RESPIRATORY

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Allergic bronchopulmonary aspergillosis: the spectrum of computed tomography appearances

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Although computed tomography (CT) of the thorax has been compared to plain chest radiography and bronchography for demonstration of central bronchiectasis (CB) in allergic bronchopulmonary aspergillosis (ABPA), the CT presentation of the disease is yet to be highlighted. With this in view, the CT appearances in 23 patients with ABPA were evaluated. The scans were assessed for bronchial, parenchymal and pleural abnormalities.

Central bronchiectasis was identified in all patients, involving 114 (85%) of the 134 lobes and 210 (52%) of the 406 segments studied. Other bronchial abnormalities such as dilated and totally occluded bronchi (11 patients), air-fluid levels within dilated bronchi (five patients), bronchial wall thickening (10 patients) and parallel-line shadows (seven patients) were also observed.

Parenchymal abnormalities, which had a predilection for upper lobes, included consolidation in 10 (43%) patients, collapse in four (17%) patients and parenchymal scarring in 19 (83%) patients. A total of six cavities were seen in three (13%) patients, and an emphysematous bullae was detected in one (4%) patient. The pleura was involved in 10 (43%) patients. Ipsilateral pleural effusion with collapse was observed in one patient, while in nine other patients, parenchymal lesions extended up to the pleura. Concomitant allergic Aspergillus sinusitis (AAS) was also detected in three (13%) of the 23 patients.

Computed tomography of the thorax in patients with ABPA provides a sensitive method for the assessment of bronchial, parenchymal and pleural abnormalities, and should constitute a part of the diagnostic work of the disease.

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Introduction

Allergic bronchopulmonary aspergillosis (ABPA) is not uncommon in India (1). As it is a potentially destructive lung disease, an early diagnosis is essential to prevent the development of end-stage lung fibrosis. Since its first description by Hinson et al. in 1952 (2), radiological techniques have been crucial to the diagnosis of the disease. Not only do imaging techniques help to establish the diagnosis, but also help to monitor the progress of the disease.

Central/proximal bronchiectasis (CB) with normal peripheral bronchi, a pathognomonic feature of ABPA, was first described by Scadding (3). Demonstration of CB is considered a sine qua non for the diagnosis of the disease (4), for which bronchography was regarded as a gold standard (5). However, computed tomography (CT) of the thorax is now accepted as an effective alternative in the diagnosis of bronchiectasis (6–8). Recently, the authors have shown that CT in comparison to bronchography, a procedure thought to be unsafe in asthma, has a sensitivity of 83% and a specificity of 92% in detecting CB in patients with ABPA (9), and could thus be the investigation of choice. Computed tomographic scan also enabled rapid and safe establishment of the diagnosis in children with

TABLE 1. Patient characteristics

Subject no.	Age/sex	Duration of illness (yr)	Stage on presentation	Peripheral blood eosinophilia (cells mm^{-3})	Serum precipitins	Serum IgE levels (IU ml^{-1}) (N=0–100)	Cutaneous reactivity		Pulmonary infiltrates
							Type I	Type III	
1	26/M	7	III	3050	+	810	+	+	+
2	35/F	28	V	1938	+	210	+	+	+
3	16/M	4	III	1444	+	610	+	+	+
4	32/F	4	III	378	+	540	+	+	+
5	55/M	45	II	258	−	580	+	+	+
6	45/M	10	III	267	+	680	+	+	+
7	32/F	6	II	528	+	120	+	+	+
8	28/M	2	III	784	+	800	+	+	+
9	48/M	47	III	920	+	670	+	+	+
10	37/M	32	III	2848	−	430	+	+	+
11	13/M	3	III	1380	+	480	+	+	+
12	25/M	5	I	1630	+	780	+	+	+
13	50/F	1·5	III	4140	−	540	+	+	+
14	50/F	12	IV	1368	+	80	+	−	+
15	54/M	11	III	2624	+	410	+	+	+
16	39/M	18	III	1664	−	480	+	+	+
17	42/M	7	III	1690	−	250	+	−	+
18	37/F	8	II	1446	+	100	+	+	+
19	42/M	11	III	1162	+	400	+	+	+
20	11/M	1	I	1440	+	560	+	+	+
21	19/F	6	III	1205	+	490	+	+	+
22	38/F	35	III	1116	+	540	+	+	+
23	29/F	5	III	1504	+	610	+	+	+

ABPA who presented with acute severe asthma (10).

