Surgical results for bronchiectasis based on hemodynamic (functional and morphologic) classification

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Objective: This study was a prospective evaluation of surgical indications and outcomes for unilateral and bilateral bronchiectasis according to hemodynamic (functional and morphologic) classification.

Methods: Between January 1998 and January 2004, the morphologic features (cystic versus cylindric) by chest computed tomography and the hemodynamic features (perfused versus nonperfused) by lung ventilation/perfusion scan were determined in 66 patients with bronchiectasis (53 unilateral and 13 bilateral). The indication for surgical resection in both groups was the presence of localized areas of cystic, nonperfused bronchiectasis.

Results: In the unilateral bronchiectasis group, there were 28 female and 25 male patients with an average age of 37.5 ± 3.8 years (range 6-40 years). Pneumonectomy was performed in 10 cases (8 left and 2 right), and lobectomy or bilobectomy was performed in 43. In the bilateral group, there were 7 male and 6 female patients with an average age of 42 ± 5.4 years (range 9-55 years). Pneumonectomy was performed in 2 cases, lobectomy in 5, and bilateral staged lobectomy in 6. There was 1 postoperative death (1.5%), and morbidity was 18% (12 patients). Four patients required reexploration for bleeding, 4 had prolonged air leak develop, 3 acquired pulmonary infections, and 1 had localized empyema develop. During a mean follow-up of 52 months (range 24-82 months), 48 patients were considered cured (73%) and 17 had symptomatic improvement (26%). *Pseudomonas* infection and underlying chronic obstructive airway disease were poor prognostic factors ($P < .05$).

Conclusion: The hemodynamic (functional and morphologic) classification provides an accurate functional classification for bronchiectasis. Its application in determining the indications and extent of surgical resection is superior to morphologic classification alone. Curative resection can be achieved in both unilateral and bilateral bronchiectasis with acceptable morbidity.

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Bronchiectasis was first described by Laennec¹ as pathologic changes of abnormal bronchial dilatation with chronic necrotizing infection. In developing countries, bronchiectasis remains a significant problem.² Medical management of bronchiectasis has reduced the associated morbidity³; however, mortality with conservative treatment still ranges from 19% to 31%.⁴ Surgical resection has been proposed for bronchiectasis since the end of the 1930s.⁵ There is a broad consensus concerning the indications for surgical resection, which is usually reserved for irreversible, localized bronchiectasis.⁶⁻⁸ The role of surgery in mixed or bilateral bronchiectasis is not yet defined, especially for patients who do not have improvement with medical treatment. We previously reported that the classification of bronchiectasis according to hemodynamic (functional and morphologic) features can define more precisely

Abbreviations and Acronyms

COPD = chronic obstructive pulmonary disease
 HRCT = high-resolution computed tomography
 TB = tuberculosis
 V/Q = ventilation/perfusion

the question of which part to resect and which to preserve.⁹ In this prospective study, we present the surgical indications and outcomes for unilateral and bilateral bronchiectasis.

Methods

Sixty-six patients with bronchiectasis were consecutively operated on at King Khalid University Hospital, Riyadh, Saudi Arabia, between January 1998 and January 2004. All patients had bronchiectasis diagnosed and were receiving medical therapy in the form of chest physiotherapy and antimicrobial therapy determined by culture and sensitivity for a mean period of 26.8 ± 5.3 months (range 2 months–18 years).

Patient Characteristics

There were 34 female and 32 male patients, with an average age of 29.9 ± 10.8 years (range 6–55 years). All patients had chronic symptoms for a mean period of 3.4 ± 2.9 years (range 1–19 years), including chronic productive cough in 73% (48 patients), with sputum quantity expectorated ranging between 60 and 300 mL/d. Other symptoms included recurrent infections in 47% (31 patients), hemoptysis in 35% (23 patients), dyspnea on exertion in 29% (19 patients), and unresolved pneumonia in 15% (10 patients). Severity of hemoptysis ranged from frequent blood-tinged sputum to massive, life-threatening hemoptysis as great as 800 mL. Twenty-three patients (35%) had a history of associated pulmonary disease, including pulmonary tuberculosis (TB) in 12 (18%) and chronic obstructive pulmonary disease (COPD) in 11 (17%). The bacteriologic, acid-fast bacilli, and fungal analyses were obtained either from sputum or by endoscopic bronchoalveolar lavage. Bacterial infection was preoperatively proven in 37 cases (56%): *Haemophilus influenzae* in 11, *Staphylococcus aureus* in 9, *Streptococcus pneumoniae* in 7, *Pseudomonas aeruginosa* in 6, *Bacteroides* species in 2, and *Klebsiella pneumoniae* in 2. All patients were studied with posteroanterior and lateral chest radiography and a high-resolution computerized tomographic (HRCT) scan to determine the affected areas and their morphologic features. Each bronchiectatic segment was indexed as cystic or cylindric. Ventilation/perfusion ($\dot{V}/\dot{Q}$) lung scan was performed in all patients to determine the hemodynamic features (perfused versus nonperfused areas).⁹ The area affected was considered indicated for surgery when perfusion was less than 10% of the expected (nonperfused; Table 1). According to computed tomographic chest and $\dot{V}/\dot{Q}$ scans, the disease was unilateral in 53 patients (80%) and bilateral in 13 (20%). In the unilateral group, there were 28 female and 25 male patients, with an average age of 37.5 ± 3.8 years (range 6–40 years). In the bilateral group, there were 7 male and 6 female patients, with an average age of 42 ± 5.4 years (range 9–55 years). Cardiopulmonary assessment included

