MAJOR ARTICLE

Clinical and Microbiologic Outcomes in Patients Receiving Treatment for *Mycobacterium abscessus* Pulmonary Disease

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(See editorial commentary by Griffith, on pages 572–574.)

Background. *Mycobacterium abscessus* can produce a chronic pulmonary infection for which little is known regarding optimal treatment and long-term outcomes.

Methods. We performed a retrospective observational study (2001–2008) including all patients who met American Thoracic Society criteria for *M. abscessus* pulmonary disease. Our aim was the evaluation of clinical and microbiologic outcomes in patients treated with combined antibiotic and surgical therapy, compared with antibiotic therapy alone.

Results. A total of 107 patients were included in the analysis. Patients were predominantly female (83%) and never-smokers (60%), with a mean age of 60 years. Fifty-nine (55%) of 107 patients had coexistent or previous history of *Mycobacterium avium* complex pulmonary infection. High-resolution chest CT showed bronchiectasis and nodular opacities in 98% of patients and cavities in 44%. Sixy-nine (46 medical, 23 surgical) patients were followed up for a mean duration of 34 months (standard deviation, 21.1 months, range, 2–82 months). Cough, sputum production, and fatigue remained stable, improved, or resolved in 80%, 69%, and 59% of patients, respectively. Twenty (29%) of 69 patients remained culture positive, 16 (23%) converted but experienced relapse, 33 (48%) converted to negative and did not experience relapse, and 17 (16%) died during the study period. There were significantly more surgical patients than medical patients whose culture converted and remained negative for at least 1 year (57% vs 28%; $P = .022$).

Conclusions. Patients with *M. abscessus* pulmonary disease who are treated with multidrug antibiotic therapy and surgery or antibiotic therapy alone had similar clinical outcomes. However, surgical resection, in addition to antibiotics, may offer a prolonged microbiologic response.

Mycobacterium abscessus is a species of nontuberculous mycobacteria (NTM) that is reported to be the third most frequently recovered respiratory NTM in the United States and accounts for 80% of rapidly growing mycobacterial respiratory isolates [1, 2]. Precise epidemiologic data of *M. abscessus* infections are lacking, but as with other NTM species, prevalence seems to be increasing. Clinically, *M. abscessus* pulmonary infection can range from asymptomatic to severe bronchiectasis and cavitary lung disease, with significant morbidity and mortality. Patients with *M. abscessus* pulmonary disease are typically nonsmoking and older women, often with no previously documented lung disease. Conditions that have been associated with *M. abscessus* pulmonary disease include achalasia, recurrent vomiting, lipoid pneumonia, coexisting mycobacterial infections [3, 4], bronchiectasis, cystic fibrosis, and lung transplantation [5–8].

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Overall, the published literature in this area is very limited. The largest study described 154 patients with rapidly growing mycobacterial infection, and 119 (82%) of 146 respiratory isolates identified were *M abscessus* [3]. *M abscessus* is inherently multidrug resistant and, therefore, is very challenging to treat. There have been no controlled studies conducted for the treatment of rapidly growing mycobacteria infection. Current treatment recommendations include multidrug therapy with combinations of intravenous and oral antibiotics and/or surgery [1].

M. abscessus pulmonary disease is a chronic infectious disease characterized by variable clinical response to therapy, recurrence, and little chance of cure. The purpose of this study was to describe the clinical, radiologic, and microbiologic features of a large cohort of patients with *M. abscessus* pulmonary disease and to compare the outcomes in patients who receive a combination of surgical resection and multidrug antibiotic therapy (surgical group), with those in patients who received multidrug antibiotic therapy alone (medical group).

METHODS

Patient Population

All patients referred to National Jewish Health (Denver, CO) who were given *International Classification of Diseases, 9th Revision,* code 031.0 (pulmonary mycobacteria) from 1 January 2001 through 31 December 2004 were reviewed (Figure 1). Patients were included in the study if they were (1) ⩾18 years of age, (2) had at least 1 respiratory sample positive for *M. abscessus,* and (3) met American Thoracic Society diagnostic criteria for NTM pulmonary disease. These criteria included (1) pulmonary symptoms, (2) nodular or cavitary opacities on chest radiograph or high-resolution CT (HRCT) of the chest that

