Effects of airway infection by *Pseudomonas aeruginosa*: a computed tomographic study

Katherine A Miszkiel, Athol U Wells, Michael B Rubens, Peter J Cole, David M Hansell

**Abstract**

**Background** — *Pseudomonas aeruginosa* commonly infects the airways of patients with bronchiectasis. A study was undertaken to examine the relationship between infection of the airways with this pathogen, the morphological pattern of bronchiectasis on thin section computed tomographic (CT) scanning, symptom duration, smoking habits of the patients, and the presence of airflow obstruction.

**Methods** — Thin section CT scans of 22 adult patients with bronchiectasis and concurrent sputum infected by *P. aeruginosa* (Pa +ve) and those of 45 randomly selected patients not infected by *P. aeruginosa* (Pa – ve) were analysed independently by two thoracic radiologists. Patients with cystic fibrosis were excluded. Each scan was scored at a lobar level for extent of bronchiectasis, severity of bronchial wall thickening and dilatation, predominant pattern of bronchiectasis, presence of mucus plugging, and degree of decreased attenuation of the lung parenchyma.

**Results** — The Pa +ve group had more extensive bronchiectasis and a greater degree of bronchial wall thickening and dilatation on the CT scan than the Pa – ve group; more extensive decreased attenuation was seen in the Pa +ve group. These findings were robust on multivariate analysis; decreased attenuation was also independently related to the duration of sputum production.

**Conclusion** — Patients with bronchiectasis infected by *P. aeruginosa* have more extensive and severe bronchiectasis on thin section CT scanning than those without *P. aeruginosa* infection. The bronchi and small airways are both involved, reflecting the end result of complex interactions between host airways and the numerous virulence factors produced by *P. aeruginosa*. (Thorax 1997;52:260–264)

**Keywords:** *Pseudomonas aeruginosa*, bronchiectasis, thin section CT scanning.

Infection of the airways by *Pseudomonas aeruginosa* occurs commonly in patients with cystic fibrosis but also occurs in patients with other forms of bronchiectasis. Although much of the morbidity and mortality of patients with bronchiectasis may be due to chronic infection with *P. aeruginosa*, chronic infection of the airways with this pathogen in patients with cystic fibrosis can be prevented by early institution of anti-pseudomonas chemotherapy. Experiments in vitro have suggested that *P. aeruginosa* plays an important part in the progression of bronchiectasis, and mucociliary clearance measurements and results in an experimental model of bronchiectasis in vitro are consistent with this. Computed tomographic (CT) scanning is an accurate and non-invasive method of imaging the bronchial tree and is the technique of choice for the diagnosis of bronchiectasis.

Nagaki et al investigated a group of non-smoking patients with a clinical diagnosis of chronic bronchitis whose airways had been infected by *P. aeruginosa* for at least one year. They found that such patients had significantly more severe bronchiectasis on CT scanning than non-infected matched patients and asymptomatic controls. Similar results were obtained in a study performed at our institution in which patients infected with *P. aeruginosa* appeared to have more extensive bronchiectasis on CT scanning and more severe airflow obstruction than non-infected patients, independent of their smoking history. However, in both these studies the assessment of bronchiectasis on the CT scan was limited.

In this study we have examined in more detail the relationship between infection of the airways by *P. aeruginosa* and the morphological pattern of bronchiectasis on thin section CT scans, and any relation between these and the severity and duration of symptoms, patients’ smoking habits, and respiratory function.

**Methods**

Consecutive adult patients undergoing investigation for known or suspected bronchiectasis between January 1991 and March 1993 were studied, provided that bronchiectasis was present on thin section CT scanning and either mucoid or non-mucoid strains of *P. aeruginosa* were cultured from sputum within three months of the scan. Exclusion criteria were (1) an abnormal sweat sodium concentration (tested in all patients), (2) a history of lobectomy or pneumonectomy (since this would affect the forced expiratory volume in one second (FEV1) and alter the CT scores), and (3) age below 16 years. The control group consisted of randomly selected patients with chronic purulent sputum production and bronchiectasis on CT scanning who were not infected by *P. aeruginosa*. Twenty two patients infected with *P. aeruginosa* and 45 controls were included.
Effects of airway infection by Pseudomonas aeruginosa

Table 1  Comparison of the demographic and clinical features obtained from the case records in patients with sputum infected with Pseudomonas aeruginosa (Pa+ve group) and those not infected (Pa−ve).

