Emergent Pneumonectomy for Lung Gangrene: Does the Outcome Warrant the Procedure?

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Background. Sloughing and gangrene of a complete lung are only very infrequently encountered complications of necrotizing pneumonia and fulminating pulmonary abscess formation. Thus far the role of emergent pneumonectomy is not established.

Methods. The outcome of patients who underwent anatomic lung resection for lung gangrene at 3 centers for thoracic surgery during the last 13 years was retrospectively analyzed. Only cases of necrotizing pneumonia were included whereas malignant lesions were excluded.

Results. Overall 44 patients were indentified (average age 56.3 years). Pulmonary sepsis (27 of 44), pleural empyema (29 of 44), persistent air leakage (14 of 44), and respiratory failure with mechanical ventilation (14 of 44) were present preoperatively. The mean Charlson comorbidity index was 2.77. Procedures were segmentectomy (7), lobectomy (26), and pneumonectomy (11). In-hospital mortality was 7 of 44; 2 following pneumonectomy and 5 after lobectomy. In comparing the pneumonectomy group with the lobectomy group we found no significant differences in age ($p = 0.59$), Charlson comorbidity index ($p = 0.18$), and postoperative mortality ($p = 1$). Charlson comorbidity index 3 or greater (odds ratio [OR], 8.41; 95% confidence interval [CI], 0.88 to 421.71; $p = 0.04$), preoperative pleural empyema (OR, 3.56; 95% CI, 0.37 to 179.62; $p = 0.39$) and preoperative persistent air leak (OR, 7.34; 95% CI, 1.00 to 89.98; $p = 0.02$) were associated with higher risk for fatal outcome. Furthermore, patients with sepsis ($p = 0.03$) and patients sustaining acute renal failure ($p = 0.04$) had significantly higher mortality.

Conclusions. Pulmonary sepsis and its complications as well as preexisting comorbidity are the major reasons for fatal outcome, whereas the extent of surgical resection shows no significant influence. Emergent pneumonectomy as ultimate ratio is not only justified but also life saving. Further improvement seems achievable by earlier surgical intervention before the onset of pulmonary sepsis.


As a consequence cavitation, abscess formation, and eventually gangrene of the lung take place and cause the disintegration of a pulmonary lobe or even the sloughing of an entire lung. In general, patients who are already suffering from conditions associated with immunodeficiency as severe comorbidity, malnutrition, alcoholism, or diabetes mellitus are affected by such a devastating deterioration of pulmonary infections. While initial medical and supportive treatment is uncontested there are no well-established indications for surgical intervention. Moreover, successful operative therapy is considerably hampered by patient-related factors as poor performance status, respiratory failure, pulmonary sepsis, and the extent of lung necrosis which determines the required range of pulmonary resection.

Surgical drainage procedures, atypical resections, and even limited anatomic resections as segmentectomy and lobectomy are more or less accepted by most chest physicians and thoracic surgeons. However, there exists substantial diversity of opinion regarding the role of
emergent pneumonectomy. There has as yet been no sustained analysis of emergent pneumonectomy as ultimate treatment option in case of gangrene of a complete lung; this study is intended to address that void.

Material and Methods
In a retrospective analysis we reviewed all cases of anatomic lung resection for necrotizing lung disorders of infectious origin as necrotizing pneumonia, pulmonary abscess formation, and lung gangrene. As these conditions are part of a spectrum of disease that is defined by the degree of inflammation as well as by the degree of parenchymal destruction, it seems justified to include these conditions into one study [5]. Pulmonary sepsis was defined as a sepsis with pulmonary source. Massive or fulminant abscess formation meant development of a large abscess or multiple abscesses with liquefaction of an extensive range of lung parenchyma. Pulmonary gangrene was defined as irreversible sloughing and devitalization of either a complete lobe or an entire lung [5]. Malignant disorders including abscess formation due to necrotic lung carcinoma were strictly kept out.

Three high-volume centers for thoracic surgery from Europe and the United States contributed to the study. The patients underwent surgery either at the Klinikum Nuremberg (Nuremberg, Germany), the PeaceHealth Southwest Medical Center (Vancouver, WA), or at the Hospital Universitario Virgen de las Nieves (Granada, Spain). The Klinikum Nuremberg is one of Germany’s largest tertiary referral hospitals, serving approximately half a million people and performing approximately 120 lobectomies for lung cancer each year. The Hospital Universitario Virgen de las Nieves is part of the University of Granada and is a major provider for thoracic surgery in southern Spain. The PeaceHealth Southwest Medical Center is a key supplier of sophisticated thoracic surgery for Vancouver (WA) and the populous Southwest Washington region.