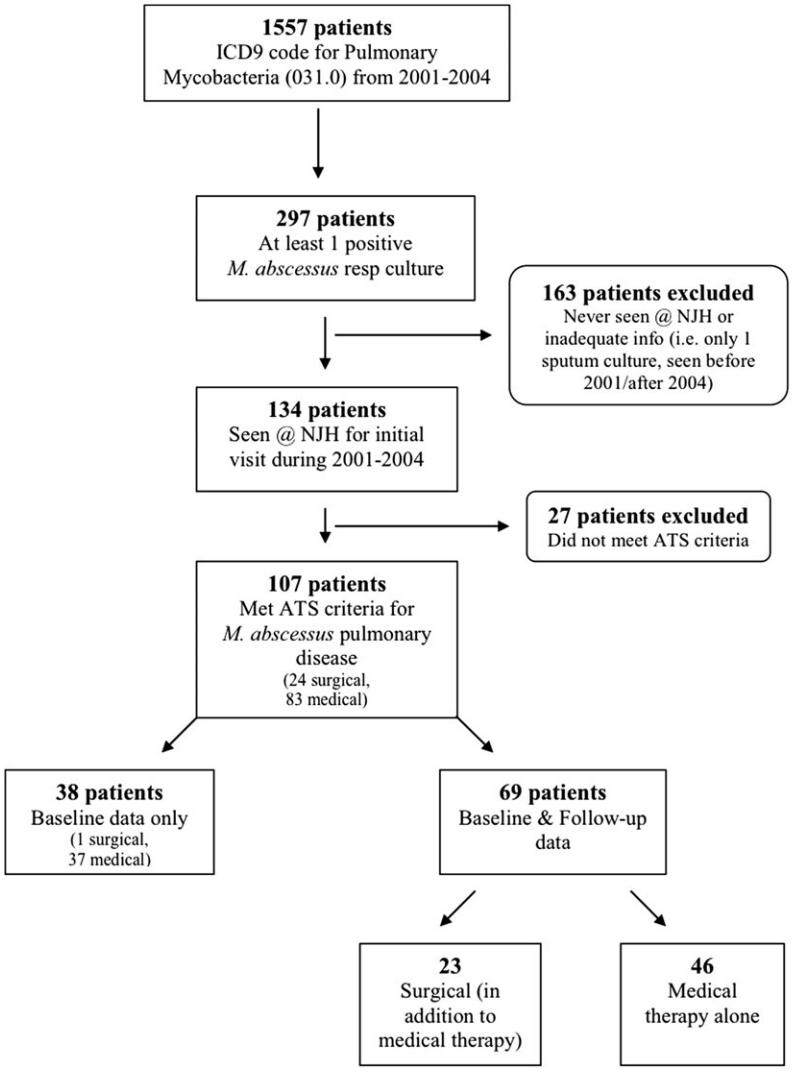

Figure 1. Patient identification flow diagram. ATS, American Thoracic Society; ICD-9, International Classification of Diseases, 9th Revision; NJH, National Jewish Health.

shows multifocal bronchiectasis and multiple small nodules and appropriate exclusion of alternate diagnosis, and (3) ⩾2 sputum cultures, 1 bronchoalveolar lavage culture, or 1 lung tissue biopsy specimen culture positive for *M. abscessus* [1]. Patients were followed up until January 2008. Approval for this study was obtained from the National Jewish Health Institutional Review Board.

Data

Baseline demographic and clinical data were collected on all patients with *M. abscessus* pulmonary disease through retrospective medical record review. Patients seen in follow-up at least once at National Jewish Health had further radiologic, clinical, and treatment data collected. At baseline, clinical symptoms (eg, fever, cough, sputum production, dyspnea, hemoptysis, weight loss, and fatigue) were recorded as absent or present, and follow-up symptoms were categorized as absent, stable, improved, resolved, or worse, based on review of clinic notes. Results of investigations for etiology of bronchiectasis were documented. HRCT reports were reviewed for radiographic abnormalities (bronchiectasis, nodular opacities, cavities, and airspace consolidation) at baseline, and changes during follow-up (absent, stable, improved, resolved, or worse) were recorded. Organisms were identified as *M. abscessus* with use of high-performance liquid chromatography, followed by biochemical testing (salt tolerance and citrate use). All National Jewish Mycobacterial Reference Laboratory mycobacterial cultures and drug susceptibility results for study patients were reviewed.

