$), *Aspergillus* ($n = 2$), *Legionella* ($n = 1$), and *Staphylococcus aureus* ($n = 1$). Sequential CR and CT scans were retrospectively reviewed. Follow-up CR and CT were evaluated for persistent abnormalities. Chest radiographs showed consolidations in 8 of the 9 patients. On CT examination, cavitary necrosis was localized to 1 lobe in 2 patients and 7 patients showed multilobar or bilateral areas of cavitary necrosis. In 3 patients of 9, the cavitary necrosis was initially shown on CT and visualization by CR was delayed by a time span varying from 5 to 9 days. In all patients with cavities, a mean number of five cavities were seen on antero-posterior CR, contrasting with the multiple cavities seen on CT. Parapneumonic effusions were shown by CR in 3 patients and in 5 patients by CT. Bronchopleural fistulae were demonstrated by CT alone ($n = 3$). No purulent pericarditis was demonstrated. The CT scan displayed persistent residual pneumatoceles of the left lower lobe in 2 patients. Computed tomography is able to define a more specific pattern of abnormalities than conventional CR in children with necrotizing pneumonia and allows an earlier diagnosis of this rapidly progressing condition. Lung necrosis and cavitation may also be associated with *Aspergillus* or *Legionella* pneumonia in the pediatric population.

Keywords Children · Respiratory system · CT · Lung infection · Necrotizing pneumonia

Introduction

Suppurative lung parenchymal complications in children include cavitary necrosis, lung abscess, pneumatocele, and bronchopleural fistula. Although necrosis and cavitation associated with S*taphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella*, and anaerobes is well known in the adult population, necrotizing pneumonia has been sparsely reported in children, mostly as a complication of *Staphylococcus aureus* or *Streptococcus pneumoniae* infections. The early detection of cavitary necrosis influences the intensity of patient monitoring, length of treatment, and timing of patient follow-up. The purpose of this article is to illustrate the imaging

Table 1 Clinical data. *ALL* acute lymphocytic leukemia; *ARDS* adult respiratory disease syndrome

Patient no.	Gender	Age (years)	Necrotizing pneumonia Side/infectious agent	Associated conditions	Length of ICU stay	Surgical treatment	Clinical outcome
1	M	8	Bilateral *Streptococcus pneumoniae*	Tetralogy of Fallot	1 month	Closure of right bronchopleural fistula	Alive
2	F	1	Bilateral, *Streptococcus pneumoniae*	Glycogen storage disease type IX	4 months	–	Alive
3	F	2	Bilateral, Streptococcus pneumoniae	Sepsis, pseudomem branous colitis	2 months	Right upper lobe resection, closure of right bronchopleural fistula	Alive
4	F	1	Bilateral, *Staphylococus aureus*, *Klebsiella*	RSV bronchiolitis	1 week	–	Alive
5	F	7	Left lung, oropharyngeal flora	ALL	1 week	–	Alive
6	M	10	Bilateral, *Aspergillus*	ALL	1 week	–	Deceased (complication of ALL)
7	M	6	Bilateral, *Aspergillus*	–	1 week	–	Alive
8	F	2	Bilateral, *Legionella pneumophila*	Tetralogy of Fallot	2 week	–	Alive
9	M	0.5	Bilateral *Haemophilus*, *Streptocuccus pneumoniae*	Burns, ARDS	2 week	–	Alive

Table 2 Chest radiographs and CT findings

Chest radiographs						CT							
Patient no.	Gender	Age (years)	Consolidation	Cavities	Parapneumonic effusion	Consolidation	Loss of lung architecture	Decreased enhancement	Cavities	Parapneumonic effusion	Drainage	Bronchopleural fistula	Follow-up
1	M	8	+	+	+	+	+	+	+	+	+	+	Pneumatocele
2	F	1	+	–	+	+	+	+	–	–	+	–	Normal
3	F	2	+	+	+	+	+	+	+	+	+	+	Normal
4	F	1	+	–	–	+	+	+	–	–	+	–	Normal
5	F	7	+	–	–	+	+	+	+	+	+	–	Normal
6	M	10	+	–	–	+	+	+	+	+	–	–	Deceased
7	M	6	–	–	–	+	+	+	–	+	–	–	Normal
8	F	2	+	–	–	+	+	+	–	–	–	–	Pneumatocele
9	M	0.5	+	+	–	+	+	+	+	–	+	+	Normal

features and sequential findings of cavitary necrosis in complicated childhood pneumonia.

