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Lung function in bronchiectasis: the influence of *Pseudomonas aeruginosa*

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Lung function in bronchiectasis: the influence of Pseudomonas aeruginosa. *S.A. Evans, S.M. Turner, B.J. Bosch, C.C. Hardy, M.A. Woodhead. ©ERS Journals Ltd 1996.*

ABSTRACT: Sputum isolation of *Pseudomonas aeruginosa* (PA) is associated with extensive disease in bronchiectasis. It is not known, however, whether infection with *P. aeruginosa* is the result or the cause of severe disease.

We compared spirometry in patients with bronchiectasis before and after infection with *P. aeruginosa*, with that of patients infected by other organisms. All patients (n=12) with chronic colonization by *P. aeruginosa* (PA group) were studied. These were compared with other patients with bronchiectasis with no isolations of *P. aeruginosa* (n=37, non-PA group).

In the PA group, forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were lower than in the non-PA group. The PA group, however, also had lower values at the time of initial colonization with *P. aeruginosa* than the current values for the non-PA group. Change in FEV_1 and FVC over time was faster in the PA group than in the non-PA group. Reduction of FEV_1 and FVC over time in the PA group prior to *P. aeruginosa* colonization was intermediate, not being statistically different from either value above.

Our results confirm the association of chronic *P. aeruginosa* colonization with poor lung function, but conclude that patients with bronchiectasis who become colonized by *P. aeruginosa* have poorer lung function when first colonized than those colonized by other organisms. Decline in lung function is faster in those chronically colonized by *P. aeruginosa* than in those colonized by other organisms. It is not clear whether chronic *P. aeruginosa* colonization causes an accelerated decline in lung function or whether it is simply a marker of those whose lung function is already declining rapidly.

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The prognosis of patients with bronchiectasis is usually good except when associated with cystic fibrosis (CF). The decline in lung function over time for the majority is no greater than that predicted due to ageing. A minority of patients, however, show a more rapid deterioration, the cause of which has not been determined [1, 2]. *Haemophilus influenzae* and *Streptococcus pneumoniae* are the bacteria most commonly isolated from sputum in patients with bronchiectasis, but *Pseudomonas aeruginosa* (PA) is also found in about 10% of cases [3]. Chronic colonization with *P. aeruginosa* is associated with a rapid decline in lung function in CF [4], and it has been suggested that this organism is associated with extensive lung disease and severe airflow obstruction in non-CF bronchiectasis; however, data in man are scarce [5]. Animal models of bronchiectasis suggest that *P. aeruginosa* results in disease of greater severity than *H. influenzae* and *Staphylococcus aureus* [6].

The aim of the present study was to establish whether patients with bronchiectasis who have chronic colonization by *P. aeruginosa* have poorer lung function than those colonized by other organisms, and to compare the rate of lung function decline in these two groups.

Methods

Patients

Patients were identified from the Respiratory Medicine department's bronchiectasis register, in which all patients attending the department with this condition are recorded (patients in register n=135; chronically infected by *P. aeruginosa* n=12; intermittently infected by *P. aeruginosa* n=4). For the purposes of this study, bronchiectasis was defined as chronic sputum production and either thickened dilated bronchi typical of cylindrical bronchiectasis or cystic lesions typical of saccular bronchiectasis on chest radiograph or thoracic computed tomography (CT) scan. Serial sputum cultures and pulmonary function tests were performed at out-patient follow-up, at three monthly intervals in most patients.

All patients (n=12) with chronic colonization with *P. aeruginosa* (PA group) were studied (median of five isolations, range 3–48). Chronic colonization was defined as >3 isolations of *P. aeruginosa* from separate sputum

samples over >3 months. Ten patients were female (mean age 60 yrs, range 52–82 yrs), and two were male (aged 60 and 78 yrs). Where a subsequent sputum culture isolated another organism but not *P. aeruginosa*, patients were excluded from the PA group and regarded as intermittently colonized. Four patients fell into this category (mean age 60 yrs, range 54–67 yrs, including one patient with rheumatoid arthritis, one with tracheobronchopathia osteochondroplastica and one with amyloidosis and chronic renal failure) and were not included in the main study. Patients were not excluded if isolations showed another organism in addition to *P. aeruginosa*.

