Surgical treatment of children with necrotizing pneumonia*

Tratamento cirúrgico de crianças com pneumonia necrosante

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Abstract

Objective: To describe the results of the surgical treatment of children with necrotizing pneumonia. **Methods:** A retrospective analysis of the medical charts of 20 children diagnosed with necrotizing pneumonia and submitted to surgical treatment between March of 1997 and September of 2008 in the thoracic surgery departments of two hospitals in the city of Manaus, Brazil. We compiled data regarding age, gender, etiologic agent, indications for surgery, type of surgical resection performed, and postoperative complications. **Results:** The mean age of the patients was 30 months. Of the 20 patients studied, 12 (60%) were female. The most common etiologic agents were *Staphylococcus aureus*, in 5 patients (25%), and *Klebsiella sp.*, in 2 (10%). The indications for surgery were sepsis, in 16 patients (80%), and bronchopleural fistula, in 4 (20%). The types of surgical procedures performed were lobectomy, in 12 patients (60%), segmentectomy, in 7 (35%), and bilobectomy, in 1 (5%). There were 8 patients (40%) who also underwent decortication. The postoperative complications were as follows: bronchopleural fistula, in 4 patients (20%); empyema, in 1 (5%); pneumatocele, in 1 (5%); and phlebitis of the left arm, in 1 (5%). Four (20%) of the patients died. **Conclusions:** Surgical resection should be considered in patients with evidence of pulmonary necrosis. Resection is indicated in cases of severe sepsis, high output bronchopleural fistula, or acute respiratory failure that are refractory to clinical treatment.

Keywords: Pneumonia; Necrosis; Lung abscess; Empyema, pleural.

Resumo

Objetivo: Descrever os resultados do tratamento cirúrgico de crianças com pneumonia necrosante. **Métodos:** Análise retrospectiva dos prontuários de 20 crianças diagnosticadas com pneumonia necrosante e submetidas ao tratamento cirúrgico nos serviços de cirurgia torácica de dois hospitais na cidade de Manaus (AM) entre março de 1997 e setembro de 2008. Dados referentes a idade, sexo, agente etiológico, motivos da indicação cirúrgica, tipo de ressecção cirúrgica realizada e complicações pós-operatórias foram compilados. **Resultados:** Dos 20 pacientes analisados, 12 (60%) eram do sexo feminino. A média de idade dos pacientes foi de 30 meses. Os agentes etiológicos mais encontrados foram *Staphylococcus aureus*, em 5 pacientes (25%), e *Klebsiella sp.*, em 2 (10%). Os motivos de indicação cirúrgica foram sepse, em 16 pacientes (80%), e fístula broncopleural, em 4 (20%). Os tipos de procedimentos cirúrgicos realizados foram lobectomia, em 12 pacientes (60%), segmentectomia, em 7 (35%), e bilobectomia, em 1 (5%). Além desses procedimentos, 8 pacientes (40%) foram submetidos à descorticação pulmonar. As complicações pós-operatórias foram as seguintes: fístula broncopleural, em 4 pacientes (20%); empiema, em 1 (5%); pneumatocele, em 1 (5%); e flebite em membro superior esquerdo, em 1 (5%). Quatro pacientes (20%) morreram. **Conclusões:** Pacientes com evidências de necrose pulmonar devem ser considerados para a ressecção cirúrgica, que está indicada em casos graves de sepse, fístula broncopleural de alto débito ou insuficiência respiratória aguda que não respondem ao tratamento clínico.

Descritores: Pneumonia; Necrose; Abscesso pulmonar; Empiema pleural.