During the last decades the perioperative management, intensive care as well as the surgical techniques in modern thoracic surgery, have considerably been improved. As this development is supposed to have substantial influence on the outcome of a procedure as emergent pneumonectomy we only included our recent experience into the analysis. The study period was between January 2000 and June 2013 to avoid bias due to outdated treatment approaches. A local ethics committee approved the study and the need for written consent was waived because of the retrospective study design.

Operative Technique
The series comprises only cases of anatomic lung resection as segmentectomy (with dissection and ligation of individual hilar structures), lobectomy, and pneumonectomy. All patients received general anesthesia with a double lumen endotracheal tube for one-lung ventilation and were placed in a lateral decubitus position. Posterior thoracotomy was routinely carried out to provide free access to all parts of the affected pleural cavity. Standard surgical equipment was used. The bronchus was closed with a commercial stapling device (TA 30-4.8 mm reloadable stapler, Covidien AutoSuture; Covidien, Mansfield, MA) and reinforced with interrupted stitches distal to the staple line. After pneumonectomy the bronchial stump was routinely covered with a large and viable muscle flap using either the latissimus dorsi or the serratus anterior muscle [6]. In case of lobectomy or segmentectomy the decision for reinforcement of the bronchial stump was based on the intraoperative findings as the extent of pulmonary gangrene and pleural empyema. As an alternative, pericardial fat pad flaps were occasionally used to protect and cover the bronchial staple line in lobectomy cases with only moderate signs of pleural empyema [7].

Postoperative Care
Postoperatively all patients were treated at the intensive care unit and received the full range of sepsis therapy, including hemodynamic monitoring and management, antibiotic therapy, hemofiltration in case of renal failure, and differentiated mechanical or noninvasive ventilation in case of respiratory failure. Spontaneous breathing was rated very high and extubation was performed as soon as possible. If prolonged ventilatory support was unavoidable tracheotomy was performed early in the postoperative period. In case of pleural empyema irrigation of the affected pleural cavity with Ringer solution was carried out twice daily through the inserted chest tubes. Moreover, all sufferers received intensive physiotherapy including inhalations with positive airway pressure to improve the pulmonary function.

Statistical Analysis
Statistical analysis was performed using R language and environment (R Foundation for Statistical Computing, Vienna, Austria; http://www.r-project.org). The independence of the studied variable pairs was tested with the Fisher exact test.

Results
A total of 44 patients were included into the study. The mean age was 56.3 years and there were 37 men and 7 women. Most patients suffered from severe pre-existing comorbidity. As a consequence, the mean Charlson comorbidity index score reached 2.77 (0 to 12) and the Charlson combined age and comorbidity score was averagely 4.21 (0 to 13) [8–10]. Chronic alcoholism (21 cases) and intravenous drug abuse (4) were also frequently encountered.

In general the right lung was more often affected than the left side. Gangrene of the entire right lung took place in 7 patients [Fig 1] and the right lower, middle, and upper lobes were affected in 11, 4, and 8 cases, respectively. Complete gangrene of the left lung was encountered in 4 cases. Moreover necrosis of either the left upper (3) or lower lobe (7) occurred in 10 patients.

Initially, all sufferers received nonoperative management at various medical departments and intensive care
units whereas thoracic surgeons were usually not consulted during the initial treatment phase. Nonoperative management included medical treatment of pneumonia, endoscopic interventions, thoracocentesis, chest drainage insertion, intensive care, and ventilatory support. In general, the patients were only referred for thoracic surgery after all these nonoperative efforts had failed. As a consequence, most patients already suffered from far advanced septic disease when they were supposed to undergo surgery. Pulmonary sepsis was already present in 27 patients at that time and pleural empyema had occurred in 29 cases. A persistent air leak with pneumothorax in consequence of perforated lung abscess or advanced sloughing of lung tissue was encountered in 14 cases. Furthermore, 14 patients had already preoperatively sustained respiratory failure and needed mechanical ventilation.

**Microbiologic Findings**

Intraoperatively, microbial samples were obtained from all patients. Tissue from the affected part of the lung as well as samples of pleural fluid and empyema were routinely collected and sent for microbiology examination. The microbial findings were available for 41 cases. A negative culture with “no growth” was seen in 6 patients. Multiple infectious agents were cultured in 24 cases [Table 1]. Fungal infections occurred in 13 patients and were mostly part of a polymicrobial disease. The most common Gram-positive bacteria were *Staphylococcus* and *Streptococcus* (α-hemolytic as well as β-hemolytic) [Table 1]. *Pseudomonas aeruginosa*, *Enterococcus*, and *Acinetobacter* were the most frequent Gram-negative bacteria. *Aspergillus* and *Candida* species were the cause for fungal infections.