<table>
<thead>
<tr>
<th></th>
<th>Pa+ve group (n=22)</th>
<th>Pa−ve group (n=45)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>54.1 (14.5)</td>
<td>43.5 (14.3)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Sex (M:F)</td>
<td>10:12</td>
<td>16:29</td>
<td>0.44</td>
</tr>
<tr>
<td>No. of smokers (ever vs never)</td>
<td>9</td>
<td>16</td>
<td>0.67</td>
</tr>
<tr>
<td>Median (range) history (pack years)</td>
<td>0 (0–40)</td>
<td>0 (0–90)</td>
<td>0.46</td>
</tr>
<tr>
<td>No. with history of asthma</td>
<td>12</td>
<td>18</td>
<td>0.26</td>
</tr>
<tr>
<td>Age at onset of sputum production (years)</td>
<td>27.0 (22.0)</td>
<td>21.2 (18.3)</td>
<td>0.26</td>
</tr>
<tr>
<td>Duration of sputum production (years)</td>
<td>27.1 (14.6)</td>
<td>22.3 (17.4)</td>
<td>0.27</td>
</tr>
<tr>
<td>FEV1 (% pred)</td>
<td>58.2 (30.1)</td>
<td>75.4 (22.9)</td>
<td>&lt;0.02</td>
</tr>
</tbody>
</table>

FEV1 = forced expiratory volume in one second. Values are mean (SD) on median (range).

The predominant pattern of bronchiectasis present in each lobe as classified by Reid (cylindrical, varicose or cystic) was recorded. The extent of bronchiectasis, severity of bronchial wall thickening, and severity of bronchial wall dilatation were recorded for each lobe using a four point scoring system (0–3): grade 0 = no bronchiectasis, normal bronchial wall thickness, or no bronchial wall dilatation; grade 1 = bronchiectasis present in none or one bronchopulmonary segment, bronchial wall thickening equivalent to half the diameter of the adjacent vessel, or bronchial wall dilatation equivalent to less than twice the diameter of the adjacent vessel; grade 2 = bronchiectasis present in more than one bronchopulmonary segment, bronchial wall thickening equivalent to 0.5–1× diameter of the adjacent vessel or bronchial wall dilatation equivalent to 2–3× diameter of the adjacent vessel; grade 3 = gross cystic bronchiectasis present, bronchial wall thickening equivalent to more than the diameter of the adjacent vessel, or bronchial wall dilatation present equivalent to more than three times the diameter of the adjacent vessel. The total score for each of these parameters was obtained by adding together the scores for the six lobes.

The presence or absence of bronchiectasis on the CT scans was determined according to the criteria described by Naidich. The CT scoring system used was that described by Reiff et al which has good interobserver agreement. The percentage predicted FEV1 was also recorded.

All CT observations were made at a lobar level with the lingula considered a separate lobe. The presence or absence of bronchiectasis was assessed from case records: (1) demographic details; (2) smoking history (“ever” versus “never”, pack years); (3) clinical history of asthma; (4) age at onset of sputum production; (5) duration of sputum production; (6) a predisposing cause, if any, for bronchiectasis. The total score for each of these parameters was obtained by adding together the scores for the six lobes.

The predominant pattern of bronchiectasis present in each lobe as classified by Reid (cylindrical, varicose or cystic) was recorded. The presence of either small centrilobular plugs or large plugs (plugging of the segmental and subsegmental airways) was recorded as present or absent. To assess involvement of the bronchioles by the disease process areas of decreased attenuation of the lung parenchyma

---

Figure 1  Thin section slices of a CT scan taken at two similar levels from two patients with bronchiectasis, both with a 29 year duration of sputum production. Sections (a) and (b) are through the upper zones and (c) and (d) are through the lower zones. Sections (a) and (c) are from a patient not infected with P aeruginosa and (b) and (d) are from a patient infected with P aeruginosa.
Table 2  Median scores (with ranges) for morphological features on CT scans in patients with sputum infected with Pseudomonas aeruginosa (Pa +ve) and those not infected (Pa –ve).

<table>
<thead>
<tr>
<th></th>
<th>Pa +ve group (n=22)</th>
<th>Pa –ve group (n=45)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent of bronchiectasis</td>
<td>9.5 (3.5–14.0)</td>
<td>5.0 (1.5–15.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Bronchial wall dilatation</td>
<td>9.5 (2.5–17.5)</td>
<td>4.0 (1.0–17.5)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Bronchial wall thickening</td>
<td>6.0 (2.5–12)</td>
<td>3.5 (0–17.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Global decreased attenuation</td>
<td>5.5 (0–12)</td>
<td>2.0 (0–11)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Large plug score</td>
<td>0.5 (0–2.5)</td>
<td>0 (0–2.5)</td>
<td>0.07</td>
</tr>
<tr>
<td>Centrilobular plug score</td>
<td>0.5 (0–5)</td>
<td>0 (0–5)</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Statistical analysis performed by Wilcoxon’s rank sum test.

were recorded as: grade 0 = normal, grade 1 = decreased attenuation involving <50% of the lobe, grade 2 = decreased attenuation involving >50% of the lobe; the total decreased attenuation score was the sum of the lobar scores. The mean scores of the two observers were used in the analysis.