The few CT studies on ABPA available so far have focused their attention on detection of CB on CT as compared to plain chest radiography (5,11,12). However, the CT presentation of ABPA is yet to be highlighted. With this in view, the spectrum of CT appearances in 23 patients with ABPA is presented.

Methods

PATIENTS

The study comprised 23 patients (Table 1) who were considered to have ABPA in view of the following criteria: (1) history of asthma; (2) peripheral blood eosinophilia; (3) transient pulmonary infiltrates; (4) presence of Type I cutaneous reactivity to aspergillin, with or without Type III reaction; (5) demonstration of serum precipitins against *Aspergillus* species; and (6) elevated total serum immunoglobulin E (IgE) levels.

The study population consisted of 14 males and nine females with a mean age of 35 years (range 11–55 years). The mean duration of illness was 13·5 years (range 1–47 years). All of the 23 patients had history of asthma, transient pulmonary infiltrates, type I skin reaction to aspergillin and elevated serum IgE levels. Peripheral blood eosinophilia (>500 cells mm^{-3}) was present in 20 (87%) of the 23 patients, and serum precipitins were positive in 18 (78%) patients. The patients, at the time of presentation, were staged (4) according to their clinical, radiological and immunological status as follows: Stage I (Acute), n=2; Stage II (Remission), n=3; Stage III (Exacerbation), n=16; Stage IV

(Steroid-dependent asthma), $n=1$; and Stage V (End-stage fibrosis), $n=1$. Three (13%) patients also had concomitant allergic *Aspergillus* sinusitis (AAS) as assessed by biopsy. Of the 23 patients, 19 (83%) patients had received antituberculous therapy before presentation.

COMPUTED TOMOGRAPHY

Non-contrast CT of the thorax was performed on a Somatom-DRH CT scanner (Siemens Erlangen, Germany), with a 512 matrix size. Computed tomographic scans were obtained at 125 kV, 210 mA, with a scan time of 3–5 s in the supine position at full end-inspiration from lung apex to base with 8-mm contiguous slices. Supplemental 4-mm contiguous slices were taken in areas where bronchi were not sharply visualized on 8-mm slices. These areas were mostly presented in the region of anterior and posterior segmental bronchi of the upper lobes, medial and lateral segmental bronchi of the middle lobes, and apical-basal segmental bronchus of the lower lobes, as these bronchi course horizontally and may not be clearly visualized on 8-mm slices due to partial volume-averaging effect. The scans were read in a random and blinded manner by a team comprising both radiologists and pulmonologists, and conclusions were reached by consensus. The scans were analysed at lobar as well as segmental level. Individual bronchopulmonary segments were identified by the anatomical division of the appropriate lobar bronchus, and its relationship with the major and minor fissures (13).

All scans were assessed for radiological abnormalities and were categorized as follows:

(1) Bronchial abnormalities in the form of (i) 'string of pearls' appearances, (ii) 'signet ring' appearances, (iii) beaded tubular opacities, (iv) bronchial wall thickening, (v) parallel line opacities, or (vi) air-fluid level within the bronchi. The criteria used to define these appearances were as described by Naidich *et al.* (14). The distance of bronchiectasis from the hilum was ascertained, and it was deemed to be central when confined to the medial two-thirds of the lung.

(2) Parenchymal abnormalities which included consolidation – lobar, segmental or patchy – cavitation, loss of volume due to collapse or fibrosis, emphysematous changes, etc.