Patients and methods

The imaging and medical records of 30 children (14 girls and 16 boys) admitted in the Pediatric Intensive Care Unit of the University Hospitals CHUV and HCUG for parenchymal or pleural complications of pneumonia between 1992 and 1999 were reviewed. The study group consisted of 9 children (5 girls and 4 boys) who underwent CT because of persistent or progressive signs such as respiratory distress or sepsis despite adequate antibiotherapy. The clinical characteristics of the patients are summarized in Table 1. The mean age was 4 years (range 9 months to 10 years). The infectious agent was *Streptococcus pneumoniae* in 4 patients, *Aspergillus* in 2 cases, *Legionella* in 1 case, and *Staphylococcus aureus* in 1 patient. No pathogenic agent could be clearly identified in 1 case with non-specific oropharyngeal flora. The infectious agent was isolated by deep tracheobronchial aspiration through the endotracheal tube in patients with *Streptococcus pneumoniae* pneumonia, and by bronchoalveolar lavage in all other patients. The aspiration and culture of fluid within cavities was performed in 2 patients using all-purpose drainage catheters placed under CT guidance. Two patients were suffering from Tetralogy of Fallot, 2 from acute lymphocytic leukemia (ALL), 1 from glycogen storage disease type 9, two from adult respiratory disease syndrome (ARDS), 1 from respiratory syncitial virus (RSV) infection with bronchiolitis, and 1 patient did not present any underlying medical condition. The CR and CT scans were reviewed in all patients and analyzed by 2 radiologists. The conclusions were reached by consensus. Sequential bedside CR of the patients were reviewed for the presence and distribution of lung consolidation, parenchymal air- or fluid-filled cavities, and pleural effusions. Follow-up CR were also reviewed to look for the persistence or resolution of lesions and for possible postoperative changes. Frontal antero-posterior CR only were available in most patients. The chest CT scans were compared with CR obtained the same day. Helical CT scans were performed on a Highspeed Advantage Scanner (General Electric Medical Systems, Milwaukee, Wis.) after the IV injection of 2 ml/kg of non-ionic contrast medium using 5-mm-thick-slice mediastinal windows and pulmonary reconstructions with lung algorithm. When possible, the breathholding technique was used and scanning was initiated using the Smart-Prep software, or 15 s after the beginning of the injection. The CT criteria for cavitary necrosis were the following: loss of normal parenchymal lung architecture; decreased parenchymal enhancement; and development of multiple thin-walled fluid- or air-filled cavities without enhancing borders. Follow-up CT scans were reviewed to study the evolution of the lesions, the results of pleural drainage, and eventual postoperative changes. When necessary, pleural drainage was performed using 8- to 10-F all-purpose drainage catheter or chest tube.

