Studies in chronic allergic bronchopulmonary aspergillosis
2 Radiological findings

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Malo, J. L., Pepys, J., and Simon, G. (1977). *Thorax*, 32, 262–268. **Studies in chronic allergic bronchopulmonary aspergillosis. 2 Radiological findings.** The characteristics and the incidence of changes in plain chest radiographs were analysed in detail in 50 asthmatic patients with chronic allergic bronchopulmonary aspergillosis in whom the diagnosis had been made from 2 to 25 years previously (mean duration 10·9 years). One thousand two hundred and forty-two chest radiographs, an average of about two per year per patient, were reviewed. Two hundred and sixty-seven acute episodes of transient shadows (a mean of 5·3 per patient), mostly homogeneous consolidations and band-like shadows, were recorded throughout the period of follow-up. Features of overinflation were present in 21 patients in the first radiograph and in 17 in the last, the decrease being attributed to the effects of permanent lung damage due to the allergic aspergillosis. Permanent changes, such as tubular and ring shadows, loss of vascular shadows, and lobar shrinkage were recorded in 41 patients at the start and in 49 at the end of the follow-up. The tubular shadows were found in 28 patients in the first radiograph and in 45 in the last, whereas ring shadows were seen in 18 and 30 patients respectively. Half of the episodes of consolidation and atelectasis left permanent changes, mainly ring shadows, as seen in the last radiograph. Of the band-like shadows, 32% were found to be followed by the subsequent appearance of tubular shadows. Statistically significant correlations were found between the duration of aspergillosis, the number of transient shadows throughout the period of follow-up, the extent of the permanent shadows, and the reduction of gas transfer factor at the time of the final follow-up.

The nature and incidence of the radiological changes in allergic bronchopulmonary aspergillosis have been described (McCarthy *et al.*, 1970). A five-year follow-up on the occurrence of the transient and permanent abnormalities in patients with asthma and aspergillosis treated with three different regimens has also been undertaken (Safirstein *et al.*, 1973). In the present nine-year follow-up permanent changes are described in more detail and related to acute episodes. Lung function tests were also made at the time of the last radiograph and correlated with the radiological findings.

Material and methods

PATIENTS

Fifty patients with asthma and allergic broncho-

pulmonary aspergillosis were studied. The criteria used in making the diagnosis were a history of asthma with at least one past episode of pulmonary shadow with blood eosinophilia together with an immediate skin prick reaction to an extract of *Aspergillus fumigatus*. The clinical characteristics and the results of the lung function tests of these patients have been analysed in another article dealing with these topics (Malo *et al.*, 1977). Thirty-three of these patients were included in a previous five-year follow-up (Safirstein *et al.*, 1973).

RADIOGRAPHIC PROCEDURE
At the last attendance each patient had a standard postero-anterior chest radiograph taken at 1·8 m on full inspiration. Thirty-six patients also had a left lateral chest radiograph. All the available previous chest radiographs of these patients were

also reviewed. From every radiograph, a record of transient and permanent shadows was made, using a description similar to the one published by McCarthy *et al.* (1970). The transient shadows include:

1 homogeneous shadow without lung shrinkage (consolidation), either large, when most of a lobe was involved, or small, when of a lesser extent;
2 non-homogeneous shadow or patchy clouding (consolidation);
3 nodular (small circular) shadow;
4 atelectasis of a lung or a lobe: homogeneous shadow with evidence of shrinkage;
5 band-like (toothpaste) and gloved-finger shadows: shadows 2–3 cm long and 5–8 mm wide without or with a rounded distal end;
6 tram-line shadows: two parallel hair-line shadows, the width of the transradiant zone between the lines being that of a normal bronchus at this level; and
7 circular shadows: well-delineated shadows with a diameter of 2–3 cm.