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Introduction

Necrotizing pneumonia (NP) is a rare complication of pulmonary infection in children that has become more prevalent since the introduction of antibiotics.[1] The terms "pulmonary gangrene", "lung abscess", and "NP" refer to extensive damage to the lung parenchyma, affecting an entire segment or lobe.[2] More specifically, NP can be defined as the consolidation of a lung segment with necrosis in its periphery, forming multiple cavities that can be seen on axial chest CT scans.[3]

The pathophysiology of pulmonary necrosis has yet to be clearly defined. It is believed that the process begins with the development of an invasive infection in a susceptible patient, with one or more risk factors, such as inappropriate immune response, massive inoculation, and more virulent bacteria. Thrombosis of the pulmonary capillaries and of the central vessels, accompanied by filling of the alveoli with inflammatory remnants, is the major factor involved in the reduction in oxygen supply to the affected segment.[2] Obstruction of blood flow to the proximal bronchus makes it difficult for the antibiotic to reach the affected region, as well as leading to the progressive destruction and loss of the lobar architecture, followed by septicemia and, possibly, the development of a bronchopleural fistula (BPF).[3]

Unlike what occurs in adults, NP has a good prognosis in children, typically resolving completely with clinical treatment alone.[4] However, a small number of patients might require invasive procedures and even surgical treatment involving resection of part of the lung parenchyma.[5,6]

The objective of the present study was to describe the results of the surgical treatment of NP in patients with an infectious process that is refractory to clinical treatment or with bronchopleural complications.

Methods

This was a retrospective study in which we analyzed the medical charts of children submitted to surgical treatment between March of 1997 and September of 2008 at the Getúlio Vargas University Hospital and at the Portuguese Beneficent Society Hospital, both located in the city of Manaus, Brazil. We collected data regarding epidemiological profile, etiology, and patient clinical status.

The diagnosis of NP was confirmed on the basis of the clinical and tomographic profile of the patients. Patients with NP were defined as those with progressive pneumonia, unresolved despite the use of ideal antibiotic therapy, accompanied by laboratory findings consistent with an inflammatory process, such as high levels of C-reactive protein, and the following axial CT features: area of consolidation without volume loss; radiolucency in this area; and single or multiple irregular pneumatoceles, without air-fluid level or abscess formation.

The criterion used for thoracotomy candidacy was the persistence of the infectious process with the development of sepsis, accompanied by tomographic findings consistent with NP or with its complications, such as high-output BPF or pleural empyema.

The type of surgical resection was decided upon at the time of the exploratory thoracotomy and was always as conservative as possible, its extent being determined by the severity of the case and the urgency of the need to operate. When necessary, decortication was performed and the pleural cavity was washed. All of the surgical specimens were sent for histopathological examination.

The patients were assessed for age, gender, etiology, clinical status, indications for surgery, diagnostic method, type of resection, postoperative evolution, complications, and length of hospital stay.

An exploratory descriptive analysis of the data was performed with Excel 2007.

The study was approved by the Research Ethics Committee of the Federal University of Amazonas (CAAE 0286.0.115.000/07).

Results

Of a total of 103 patients with pleuropulmonary infection treated in the thoracic surgery departments of the two hospitals, 20 underwent lung resection for the treatment of NP. Of those 20 patients, 12 (60%) were female. The average age of the patients was 30 months (range: 10-48 months). At the time of admission, all 20 patients had productive cough, fever, signs of respiratory distress, and areas of pulmonary consolidation on chest X-rays. In 15% (75%) of the patients, the suspicion of NP was initially based on chest

X-ray findings of cavities. All of the patients underwent axial chest CT, which revealed multiple cavities of different sizes, indicating necrosis of the lung parenchyma. The average length of preoperative hospital stay was 10 days. The principal clinical characteristics, as well as the principal radiographic and tomographic findings, are shown in Table 1.

In 11 patients (55%), the etiologic agent was identified by culture of pleural liquid and remnants. The most common etiologic agents were *Staphylococcus aureus*, which was identified in 5 cases (25%), and *Klebsiella* sp., which was identified in 2 (10%). The other identified etiologic agents were *Micrococcus* sp., β-hemolytic streptococci, *Staphylococcus epidermidis*, and *Mycobacterium tuberculosis*, the last having been identified on the basis of the histopathological findings in the surgical specimen (Table 2).