Results are expressed as medians with ranges. A p value of <0.05 was regarded as statistically significant. Group comparisons were made using the Student’s t test, χ2 statistics, or Wilcoxon’s rank sum test. Agreement between observers was expressed as the kappa coefficient; kappa values of >0.60 were taken to indicate good agreement between observers. Correlations were examined by multiple linear regression or, when appropriate, by logistic regression (Stata Data Analysis, Computing Resonance Center, Santa Monica, California, USA).

Results

During the study period 327 patients with chronic purulent sputum and known or suspected bronchiectasis underwent CT scanning. Thirty five (10.7%) were infected with P. aeruginosa, but 13 were excluded because of previous pneumonectomy or lobectomy (n=9), P. aeruginosa not cultured within three months of CT scan (n=2), and incomplete data (n=2). Of the remaining 22 patients, 14 (63.6%) were continuously infected by P. aeruginosa. Patients positive for P. aeruginosa and controls were well matched for sex, history of asthma, the age at onset of sputum production, and the duration of sputum production (table 1). Five of the 22 patients (22.7%) infected with P. aeruginosa (Pa +ve) and 11 (24.4%) of the 45 control patients (Pa –ve) had an underlying cause of bronchiectasis (allergic bronchopulmonary aspergillosis, previous pulmonary tuberculosis, hypogammaglobulinaemia, primary ciliary dyskinesia, Kartagener’s syndrome, or Young’s syndrome).

P. aeruginosa infection was associated with increasing age (p<0.01) and a lower FEV1 (p<0.02; table 1). On logistic regression infection by P. aeruginosa was independently associated with a longer duration of sputum production (odds ratio 1.06; 95% CI 1.01 to 1.12; p = 0.04) but not with increasing age at onset of sputum production (p = 0.08), pack years of smoking (p = 0.41), sex (p = 0.72), a history of asthma (p = 0.33), or the presence of an underlying cause of bronchiectasis (p = 0.97).

The extent and severity of bronchiectasis, the severity of bronchial wall thickening, and the extent of decreased attenuation were significantly greater in the Pa +ve group than in the Pa –ve group (fig 1; table 2). Both observers agreed that cystic and/or varicose bronchiectasis was present in 15 of the 67 patients (22.5%); the kappa coefficient of agreement was 0.71. Cystic and/or varicose bronchiectasis was present more often in the Pa +ve group (10/22, 45%) than in the Pa –ve group (5/45, 11%; p <0.0002).

Multiple regression analysis was performed to evaluate associations between the presence of P. aeruginosa and morphological features on the CT scan independently of other factors associated with P. aeruginosa (age and duration of sputum production). As shown in table 3, the presence of P. aeruginosa was associated with more extensive and severe bronchiectasis (both p<0.0005), greater bronchial wall thickening (p<0.0005), and more extensive decreased attenuation (p<0.0005). A longer history of sputum production was associated with a more extensive decreased attenuation score (p<0.05) and a shorter history of sputum production was associated with more extensive centrilobular mucus plugging (p<0.04). There were no independent relationships between morphological features of the CT scan and patient age.

Logistic regression was performed to evaluate independent associations between individual CT morphological features and P. aeruginosa infection. The presence of P. aeruginosa was independently related to increasing bronchial wall thickness (odds ratio 1.74; 95% CI 1.00 to 1.73; p<0.05) but not to the severity of bronchial wall dilatation, the global extent of bronchiectasis, or the extent of regional air trapping.

Discussion

We have shown that patients who persistently expectorate sputum infected with P. aeruginosa have more extensive and severe bronchiectasis on thin section CT scanning than patients whose sputum is not infected with P. aeruginosa. The global decreased attenuation score in these


Effects of airway infection by Pseudomonas aeruginosa: a computed tomographic study.

K A Miszkiel, A U Wells, M B Rubens, P J Cole and D M Hansell

Thorax 1997 52: 260-264
doi: 10.1136/thx.52.3.260

Updated information and services can be found at:
http://thorax.bmj.com/content/52/3/260

These include:

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Topic Collections
Articles on similar topics can be found in the following collections

Radiology (diagnostics) (812)
Cystic fibrosis (525)
Health education (1223)
Smoking (1037)
Tobacco use (1039)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/