**Indications for Surgery**

As pointed out above, the indication for surgery was always failed nonoperative management. Indications included critical deterioration of the patient’s clinical condition despite the full range of nonoperative therapy, persistent air leak with respiratory failure, and advanced pleural empyema. Furthermore, pulmonary sepsis, septic organ failure (renal or respiratory failure), and occurrence

### Table 1. Microbiology Findings

<table>
<thead>
<tr>
<th>Infectious Agent</th>
<th>Number of Positive Cultures</th>
</tr>
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<tbody>
<tr>
<td><strong>Gram-positive bacteria</strong></td>
<td></td>
</tr>
<tr>
<td><em>Streptococcus</em> (alpha- and beta-hemolytic)</td>
<td>11</td>
</tr>
<tr>
<td><em>Staphylococcus</em> (aureus, et al)</td>
<td>7</td>
</tr>
<tr>
<td><em>Enterococcus</em> (faecium, faecalis)</td>
<td>6</td>
</tr>
<tr>
<td><em>Corynebacterium</em> species</td>
<td>1</td>
</tr>
<tr>
<td><em>Mycobacterium intracellulare</em></td>
<td>1</td>
</tr>
<tr>
<td><strong>Gram-negative bacteria</strong></td>
<td></td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>7</td>
</tr>
<tr>
<td><em>Acinetobacter</em></td>
<td>5</td>
</tr>
<tr>
<td><em>Klebsiella pneumoniae</em></td>
<td>5</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>4</td>
</tr>
<tr>
<td><em>Fusobacterium necrophorum</em></td>
<td>2</td>
</tr>
<tr>
<td><em>Citrobacter</em></td>
<td>1</td>
</tr>
<tr>
<td><em>Enterobacter aerogenes</em></td>
<td>1</td>
</tr>
<tr>
<td><em>Proteus mirabilis</em></td>
<td>1</td>
</tr>
<tr>
<td><em>Hafnia alvei</em></td>
<td>1</td>
</tr>
<tr>
<td><em>Fungi</em></td>
<td></td>
</tr>
<tr>
<td><em>Aspergillus</em> species</td>
<td>7</td>
</tr>
<tr>
<td><em>Candida</em> (albicans, glabrata, tropicalis)</td>
<td>6</td>
</tr>
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of hyperdynamic septic shock gave reason for surgical intervention. Surgery was only considered when all possibilities of successful nonoperative management (including interventional endoscopy and radiology) had been exhausted. The primary goal of operative therapy was to remove the septic focus.

**Surgical Management**

As advanced pulmonary gangrene was already present at the time of surgical intervention, limited resection was no longer a practicable option in most of our cases. Hence, anatomic segmentectomy was only feasible in 7 patients. Overall lobectomy was the most common procedure and was performed in 26 patients. Pneumonectomy was unavoidable in 11 cases. As a consequence of pleural empyema most patients underwent decortication and pleural debridement with removal of all suppuration, fibrinous coating, and necrotic detritus.

**Outcome**

In 2 cases we intraoperatively encountered sever diffuse bleeding caused by massive inflammation of the affected chest. These patients required tamponade of the pleural cavity with towels, which were removed after 48 hours. Septic shock with multiorgan failure caused acute renal failure in 6 patients who received hemofiltration. Slow respiratory weaning was rather common and several patients required tracheotomy to wean off mechanical ventilation. The postoperative mortality was 7 out of 44 patients. Two patients died after pneumonectomy and 5 after lobectomy whereas all of the segmentectomy cases survived. Fatal outcome after lobectomy was caused by severe pulmonary sepsis with septic shock and multiorgan failure in 4 cases and by bronchopleural fistula in 1 case. Here, breakdown of the bronchial stump occurred despite the fact that it had initially been reinforced with a serratus anterior muscle flap. The patient underwent rethoracotomy and the bronchus was covered with the greater omentum [11]. Nevertheless he suffered from persistent pleural empyema and therefore he eventually received an open window thoracostomy. Despite all efforts he died from ongoing sepsis.

After emergent pneumonectomy 1 patient died from fulminant pulmonary sepsis and 1 from bronchopleural fistula after right pneumonectomy. In this case the staple line at the bronchial stump had already been reinforced with sutures and a latissimus dorsi muscle flap during the initial procedure. As the patient had undergone gastrectomy years ago there was no omentum available. Therefore, we aimed to close the leakage with a j-shaped tracheobronchial stent. While successful stent placement was initially accomplished, reopening of the leak soon took place and the patient died from respiratory failure.