Sepsis was the indication for surgery in 16 patients (80%), of whom 3 also had BPF and 8 also had empyema. In 4 patients (20%), BPF was the sole indication for surgery (Table 2).

The types of surgical procedures performed were as follows: lobectomy, in 12 patients (60%); segmentectomy, in 7 (35%); and bilobectomy, in 1 (5%). There were 8 patients (40%) who also underwent decortication (Table 2).

The postoperative care of the NP patients submitted to resection was performed in accordance with the general principles of postoperative management in thoracic surgery, with attention to early extubation and to ventilation controlled by low volume and low positive end-expiratory pressure in order to prevent hyperdistension of the remaining pneumatoceles.

The most common postoperative complication was persistent air leak through a BPF, which occurred in 4 patients (20%), all of whom had undergone segmentectomy. The other complications were as follows: pneumatocele, in 1 patient (5%); empyema, in 1 (5%); and phlebitis of the left arm, in 1 (5%). There were 9 patients (45%) who had no postoperative complications and were discharged, on average, on postoperative day 10 (Table 2). Figures 1, 2, and 3, respectively, show the radiographic, tomographic, and surgical findings in 1 patient submitted to resection of segment VI.

Table 1 - Principal clinical characteristics, radiographic findings, and tomographic findings.[a]

Variable	Value
Age, months[b]	30 (10-48)
Female gender	12 (60)
Preoperative sepsis	16 (80)
Preoperative bronchopleural fistula	8 (40)
Postoperative bronchopleural fistula	4 (20)
Preoperative empyema	8 (40)
Preoperative mechanical ventilation	12 (60)
Length of preoperative hospital stay, days[b]	10 (3-21)
Length of postoperative hospital stay, days[b]	10 (2-60)
Radiographic findings	
Consolidation	20 (100)
Cavity	15 (75)
Pleural effusion	8 (40)
Tomographic findings	
Consolidation	20 (100)
Loss of architecture	14 (70)
Cavity	20 (100)
Pleural effusion	13 (65)

[a]Values expressed as mean (%), except where otherwise indicated.
[b]Values expressed as mean (range).

There were 4 in-hospital deaths (20%). The first death was from acute respiratory failure (ARF) and occurred on postoperative day 2; the second was from meningitis and occurred 60 days after the surgical procedure, although the patient was still hospitalized; the third was from cardiopulmonary arrest and occurred on postoperative day 7; and the last was from hyperdistension of a contralateral pneumatocele and occurred on postoperative day 3, while the patient was still on invasive ventilation (Table 2).

The histopathological analysis of all of the surgical specimens revealed necrosis of the lung parenchyma accompanied by thrombosis in the pulmonary artery branches.

Discussion

Necrosis of the lung parenchyma was originally designated "pulmonary gangrene", a term used to describe a necrotic mass in the pleural cavity.[2] Currently, the terms "pulmonary gangrene" and "lung abscess", despite being frequently used as synonyms for NP, refer to entities that are separate from NP. Whereas NP is defined as an area of pulmonary consolidation with peripheral necrosis, containing multiple and small cavities, lung abscess is defined as

Table 2 - Epidemiological characteristics, indications for thoracotomy, type of surgical procedure performed, and postoperative complications in the patients studied.