The permanent shadows include:

1 tubular shadows (parallel line shadows): similar to tramline shadows but with a width larger than that seen in a normal bronchus at that level;
2 ring shadows: hair-line ring shadows 1–2 cm in diameter;
3 shrunken but aerated segment or lobe;
4 narrowing or loss of vessel shadows; and
5 long line shadows.

In addition, the basic features in the first and last radiographs of every patient were analysed. The length and width of the lung were measured according to the method described by Hodson *et al.* (1974). The transverse cardiac diameter, the position and shape of both domes of the diaphragm, and the diameter of the right basal artery were measured according to Simon (1974). The diameter of the left basal artery was taken when the right was ill defined. The normal values for the above parameters were taken from Simon (1974). The lung vascular shadows were also assessed.

The lung fields were separated into the conventional six zones. The extent of the permanent changes mentioned above (except the long lines) was measured from the first and last radiographs by counting the number of lung zones affected.

One thousand two hundred and forty-two postero-anterior chest radiographs were available for study. The mean age of the patients at the time of the first radiograph was 33±13 years and 44±13 years at the last. The period of follow-up was from 2 to 25 (mean 10·9±5) years and the mean number of chest radiographs per patient per year was 2·16.

Results

ACUTE EPISODES

The number and sites of transient shadows are shown in Table 1. Two hundred and sixty-seven acute episodes were recorded, and in 53 episodes two or more of the listed transient shadows were recorded in the same radiograph. The mean number of episodes per patient was 5·3. The notes of patients showed that 59 episodes (22·1%) were apparently 'asymptomatic'. Homogeneous opacities without shrinkage (consolidations) and band-like shadows were the most common transient shadows. The consolidations affected equally the upper, middle or lower zones but the band-like shadows were more frequent in the upper zones. The right side was more affected than the left. Four transient pleural effusions were reported.

OVERINFLATION

Seven patients were found to have a completely normal chest radiograph at the start, and only one had a normal chest radiograph at the end of the follow-up. In Table 2 are shown the number of patients who fulfilled the criteria of overinflation as described by Hodson *et al.* (1974) in the first and last radiographs. Twenty-one patients (42%) had two or more of the features of overinflation at the time of the first radiograph and 17 (34%) in the last radiograph. A small cardiac diameter and an increased lung length/width ratio were the

Table 1 *Number of transient shadows in relation to their sites*

Zone	Homogeneous consolidation		Non-homogeneous consolidation		Bandlike	Atelectasis	Circular	Tramline
	Large	*Small*	*Patchy*	*Nodular*				
Upper	28	59	4	3	58	6	7	11
Middle	33	58	4	1	7	0	6	0
Lower	41	52	2	5	8	5	1	0

See text for definitions of transient shadows.

Table 2   *Number of patients with features of simple overinflation*

Radiograph	Lung length/width ratio ⩾ 1	Transverse cardiac diameter < 11·5 cm	Diaphragm below ant. rib level of 6½	Retrosternal space* > 3·5 cm	Two or more features
First	25	29	7	11	21
Last	20	21	5	5	17

*Measured in 34 lateral radiographs at time of first radiograph and in 36 at time of last.

most common abnormalities. Only two patients had flat diaphragmatic domes in the first as well as in the last radiographs. The diameter of the right basal artery (or the left when the right was ill defined) was within normal limits in all patients and did not change in the period of follow-up.

PERMANENT CHANGES
In Table 3 are described the permanent changes in the first and last radiographs. Nine patients had none of the listed permanent shadows in the first radiograph and in only one patient was the radiograph still normal at the end of the follow-up. Tubular shadows were present in 28 patients at the start and in 45 at the time of the final follow-up, whereas ring shadows were seen in the radiographs of 18 patients at the start and of 30 at the end. There were also more lung zones affected with the different permanent shadows in the last radiograph than in the first (197 against 118). Twenty-two patients had at least two different lung zones affected at the start and 38 at the end. As shown in the same table, the tubular shadows, the lobar shrinkage, and the reduction in vascular shadows affected mainly the upper zones, whereas the ring shadows were predominantly in the middle zones. Two patients had a shadow indicating a mycetoma. In 13 patients a single long-line shadow was noticed, and in seven of them it persisted in all the following radiographs. In Fig. 1 (A and B) are shown the radiographs of a patient at the start and at the end of the follow-up. In Figs 2, 3, and 4 are shown examples of some of the permanent changes.