Treatment and Outcomes

The number of months that a patient received an individual antibiotic for treatment of *M. abscessus* pulmonary disease was recorded, and the total number of antibiotic-months was calculated (eg, 3 antibiotics for 10 months was equal to 30 antibiotic-months). The actual number of months that a patient received antibiotics was less than the cumulative total, because all patients received combination antibiotic treatment (⩾2 drugs), often with multiple courses of treatment. The number and type of surgical procedure was recorded. The Social Security Death Index was reviewed in January 2008 to determine the number of deaths during the study period. Information regarding the cause of death was not available.

Statistical Analysis

Statistical analysis was performed using SAS software, version 9.1 (SAS Institute). Categorical variables were compared using the χ^2 or Fisher's exact test. Continuous variables were compared using Student t test or Wilcoxon rank sum test. McNemar's test was used to assess the association between clinical history of gastroesophageal reflux disease (GERD) and abnormal esophagram findings. Survival analysis method was used to compare groups for survival and for time to sputum conversion. For all analyses, 2-tailed tests were used, and P values $<.05$ were designated as statistically significant.

RESULTS

Patient Population

One hundred seven patients with *M. abscessus* pulmonary disease were seen for an initial visit during 2001–2004. Sixty-nine patients were followed up for a mean duration of 34 months (standard deviation [SD], 21.1 months; range, 2–82 months). The mean number of follow-up visits was 2.6 (range, 1–8). Patients were predominantly female (83%), thin (mean body mass index [calculated as the weight in kilograms divided by the height in square meters], 21.4; SD, 3.8; range, 13–36), with a mean age of 60 years (range, 20–85 years) (Table 1). All patients were nonsmokers, with 60% never-smokers. Fifty-nine (55%) of 107 had coexistent or history of *Mycobacterium avium* complex (MAC) infection. None of the patients had a history of gastrointestinal disease (eg, recurrent vomiting, achalasia, or known recurrent aspiration). Patients were from 36 different states in the United States, with 25% of patients living in Florida. There were no differences in patient demographic characteristics or clinical characteristics between medical and surgical groups.

Clinical Symptoms, Radiology, and Pulmonary Function Testing

At the initial visit, the majority of the 107 patients had symptoms of cough (97%), sputum production (91%), fatigue (87%), and dyspnea (70%). Hemoptysis and weight loss were reported less frequently (37% and 38%, respectively). Cough, sputum production, and fatigue remained stable, improved, or resolved in 80%, 69%, and 59% of follow-up patients, respectively. At the last visit, there was no difference in any of the clinical symptom categories between the medical and surgical groups. At baseline, chest HRCT revealed bronchiectasis and nodular opacities in 98% of patients; 53% had air-space consolidation, and 44% had cavities. There was no statistically significant difference in the number of patients with cavitary disease between patients with and without coexistent or previous MAC infection ($P = .74$). Most patients had bilateral abnormalities (92%), with ⩾3 lobes involved in 93%. There was no difference in baseline pulmonary function test variables between the medical and surgical groups (Table 1). There was a statistically significant decrease in percentage of predicted forced expiratory volume in one second (FEV1) (mean change, −4.85%) for the whole group and the surgery group (−7.64%) and a statistically significant decrease in percentage of predicted forced vital capacity (FVC) for the surgery group (−6.71%) (Supplement Table 1).

Results of Investigations for Bronchiectasis

Twenty-six (26%) of 101 patients had at least 1 genetic abnormality identified (either cystic fibrosis transmembrane

