Outcomes of Adjunctive Surgery for Nontuberculous Mycobacterial Pulmonary Disease

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Research Article

Abstract

Background

Owing to the unsatisfactory results of antibiotic treatment alone, surgical resection is currently considered as adjunctive therapy in patients with nontuberculous mycobacterial pulmonary disease (NTM-PD). However, reports regarding the outcomes of surgery vary considerably by institution. Here, we investigated the surgical outcomes and risk factors associated with unfavorable outcomes after surgery.

Methods

We analyzed patients with NTM-PD who underwent pulmonary resection at Seoul National University Hospital between January 1, 2006, and December 31, 2020, and assessed the types of surgical procedures, complications, and long-term outcomes. Multivariate logistic regression analysis was used to identify the risk factors associated with treatment refractoriness or recurrence after surgery.

Results

Among 67 patients who underwent surgery during the study period, the most common indication for surgery was persistent culture positivity despite rigorous medical treatment (80.6%), followed by longstanding cavitary lesions or radiographic aggravation (10.4%) and massive hemoptysis (4.5%). Among 53 patients with positive mycobacterial cultures at the time of surgery, 38 (71.7%) achieved initial negative culture conversion, 9 (17.0%) of whom experienced recurrence. Nine (14.3%) patients experienced postoperative complications, which were managed without lasting morbidity and mortality. Female sex (adjusted odds ratio [aOR], 6.63; 95% confidence interval [CI], 1.04–42.4; P = .046), preoperative positive mycobacterial culture (aOR, 5.87; 95%CI, 1.04–33.08; P = .045), and residual lesions (aOR, 6.86; 95%CI, 1.49–31.56; P = .013) were associated with refractoriness or recurrence.

Conclusions

Pulmonary resection is a reasonable treatment modality for patients with refractory NTM-PD or major complications such as massive hemoptysis. The potential risk factors for unfavorable outcomes included female sex, preoperative positive mycobacterial culture, and residual lesions after surgery.

Background

The burden of infection caused by nontuberculous mycobacteria (NTM), defined as mycobacteria other than *M. leprae* and *M. tuberculosis complex*, is increasing globally [1]. While NTM can involve organs such as the skin, soft tissue, and lymph nodes, it predominantly causes infection in the lungs. *M. avium complex* (MAC), which includes *M. avium* and *M. intracellulare*, is the most common cause of NTM pulmonary disease (NTM-PD). *M. abscessus* complex (MABC), to which the *M. abscessus* subspecies *abscessus (M. abscessus)*, *M. abscessus* subspecies *massiliense (M. massiliense)*, and *M. abscessus* subspecies *bolletii* belong, is the next-most common etiology in many countries, including South Korea [2].

While recent practice guidelines for NTM-PD recommend treatment initiation rather than "watchful waiting" for patients meeting the clinical, radiographic, and microbiological criteria for diagnosis [3], the success rate of antibiotic treatment is unsatisfactory, with rates of 60.0–65.7% for MAC [4, 5] and 34.0–45.6% for MABC [6, 7]. Consequently, surgical resection is considered a reasonable adjunctive therapy, especially for patients with refractory disease despite rigorous medical treatment, with large cavitary lesions expected to be less penetrable by antibiotics, or with severe disease-related complications such as massive hemoptysis [1, 3, 8].

While previous studies on the surgical outcomes of adjunctive surgery have provided meaningful guidance and insight, these findings varied considerably by institution. For example, major outcomes such as negative sputum culture conversion or postoperative complications ranged from 57–100% and 0–46%, respectively [9–20]. Conflicting results and lack of standardized guidelines provide little help for patients and clinicians alike regarding the decision to perform surgery.

To resolve this uncertainty, more evidence on surgical outcomes is needed. This study described the outcomes of patients with NTM-PD who underwent surgical resection at a tertiary referral center in South Korea and provided a detailed account of complications and risk factors for NTM-PD refractoriness or recurrence after surgery.