Patient	Age, months	Gender	Etiologic agent	Indication	Types of surgery	Complication
1	28	M	*Staphylococcus aureus*	BPF, ARF	Lobectomy (LUL)	None
2	21	F	*S. aureus*	Sepsis, BPF, ARF	Lobectomy (RLL)	BPF
3	22	M	β-hemolytic streptococci	BPF, ARF	Segmentectomy (RUL and RLL)	BPF
4	10	F	*S. aureus*	Sepsis, BPF, ARF	Segmentectomy (LUL and LLL)	Death from ARF
5	33	F	No growth	ARF, empyema	Left segmentectomy + decortication	None
6	40	F	*Micrococcus* sp.	ARF, empyema	Lobectomy (RLL) + decortication	None
7	43	F	*S. epidermidis*	ARF, sepsis, empyema	Lobectomy (ML)	None
8	26	F	*S. aureus*	BPF, empyema	Lobectomy (LLL)	None
9	48	F	No growth	Sepsis, BPF, ARF	Segmentectomy (LUL) + decortication	Pneumatocele
10	12	M	No growth	ARF, sepsis, empyema	Lobectomy (RUL) + decortication	BPF
11	28	F	*Klebsiella* sp.	ARF, sepsis, empyema	Bilobectomy (ML and RLL)	Death from meningitis
12	31	M	*Klebsiella* sp.	ARF, sepsis	Lobectomy (RUL) + decortication	Empyema
13	33	M	No growth	ARF, sepsis	Left segmentectomy + decortication	None
14	26	F	No growth	ARF, sepsis, empyema	Lobectomy (LUL)	None
15	24	M	No growth	BPF	Lobectomy (RUL) + decortication	None
16	48	M	*Mycobacterium tuberculosis*	ARF, HUS, sepsis, BPF	Anterior segmentectomy (RUL)	BPF
17	48	M	No growth	Sepsis, empyema	Lobectomy (LLL) + decortication	Phlebitis of the LA
18	19	F	MRSA	Empyema, sepsis	Lobectomy (ML)	None
19	43	F	No growth	Empyema, sepsis	Right segmentectomy + decortication	Death from CPA
20	18	F	No growth	Sepsis	Lobectomy (LUL)	Death from hyperdistension of a contralateral pneumatocele

M: male; F: female; MRSA: methicillin-resistant *Staphylococcus aureus*; BPF: bronchopleural fistula; ARF: acute respiratory failure; HUS: hemolytic uremic syndrome; LUL: left upper lobe; LLL; left lower lobe; ML: middle lobe; RUL: right upper lobe; RLL: right lower lobe; LA: left arm; and CPA: cardiopulmonary arrest.

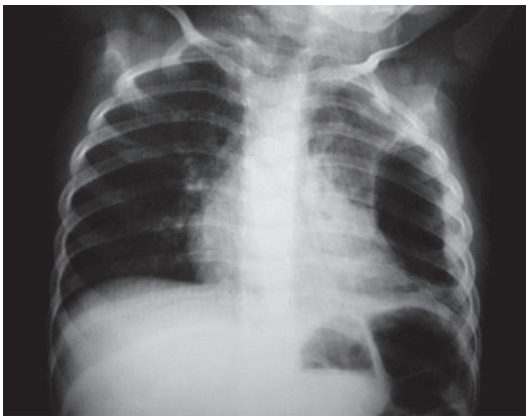

Figure 1 - Chest X-ray revealing a pneumatocele and small air-filled cavities in the lower third of the left lung, as well as obliteration of the costophrenic sulcus.

a single and more extensive cavitary lesion.[1] Pulmonary gangrene occurs as a complication of NP due to obstruction of the central or bronchial circulation, leading to liquefaction of tissue and to the presence of necrotic remnants or fragments of lung parenchyma in the liquefied material.[3,7]

Chest pain, signs of respiratory distress, persistent fever, a worsening of the clinical status, and new complications secondary to pneumonia despite the use of optimal antibiotic therapy are all suggestive of pulmonary necrosis.[6,8,9] In patients meeting any of those criteria, axial chest CT is indicated, even if chest X-rays reveal no abnormalities, since chest X-rays have low sensitivity and early findings characteristic of necrotic complications are rare.[8-10] The most characteristic axial chest CT findings in NP are areas of lower density and multiple cavities, with or without air-fluid level, that can coalesce and form a single, extensive cavity.[10,11] In the present study, all of the patients underwent axial chest CT, and the most common finding was multiple cavities. In 75% of the patients, these cavities were seen on chest X-rays taken before axial CT.