Table 1. Patient Characteristics

Characteristic	All patients (n = 107)	Medical (n = 83)	Surgery (n = 24)	p-value[a]
Female sex	89 (83)	69 (83)	20 (83)	NS
Ethnicity				
Non-Hispanic white	77 (72.0)	60 (94)	17 (94)	NS
Asian/Pacific Islander	4 (3.7)	3 (5)	1 (6)	
Hispanic	1 (.9)	1 (1)	0	
Missing data	25 (23.3)			
Age at diagnosis, mean ± SD (range), years	60.2 ± 11.9 (20–85)	60.9 ± 12.0 (20–85)	57.7 ± 11.1 (30–73)	NS
Previous pulmonary tuberculosis	9 (8.5)	7 (8.5)	2 (8.3)	NS
Known pulmonary disease (excluding TB) at initial assessment[b]	19 (17.8)	17 (20.5)	2 (8.3)	NS
Clinical history of GERD	34 (31.8)	27 (32.5)	7 (29.2)	NS
Coexistent/previous MAC infection	59 (55.1)	46 (55.4)	13 (54.2)	NS
BMI, mean ± SD (range)	21.4 ± 3.8 (13–36)	21.6 ± 4.1 (13–36)	21.2 ± 2.5 (17–28)	NS
Smoking status - never smoker	64 (60)	48 (59)	16 (67)	NS
Mean FVC % predicted (absolute value ± SD)	72 (2.57 ± .86)	71 (2.50 ± .85)	75 (2.80 ± .88)	NS
Mean FEV1 % predicted (absolute value ± SD)	69 (1.87 ± .71)	68 (1.80 ± .66)	72 (2.07 ± .82)	NS
Mean FEV1/FVC	72 ± 9.3	72 ± 9.44	74 ± 8.72	NS
Mean percent predicted DLCO ± SD	61 ±16.9	59 ± 16.50	65 ± 17.90	NS
Baseline Chest CT findings				
Bronchiectasis & Nodular opacities	105 (98)	81 (98)	22 (92)	NS
Cavities	47 (44)	39 (48)	8 (33)	NS
Consolidation	57 (53)	47 (57)	10 (42)	NS
Bilateral	98 (92)	75 (90)	23 (96)	NS
Multilobar (≥3 lobes with abnormalities)	99 (93)	77 (93)	22 (91)	NS

NOTE. Data are no.(%) of patients, unless otherwise indicated. BMI, body mass index; GERD, gastroesophageal reflux disease; MAC, *Mycobacterium avium* complex; NS, not significant ($P \geq .05$); SD, standard deviation; TB, tuberculosis.

[a] Medical and surgical groups were compared using χ^2 test or Fisher's exact test for comparisons on categorical variables. Student's t test or Wilcoxon rank sum test was used for continuous variable comparisons.

[b] Multiple etiologies- moderate-severe chronic obstructive pulmonary disease or asthma (6), alpha-1 antitrypsin deficiency (2), cystic fibrosis (2), Kartagener syndrome (1), fungal ball (1), sarcoidosis (1), previous radiation for lung cancer (1), graft versus host disease postallogenic bone marrow transplant (1), hypersensitivity pneumonitis (1), previous pneumonia and weakness due to Guillam-Barre syndrome (1).

conductance regulator mutation or abnormal alpha-1 antitrypsin [AAT] phenotype) (Table 2). Seven patients met diagnostic criteria for cystic fibrosis (2 cystic fibrosis transmembrane conductance regulator mutations and compatible clinical phenotype). Only 1 patient with an abnormal AAT phenotype had a low AAT level. Forty (43%) of 94 had an abnormal tailored barium swallow (3% with severe abnormality, with high risk for aspiration). One-half of patients had at least mild esophageal dysmotility, and 26 (29%) of 90 showed gastroesophageal reflux on esophagram. The agreement between clinical history of GERD and an abnormal esophagram showing reflux was poor (McNemar's test, $P = 1.00$). Fourteen (54%) of 26 patients with reflux on esophagram, including 2 patients with severe GERD, did not have clinical symptoms.

Treatment

Antibiotic therapy was individualized on the basis of drug susceptibility results and patient tolerance. Sixteen different antibiotics were used in 42 different combinations (Table 3 and Supplement Table 2). Sixty-seven (97%) of the 69 patients who had follow-up data received a macrolide, and 74% received a macrolide and intravenous amikacin with or without another antibiotic. The most frequently used intravenous (IV) antibiotics were amikacin (71%), imipenem (55%), and cefoxitin (30%). Patients received a mean of 4.6 drugs over the course of therapy and a mean ± SD of 52 ± 40.6 antibiotic-months, with a median of 6 months of IV antibiotic-months. There was no statistically significant difference in the total antibiotic months or total months of IV antibiotics between medical and surgical groups (data not shown).

The percentage of patients who received a given drug to which their isolate was susceptible, intermediate, or resistant can be seen in Supplemental Table 3. Thirty-two patients received at least 1 drug to which their isolate was resistant. The majority of patients who received azithromycin, clarithromycin, and IV amikacin were susceptible to these agents (85%, 82%, and 92%, respectively). The majority of patients who received cefoxitin and imipenem had intermediate susceptibility (76% and 50%, respectively).