Methods

Study design and patient selection

This retrospective cohort study analyzed the medical records of patients with NTM-PD who met the diagnostic criteria of the American Thoracic Society/European Respiratory Society/European Society of Clinical Microbiology and Infectious Diseases/Infectious Diseases Society of America guidelines [3] and underwent surgical resection as adjunctive therapy between January 1, 2006, and December 31, 2020, at Seoul National University Hospital in South Korea. For patients with multiple pulmonary resections, the analysis considered only the first resection. This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. 2104-094-1211).

Data collection

Baseline patient demographics at the time of surgery, including age, sex, body mass index (BMI), smoking history, and underlying disease were collected. Data on acid-fast bacilli smear, mycobacterial culture, mycobacterial species identification using 16S rRNA and *rpo*B sequencing [21, 22], and drug susceptibility test (DST) results; antibiotic regimen; and treatment duration before and after surgery were also obtained. DSTs were performed at the Korean Institute of Tuberculosis using the broth microdilution method. Inducible resistance was tested by extending the incubation with clarithromycin to 14 days. Preoperative chest computed tomography (CT) images were acquired and classified as 'fibrocavitary', 'non-cavitary nodular bronchiectatic', or 'cavitary nodular bronchiectatic' by two pulmonologists blinded to the clinical data. The extent of disease was also evaluated. The presence of postoperative residual lesions, defined by remaining nodular, cavitary opacities, or multifocal bronchiectasis consistent with radiologic findings of NTM-PD, was assessed by comparing CT images before and after surgery. Discrepancies were resolved through discussion. Data on preoperative pulmonary function test results, surgical procedure, immediate postoperative complications, and their management were also collected. We also reviewed the pathology reports of the surgical specimens.

Treatment outcome assessment

We assessed treatment outcomes according to the definitions provided by the NTM-NET consensus statement [23] and recent studies [16–20]. Negative culture conversion was defined as three or more consecutive negative mycobacterial cultures from respiratory samples collected over at least 3 months. Patients who did not achieve negative culture conversion after surgery were defined as refractory cases. Patients with sustained multiple consecutive negative mycobacterial cultures without positive cultures until the end of follow-up were considered microbiologically cured. Recurrence was defined as the re-emergence of at least two positive mycobacterial cultures from respiratory specimens following negative culture conversion after surgery.

Statistical analysis

Categorical variables were reported as frequencies (percentages), while continuous variables were summarized as medians with interquartile ranges (IQRs). Patient groups were compared using Pearson's chi-square or Fisher's exact tests for categorical variables and Mann–Whitney U tests for continuous variables. Univariate logistic regression analysis was performed to identify the potential risk factors for refractoriness or recurrence. Clinically significant variables described in previous studies along with variables with p-values < .2 in the univariate analysis were selected for inclusion in the multivariate logistic regression analysis. $P < .05$ was considered statistically significant. Statistical analyses were conducted using R software (version 4.0.4, R Foundation for Statistical Computing, Vienna, Austria) using the *moonBook* package for descriptive analysis and fitting generalized linear models for logistic regression modeling.

Results

Patient characteristics

During the study period, 67 patients with NTM-PD (female, 53 [79.1%]; male, 14 [20.9%]) underwent surgical resection and were included in the study. The baseline characteristics of the patients at the time of surgery are summarized in Table 1. The median age and BMI

were 57 years (IQR, 50–65 years) and 20.1 kg/m^2 (IQR, 18.7–21.3 kg/m^2), respectively. Fifty-nine (88.1%) patients had never smoked cigarettes and 10 (14.9%) patients had a previous history of pulmonary tuberculosis.