Results

The radiographs and CT findings of our patients are summarized in Table 2. On CR, 8 of the 9 patients showed consolidations. One patient had consolidation of a single lobe and 7 patients had multilobar and/or bilateral consolidations. On CR, 5 of the 9 patients had cavities. On CT examinations, cavitary necrosis was localized to one lobe in 2 patients and 7 patients showed multilobar or bilateral zones of cavitary necrosis. A pattern of decreased parenchymal enhancement was seen in the areas of cavitary necrosis and varied from homogeneous to patchy low attenuation (Fig. 1). On CR, air–fluid levels were seen in 3 patients and in 4 patients on CT. On CR, a mean number of five cavities were seen in all patients presenting with cavities, contrasting with the multiple cavities seen on CT (Fig. 2). The diameter of the cavities ranged from 5 mm to 7 cm. In 3 patients of 9, the cavitary necrosis was initially shown on CT and visualization by CR was delayed by a time span varying from 5 to 9 days. On CR, 3 patients had parapneumonic effusions and 5 patients on CT. Percutaneous drainage was performed under CT guidance in 5 patients using chest tubes. In 2 patients, additional all-purpose drainage catheters 8–10 F were also placed under CT guidance. Bronchopleural fistulae were demonstrated only by CT in 3 patients (Figs. 3, 4). No purulent pericarditis was demonstrated. Eight children of 9 eventually recovered from the acute illness associated with their pneumonia and 1 patient died from a relapse of his ALL. Two patients underwent a right thoracotomy to close bronchopleural fistulae and resect pneumatoceles. The pathologic examination of the resected lobes revealed purulent lung tissue with areas of necrosis.

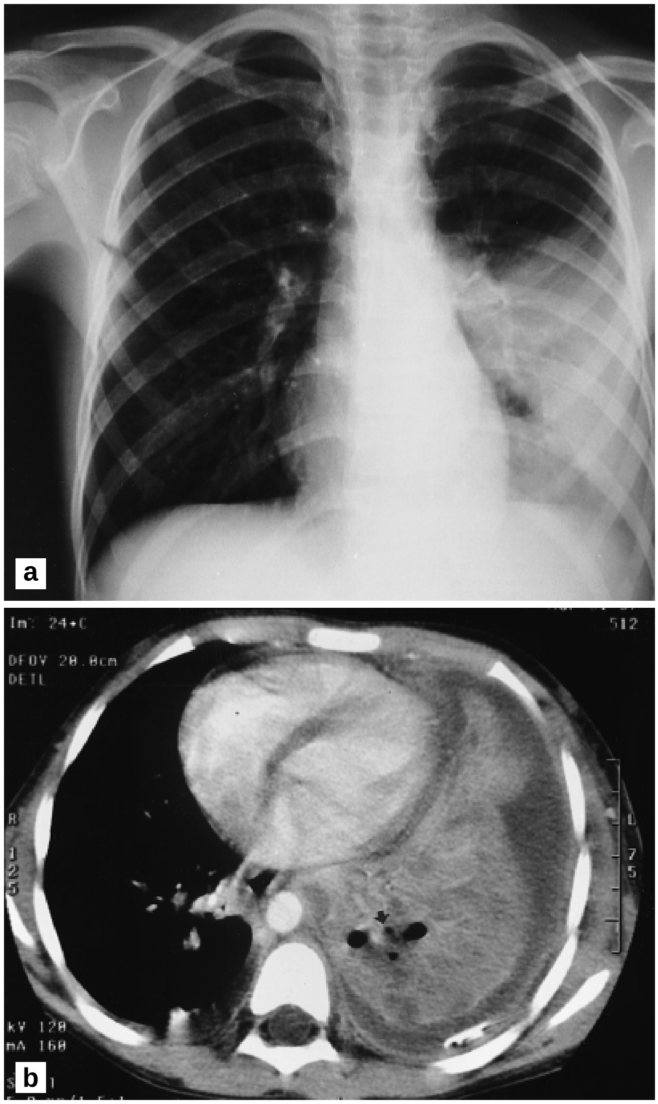

Fig. 1 **a** Chest radiograph shows a left lower lobe air-space consolidation without evidence of cavity. **b** Contrast-enhanced axial CT scan obtained same day as **a** shows numerous areas of low attenuation *(arrow)*, loss of normal lung architecture, and several air- and fluid-filled cavities. A chest tube has been inserted posteriorly to drain a large parapneumonic pleural effusion