At least 1 drug was stopped because of adverse effects or toxicity in 65% of patients. Cefoxitin and amikacin were most likely to cause adverse effects. Twenty (35%) of the 57 patients who received amikacin (typically in a dose of 3 times weekly) developed ≥1 adverse effects, including tinnitus, hearing loss,

Table 2. Results of Bronchiectasis Investigations

Variable	No. (%)
Abnormal cystic fibrosis genetic testing[a]	13 (13)
2 Cystic fibrosis mutations present	7 (7)
Low alpha-1 antitrypsin level <72 mg/dL	1 (1)
Alpha-1 antitrypsin phenotype	
MM	87 (87)
MS or MZ	11 (11)
ZZ	2 (2)
Abnormal tailored barium swallow	40 (43)
Abnormal esophagram	54 (59)
Dysmotility	45 (51)
Gastroesophageal reflux disease	26 (29)
Positive antinuclear antibody test result[b]	14 (18)
Elevated rheumatoid factor[c]	5 (7)

[a] At least 1 known cystic fibrosis mutation detected in genetic analysis for ⩾86 mutations.

[b] Includes 10 patients with ANA titer >1:40 to 1:160 and 4 patients with a titer >1:160.

[c] Elevated rheumatoid factor is defined as >20 IU/mL.

vestibular dysfunction, or renal dysfunction. Rash was the most common adverse effect of cefoxitin therapy.

Surgery

Twenty-four patients underwent 29 separate surgical procedures. Three patients had 2 surgical procedures, and 1 patient had 3 surgical procedures. In total, 25 lobectomies, 6 pneumonectomies, 3 segmentectomies, and 1 wedge resection were performed. Right middle lobectomy was the most common procedure, performed in 9 patients (38%). Indications for surgery were localized bronchiectasis (86%), cavitary disease (37%), and hemoptysis (11%). Surgery was not offered to many patients because of extensive disease; 44 of 47 patients with cavitary disease had bilateral and multilobar (⩾3 lobes) disease. Postoperative complications were reported in 6 patients (25%). Complications included postoperative hemorrhage (1 patient), bronchopleural fistula (1), frozen shoulder (1), wound infection (1), brachial plexus injury (1), and respiratory failure and/or death (1).

Table 3. Antibiotic Therapy Used and Duration of Use

Drug	Percentage of patients who received antibiotic for at least 1 month	Median no. of months of antibiotic use
Azithromycin	77	18
Intravenous amikacin	71	3
Imipenem	55	3
Clarithromycin	49	16.5
Ciprofloxacin	43	12
Cefoxitin	30	3
Inhaled amikacin	28	12
Moxifloxacin	12	12
Clofazimine	9	12.5
Minocycline	6	21.5
Bactrim	4	15
Levofloxacin	4	4
Linezolid	3	5.5
Tigecycline	3	2
Gatifloxacin	1	11
Doxycycline	1	4
Meropenem	1	2

Table 4. Culture Conversion Results

Culture conversion status	Total No. (%)	Medical No. (%)	Surgical No. (%)	P[a]
Converted with no relapse	33 (48)	18 (39)	15 (65)	.041
Never converted or relapsed	36 (52)	28 (61)	8 (35)	

[a] From $\chi 2$ test for medical vs surgical groups.

Outcomes

Microbiology. The frequency of sputum sampling varied widely, because there was no standardized interval of collection. Therefore, it is difficult to calculate a meaningful time to culture conversion. Twenty (29%) of 69 patients remained culture positive, and 49 patients (71%) had sputum cultures convert to negative. Of the latter, 16 (23%) had their sputum culture convert to negative but experienced relapse and 33 (48%) had cultures convert to negative and did not experience relapse (Table 4). Twenty-six (38%) of 69 were culture negative for at least 1 year. There were significantly ($P < .05$) more surgical patients who had culture converted and remained negative for at least 1 year, compared with medical patients (57% vs 28%; $P = .022$). Thirteen (19%) of the 69 patients were culture negative and were not receiving antibiotics for at least 1 year; the difference between surgical and medical groups was not statistically significant (15% vs 30%; $P = .633$). Five (2 surgical, 3 medical) patients were culture negative and were not receiving antibiotics for >2 years and 2 (both medical) patients for >3 years. Of the 20 patients who did not have sputum cultures convert to negative, 5 (25%) developed resistance to at least 1 drug.

Death. Seventeen (15.9%) of 107 patients died during the study period: 13 in the medical group and 4 in the surgical group. There was no difference in the percentage of deaths between the medical and surgical groups (15.7% vs 16.7%; $P = >.99$).