The PA group were compared with those with no isolations of *P. aeruginosa* (non-PA group), comprising all other female patients with bronchiectasis aged >50 yrs (n=34, mean age 62 yrs, range 51–79 yrs), and 6 males from the bronchiectasis register matched for age to those in the PA group. Medical records were obtained in 37 cases. Recent sputum cultures showed *H. influenzae* in 22 cases, *Moraxella catarrhalis* in 4, *S. pneumoniae* in 1, *Stenotrophomonas maltophilia* in 1, and growth of only "normal flora" in 9. The median number of sputum isolations in this group was 3 (range 2–13).

Clinical details and pulmonary function were retrieved from case records by a single observer (SAE).

Lung function

Spirometry was measured using a wedge bellows spirometer (Vitalograph TM Ltd, Buckingham UK) by two pulmonary function technicians (SMT and BJB). Measurements were repeated until the two highest measurements differed by <5% - the highest was accepted. Spirometry measured during exacerbations was not used for analysis, and measurements more than 5% lower than the following three monthly value were also excluded from analysis, on the assumption that such values may have been the result of either poor technique or an unidentified exacerbation.

Deoxyribonucleic acid (DNA) analysis

Patients in the PA group had mouth wash cell samples examined for ΔF508, G542X, G551D, and 621+1(G>T). These mutations account for more than 88% of CF genes in the North West Region of the UK [7].

Statistics

Pulmonary function was analysed both as absolute and percentage predicted [8]. The characteristics of the groups were compared using the Mann-Whitney U test.

Results

Causes of bronchiectasis and associated conditions are displayed in table 1. Time since diagnosis was significantly different between the two groups (PA 28±16 (mean± SD) yrs *versus* non-PA 17±18 yrs; p<0.05).

Smoking habit

None of the PA group was a smoker during the study period, eight being life-long nonsmokers and two past smokers, with prestudy data being unavailable in two. Six of the non-PA group smoked during follow-up, 12 were life-long nonsmokers and 10 past smokers, with prestudy data being unavailable in nine.

Table 1. – Causes of bronchiectasis and associated conditions

	PA group (n=12)	Non-PA group (n=37)
Post-tuberculous	2	4
Hypogammaglobulinaemia	0	2
Connective tissue disease	3	3
Idiopathic	7	28

PA: *Pseudomonas aeruginosa*.

Previous thoracic surgery

One patient in the PA group had had a lobectomy, and one a thoracoplasty and phrenic nerve crush, both before the study period. Three of the non-PA group had had lobectomies, all being before the study period.

Hospital admissions

In the PA group, the frequency of hospital admissions before and after *P. aeruginosa* infection were not significantly different (1.0±1.6 versus 2.4±3.1·yr^{-1}; p>0.1). The frequency of hospital admission in the 5 yrs before *P. aeruginosa* infection was not significantly different from that in the last 5 yrs of the non-PA group (1.0±1.6 *versus* 0.5±1.2·yr^{-1}; p>0.1). Admission data were only available for our institution and do not, therefore, take account of possible admissions to other hospitals. However, since most patients lived within the catchment area of this hospital, admissions elsewhere are likely to have been few.

Antibiotic treatment

Three out of 10 patients from the PA group (data unavailable in two) were known to have received continuous antibiotic therapy for more than 3 months prior to *P. aeruginosa* colonization, compared to 4 out of 37 in the non-PA group (p>0.05). Four out of 12 patients received continuous antibiotic therapy for more than 3 months after *P. aeruginosa* colonization (oral or nebulized), compared to 4 out of 37 in the non-PA group (p=0.07). The frequency of antibiotic courses were similar in the two groups (3.6±2.8 *versus* 3.0±2.3 courses·yr^{-1}; p>0.1), but these data are almost certainly incomplete, as courses of antibiotics given by the patient's general practitioner are often not documented in the hospital records.

Lung function

The mean length of time over which lung function was monitored was 10.2±5.5 yrs for the PA group and 8.9±2.6 yrs for the non-PA group (p>0.05). Lung function data in the PA group was monitored for a mean of 4.9±4.4 yrs while infected with *P. aeruginosa*, with lung function data prior to *P. aeruginosa* infection being available in eight patients.