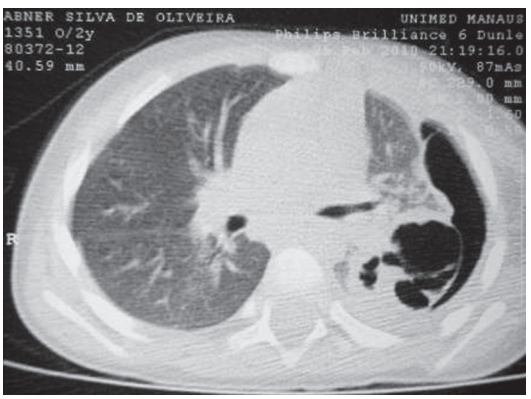

Figure 2 - Axial chest CT scan showing multiple cavities of various sizes, as well as pneumothorax, in the middle and lower third of the left hemithorax.

Identifying the etiologic agent responsible for severe, rapidly progressive pneumonia could improve antibiotic therapy strategies. However, this is not always possible. The most widely used techniques are blood culture and pleural fluid analysis in cases in which there is accompanying pleural effusion. In both methods, the result is positive in a variable percentage of cases, depending on the etiologic agent, the age of the patient, and the prior use of antibiotics. In practice, the main impediment to isolating the pathogen is the prior use of antibiotics.[12] The adoption of invasive methods, such as bronchoscopy, to obtain material for bacteriological study remains controversial.[4]

In the past, the etiologic agents most commonly involved in the development of pulmonary necrosis were *S. aureus*, gram-negative bacteria (such as *K. pneumoniae* or *Pseudomonas aeruginosa*), and anaerobic agents, all of which are considered rare in previously healthy patients with community-acquired pneumonia.[1,8,13] More recently, there has been a significant increase in the number of cases of pulmonary necrosis caused by community-acquired *Streptococcus pneumoniae*, a condition that used to be considered rare, especially in children.[10,14-16] In the present study, the most common pathogens were *S. aureus* and *Klebsiella* sp. We also identified cases of NP caused by *Micrococcus* sp., β-hemolytic streptococci, *S. epidermidis*, and *M. tuberculosis*. We found no cases of pneumococcal infection.

Because it can be caused by methicillin-resistant or methicillin-susceptible strains, staphylococcal NP can occur even in immunocompetent individuals and in those with community-acquired pneumonia. In either case, the tendency is toward severe pneumonia, with high mortality, especially in the presence of ARF.[17,18] In the present study, we identified one case of NP caused by methicillin-resistant *S. aureus* and one death from ARF-induced staphylococcal NP.

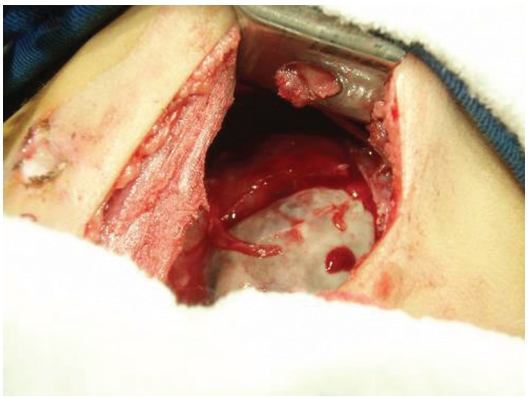

Figure 3 - Intraoperative photograph of the necrotic tissue in the superior segment of the left lower lobe, contrasting with that of the viable parenchyma.

Infections with *Klebsiella* sp. are rare in young, previously healthy patients. This bacterium is known to express various virulence factors that allow the development of different invasive forms of infection, including pneumonia, liver abscess, meningitis, and endophthalmitis. However, it is the individual characteristics of the host that define the clinical manifestations of the infectious process. In some cases, genotypically related strains would be able to cause pneumonia concomitantly with liver abscess or meningitis.[19] In the present study, one of the patients with NP attributed to *Klebsiella* sp. died from meningitis.