DISCUSSION

This study documents the clinical presentation and treatment outcomes in patients with pulmonary disease due to *M. abscessus*. The majority of our patients were older, nonsmoking white women who had a low body mass index and no obvious comorbidities. Treatment outcomes were poor, with 29% of patients remaining culture positive despite prolonged antibiotic therapy.

In addition, 23% of the patients had cultures convert but later experienced relapse. Thirty-three patients (48%) had their sputum cultures convert to negative and did not experience relapse, and there were significantly more surgical patients who had their cultures convert to negative and remained negative for at least 1 year, compared with medical patients (57% vs 28%; $P = .022$).

The demographic and clinical findings are similar to those in previous reports of *M. abscessus* and other NTM lung disease, such as MAC [9]. Compared with the largest study to date [3], we found a much higher rate of previous and/or concurrent MAC coinfection (55%) than was previously reported (13%). In addition, HRCT revealed >90% of patients with bilateral and multilobar disease, primarily resulting from small nodules and bronchiectasis. Although patients may have areas of severe localized disease, the vast majority will have nodularity in multiple lobes implying diffuse infection and/or inflammatory reaction [10]. A slightly larger number of patients in our study had cavitary lesions (44%), compared with previous studies (14%–42%) [3, 10, 11].

Abnormal AAT phenotypes (MS, MZ, and ZZ) were present in 13% of patients with *M. abscessus* pulmonary disease, compared with 21% in a cohort of patients with rapidly growing mycobacterial lung disease (64% isolated *M. abscessus*) and 8.2% prevalence in the North America population [12, 13]. We detected cystic fibrosis gene mutations in 13% of our patients, compared with reported cystic fibrosis gene mutation carrier rate of 4% in the general white North American population [14]. Twenty-nine percent of our study patients had evidence of GERD on esophagram; these results are similar to those in a Korean study that documented GERD in 10 (32%) of 31 patients with *M. abscessus* infection with nodular bronchiectasis with use of 24-h esophageal pH monitoring [15]. In both studies, the majority of patients with GERD were asymptomatic. Our study highlights the frequency of associated conditions, such as GERD, MAC infection, and specific genetic abnormalities, possibly predisposing patients to *M. abscessus* lung disease.

Forty-eight percent of patients had sputum cultures convert to negative and did not experience relapse during the study period. Surgical patients were more likely to be culture negative after at least 1 year than were patients treated with medical therapy alone, but both groups were equally likely to be culture negative and not receiving antibiotics for at least 1 year. In contrast, 29% of patients continued to have positive sputum culture results despite multidrug antibiotic therapy, with surgical resection in 5 of these patients. This subgroup of patients may respond clinically to antibiotic therapy, but the degree and duration of response is variable and they frequently have persistent symptoms and progressive disease. Griffith et al [3] reported 10 (8.4%) of 119 *M. abscessus*–infected patients, including 7 surgical patients, were cured as defined by the return of respiratory symptoms to baseline and reversion of sputum to acid-fast bacilli smear and culture negativity for at least 1 year. Overall, the number of patients in our study with a prolonged response was small. The poor response to therapy is likely attributable to a number of factors, including the presence of biofilms [16, 17], lack of bactericidal drugs, and presence of a novel erm (41) gene that has been found in *M. abscessus* [18].

The majority of patients in this study received periodic multidrug therapy, including a macrolide and ⩾1 intravenous agent (amikacin, imipenem, or cefoxitin), often guided by the results of in vitro drug susceptibility testing. Similar microbiologic responses (28% without conversion and 72% with culture conversion) have been reported in patients infected with *M. abscessus* treated with a 24-month standardized regimen, including clarithromycin, ciprofloxacin, doxycycline, and 4 weeks of amikacin and cefoxitin [19]; sputum conversion and relapse rates were associated with clarithromycin resistance. Holding regimens of 2 oral therapies were used in some patients. Because of the limited therapeutic options, inhaled amikacin was also used in several patients as part of a maintenance regimen or in patients with a relative contraindication for an intravenous aminoglycoside. One case series reported the safe use of inhaled amikacin in 6 patients with MAC lung disease, but additional studies are needed to systematically assess safety and efficacy [20]. Adverse effects of therapy for *M. abscessus* lung disease are common, and as a result, patients need to be followed up closely.