**Statistical Analysis From the Whole Series**

A strong correlation between the preoperative condition of the patients, which comprises the acute pulmonary disease as well as the preexisting comorbidity, and the outcome of emergent surgery was observed. The occurrence of pulmonary sepsis was associated with significantly higher postoperative mortality (7 of 27 vs 0 of 17; \( p = 0.03 \)). The preoperative manifestation of a persistent air leak was also related to significant higher risk for adverse outcome (5 of 14 vs 2 of 30; OR, 7.35; 95% CI, 1.00 to 89.98; \( p = 0.025 \)). Significant higher mortality was also recognized in case of acute renal failure (3 of 6 vs 4 of 38; OR, 7.86; 95% CI, 0.79 to 82.94; \( p = 0.04 \)).

Moreover we observed strong trends toward higher mortality in cases with preoperative pleural empyema (OR, 3.56; 95% CI, 0.37 to 179.62) and preoperative respiratory failure. Overall 6 out of the 7 cases of fatal outcome had a preoperative pleural empyema (6 of 29 vs 1 of 15; \( p = 0.39 \)). Preoperative respiratory failure was associated with 2 times higher odds for postoperative death (OR, 1.75; 95% CI, 0.22 to 12.35; \( p = 0.66 \)).

Preexisting comorbidity had also a significant influence on the postoperative mortality. A significantly higher Charlson comorbidity index score was observed for cases with fatal outcome (\( p = 0.04 \)). Furthermore the statistical analysis showed that Charlson comorbidity index score 3 or greater was associated with significantly higher mortality (6 of 21 vs 1 of 23; \( p = 0.04 \)). Patients with a Charlson score of 3 or greater had 8 times greater odds for fatal outcome than patients with a Charlson score less than 3 (OR, 8.41; 95% CI, 0.88 to 421.71; \( p = 0.042 \)).

**Lobectomy Versus Pneumonectomy**

We formed 2 groups for statistical analysis. The purpose of this maneuver was to prove statistically whether or not pneumonectomy was associated with higher postoperative mortality. The lobectomy group included all 26 cases of lobectomy and the pneumonectomy group comprised the 11 cases of emergent pneumonectomy. There were no statistically significant differences in age (\( p = 0.59 \)), Charlson comorbidity index score (\( p = 0.18 \)), and Charlson combined age and comorbidity score (\( p = 0.10 \)) between the 2 groups. Moreover, we observed no significant difference in postoperative mortality between the 2 groups (5 of 26 vs 2 of 11; OR, 1.07; 95% CI, 0.14 to 13.22; \( p = 1 \)).

**Comment**

Putrid lung abscess used to be a frequent complication of pneumonia, tonsillitis, and dental disease in the early decades of the twentieth century [1]. During the 1930s and 1940s successful operative strategies for surgical abscess drainage were developed and helped to decrease the mortality of pulmonary abscess formation from 75% to about 2.5% [1, 12, 13]. Moreover, the soon ubiquitously available antibiotics caused also a sharp decline in the incidence of putrid lung abscess. In modern times pulmonary abscess has become an uncommon disease.

The breakthrough of antibiotics did not only bring about much lower numbers of patients suffering from lung abscess but also a substantial shift of the spectrum of disease. In the pre-antibiotic era mainly cases of solitary putrid lung abscess in otherwise healthy patients were referred for surgical intervention. Nowadays only patients with failed initial medical treatment are referred for
thoracic surgery. Here necrotizing pneumonia with multiple abscess formation, cavitation, and finally pulmonary gangrene is encountered as well as severe preexisting comorbidity and well-known risk factors. Simple surgical drainage procedures are no longer effective to manage this devastating condition, which is often associated with life-threatening pulmonary sepsis. Already in the year 1942 Robert Shaw stated that “lobectomy and total pneumonectomy may at times be procedures of choice in dealing with multiple chronic abscesses” [14].

Despite the urgency of the matter there is a remarkable paucity of studies on the results of emergent pneumonectomy for necrotizing lung disorders. The literature comprises mainly case reports and small case series stretching over a study period of 2 or even 3 decades [15–18]. In 1983 Hagan and Hardy published a series of 184 cases of lung abscess, which they encountered at the University of Mississippi between the years 1960 and 1982 [15]. Most cases were managed nonoperatively, whereas only 19 patients required surgical intervention. One of the surgical patients died; however, it was not specified whether fatal outcome occurred after lobectomy or after pneumonectomy. The authors observed an overall mortality rate of 22% in the 1960s, 25% in the 1970s, and 28% in 1980 to 1982 [15].