PROGRESS OF CHANGES
In 24 of the 33 patients included in the previous five-year follow-up (Safirstein et al., 1973) there was no progress in the extent of the permanent changes from that time, four years before, up to the present study. The nine other patients showed progress of the permanent shadows with either more tubular and ring shadows or more lobar shrinkage.

One hundred and forty-eight acute episodes of consolidation or atelectasis (49·8%) throughout the follow-up period were followed by one or more signs of permanent damage in the last radiograph. The consolidations usually left ring shadows as they resolved. Consolidation in 19 out of 26 lung zones which were considered as normal at the start was followed by ring shadows evident in the last radiograph. Thirteen (32·2%) of the transient band-like shadows were found to be followed by the subsequent appearance of tubular shadows. In five instances, homogeneous circular shadows were shown to occur in regions where ring shadows had previously been present. One of these episodes is illustrated in Fig. 4 (A and B). On 32 occasions band-like shadows were shown to 'fill' the tubular shadows already present in previous radiographs. This is illustrated in Fig. 5 (A and B).

CORRELATIONS BETWEEN RADIOLOGICAL, CLINICAL, AND PHYSIOLOGICAL FINDINGS
There was a statistically significant ($p < 0.001$) correlation between the number of transient shadows throughout the period of follow-up and the extent of ring and tubular shadows in the last radio-

Table 3   *Incidence of permanent shadows in relation to their sites in the first and last radiographs*

Zone	Tubular shadow		Ring shadow		Reduced vascular shadow		Lobar shrinkage	
	First	Last	First	Last	First	Last	First	Last
Both upper	10	18	2	3	5	6	3	5
One upper	17	25	8	11	10	10	7	7
Both middle	0	1	1	5	0	0	0	0
One middle	7	11	9	17	1	1	1	3
Both lower	0	3	0	1	2	2	0	0
One lower	4	9	0	3	5	8	3	6
No. of patients with at least one abnormality	28	45	18	30	19	22	14	18

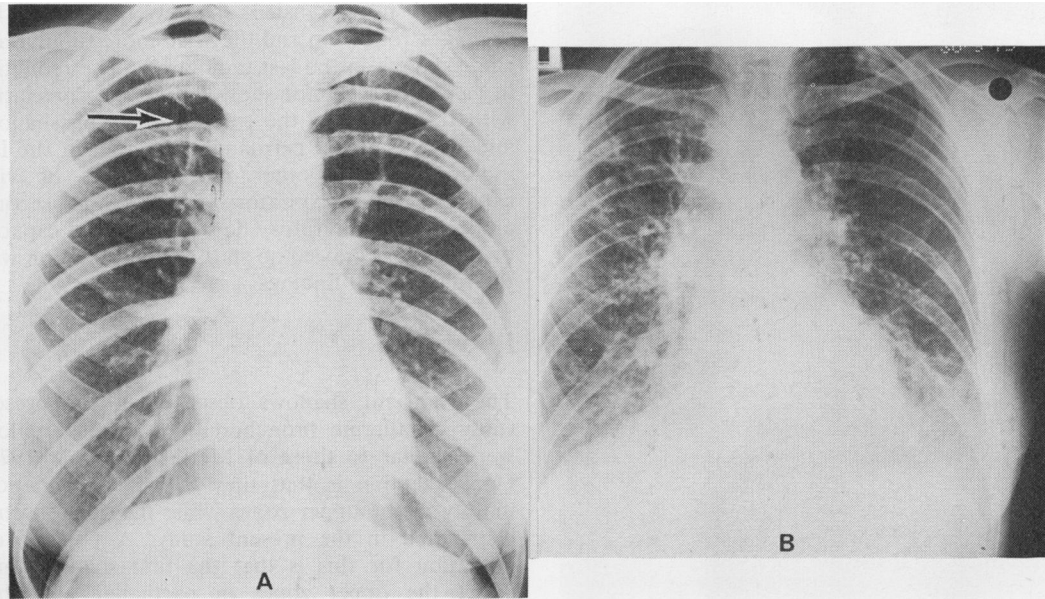See text for definitions of permanent shadows.