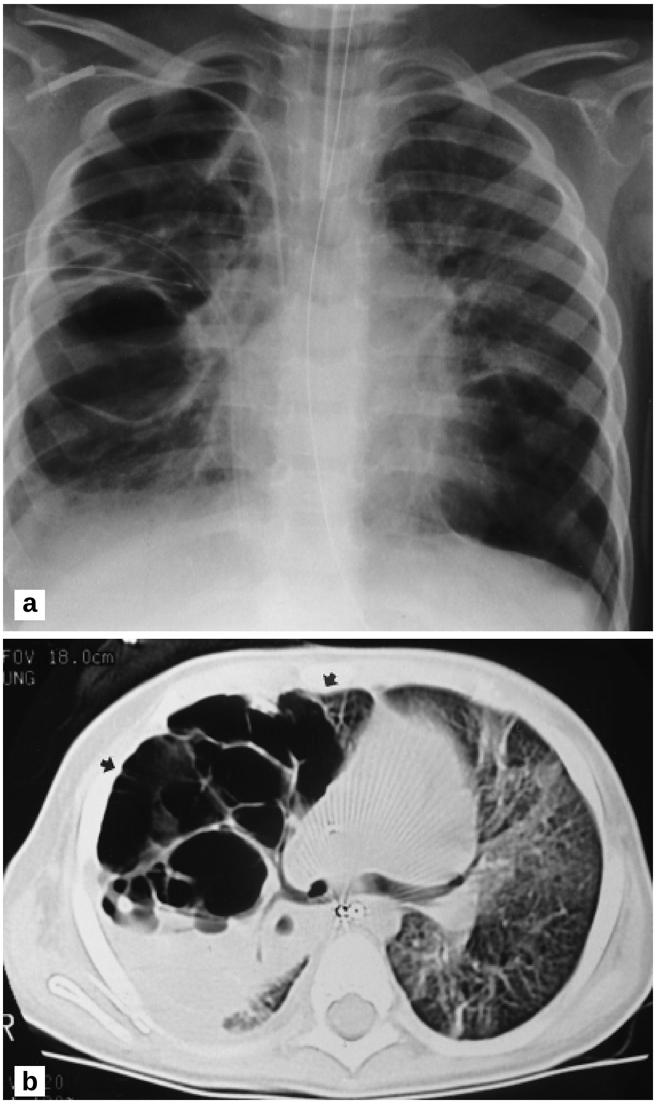

Fig. 2 **a** Bilateral *Streptococcus pneumoniae* pneumonia in a 2-year-old girl. Chest radiograph shows three to four cavities in the right lung. **b** Axial CT scan of the same child shows multiple thin-walled cavities within the anterior and apical segments of the right upper lobe (RUL; *arrows*). The posterior segment is totally consolidated. The patient underwent surgical resection of the RUL

Fig. 3 a, b Bronchopleural fistula complicating *Streptococcus pneumoniae* pneumonia in an 8-year-old boy. **a** Axial CT scan shows cavitary necrosis of the right upper lobe with large central cavity. **b** There is direct communication *(curved arrow)* between the lung and the fluid-filled pleural space. A chest tube has been placed in the cavity *(arrow)*. Note multiple air-filled cavities consistent with pneumatoceles in the left lung

Follow-up radiographs were available for a mean time span of 6 months (range 1–18 months) after initial diagnosis.

Follow-up CT scans, available in 8 patients, were obtained from 12 days to 19 months after diagnosis. On CR, pulmonary opacities decreased and changed from air-space consolidation to linear densities, which completely cleared. The CT scans showed the complete resolution of cavities in 6 patients (Fig. 4). In 2 patients CT scans displayed persistent residual pneumatoceles of the left lower lobe 2 and 4 months, respectively, after initial diagnosis.