Table 1
Baseline characteristics of 67 patients who underwent surgical resection

Characteristics	n = 67
Age years, median (IQR)	57 (50, 65)
Female sex, n (%)	53 (79.1)
BMI kg·m^{-2} (n = 47), median (IQR)	20.1 (18.7, 21.3)
Smoking status, Never/former, n (%)	59 (88.1)/8 (11.9)
Underlying disease	
History of pulmonary TB, n (%)	10 (14.9)
Lung cancer, n (%)	2 (3)
Asthma, n (%)	2 (3)
COPD, n (%)	1 (1.5)
Other malignancy, n (%)	5 (7.5)
Diabetes mellitus, n (%)	3 (4.5)
Causative Mycobacterium **species**	
MAC, n (%)	39 (58.2)
M. avium, n (%)	18 (26.9)
M. intracellulare, n (%)	21 (31.3)
MABC, n (%)	24 (35.8)
M. abscessus, n (%)	16 (23.9)
M. massiliense, n (%)	8 (11.9)
M. kansasii, n (%)	3 (4.5)
M. fortuitum, n (%)	1 (1.5)
Clarithromycin resistance in MABC	
M. abscessus (n = 13), S/IR or R, n (%)	2 (3)/11 (16.4)
M. massiliense (n = 8), S/IR or R, n (%)	7 (87.5)/1 (12.5)
Preoperative positive NTM culture, n (%)	54 (80.6)
CT pattern	
Non-cavitary nodular bronchiectatic, n (%)	19 (28.4)
Cavitary nodular bronchiectatic, n (%)	34 (50.7)
Fibrocavitary, n (%)	14 (20.9)
Disease extent	
Involving a single lobe, n (%)	7 (10.4)
Involving more than three lobes, n (%)	46 (68.7)
Bilateral involvement, n (%)	49 (73.1)
Involving all lobes, n (%)	12 (17.9)

Abbreviations: IQR, interquartile range; BMI, body mass index; TB, tuberculosis; MAC, *Mycobacterium avium* complex; MABC, *Mycobacterium abscessus* complex; IR, inducible resistance; R, resistance; NTM, nontuberculous mycobacterium; CT, computed tomography; PFT, pulmonary function test; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; DLCO, diffusing capacity of the lungs for carbon monoxide.

Characteristics	n = 67
Preoperative PFT	
FEV1/FVC ratio, median (IQR)	76.5 (70, 80.8)
% predicted FEV1, median (IQR)	94 (83.3, 101.8)
% predicted FVC, median (IQR)	90 (81, 99)
% DLCO, median (IQR)	87 (77, 96.5)
Preoperative NTM treatment	
On antibiotics treatment prior to surgery, n (%)	61 (91)
Macrolide-based regimen with intravenous drugs, n (%)	29 (43.3)
Macrolide-based regimen without intravenous drugs, n (%)	31 (46.3)
Non-macrolide-based regimen, n (%)	1 (1.5)
Treatment duration, months, median (IQR)	14 (9, 25)
No antibiotic treatment before surgery, n (%)	6 (9)
Surgical indication	
Persistent NTM culture positivity, n (%)	54 (80.6)
Radiographic aggravation and/or persistent cavity, n (%)	7 (10.4)
Massive hemoptysis, n (%)	3 (4.5)
Initiation of therapy, n (%)	1 (1.5)
Others, n (%)	2 (3)

Abbreviations: IQR, interquartile range; BMI, body mass index; TB, tuberculosis; MAC, *Mycobacterium avium* complex; MABC, *Mycobacterium abscessus* complex; IR, inducible resistance; R, resistance; NTM, nontuberculous mycobacterium; CT, computed tomography; PFT, pulmonary function test; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; DLCO, diffusing capacity of the lungs for carbon monoxide.

Thirty-nine patients (58.2%) were positive for MAC (*M. avium*, 18 [26.9%]; *M. intracellulare*, 21 [31.3%]), while 24 (35.8%) patients were positive for MABC (*M. abscessus*, 16 [23.9%]; *M. massiliense*, 8 [11.9%]). Among the 61 patients whose DSTs were available, 11 (84.6%) of 13 patients infected with *M. abscessus* and one (12.5%) of eight patients infected with *M. massiliense* showed resistance and inducible resistance to clarithromycin, respectively. The most prevalent CT pattern in the study group was cavitary nodular bronchiectasis (34; 50.7%), followed by non-cavitary nodular bronchiectasis (19; 28.4%) and fibrocavitary bronchiectasis (14; 20.9%). Forty-nine (73.1%) patients showed bilateral involvement of the disease, while seven (10.4%) patients showed single-lobe involvement.

Before surgery, most patients (61; 91%) received antibiotic treatment for NTM-PD. Among these patients, all but one with *M. kansasii* infection were administered macrolide (azithromycin or clarithromycin)-based regimens. The median duration of antibiotic treatment before surgery was 14 months (IQR, 9–25 months).