A more recent study from Tsai and colleagues [19] did not include any cases of pneumonectomy. Therefore, we may conclude that there is currently no established knowledge regarding the usefulness of emergent pneumonectomy for necrotizing, nonmalignant lung disorders. Against this background, our study is intended to address this obvious void and to shed light on the current outcome of emergent pneumonectomy.

All 3 participating institutions of this study are not only high-volume centers in the field of thoracic surgery but are specialized on advanced, technically demanding lung resections. At each center 1 senior thoracic surgeon performed the vast majority of the procedures. As a consequence, we are able to rule out that our results were impaired by a lack of surgical experience or the well-established correlation between hospital volume and general outcome [20, 21]. Moreover, we may assume that all patients received the best possible perioperative care by an experienced team well capable to handle difficult cases after emergent thoracic surgery.

The lobectomy and the pneumonectomy group were very well comparable regarding general demographic characteristics and preexisting comorbidity. We found no statistically significant differences in age, prevalence of chronic alcoholism, Charlson comorbidity index score, and Charlson combined age and comorbidity score between the 2 groups. Therefore, it is safe to conclude that there was no bias caused by discrepancies in age and preexisting comorbidity. Moreover, the characteristics of our study population confirm the observation that mainly patients with certain risk factors are affected by necrotizing lung disorders. Already in the series of Hagan and Hardy 18.5% of the sufferers were alcoholics [15]. In our study 21 out of 44 patients had a history of chronic alcoholism and 2 had even sustained alcoholic liver cirrhosis. Furthermore 4 of our patients were intravenous drug addicts. These patients have not only a higher risk for aspiration of oral contents but are also immunocompromised by malnutrition and other side effects of substance abuse.

We found no statistical significant difference in postoperative mortality between the pneumonectomy and the lobectomy group. As the general characteristics of the 2 groups were well comparable and as we were able to rule out bias by hospital volume or surgical experience, the main result of our study is that the extent of lung resection has no significant influence on the postoperative mortality. The risk for fatal outcome is rather determined by the occurrence of pulmonary sepsis and sepsis-related complications as respiratory and renal failure.

Limitations of our study are the retrospective design and the size of the study population. For the same reason we are not able to absolutely preclude an error of the second kind. Due to the study size it is within the realms of possibility that we erroneously failed to recognize a difference in mortality between the lobectomy and the pneumonectomy group. However, neither prospective nor larger studies are to be expected. Against this background, the results of our study justify the conclusion that the outcome of emergent pneumonectomy for lung gangrene warrants the procedure.

All our patients had already received the full range of nonoperative therapy before they were referred for thoracic surgery. There were no other options left than surgical intervention. The fact that pleural empyema (29), pulmonary sepsis (27), respiratory failure (14), persistent air leak (14), and acute renal failure (6) were so frequently encountered demonstrates the severity of septic disease. Under these circumstances it is crucial to get control over the septic focus. In case of advanced necrotizing pneumonia with gangrene of substantial parts of the lung or massive abscess formation control over the septic focus can hardly be achieved by applying simple drainage procedures. In our opinion, traditional surgical drainage operations [22] with unroofing of the abscess cavity are not suitable for dealing with pulmonary sepsis caused by severe necrotizing pneumonia and lung gangrene because they fail to remove the devitalized, necrotic lung, which acts as septic focus. Thoracomyoplasty and muscle flaps, which are useful alternatives to lung resection in patients suffering from chronic lung abscess without signs of systemic sepsis, have the same problem [23]: the septic focus remains. Persistent pulmonary and systemic sepsis is the consequence. For the same reason we disapprove of staged procedures with delayed resection of the affected lung. It has occasionally been suggested to perform an open window thoracostomy at first [16]. After improvement of pleural empyema and sepsis, lung resection is supposed to be carried out in a second step [16]. As a consequence, establishing control over the septic focus is unnecessarily postponed in time by delaying the removal of the devitalized lung. Our study proves convincingly that advanced pulmonary sepsis is the main reason for fatal outcome. Therefore, it would be desirable to establish control over the septic focus as soon as possible.
In conclusion, emergent pneumonectomy for lung gangrene is not only justified but life saving. The results are comparable with lobectomy. Fatal outcome is not determined by the range of pulmonary resection but by the occurrence of pulmonary sepsis and sepsis-associated complications. Further improvement seems achievable by more timely surgical intervention before the onset of pulmonary sepsis.

References