American Thoracic Society guidelines state that the best chance for curative therapy of limited (focal) *M. abscessus* lung disease is surgical resection of the involved lung, combined with multidrug chemotherapy. Favorable microbiologic and clinical outcomes have been reported in the majority of patients selected for surgical resection but are often accompanied by relatively high complication rates (18%–35%) [21–24]. Mitchell et al [22] published their experience of lung resection (1983–2006) in 236 patients with NTM, including 32 patients with *M. abscessus* pulmonary disease. The operative mortality and morbidity rates in the entire NTM group were 2.6% and 18.5%, respectively [22]. The surgical patients from our study, a subgroup of this larger surgical cohort, had an operative morbidity of 25%. Our study supports the use of surgery as an adjunct to chemotherapy in patients with areas of focal severe bronchiectasis and/or cavitary disease, with the aim of decreasing the mycobacterial load and removing a reservoir for infection. Surgery should be performed by an experienced team in conjunction with perioperative antibiotic therapy to try to minimize surgical complications.

There are several limitations to our study. The spectrum of patients with *M. abscessus* lung disease in our study cohort was likely to have been influenced by referral bias and, thus, skewed toward chronic cases with relatively more severe disease. Patients were seen in follow-up at variable intervals; therefore, some information between visits was lacking. The retrospective nature of this study limited the data

collection, because clinical symptoms, radiologic findings, and microbiologic findings were not assessed in a standardized fashion. Treatment regimens were not standardized and ranged from short-course dual antibiotic therapy to prolonged multidrug antibiotic therapy and resectional surgery. Surgical patients were carefully selected (eg, focal disease and good clinical status); therefore, the benefit of surgery may be overestimated, when compared with patients with diffuse disease and/or poor clinical status. During our study, extensive molecular identification was not available to distinguish *M. abscessus* from 2 closely related species (*Mycobacterium massiliense* and *Mycobacterium bolletii*). Limited clinical data have varied on the clinical significance of this distinction [25, 26].

CONCLUSION

M. abscessus pulmonary disease remains a challenging disease to manage. The majority of patients respond clinically and microbiologically to antibiotic and/or surgical therapy, but response is often temporary. Surgical resection, in addition to antibiotics, may offer a prolonged microbiologic response. Prolonged remission and possible cure are currently attainable in only a minority of patients. Prospective studies with long-term follow-up and new antibiotic and therapeutic options are required to improve outcomes in these patients.

Supplementary Material

Supplementary materials are available at Clinical Infectious Diseases online (http://www.oxfordjournals.org/our_journals/cid/).

Supplementary materials consist of data provided by the author that are published to benefit the reader. The posted materials are not copyedited. The contents of all supplementary data are the sole responsibility of the authors. Questions or messages regarding errors should be addressed to the author.

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Potential conflicts of interest. GH has had board membership and served on the speakers bureau for Hill-Rom and has given expert testimony for Lamson, Dugan, and Murray, LLP, and Hassard Bonning, LLP. All other authors: no conflicts.