Fig. 1   *Radiographs of the same patient taken 22 years apart: (A) minimal abnormalities: arrow points to a single tubular shadow; (B) gross abnormalities: tubular shadows in both upper zones, ring shadows in right upper, both middle, and right lower lones, and band-like shadows in right middle and lower zones.*
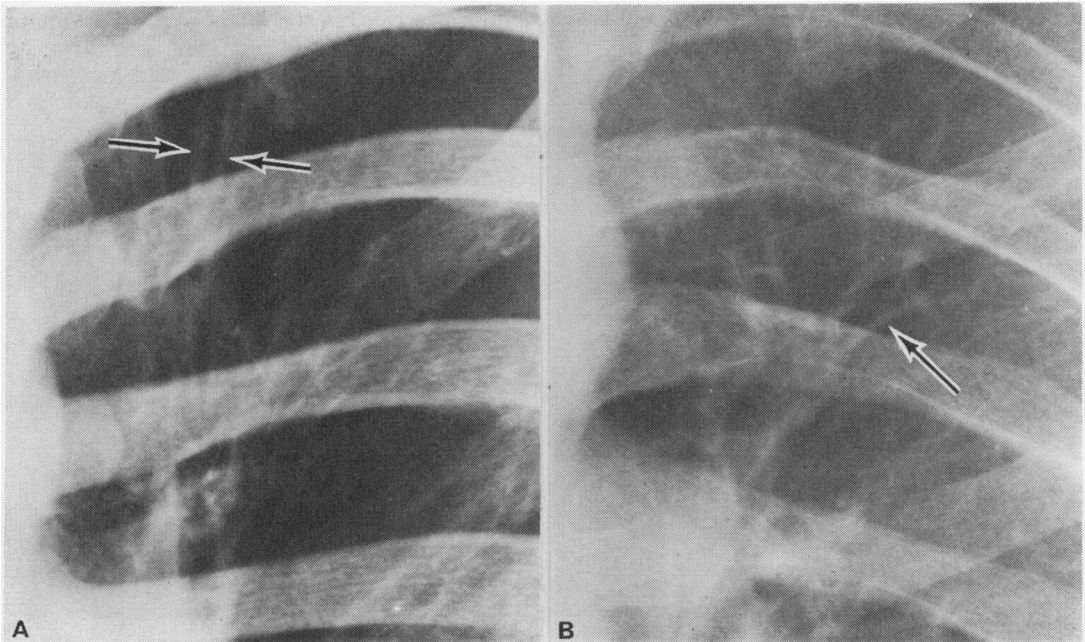

Fig. 2   *Radiographs of two different patients showing tubular shadows. The arrows point to both walls of a tubular shadow in (A) and to one wall in (B).*
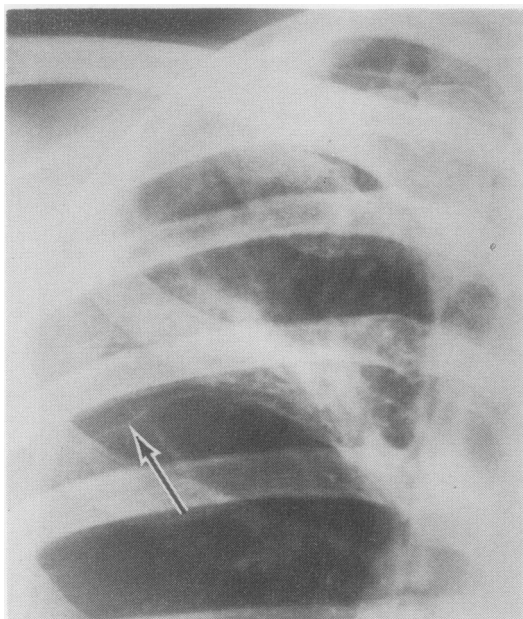
Fig. 3 *Radiograph showing right upper lobe shrinkage. Arrow points to the small fissure.*