TABLE 1. Perfusion percentages (mean and range) of the resected lung

Surgical procedure	No.	Perfusion (% predicted)	
		Mean	Range
Lobectomy	37	5%	2%-6%
Bilobectomy	17	8%	3%-9%
Pneumonectomy	12	9%	5%-10%

blood gas analysis, full pulmonary function tests, and electrocardiography. Lung function studies revealed normal forced vital capacity and 1-second forced expiratory volume in 43 patients (65%). Eleven patients (17%) had obstructive lung disease, with the ratio of 1-second forced expiratory volume to forced vital capacity less than 75%. The remaining 12 patients (18%) had restrictive lung disease. Bronchoscopic examination with a flexible bronchoscope or intraoperative rigid bronchoscope was performed in all cases to exclude obstructive causes, such as tumor or foreign body, and to determine the segments involved in hemoptysis. Patients with endobronchial obstruction, active TB, and systemic disease (eg, cystic fibrosis and primary ciliary dyskinesia) were excluded from this study.

Our target area for surgical resection according to our hemodynamic classification, which includes combination of morphologic classification (cystic versus cylindric according to HRCT) and functional classification (perfused versus nonperfused according to $\dot{V}/\dot{Q}$ scan), was the cystic nonperfused localized bronchiectasis. The $\dot{V}/\dot{Q}$ scan was of help when doubtful morphologic areas of bronchiectasis were noted and there was a question regarding the need for surgical resection. In such cases, we adopted a policy of evaluating perfusion. Only if the perfusion percentage was less than 10% of the expected was surgical resection advised.

Operative Technique

Toilet bronchoscopy was performed routinely preoperatively. Tracheal intubation with a double-lumen tube for single-lung ventilation with early isolation was carried out. With the patient in the lateral decubitus position, a posterolateral thoracotomy was performed. After surgical resection, careful hemostasis was performed, and two chest drains were inserted. All the lung specimens resected had histopathologic and culture studies, including TB examinations. Epidural analgesia was routinely used, and respiratory physiotherapy, intravenous antibiotic therapy according to culture and sensitivity, and COPD therapy were initiated immediately postoperatively.

Follow-up

Patients had a mean follow-up of 52 months (range 24–82 months). During the follow-up, patients were assessed according to symptoms, sputum culture and sensitivity, and radiologic evaluation. Selected patients underwent chest HRCT.

Statistical Analysis

Data including age, sex, symptoms, type of bronchiectasis, type of operation, operative morbidity, and mortality were analyzed for these 66 patients. The outcome of the operation was classified as

“cured,” meaning complete absence of preoperative symptoms leading to surgery, “improved,” meaning reduction in the preoperative symptoms, or “no change,” meaning the preoperative symptoms persisted. Clinical data are reported as means with ranges. The unpaired Student *t* test and χ^2 test were used for group comparisons as appropriate. Prognostic factors including age, sex, symptoms, predisposing factors (COPD, TB), organism of infection, and type of operation were studied.