Discussion

Suppurative parenchymal complications represent a spectrum of abnormalities such as cavitary necrosis, pulmonary gangrene, lung abscess, pneumatocele, and bronchopleural fistula [1]. Necrotizing pneumonia has been distinguished from lung abscess by the presence of a dominant area of non-enhancing necrosis surrounded by a thin wall or without visible wall in a parenchymal consolidation, rather than the solitary cavity with thick contrast-enhancing walls of an abscess. Necrotizing

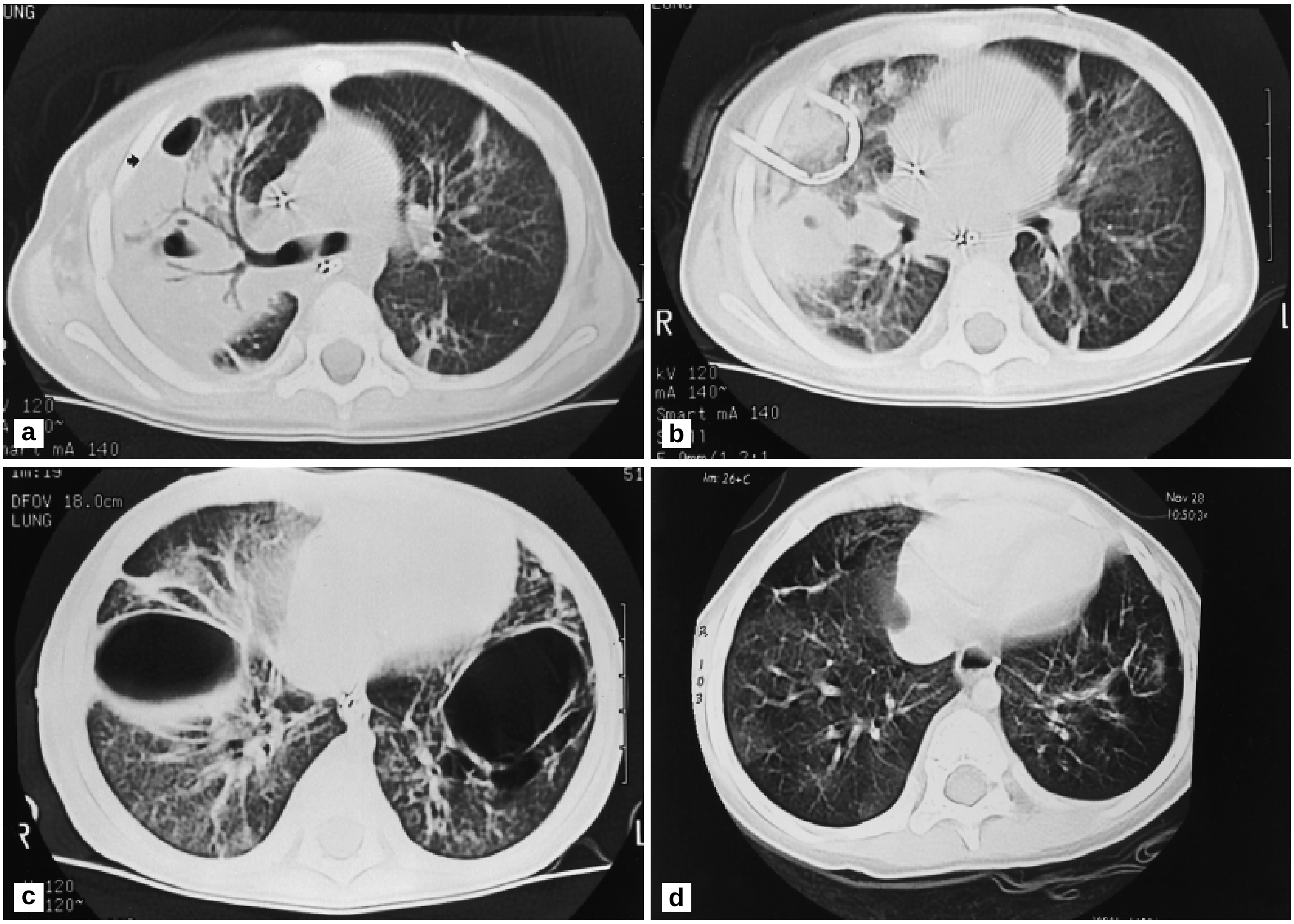

Fig. 4 a–d Sequential findings in a 2-year-old girl with bilateral pneumonia. **a** Axial CT scan shows the development of a cavitary necrosis *(arrow)* of the RUL. **b** An 8-F drainage catheter has been positioned within both areas of lung necrosis. **c** Follow-up CT scan obtained 4 weeks after the initial CT scan shows multiple bilateral residual pneumatoceles, and **d** a striking complete clearing of the lesions on a CT examination performed 19 months later