Chief among the complications of NP are complicated parapneumonic effusion, the development of empyema with trapped lung, the formation of a BPF, and the formation of pneumatoceles.[1,6] Whereas a BPF results from the expansion of NP toward the periphery of the necrotic lung adjacent to the pleura,[6] pneumatoceles arise from a valvular mechanism at the level of the distal bronchiole that leads to air trapping in the distal alveolar spaces and to the destruction of the alveolar walls, forming single or multiloculated, thin-walled cystic cavities, usually without air-fluid levels.[20] In our study, 40% of the patients had a preoperative BPF and 50% had preoperative empyema. In the postoperative period, pneumatoceles occurred in 2 patients, one of whom developed hyperdistension during mechanical ventilation and died.

The surgical treatment of NP remains a controversial issue in the literature. Whereas some authors recommend surgery only as an alternative to optimal antibiotic therapy in order to prevent septic complications and death, others advocate early resection of the damaged tissue.[3,18] Despite these differences, it is known that complete resolution of pulmonary necrosis requires appropriate antibiotic therapy together with removal of all necrotic remnants.

Some authors recommend that the treatment of pulmonary infections be conservative and that invasive procedures be performed only if the child remains seriously ill and the infection is refractory to antimicrobial therapy. Surgery is considered to be the last resort in the treatment of pulmonary abscess and NP, being reserved for cases in which less invasive procedures are ineffective.[4] In contrast, other authors advocate that, once a necrotic process is diagnosed, the impaired segment or lobe should be resected promptly, especially in cases in which there is a high output BPF and ARF.[21] In the present study, the major indications for exploratory thoracotomy were as follows: BPF; ARF; sepsis; and empyema with trapped lung.

After the surgical procedure has been scheduled, all of the necrotic material should be removed. In cases in which lung parenchyma resection is chosen, it is preferable that the procedure be performed early, while the disease is still localized. Massive necrosis of multiple lung segments or of the entire lung calls for pneumonectomy, since the diseased lung can act as an additional source of infection, resulting in damage to the healthy lung.[4] Lung resection in the presence of empyema is associated with a higher incidence of postoperative complications, especially BPF,[18] which was found in 4 of our patients, all of whom had undergone segmentectomy. One of those 4 had preoperative empyema.

In a recent study involving 131 patients undergoing surgery for the treatment of pleural empyema, 36 cases of NP were reported, although the extent of the pulmonary necrosis was not reported and the authors chose to preserve the necrotic tissue.[22] In contrast, most of the patients (80%) in our sample underwent more extensive lung resection, because the area of necrosis always encompassed a segment or the entirety of a lung lobe. Another group of authors also cases of NP that required more extensive lung resection.[23]

It has recently been proposed that video-assisted thoracic surgery can be an effective diagnostic and therapeutic procedure in suspected cases of NP. This procedure can be used for debridement, excision of necrotic tissue, and drainage of the chest, being as efficient as is open lung thoracotomy and having the advantage of being associated with less postoperative pain, better aesthetic results, and shorter hospital stays.[24]

Surgical results depend on the extent of the disease and on patient clinical status. In comparison with localized forms, extensive areas of necrosis are associated with higher mortality.[3] In the present study, the mortality rate was 20%, which is higher than that reported in other studies.[6,9,24] However, two of the deaths were from causes unrelated to the surgical procedure. One occurred 60 days after surgery and was attributed to meningitis. The other occurred on postoperative day 7, when the patient had already been discharged from the semi-intensive care unit and the chest tube had already been removed. In that case, no autopsy was performed and the cause of death therefore remained unknown. In some cases, dire circumstances related to complications of NP call for emergency surgical procedures, despite the high rates of morbidity and mortality associated with such interventions.[18,25]

In conclusion, we underscore the idea that, for the early detection of necrosis of the lung parenchyma, axial chest CT should be performed in children with pneumonia who also present with persistent fever, worsening of clinical status, or pleural complications despite the use of appropriate antimicrobial therapy. Once a diagnosis of NP has been confirmed, patients should be evaluated for the possibility of surgical resection of the damaged segment in order to improve the prognosis. For NP patients with septicemia, a high output BPF, or ARF, emergency surgery is indicated, although the associated rates of morbidity and mortality rates are high.

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