Results

Surgical resection was guided according to chest HRCT and lung $\dot{V}/\dot{Q}$ scan findings. There were 53 patients (80%) with unilateral bronchiectasis and 13 (20%) with bilateral bronchiectasis. Classification of bronchiectasis according to the hemodynamic (functional and morphologic) classification showed that in the unilateral group there were 32 patients with localized cystic nonperfused bronchiectasis affecting only one lobe, 11 with multisegmental localized cystic nonperfused bronchiectasis affecting two lobes, and 10 patients with cystic nonperfused bronchiectasis affecting the whole lung. Of the 13 patients with bilateral bronchiectasis, 6 patients had multisegmental localized cystic nonperfused bronchiectasis affecting two lobes bilaterally, 5 patients had localized cystic nonperfused bronchiectasis affecting one lobe on one side and scattered cylindric perfused bronchiectasis on the contralateral side, and 2 patients had cystic nonperfused bronchiectasis affecting the whole lung on one side and scattered cylindric perfused bronchiectasis on the contralateral side. In total, the disease was considered localized in 59 patients (53 unilateral and 6 bilateral) and was considered mixed (localized cystic nonperfused and scattered cylindric perfused) in 7 patients.

In the unilateral group, curative surgical resection was carried out in all cases: pneumonectomy was performed in 10 patients (8 left and 2 right), lobectomy in 32, and bilobectomy in 11. In the bilateral group, curative surgical resection was performed in 6 patients in the form of bilateral staged lobectomy. Five patients with localized cystic bronchiectasis affecting one lobe on one side and scattered cylindric bronchiectasis on the contralateral side underwent lobectomy of the cystic lobe. Two patients with cystic bronchiectasis affecting the whole lung on one side and scattered cylindric bronchiectasis on the contralateral side underwent emergency pneumonectomy (2 left) as a palliative treatment for massive, life-threatening hemoptysis; however, previous assessment of these 2 patients had shown perfusion values of the contralateral lung greater than 90% of the expected, with no perfusion defect in both cases.

There was 1 postoperative death (1.5%). A patient with massive hemoptysis with cystic bronchiectasis affecting one lung and scattered cylindric bronchiectasis on the contralateral side had postoperative pneumonia develop. Morbidity occurred in 18% of cases (12 patients). Four patients required reexploration for bleeding, 4 in the lobectomy group

had prolonged parenchymal air leak (mean of 7 days), 3 had pulmonary infection, and 1 had localized empyema that necessitated computed tomography-guided drainage.

During a mean follow-up of 52 ± 9.4 months (range 24–82 months), 48 patients were considered cured (73%) and 17 had symptomatic improvement (26%). In the unilateral group, 43 of 53 patients were cured (81%) and the remaining 10 had improvement (19%). Of the 32 patients who underwent lobectomy, 25 patients were cured (78%). Of the 11 patients who underwent bilobectomy, 8 patients were cured (73%). Of the 10 patients with cystic bronchiectasis affecting the whole lung, all were considered cured. In the bilateral group, 5 of 6 patients who underwent staged bilobectomy were cured, and the remaining 6 with residual cylindric bronchiectasis had improvement. Among the 17 patients with postoperative improvement, residual symptoms were explained by the presence of associated scattered cylindric bronchiectasis in 6 cases. Of the remaining 11 patients, 5 had *Pseudomonas* infection and 6 had associated COPD. In the improvement group, follow up chest HRCT was performed at a mean of 1.9 years. No deterioration of the unresected cylindric bronchiectasis was noted, and all patients showed no progressive deterioration in symptoms during follow-up. *Pseudomonas* infection (1 patient from 6 patients cured) and underlying COPD (4 patients from 11 cured) were poor prognostic factors ($P < .05$).

Discussion

In developing countries, bronchiectasis is still common and is a significant major cause of morbidity and mortality.² As the disease progresses, physical activities become increasingly limited, patients fail to thrive, and ultimately they suffer from social deprivation, intrinsic depression, and respiratory failure. Although antibiotics and postural drainage are widely applied in the medical management of the disease, resection of the involved segment remains the only treatment modality that can offer a potential cure.¹⁰ Proper treatment of early chest infections during childhood and improved health awareness may have contributed to the reduction of the incidence of bronchiectasis in the developed countries. In our series, a predisposing cause was identified in 23 patients (35%), predominantly previous TB infection; however, most cases remained idiopathic. Secondary bronchiectasis has a different pathology and management, and attempts to discriminate obstruction or systemic disease should be made in patients with a chronic productive cough or hemoptysis. We have previously reported the incidence of bronchiectasis with overlooked foreign body.¹¹