Indications and types of surgical resection

The main indication for surgery was persistent positive mycobacterial culture (54; 80.6%) followed by longstanding cavity or radiographic aggravation (7; 10.4%) despite rigorous antibiotic treatment. Three patients underwent resection due to massive hemoptysis (4.5%). Another patient (1.5%) had his right middle lobe, the only region destroyed by *M. abscessus*, removed as initiation of NTM therapy. The remaining two patients (4.5%) underwent resection of a solitary nodule or cavitary lesion for diagnostic purposes. No patient died during the surgery or hospital stay. Fifty-eight patients (86.6%) underwent video-assisted thoracoscopic surgery (VATS); the others underwent open thoracotomy. The surgical procedures included pneumonectomy (4; 6.0%), bilobectomy with wedge resection (1; 1.5%), bilobectomy without segmentectomy or wedge resection (1; 1.5%), lobectomy with segmentectomy or wedge resection (15; 22.4%), lobectomy without segmentectomy or wedge resection (18; 26.9%), segmentectomy with wedge resection (11; 16.4%), segmentectomy without wedge resection (5; 7.5%), and wedge resection (12; 17.9%) (Table 2). The median length of hospital stay for surgery was 6 days (IQR, 4–9 days).

Table 2
Types of procedures

Type of procedure	No. (%)
Pneumonectomy	4 (6)
Left	3 (4.5)
Right	1 (1.5)
Bilobectomy with wedge resection	1 (1.5)
Bilobectomy without wedge resection	1 (1.5)
Lobectomy with segmentectomy or wedge resection	15 (22.4)
Lobectomy without segmentectomy or wedge resection	18 (26.9)
Segmentectomy with segmentectomy or wedge resection	11 (16.4)
Segmentectomy without segmentectomy or wedge resection	5 (7.5)
Wedge resection with or without wedge resection	12 (17.9)
Video-assisted thoracoscopic surgery	58 (86.6)
Open thoracotomy	9 (13.4)

Postoperative complications

The postoperative complications are summarized in Table 3. Nine patients experienced immediate postoperative complications, more commonly those who underwent open thoracotomy (five following open thoracotomy and four following VATS; $P = .001$). The most common postoperative complication was prolonged air leakage (3; 33.3%). Wound dehiscence requiring surgical closure occurred in patients who underwent VATS. One patient experienced delayed surgical site bleeding, which was successfully managed by hemoclipping. Only one patient in our study developed a bronchopleural fistula.

Table 3
Surgical complications and management

No.	Complication	Age	Sex	*Mycobacterial species*	Type of procedure	Thoracotomy	LOS, days	Management	Outcome
1	Prolonged air leakage	72	M	*M. avium*	RUL posterior and RLL superior bisegmentectomy	Yes	19	Pleurodesis	Controlled
2	Wound dehiscence	65	F	*M. abscessus* subsp. *Abscessus*	RUL lobectomy	No	9	Primary wound closure	Controlled
3	Prolonged air leakage	73	F	*M. intracellulare*	RUL lobectomy with RLL wedge resection	Yes	34	Pleurodesis	Controlled
4	Postoperative delayed bleeding	45	F	*M. abscessus* subsp. *abscessus*	RUL wedge resection	No	8	Hemoclipping	Controlled
5	Pneumonia with parapneumonic effusion	68	M	*M. avium*	RUL lobectomy	Yes	21	Antibiotics	Controlled
6	Bronchopleural fistula, atrial fibrillation	84	M	*M. abscessus* subsp. *abscessus*	Lt. pneumonectomy	Yes	11	Closed tube thoracostomy, antibiotics	Controlled
7	Pneumonia	62	M	*M. intracellulare*	Lt. pneumonectomy	Yes	44	Antibiotics	Controlled
8	Wound dehiscence	46	F	*M. intracellulare*	RLL lobectomy	No	7	Primary wound closure	Controlled
9	Prolonged air leakage	60	M	*M. abscessus* subsp. *abscessus*	RML lobectomy	No	16	Pleurodesis, RUL wedge resection	Controlled

Abbreviations: LOS, length of stay; RUL, right upper lobe; RLL, right lower lobe; subsp, subspecies; Lt, left; RML, right middle lobe; VATS, video-assisted thoracoscopic surgery.