(3) Pleural abnormalities which included pleural thickening and free fluid.

(4) Any other abnormal features not described by the above categories.

Results

In the 23 patients of ABPA whose CT scans were evaluated, there were 138 lobes available for study, as the lingula, for analysis purposes, was counted as a separate lobe. However, one patient who had previously undergone a left lower lobectomy for an aspergilloma, presented with collapse of the remaining two left lobes along with an associated ipsilateral pleural effusion (15), thus leaving a total of 135 lobes for study, comprising 408 segments, which also included two extra subapical segments in two patients.

BRONCHIAL ABNORMALITIES

One more lobe had to be excluded while analysing bronchial abnormalities, due to the left upper lobe consolidation in one patient which left a total of 134 lobes with 406 segments.

Central Bronchiectasis

Central bronchiectasis, as evidenced by 'string of pearls' (Plate 1) and 'signet-ring' (Plate 2) appearances, was a universal finding in all 23 (100%) patients, and this involved 114 (85%) of 134 lobes. Of these 114 lobes, 80 (70%) had CB with normal peripheral bronchi, while in 34 (30%) lobes [in 17 (74%) patients] CB also extended to the periphery. The remaining 20 (15%) lobes had normal bronchi.

At the segmental level, of the total 406 segments, 210 (52%) had CB, of which 165 (79%) had normal tapering bronchi peripherally, while in 45 (21%) lobes, CB extended to the periphery. The remaining 196 (48%) segments had normal bronchi. Supplemental 4-mm scans, performed in eight patients, gave a sharper picture of the bronchi and were helpful in assessment of 48 (12%) of the 406 segmental bronchi studied.

Distribution According to Site

The distribution of the 134 lobes available for study is summarized in Table 2. Of the 44 upper
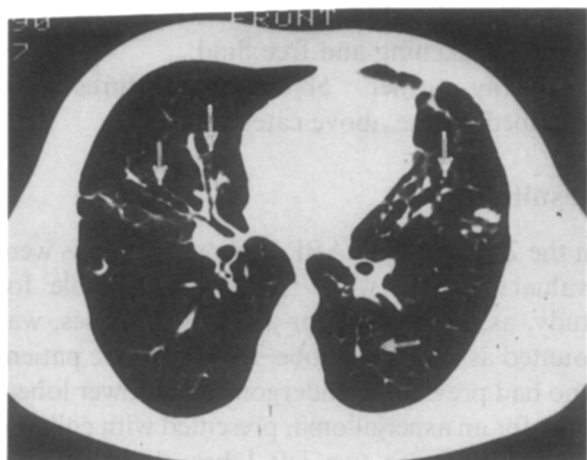
PLATE 1. Computed tomographic scan of Patient 1 at the level of right middle lobe bronchus showing 'string of pearls' appearances (arrows), involving both medial and lateral segments of the right middle lobe bronchus, inferior lingular bronchus and the apical segmental bronchus of the left lower lobe.

lobes available for study, 39 (89%) had CB, of which 24 had CB with normal periphery, while 15 lobes had CB which also extended to the periphery. Two or more segments were involved in 16 (73%) of the 22 right upper lobes (RULs) affected, compared to 10 (59%) of the 17 left upper lobes (LULs) affected. In the 19 right middle lobes (RMLs) affected, 16 (84%) medial segments had CB, while both segments were
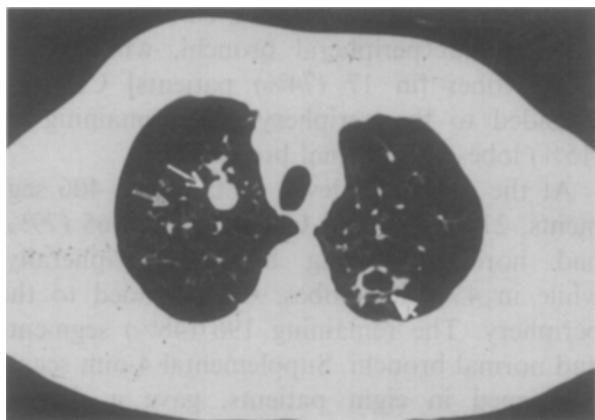