Chronic productive cough is usually the most common presenting symptom and should warrant further radiologic evaluation. Complications of bronchiectasis may be the presenting symptoms, mainly hemoptysis. HRCT is cur-

rently the modality of choice in the diagnosis of bronchiectasis.¹² In view of the general criticism of the traditional morphologic classification of bronchiectasis as inadequate,² the addition of functional classification not only reflects the degree of severity of the disease process but predicts which type may have a measured respiratory function. Thus this hemodynamic classification, which includes morphologic (cystic versus cylindric) and functional features (perfused versus nonperfused), is useful in selection of cases for surgical resection, because the question of which area to resect and which to preserve is defined more precisely, especially in cases with diffuse or bilateral bronchiectatic changes, to have maximum improvement in symptoms with minimal deterioration of lung function and gas exchange.^{9,10} Ashour⁹ stated that the morphologic features of bronchiectasis were correlated with angiographic findings; two types of bronchiectasis were recognized, nonperfused and perfused. All lungs with cylindric bronchiectatic changes were found to be perfused, whereas those with cystic changes were nonperfused. This discrepancy in the pattern of pulmonary perfusion reflected the difference in the severity of the disease process. The pulmonary perfusion was retained in the area of cylindric changes, and this type therefore was not a primary indication for surgical resection, with surgery reserved for more damaged territories.⁹

There is a broad consensus concerning the indications for surgical resection. Most physicians and surgeons reserve this treatment for localized bronchiectasis.⁶⁻⁸ Multisegmental or bilateral bronchiectasis is generally regarded as a contraindication for surgery.¹³ Nevertheless, we are confronted with cases of bronchiectasis involving multiple segments and lobes, with failure of conservative therapy, for which surgical intervention may be considered. From the end of the 1970s onward, few thoracic surgeons have suggested that bilateral bronchiectasis is not a contraindication to resection.^{5,14-16} This policy was avoided by many physicians because of high mortality and poor outcome.¹⁷

We believe that surgery should be reserved for patients in whom curative resection can be achieved, and these are usually cases of localized cystic unilateral bronchiectasis but can also extend to bilateral localized bronchiectasis or complete lung destruction in the absence of other diseased areas, and for patients with good respiratory performance.¹⁸ We also have learned that resection of localized cystic bronchiectasis in the presence of scattered cylindric bronchiectasis can improve symptoms and quality of life with low operative morbidity. Such instances represented only 11% of our patients. Transplantation remains indicated for diffuse cystic disease with seriously compromised pulmonary function and chronic respiratory failure.¹⁹⁻²¹

Pneumonectomy was done in 12 patients, predominantly as expected on the left side because of the anatomy of left bronchus syndrome.²² Complications usually range between

9.4% and 24.6%.^{3,6,8,14} We saw an 18% complication rate, mainly related to bleeding and prolonged air leak, emphasizing the need for good hemostasis and careful dissection. Our study showed the medium-term benefit of surgery in unilateral and bilateral bronchiectasis as indicated by hemodynamic classification. Forty-eight patients were considered cured (73%), and 17 had symptomatic improvement (26%). In our cases of mixed bilateral localized cystic and scattered cylindric bronchiectasis, all patients had improvement with low morbidity after resection of the localized cystic areas. In cases of bilateral cystic bronchiectasis, the role of surgery is limited to life-threatening complications as a palliative measure, and such patients should be listed for lung transplantation if respiratory failure occurs.²¹

Pseudomonas infection and underlying COPD were poor prognostic factors ($P < .05$) in our study. Other studies²³ have described several prognostic factors that predicted good operative results, such as a history of pneumonia, no or minor airway obstruction, absence of sinusitis-rhinitis, young age at the time of operation, and restricted unilateral bronchiectasis in the basal segments of the lower lobes. Fujimoto and colleagues¹⁴ showed three variables as significant prognostic factors: cylindric type of bronchiectasis, absence of sinusitis, and complete resection of the diseased parenchyma.

In the 17 patients who had improvement, follow-up chest HRCT showed no deterioration of the unresected cylindric bronchiectasis. All 17 showed no progressive deterioration in symptoms during follow-up.

Combined morphologic and hemodynamic assessment provides an accurate functional classification for bronchiectasis. This system is superior to morphologic classification alone in determining the indications and extent of surgical resection, especially in the presence of scattered bronchiectasis. Curative resection can be achieved in both unilateral and bilateral localized bronchiectasis, with acceptable morbidity. Selected patients with mixed cystic and scattered cylindric bronchiectasis may benefit from surgery, with no deterioration during follow-up. COPD and *Pseudomonas* infection are poor prognostic factors.

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Discussion

Dr John R. Benfield (Los Angeles, Calif). Dr Al-Kattan and colleagues are exemplary for having cared for 66 patients in 6 years with severe bronchiectasis with only a single death, even though 12 of these patients required pneumonectomy, including 2 who were treated for massive hemoptysis. This is in large part because of technically sound surgery and good postoperative care but in part also because these patients were young.