pneumonitis has been sparsely described in the pediatric population [1, 2, 3, 4] and descriptions are limited to small outbreaks in children and adults [2]. Typically caused by *S. aureus* in the past, necrotizing pneumonia has been more frequently described in recent years as a complication of *Streptococcus pneumoniae* pneumonia. In the adult population, necrotizing pneumonia has been associated with mixed anaerobic infections; however, cavitary necrosis in children has not been proven to be associated with aspiration or mixed anaerobic infections and may occur sporadically [2]. In this series, necrotizing pneumonia has been associated with *Streptococcus* pneumonia in 4 patients, *Aspergillus* in 2 patients, *Staphylococcus aureus* in one and *Legionella* in 1 case. Although necrotizing pneumonia caused by *Aspergillus* has been reported in adults [5], pulmonary necrosis complicating *Aspergillus* or *Legionella* pneumonia has not been reported to date in the pediatric literature. Chest radiographs have been considered accurate in detecting lung parenchymal and pleural disease; however, CR is less sensitive than CT, and only 41 % of the cases detected by CT have been identified on CR in one study [4]. Fluid-filled cavities may have attenuation values similar to adjacent lung consolidations and may be missed by the reader on CR. The ability of CT to identify cavitary necrosis and lung abscess has been reported, and CT may disclose these complications of pneumonia before they become visible on CR [4]. Computed tomography may also detect fluid-filled bowel loops of a diaphragmatic hernia masquerading as pleuropneumonia [5]. Computed tomography is able to show the decrease in parenchymal enhancement characteristic of necrotizing pneumonia and to detect fluid-filled cavities without air occurring when the necrotic lung first liquefies, thus explaining the previous detection rate on CT scans [1, 4]. In our series, the delay between identification of necrotizing pneumonia by CT and visualization by CR varying from 5 to 9 days is consistent with data from the literature [1, 4]. In addition, CT only showed bronchopleural fistulae in 3 of our patients. Recently, the role of MR imaging in the early diagnosis of necrotizing pneumonia not shown on CT has been reported in the adult population [6]. The pathogenesis of necrotizing pneumonia is still discussed and thrombotic occlusion of alveolar capillaries associated with adjacent inflammation is believed to cause ischemia and subsequent necrosis [4, 7]. This mechanism could explain the decreased enhancement seen on contrast CT, which is related to developing ischemia and infarct. In our series, there was no focal bronchial or esophageal predisposition visible on CT. Uncompletely drained parapneumonic effusions with persistent loculated effusions were a source of recurrent episodes of fever and sepsis in our series as well as in other reported series [1, 4, 7, 8, 9, 10, 11, 12]. Children with cavitary necrosis are severely ill and most require admission to intensive care units, as did all our patients. Despite the intensity of the illness, 2 patients only required surgical resection and 1 patient died of the combined complications of ALL and necrotizing pneumonia. A temporal pattern of resolution was seen on CR with progressive resolution of the cavities. Follow-up CT scans confirmed the complete resolution of the consolidations and cavities in 6 of 8 patients, or uncomplicated post-operative findings in the 2 patients requiring surgery. Despite a high mortality rate in adults, surgical resection of cavitary necrosis is rarely indicated. The follow-up CT findings in our series support also the opinion that the presence of cavitary necrosis complicated pneumonia in children is not an absolute indication for surgical resection [4, 7, 8, 9, 10,11, 12].

In conclusion, we think that CT is more sensitive than CR in detecting cavitary necrosis, when the early detection of cavitary necrosis influences the patient's monitoring, duration of treatment, and follow-up. Even if long-term follow-up CR is not considered necessary in children, CT may also help in detecting the rare long-term non-specific sequelae such as persistent pneumatoceles [13].

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