PLATE 2. Computed tomographic scan of Patient 1 across upper lobes showing 'signet-ring' appearances (arrow) involving multiple segmental bronchi, a dense circular opacity (arrow) in the apical segmental bronchus of the right upper lobe and bronchial wall thickening (arrow head) in the dilated apicoposterior segmental bronchus of the left upper lobe.

involved in nine (47%) lobes. On the left side, both segments were involved in 12 (67%) out of 18 lingulas. Of the 45 lower lobes available for study, CB was detected in 38 (84%). The apical segment was the only segment affected in 16 (42%) lower lobes, five on the right and 11 on the left side.

Other Bronchial Abnormalities

Dilated and totally occluded bronchi as evidenced by beaded tubular opacities (Plate 2) and dense circular opacities (Plate 3) were observed in 11 (48%) patients. Air-fluid levels within dilated bronchi were visualized in five (22%) patients. Bronchial wall thickening (Plate 3) was present in 10 (43%) patients, while parallel line opacities extending up to the periphery were seen in seven (30%) patients.

PARENCHYMAL ABNORMALITIES

Consolidation (Plate 4) was seen in 10 (43%) patients. One patient had consolidation of the LUL, while consolidation was observed in isolated segments in nine patients (five RULs, one RML, one RLL, two LLLs). Non-homogeneous patchy consolidation was noted in 15 (67%) patients. Collapse was detected in four patients, three of whom had segmental collapse (one each in RUL, RML and LLL), while the patient (15) who had earlier undergone a left lower lobectomy presented with collapse of the remaining two left lobes (Plate 5). Parenchymal scarring of varying extent was present in 19 (83%) patients. Six cavities (Plate 4) were observed in three (13%) patients (two RULs, two LULs, one RML and one LLL). An emphysematous bullae was seen in one (4%) patient in LUL.

PLEURAL ABNORMALITIES

The pleura was involved in 10 (43%) of the 23 patients. Ipsilateral pleural effusion was seen in the patient (15) who had earlier undergone left lower lobectomy, and had presented with collapse of the remaining two lobes (Plate 5). In nine other patients, parenchymal lesions extended up to the pleura.

Distribution of Lesions According to the Stage of Disease

As mentioned earlier, all patients had central bronchiectasis. In the two patients classified as

TABLE 2. Lobar distribution of central bronchiectasis (CB) in the 23 patients with allergic bronchopulmonary aspergillosis

	Total lobes for study	Normal lobes	Lobes with CB	Lobes with CB with normal periphery	Lobes with CB with peripheral bronchiectasis
RUL	23	1	22 (96%)	14	8 (36%)
LUL	21*	4	17 (81%)	10	7 (41%)
RML	23	4	19 (83%)	14	5 (26%)
Lingula	22*	4	18 (82%)	11	7 (39%)
RLL	23	3	20 (87%)	15	5 (25%)
LLL	22*	4	18 (82%)	16	2 (11%)
Totals	134	20	114 (85%)	80	34 (30%)

*Four lobes excluded from study (one patient had LUL consolidation, and one patient who had left lower lobectomy presented with collapse of LUL and lingula).
RUL, right upper lobe; LUL, left upper lobe; RML, right middle lobe; RLL, right lower lobe; LLL, left lower lobe.