Treatment outcomes

Fifty-nine (93.7%) patients were administered antibiotics postoperatively for a median of 17.5 months (IQR, 10.25–23.75 months). Of the 54 patients with persistent positive mycobacterial culture before surgery (one was omitted due to planned sequential operation within 3 months), 38 (71.7%) achieved initial negative culture conversion postoperatively. Among them, 27 (50.9%) patients maintained negative culture conversion throughout the median follow-up period of 38 months (IQR, 17.5–59.5 months) while 9 (17.0%) experienced recurrence. Fifteen (28.3%) patients displayed persistently positive mycobacterial cultures and were defined as refractory cases. One patient with recurrence and six refractory patients underwent sequential surgery, five of whom subsequently achieved negative culture conversion. The details of the treatment outcomes are summarized in Fig. 1. All three patients whose indications for surgery were massive hemoptysis despite bronchial artery embolization remained stable without hemoptysis for a median of 14 months (range, 10–90 months) and none underwent additional intervention.

Concomitant fungal infections

Five of the 67 patients had an account of numerous hyphae, suggestive of aspergillosis. The patient ages ranged from 47 to 69 years, and only one patient was male. None of the patients had underlying disease and four (80%) had complained of hemoptysis before surgery. The causative mycobacterial species included *M. avium* in two patients and *M. intracellulare*, *M. abscessus*, and *M. massiliense* in one patient each. Three patients had cavitary lesions; the other two showed extensive bronchiectasis and parenchymal destruction. Only one patient's surgical specimen exhibited fungal organisms infiltrating the surrounding lung parenchyma, consistent with invasive pulmonary aspergillosis (IPA). This patient was consequently treated with itraconazole for 1 year, while others were closely followed without the administration of any antifungal agent.

Risk factors of refractoriness or recurrence

A total of 15 refractory and 12 recurrent patients were grouped for logistic regression analysis. This analysis indicated postoperative residual lesions (odds ratio [OR] 4.74, 95% confidence interval [CI], 1.32−16.96, $P = .017$) as a potential predictor of refractoriness or recurrence after surgery. Multivariate analysis revealed that female sex (adjusted OR, 6.63; 95% CI, 1.04−42.4; $P = .046$), preoperative positive mycobacterial culture (adjusted OR, 5.87; 95% CI, 1.04−33.08, $P = .045$), and residual lesions after surgery increased the odds of refractoriness or recurrence (adjusted OR, 6.86; 95% CI, 1.49−31.56; $P = .013$), while age, BMI, and type of surgical procedure were not associated with treatment outcomes (Table 4).

Table 4
Risk factors associated with NTM-PD refractoriness or recurrence after surgery

Characteristics	OR (95%CI)	*P*-value	aOR (95%CI)	*P*-value
Age	1.03 (0.98−1.08)	.314	1.03 (0.96−1.11)	.350
Female sex	2.78 (0.66−11.80)	.165	6.63 (1.04−42.4)	.046
BMI kg·m^{-2}	0.83 (0.65−1.07)	.150	0.77 (0.58−1.03)	.079
Causative *Mycobacterium* **species**		< .99		
Mycobacterium avium complex	Ref			
Mycobacterium abscessus complex	1 (0.33−3.02)			
Preoperative positive NTM culture	2.78 (0.66−11.80)	.165	5.87 (1.04−33.08)	.045
Surgical procedure and complications				
Thoracotomy	1.17 (0.26−5.23)	.833		
Pneumonectomy	2.40 (0.21−28.05)	.485	1.80 (0.10−32.59)	.692
Complications	2.12 (0.46−9.86)	.337		
Postoperative radiologic findings				
Residual lesions	4.74 (1.32−16.96)	.017	6.86 (1.49−31.56)	.013
Residual cavity	2.36 (0.61−9.18)	.215		
Abbreviations: NTM-PD, nontuberculous mycobacterial pulmonary disease; OR, odds ratio; CI, confidence interval; aOR, adjusted odds ratio.				