A comparison of lung function in the PA and non-PA groups is presented in table 2. In the PA group, current FEV_1 and FVC at the time of data analysis were lower

Table 2. – Pulmonary function and change of pulmonary function over time

		PA group (n=12)	Non-PA group (n=37)
Latest FEV1	L	0.68±0.28*	1.21±0.59
	% pred	33±15*	53±20
Latest FVC	L	1.26±0.36*	2.07±0.8
	% pred	50±14*	73±20
FEV1 at time of PA colonization	L	0.76±0.27†	
	% pred	37±13†	
FVC at time of PA colonization	L	1.41±0.45†	
	% pred	52±17†	
Change in FEV1	mL·yr^{-1}	-52±61 post-PA	-14±58
	% pred	-3.0±4.7 post-PA*	-0.1±1.4
Change in FVC	mL·yr^{-1}	-161±208 post-PA*	+3±81
	% pred	-4.0±7.4 post-PA*	+0.2±2.2

Values are presented as mean±SD. PA: *Pseudomonas aeruginosa*; FEV1: forced expiratory volume in one second; % pred: percentage of predicted value; FVC: forced vital capacity. *: $p<0.05$, compared to the non-PA group (see text). †: $p<0.05$, compared to the latest values for the non-PA group.

than in the non-PA group. The PA group, however, also had lower values at the time of initial *P. aeruginosa* infection than the current values for the non-PA group. Lung function was not related to time from diagnosis (% FEV1 against time from diagnosis r= -0.26 (p=0.12), %FVC against time from diagnosis r= -0.23 (p=0.18)).

The four patients who were intermittently colonized by *P. aeruginosa* had comparatively well-preserved lung function (mean FEV1 1.56 L (59% pred), FVC 2.82 L (77% pred)).

Change in pulmonary function over time

Reduction in percentage predicted FEV1 and FVC over time, was faster in the PA group after *P. aeruginosa* infection, than in the non-PA group. Reduction of percentage predicted FEV1 and FVC over time in the PA group prior to *P. aeruginosa* infection (n=6) was intermediate to, and not statistically different from, either value above (FEV1 -0.8±2.7% pred·yr^{-1}; FVC -1.94±4.9% pred·yr^{-1}). Assessment of pulmonary function using absolute values gave similar results. Change in pulmonary function over time was not related to time from diagnosis in either group.

The four patients who were intermittently colonized by *P. aeruginosa* had a moderate fall in FEV1 (-38 mL·yr^{-1} or -0.98% pred·yr^{-1}).

DNA analysis

Mouth wash samples sent for genetic analysis from the PA group (n=9; three patients having died before samples were obtained) were all negative for ΔF508, G542X. G551D, and 621+1(G>T).

Discussion

This study has shown that patients with bronchiectasis chronically colonized by *P. aeruginosa* have poorer lung function than those colonized by other organisms. It has also shown that such patients have an increased rate of lung function decline compared to patients infected by other organisms, the rate of decline being comparable to that seen in CF patients colonized by *P. aeruginosa* [9]. The decline in lung function observed in those colonized by other organisms is similar to that seen in normal subjects [1]. It was also found, however, that those patients colonized by *P. aeruginosa* had poorer lung function at the time of initial colonization, compared to those colonized by other organisms.

The possibility that *P. aeruginosa* itself might cause a rapid decline in lung function, is supported by animal studies of experimental bronchiectasis, where *P. aeruginosa* innoculated into the bronchial lumen distal to a partially ligated bronchus produced more severe bronchiectatic changes than when equal numbers of *H. influenzae* or *S. aureus* were injected [6]. *P. aeruginosa* is a good candidate to cause progressive lung damage, as it produces toxins and virulence factors (*e.g.* exotoxin A, exotoxin S, phospholipase C, lipase, leukocidin, lipopolysaccharide and alginate) and proteolytic enzymes (*e.g.* alkaline protease and elastase), which interfere with host defence mechanisms [10–13]. In addition, *P. aeruginosa* produces factors which lead to epithelial disruption and reduced ciliary function, which could contribute to progressive lung damage [14, 15].