The basic principle of operation for bronchiectasis is to resect as little lung as one can in a palliative manner. Therefore I think it is somewhat surprising that 12 patients (18%) underwent pneumonectomy whereas there were no segmentectomies. Dr Al-Kattan, can you explain or enlarge on that fact?

Dr Al-Kattan. Eleven of our 66 patients had old TB, and we frequently see complete destruction of one lung in such patients and usually do not interfere surgically unless they have symptoms. We have previously described the left bronchus syndrome, in which the left lung is more destroyed than the right. In 2 patients

we had to perform the surgery because of massive hemoptysis, but in the remaining 10 cases the contralateral lung was clear and there was severe bronchiectasis in the other lung. I think this was probably due to a history of TB, and these patients were coming in with recurrent chest infection and recurrent productive cough for a long time, which necessitated the surgery.

Dr Benfield. How do you reconcile this with your exclusion criteria of TB?

Dr Al-Kattan. At the time of surgery, these patients didn't have TB. This is quite important. We excluded the patients who had active TB or were receiving anti-TB treatment, because they had a different line of management. A few patients had a history of TB that had been treated in the past. So I think the bronchiectasis represented a sequela of TB but not active TB.

Dr Benfield. What is really new about this report? One thing that is new, or at least relatively new, is the use of perfusion studies ($\dot{V}/\dot{Q}$ scans) in addition to HRCT to define what needed to be resected. I support the effort to know as much as you can about what needs to be resected. In reading the manuscript, however, I really couldn't tell how or even whether the information that you got from the $\dot{V}/\dot{Q}$ scans actually changed what you did. How did the perfusion studies alter what you would have done had the information available to you been a good bronchogram or a good HRCT scan?

Dr Al-Kattan. Actually, as you said, in our hemodynamic study, we noted that all cases of severely cystic bronchiectasis were nonperfused. So the addition of $\dot{V}/\dot{Q}$ scan at that time was merely supportive. But we find it important in cases of mixed bronchiectasis, where you have cystic and cylindric bronchiectasis, and those patients have symptoms. And it's a difficult decision whether to actually offer them surgery or not. You know that you can improve their symptoms, but you also do not want to compromise their pulmonary function. So when we know that these areas are nonperfused, we can go ahead, knowing that this is an irreversibly damaged lung and that it will not compromise their pulmonary function postoperatively and probably will sometimes improve it because of the avoidance of the shunt. So I believe that the supportive $\dot{V}/\dot{Q}$ scan, especially with scattered cylindric bronchiectasis, is quite important in making the decision and predicting the postoperative status after resection.

Dr Benfield. If one adds the number of pneumonectomies, which was 12, to the number of bilobectomies, which was 27, about 40% of your patients required significant pulmonary resections, which would impair lung function in the long term. The fact that 73% of your patients were cured of bronchiectasis is excellent, but we also need to have long-term follow-up with regard to exercise tolerance and lung function. Do you have any information about that?

Dr Al-Kattan. Actually, no. These patients usually have poor pulmonary function in comparison with normal. They usually have good arterial blood gas values, and the 6-minute walk is usually fairly good. So it's difficult to compare. But we have not observed deterioration with respect to oxygen exchange after resection, and I think that is because the areas we removed were actually in nonperfused areas and were actually adding to the shunt. Of course, when you have more disease, those patients are not candidates for surgery because they will not tolerate this, and they are listed for lung transplantation. In

our lung transplantation list, the number one indication of suppurative lung disease for transplantation is actually bronchiectasis. We wait until they are in the range of the lung transplantation zone, and then they are put on the waiting list. But I agree that the more resection you do, the more you should worry about the pulmonary reserve, and you should compare it with the outcome.

Dr Benfield. For the people of Saudi Arabia, it would be good if pediatric care could somehow be improved and if antibiotics were to be more readily available, to prevent bronchiectasis from occurring. Is there reason to hope that that such favorable change in pediatric care is happening or that it will happen in the future?

Dr Al-Kattan. Prevention is always better than cure. Vaccinations in Saudi Arabia have been obligatory for probably the last 20 years, and actually you cannot get a birth certificate until your child is 5 years old and has finished all the vaccinations, just to force the people to go in for vaccines. Traditionally, bronchiectasis is considered to be due to childhood infections, such as measles or whooping cough. I really don't know if this is completely true, because some affected children actually have been vaccinated against these diseases and have had good primary care. So probably there is more than just incomplete treatment of childhood infection, but at least it is a preventive measure to give more education to the pediatrician to deal more seriously with children's infections.

Dr Benfield. Thank you for catching us up to date.

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