Discussion

This study investigated the outcomes of adjunctive surgical treatment in 67 patients with NTM-PD and derived the risk factors for unfavorable outcomes. Following surgical resection, 70% of the patients who were refractory to prior antibiotic treatment achieved initial negative culture conversion. After achieving culture conversion, half of these patients remained culture-negative during a median follow-up of 38 months. In addition to mycobacterial eradication, surgical resection also resolved uncontrolled hemoptysis. Although approximately 13% of patients experienced postoperative complications, all of them recovered with appropriate measures and none died due to surgical resection. However, 15 patients were non-responsive to surgical resection. Unfavorable outcomes were associated with female sex, preoperative positive mycobacterial culture, and residual lesions after surgical resection. While these are acceptable outcomes, the culture conversion rate in our study was lower than those reported previously [9−13, 15−20, 24, 25]. This may be explained by different patient compositions and outcome definitions across studies. For instance, while many studies did not include or had few patients with MABC infections, which are difficult to treat and resistant to many antibiotics, one-third of our study population was positive for MABC infection. Moreover, unlike other studies, we took a more conservative approach of assessing 'true' postoperative negative culture conversion among those who showed persistent positive mycobacterial cultures before surgery.

Our study results indicated that surgical resection in patients with NTM-PD can be performed safely without long-lasting morbidities. Although postoperative complications occurred in 13.4% of patients, all were managed without enduring morbidity. Only one patient required an additional surgical procedure, while the others recovered with conservative management. A larger proportion (86.6%) of patients who received VATS in the present study compared to those in other studies [9, 11, 12, 17, 18, 20, 26] may have improved the postoperative complication rate in our study.

Chronic pulmonary aspergillosis (CPA) following NTM-PD, which is caused by *Aspergillus* species, has been increasingly reported. The prevalence of CPA in NTM-PD ranges from 3.9–16.7% [27, 28]. The risk factors associated with concomitant CPA in NTM-PD include the presence of fibrocavitary lesions or emphysema and the use of corticosteroids [29]. In our study, five patients had pathologic findings suggestive of CPA, one of whom was treated with an antifungal agent. This result emphasizes the importance of an awareness of combined fungal infections when treating NTM-PD.

In this study, female sex, preoperative positive mycobacterial culture, and postoperative residual lesions were associated with NTM-PD refractoriness or recurrence after surgery. The unfavorable outcomes in female patients could be explained in terms of female predilection for NTM-PD [30, 31], which might lead to higher recurrence rates in female patients. In this study, all of the recurrent cases were women. This predilection could be caused by genetic or hormonal differences [30, 31]. Interestingly, previously reported risk factors such as old age, longer period from initial medical treatment to surgery, and infection by non-*M. avium* species were not predictors of outcome in the present study. This may be due to differences in the size and composition of the study population. However, we confirmed the importance of residual lesions after surgery [17, 32, 33]. Most patients in our study underwent surgery in order to minimize the mycobacterial burden in otherwise palliative setting. Thus, we adopted limited resection strategy to conserve pulmonary function. But, as Yamada and colleagues suggested [33] and our result underscores, extensive resection that minimizes residual lesion may be required for proper disease control. As Togo and colleagues emphasized [32], more study regarding acceptable extent of remnant lesions after surgery may be necessary.

Our study has several limitations. This retrospective cohort study was conducted in a single institution. Patients were highly selected for surgery, which could have biased the results. Treatment outcomes were evaluated according to a widely used operational definition, which is mainly based on expert consensus. Thus, a cautious interpretation of the results is advised. Well-designed prospective randomized control trials comparing the outcomes of antibiotic-only treatment and adjunctive surgery are required. However, our study included a relatively large number of patients with MABC compared to other studies. Moreover, most of the patients in our institution were treated with VATS, which depicts a more realistic and updated picture of surgical outcomes of patients with NTM-PD.

Conclusion

In conclusion, pulmonary resection can be a valuable treatment option for patients with NTM-PD who are refractory to antibiotic treatment or experience disease-related complications such as hemoptysis. The potential risk factors for unfavorable outcomes included female sex, preoperative positive mycobacterial culture, and residual lesions after surgery. Postoperative complications can be managed with low morbidity and mortality rates in experienced institutions.