Stage I (Acute), one had lobar and the other had segmental consolidation. In the three patients classified as Stage II (Remission), apart from CB, collapse of RUL was detected in one patient. Of the largest group of 16 patients, categorized as Stage III (Exacerbation), 13 had either segmental or patchy consolidation, while three had evidence of collapse. This also included two of the three patients with cavities. In the single patient in Stage IV (Corticosteroid-dependent asthma), extensive parenchymal scarring with fibrotic bands were seen. The only patient who was categorized as Stage V (Fibrotic lung) had extensive fibrocavitary disease associated with loss of volume.

Discussion

Central bronchiectasis with normal peripheral bronchi is, radiologically, the most striking feature of ABPA, and when present, it is
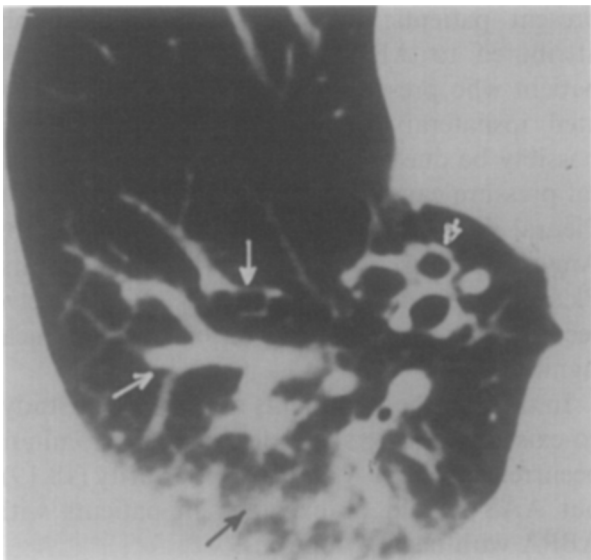

PLATE 3. Computed tomographic scan of Patient 12 across right lower lobe showing beaded tubular opacities (white arrows), bronchial wall thickening (arrow head) and parenchymal infiltrates in the posterior segment (black arrow).
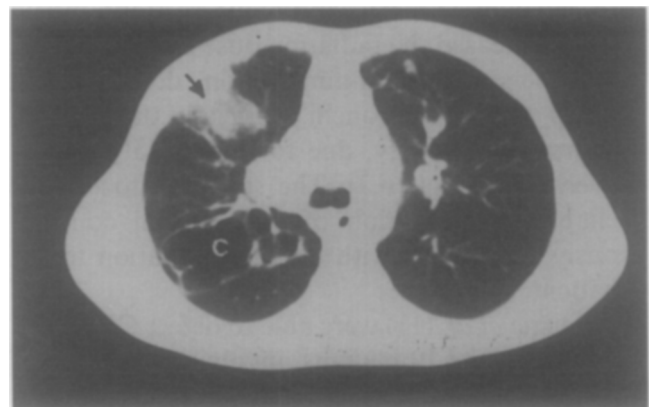

PLATE 4. Computed tomographic scan of Patient 17 across right upper lobe showing consolidation (black arrow) of the anterior segment and a cavity (C) in the posterior segment.
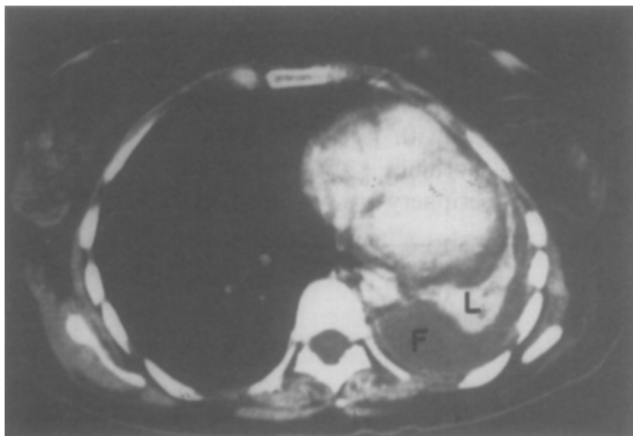
PLATE 5. Computed tomographic scan of Patient 22 showing collapsed left lobe (L) along with associated pleural effusion (F).

diagnostic of the disease. However, CB may not be present in the early phase of the disease (4). Allergic bronchopulmonary aspergillosis is not infrequent in cystic fibrosis (CF), a disease in which CB is also seen but normal peripheral bronchi are not seen (4).