Our finding that those patients colonized by *P. aeruginosa* had poor lung function at the time of initial colonization, compared to those infected by other organisms, suggests, however, that *P. aeruginosa* merely colonizes those patients who already have rapidly declining lung function, and does not directly contribute to this decline. Experimental data suggest that bronchial wall damage is a necessary prerequisite for *P. aeruginosa* to adhere to respiratory epithelium [16, 17]. Interestingly, in CF, while colonization with *P. aeruginosa* is associated with poor lung function and a poor prognosis [9, 18–20], a causal relationship has not been shown, with CF patients infected by *P. aeruginosa* having a similar rate of lung function decline to CF patients infected by other organisms [9].

Another possibility is that *P. aeruginosa* colonises those with already rapidly deteriorating lung function but then causes an additional acceleration in lung function decline. We were unable to demonstrate a change in the rate of lung function decline after infection by *P. aeruginosa*, however, but were limited by the small number of patients with lung function measurements available prior to *P. aeruginosa* colonization.

The final explanation, is that the observations made were due to confounding factors. and did not relate to infection by *P. aeruginosa*. Data on potential confounding factors were collected, and there is no reason to believe that the group differences found were due to these. The six patients who smoked during the follow-up period were all in the non-PA group, and a history of past smoking was also more common in this group. No patients underwent thoracic surgery during the follow-up period. The causes of bronchiectasis are incompletely understood, but the apparent causes and associated diseases were similar in both groups. "Missed" CF has been described in some patients with apparent idiopathic bronchiectasis, but the genotype studies performed in our patients make this an unlikely confounding factor in the present study. While the patients in the PA group had been diagnosed as having bronchiectasis for a greater length of time, there was

no relationship between time since diagnosis and pulmonary function or change in pulmonary function, making this an unlikely confounding factor. A final confounding factor, which may be relevant, is that of antibiotic therapy. A history of long-term antibiotic therapy was not significantly more frequent in either group, suggesting that treatment effects are unlikely to account for the differences found. Whilst the PA group tended to have at least as much antibiotic therapy as the non-PA group, it may have been less effective because of the antibiotic resistance which is a feature of the organism.

Our study has several limitations, which should be noted. It could be argued that lung function is not the best measure of the clinical status of a patient with bronchiectasis. The extent of radiological disease, symptoms, or performance scores might be more relevant parameters. Secondly, the growth of *P. aeruginosa* as the predominant bacterium on sputum culture, does not exclude the simultaneous presence of other organisms that might contribute to the decline in lung function observed. Finally, the small size of the PA group does limit the conclusions that can be drawn from this study.

In conclusion, the results of the present study confirm the association of *P. aeruginosa* colonization in patients with bronchiectasis with severe airflow obstruction, but it was also demonstrated that patients with bronchiectasis who become colonized by *P. aeruginosa* have poorer lung function at the time of colonization than those colonized by other organisms. It therefore appears that *P. aeruginosa* selectively colonizes those patients with poor lung function. Whether *P. aeruginosa* has a role in any subsequent decline in lung function is unclear. Decline in lung function is faster in those colonized by *P. aeruginosa* compared with those colonized by other organisms, but it was not possible to demonstrate an accelerated decline in lung function after *P. aeruginosa* colonization compared with before. Further study would be useful in addressing this issue but would be difficult to perform in view of the patient numbers needed and the length of follow-up required.

P. aeruginosa may, therefore, have a causal role in the rapid decline in lung function seen in these patients, or it may be only a marker of those whose lung function is already declining rapidly. Although *P. aeruginosa* colonization occurs in only a small proportion of patients with bronchiectasis, its association with rapidly declining lung function means that a better understanding of the factors leading to colonization may be an important step in preventing severe lung damage in this group.