References

1. Griffith DE, Aksamit T, Brown-Elliott BA, et al. An official ATS/IDSA statement: diagnosis, treatment, and prevention of nontuberculous mycobacterial diseases. Am J Respir Crit Care Med **2007**; 175:367–416.
2. Brown-Elliott BA, Wallace RJ Jr. Clinical and taxonomic status of pathogenic nonpigmented or late-pigmenting rapidly growing mycobacteria. Clin Microbiol Rev **2002**; 15:716–46.
3. Griffith DE, Girard WM, Wallace RJ Jr. Clinical features of pulmonary disease caused by rapidly growing mycobacteria: an analysis of 154 patients. Am Rev Respir Dis **1993**; 147:1271–8.
4. Daley CL, Griffith DE. Pulmonary disease caused by rapidly growing mycobacteria. Clin Chest Med **2002**; 23:623–32, vii.
5. De Groote MA, Huitt G. Infections due to rapidly growing mycobacteria. Clin Infect Dis **2006**; 42:1756–63.
6. Levy I, Grisaru-Soen G, Lerner-Geva L, et al. Multicenter cross-sectional study of nontuberculous mycobacterial infections among cystic fibrosis patients, Israel. Emerg Infect Dis **2008**; 14:378–84.
7. Chernenko SM, Humar A, Hutcheon M, et al. *Mycobacterium abscessus* infections in lung transplant recipients: the international experience. J Heart Lung Transplant **2006**; 25:1447–55.
8. Olivier KN, Weber DJ, Wallace RJ Jr., et al. Nontuberculous mycobacteria. I: multicenter prevalence study in cystic fibrosis. Am J Respir Crit Care Med **2003**; 167:828–34.
9. Field SK, Fisher D, Cowie RL. *Mycobacterium avium* complex pulmonary disease in patients without HIV infection. Chest **2004**; 126:566–81.
10. Han D, Lee KS, Koh WJ, Yi CA, Kim TS, Kwon OJ. Radiographic and CT findings of nontuberculous mycobacterial pulmonary infection caused by *Mycobacterium abscessus*. AJR Am J Roentgenol **2003**; 181:513–7.
11. Chung MJ, Lee KS, Koh WJ, et al. Thin-section CT findings of nontuberculous mycobacterial pulmonary diseases: comparison between *Mycobacterium avium*-intracellulare complex and *Mycobacterium abscessus* infection. J Korean Med Sci **2005**; 20:777–83.
12. De Serres F. Worldwide racial and ethnic distribution of alpha1-antitrypsin deficiency:summary of analysis of published genetic epidemiologic surveys. Chest **2002**; 122:1818–29.
13. Chan ED, Kaminska AM, Gill W, et al. Alpha-1-antitrypsin (AAT) anomalies are associated with lung disease due to rapidly growing mycobacteria and AAT inhibits *Mycobacterium abscessus* infection of macrophages. Scand J Infect Dis **2007**; 39:690–6.
14. Gynecologists ACoOa. ACOG Committee Opinion—Update on carrier screening for cystic fibrosis. Obstet Gynecol **2005**; 106:1465–8.
15. Koh WJ, Lee JH, Kwon YS, et al. Prevalence of gastroesophageal reflux disease in patients with nontuberculous mycobacterial lung disease. Chest **2007**; 131:1825–30.
16. Howard ST, Rhoades E, Recht J, et al. Spontaneous reversion of *Mycobacterium abscessus* from a smooth to a rough morphotype is associated with reduced expression of glycopeptidolipid and reacquisition of an invasive phenotype. Microbiology **2006**; 152:1581–90.
17. Greendyke RaTRB. Differential antibiotic susceptibility of *Myocbacterium abscessus* variants in biofilms and macrophages compared to that of plaktonic bacteria. Antimicrob Agents Chemother **2008**; 52:2019–26.
18. Nash KA, Brown-Elliott BA, Wallace RJ Jr. A novel gene, erm(41), confers inducible macrolide resistance to clinical isolates of *Mycobacterium abscessus* but is absent from *Mycobacterium chelonae*. Antimicrob agents chemother **2009**; 53:1367–76.
19. Jeon K, Kwon OJ, Lee NY, et al. Antibiotic treatment of *Mycobacterium abscessus* lung disease. Am J Respir Crit Care Med **2009**; 180:896–902.
20. Davis KK, Kao PN, Jacobs SS, Ruoss SJ. Aerosolized amikacin for treatment of pulmonary *Mycobacterium avium* infections: an observational case series. BMC Pulm Med **2007**; 7:2.
21. Koh WJ, Kim YH, Kwon OJ, et al. Surgical treatment of pulmonary diseases due to nontuberculous mycobacteria. Korean Med Sci **2008**; 23:397–401.
22. Mitchell JD, Bishop A, Cafaro A, Weyant MJ, Pomerantz M. Anatomic lung resection for nontuberculous mycobacterial disease. Ann Thorac Surg **2008**; 85:1887–93.
23. Shiraishi Y, Nakajima Y, Katsuragi N, Kurai M, Takahashi N. Pneumonectomy for nontuberculous mycobacterial infections. Ann Thorac Surg **2004**; 78:399–403.
24. Sherwood JT, Mitchell JD, Pomerantz M. Completion pneumonectomy for chronic mycobacterial disease. J Thorac Cardiovasc Surg **2005**; 129:1258–65.
25. Zelazny AM, Root JM, Shea YR, et al. Cohort study of molecular identification and typing of *Mycobacterium abscessus, Mycobacterium massiliense,* and *Mycobacterium bolletii* **2009**; 47:1985–5.
26. Koh WJ, Jeon K, Lee NY, et al. Clinical significance of differentiation of *Mycobacterium massiliense* from *Mycobacterium abscessus*. Am J Respir Crit Care Med **2010.**