Previously, the present authors have demonstrated that CT, compared to bronchography, has the potential of being the investigation of choice for the demonstration of CB in ABPA (9,10). Although high-resolution CT (HRCT) is now the accepted technique of choice for the diagnosis of bronchiectasis, contiguous 8-mm scans with supplemental 4-mm scans were performed in selected areas in eight patients. Contiguous scans were done to avoid missing any lesions, as bronchiectasis in ABPA is often small, localized and widely scattered. Very thin (2 mm) to medium (5 mm) contiguous sections would have increased the radiation dose to the patients, and the standard 10-mm sections do not give a sharp picture of bronchi, especially those which course horizontally, due to the partial volume-averaging effect (6,7). The study protocol thus enabled visualization of the bronchi continuously and clearly with minimal radiation to the patient.

Currie et al. (11) were able to detect CB on CT in nine of the 10 patients, involving 31 (57%) of the 54 lobes, while Neeld et al. (5) detected CB in six of their eight patients, involving 19 (41%) of the 46 lobes. A similar study from India (12) in 15 patients detected CB in 57 (63%) of the 90 lobes studied, and Angus et al. (16) detected CB

in 14 of their 17 patients involving 43 (42%) of the 102 lobes. However, none of these studies analysed CB at segmental level. The relatively higher occurrence of CB (85% lobes and 52% segments) in the present patients was most probably due to the delay in diagnosis caused by the radiological similarity to pulmonary tuberculosis. This led to 19 (83%) patients receiving anti-tuberculosis therapy for long durations before presenting to the authors, during which time lung damage continued to occur relentlessly.

Extension of CB to the periphery seen in 30% of the lobes and 21% of the segments had also been observed by others (5,11,12,16). Neeld et al. (5) and Angus et al. (16) also observed CB in 15 and 6%, respectively, of their asthma patients with a positive skin test to A. fumigatus. It appears that CB may extend to the periphery in a small number of segments. Concurring with the views expressed recently by Angus et al. (16), the authors feel that CB with normal peripheral bronchi should continue to be regarded as the diagnostic feature of ABPA.

As observed previously (5,11,12), the disease also predominantly affected the upper lobes, the right more than the left lobe. In contrast, 'usual' bronchiectasis is more commonly seen in the lower lobes, the left more than the right lobe (17).

Involvement of the pleura, seen in 43% of the present patients, is a feature not commonly attributed to ABPA. This also included one patient who presented with collapse and associated ipsilateral pleural effusion, which could possibly be due to increased negative intrapleural pressure caused by collapse of the lung (15). Pleural thickening was also observed on CT by Angus et al. (16) in 14 (82%) of their 17 patients. Pleural involvement in ABPA is yet to receive recognition, but may not be of major clinical significance.

In three of the 23 patients of the present study, co-existent AAS was also detected. Concomitant occurrence of ABPA and AAS is a rarity (18,19), but AAS should be excluded in patients with ABPA with nasal symptoms.

Computed tomography of the thorax has already emerged as a safe, rapid, effective and acceptable alternative to bronchography for the demonstration of central bronchiectasis in ABPA (9,10). This study suggests that CT can

provide a sensitive method not only for the assessment of bronchial abnormalities, but also for parenchymal and especially pleural involvement, an aspect which is yet to be highlighted. Although CB can extent to the periphery in ABPA, demonstration of CB with normal peripheral bronchi which occurs in the majority of segments should continue to be regarded as a *sine qua non* for the diagnosis of ABPA. The authors feel that in a patient in whom APBA is considered as a possible diagnosis, evaluation with CT of the thorax should constitute a part of the diagnostic work-up.

Acknowledgements

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