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References

1. Ellis DA, Thornley PE, Wightman AJ, Walker M, Chalmers J, Crofton JW. Present outlook in bronchiectasis: clinical and social study and review of factors influencing prognosis. *Thorax* 1981; 36: 659–664.
2. Cole PJ. Bronchiectasis. *In*: Brewis RAL, Gibson GJ, Geddes DM, eds. Respiratory Medicine. London, Balliere Tindall, 1990; pp. 726–759.
3. Roberts DE, Cole PJ. Use of selective media in bacteriological investigation of patients with chronic suppurative respiratory infection. *Lancet* 1980; i: 796–797.
4. Packe GE, Hodson ME. Changes in spirometry during consecutive admissions for infective pulmonary exacerbations in adolescent and adult cystic fibrosis. *Respir Med* 1992; 86: 45–48.
5. Wells A, Desai S, Whetton C, Wilson R, Cole P. The isolation of *Pseudomonas aeruginosa* from sputum in idiopathic bronchiectasis: an association with extensive disease and severe airflow obstruction (Abstract). *Am Rev Respir Dis* 1993; 147(4): A645.
6. Guerreiro D, Florio R, Todd H, Rohde J, Sheppard M, Cole PJ. Relative abilities of bacteria from bronchiectasis sputum to produce experimental bronchiectasis (Abstract). *Am Rev Respir Dis* 1993; 147(4): A400.
7. Ferrie RM, Schwarz M, Robertson NH, *et al.* Development, multiplexing and application of ARMS tests for common mutations of the CFTR gene. *Am J Hum Gene* 1992; 51: 251–262.
8. Cotes JE. Lung function, assessment and application in medicine. 4th Edn. Oxford, Blackwell Scientific, 1979; pp. 365–387.
9. Kerem A, Corey M, Gold R, Levison H. Pulmonary function and clinical course in patients with cystic fibrosis after pulmonary colonisation with *Pseudomonas aeruginosa*. *J Pediatr* 1990; 116: 714–719.
10. Hoiby N. *Hemophilus influenzae*, *Staphylococcus aureus*, *Pseudomanas cepacia*, and *Pseudomonas aeruginosa* in patients with cystic fibrosis. *Chest* 1988; 94: 97s–102s.
11. Pederson BK, Kharazmi A. Inhibition of human natural killer cell activity by *Pseudomonas aeruginosa* alkaline protease and elastase. *Infect Immun* 1987; 55: 986–989.
12. Kharazmi A, Hoiby N, Doring G, Valerius NH. *Pseudomonas aeruginosa* exoproteases inhibit neutrophil chemiluminescence. *Infect Immun* 1984; 445: 87–91.
13. Vasil ML. *Pseudomonas aeruginosa*: biology, mechanisms of virulence, epidemiology. *J Pediatr* 1986; 108: 800–805.
14. Wilson R, Pitt T, Taylor G, *et al.* Pyocyanin and 1-hydroxyphenazine inhibit the beating of human respiratory cilia *in vitro*. *J Clin Invest* 1987; 79: 221–229.
15. Wilson R, Munro N, Hastie S, *et al.* *Pseudomonas aeruginosa* produces low molecular weight molecules which damage human respiratory epithelium *in vitro* and slow mucociliary transport in the guinea-pig trachea *in vitro*. *Chest* 1989; 95: 214s.
16. Plotkowski MC, Chevillard M, Peirrot D, *et al.* Differential adhesion of *Pseudomonas aeruginosa* to human respiratory epithelial cells in primary culture. *J Clin Invest* 1991; 87: 2018–2028.
17. Plotkowski MC, Beck G, Tournier JM, Bernardo-Filho M, Marques EA, Puchelle E. Adherence of *Pseudomonas aeruginosa* to respiratory epithelium and the effect of leucocyte elastase. *J Med Microbiol* 1989; 30: 285–293.
18. Kulczycki LL, Murphy TM, Bellanti JA. Pseudomonas colonisation in cystic fibrosis: a study of 160 patients. *JAMA* 1978; 240: 30–34.
19. Hoiby N. *Pseudomonas aeruginosa* infection in cystic fibrosis. *Acta Pathol Microbiol Scand* 1977; 262 (Suppl.): 1–94.
20. Knocke JD, Stern RC, Doershuk CF, Boat TF, Matthews LW. Cystic fibrosis: the prognosis for five year survival. *Pediatr Res* 1978; 12: 676–679.