List Of Abbreviations

Adjusted odds ratio: aOR; Body mass index:　BMI; Chronic pulmonary aspergillosis: CPA; Computed tomography: CT; Confidence interval: CI; Drug susceptibility test: DST; Interquartile range: IQR; Invasive pulmonary aspergillosis: IPA; Mycobacterium abscessus complex: MABC; Mycobacterium avium complex: MAC; Nontuberculous mycobacteria: NTM; Nontuberculous mycobacterial pulmonary disease: NTM-PD; Video-assisted thoracoscopic surgery: VATS

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the amended Declaration of Helsinki. The study protocol was approved by the Institutional Review Board of Seoul National University Hospital and informed consent was waived due to its retrospective design posing minimal risk to the study participants (IRB No. 2104-094-1211).

Consent for publication

Not applicable.

Availability of data and materials

The dataset used are available from the corresponding author on reasonable request.

Competing interests

Funding

Authors' contributions

J-YK, JJY, and NK participated in the design of the study. J-YK, SP, IKP and CHK reviewed medical records of study patients and contributed to acquisition of data. J-YK and NK assessed radiographic imaging of study patients and JK reviewed pathology of surgical specimen. J-YK and NK performed main statistical analysis, and SP, IKP, CHK, YTK, JK, and JJY critically appraised those results. J-YK wrote the initial draft of the manuscript, and NK revised it critically. All authors had access to final version of the manuscript and approved it to be published.

Acknowledgments

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Figures
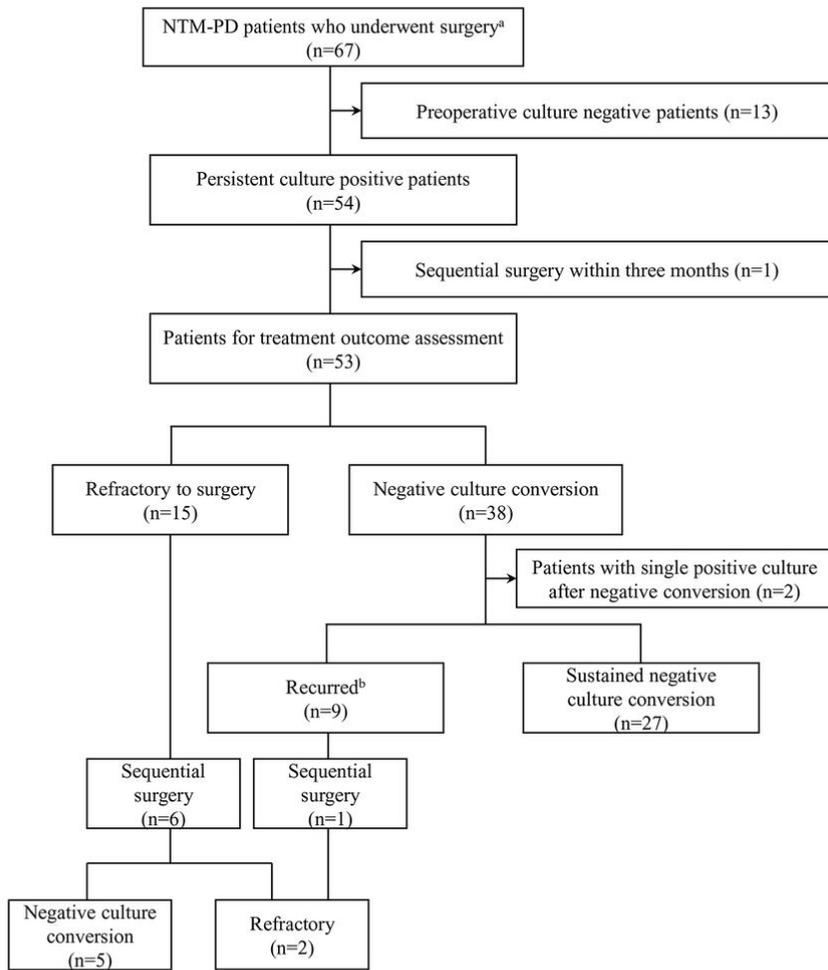
Figure 1

Treatment outcomes of 67 patients based on mycobacterial culture results