presented more transient shadows throughout the period of follow-up and they had more tubular and ring shadows in the last radiograph. The reduction in gas transfer factor showed a strong correlation with the extent of the tubular and ring shadows and with the total permanent shadows in the last radiograph. The other measurements of vital capacity, forced expiratory volume in one second, and maximal expiratory flow at 50% vital capacity breathing air showed no statistical correlation with the radiological findings.

Discussion

The transient shadows observed in the present study of allergic bronchopulmonary aspergillosis were similar to those of McCarthy *et al.* (1970). One exception is that they found consolidations mainly in the upper zones while they were evenly distributed in the present study. A possible explanation for this is that the first shadows may affect the upper zones in particular and then develop in other zones with the progress of the disease, as may have occurred during the longer period of our observation. Twenty-two per cent of these shadows were apparently 'asymptomatic', and this is in agreement with the findings of Safirstein *et al.* (1973).

graph. The correlations between the radiological features and some of the clinical and physiological findings are shown in Table 4. The patients with a longer duration of aspergillosis were found to have

The patients with bronchopulmonary aspergillosis described in this study were all asthmatics.
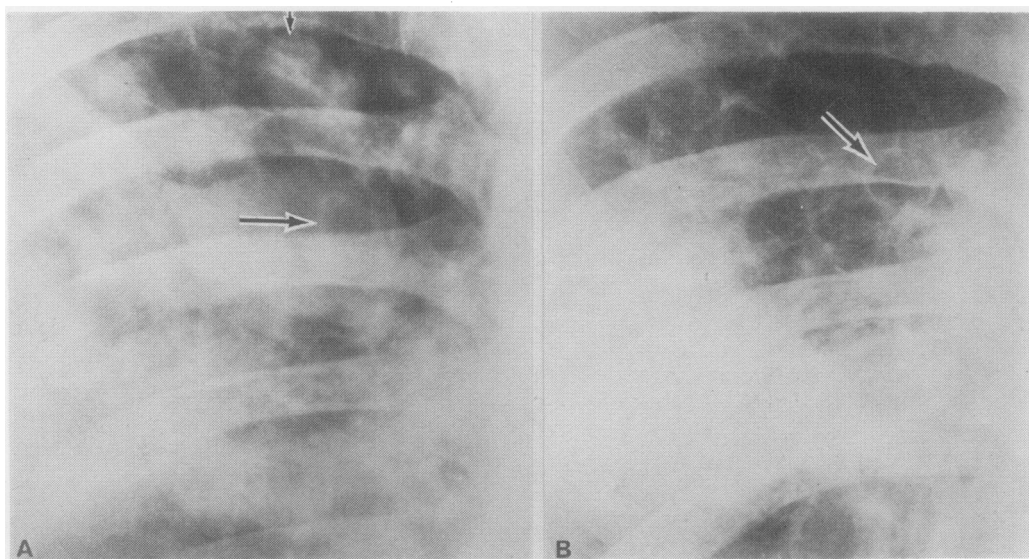

Fig. 4 *Radiographic appearances of ring and circular shadows: (A) massive opacity of right middle zone towards axilla; ring shadow opposite horizontal arrow and circular shadow opposite vertical arrow; (B) partial clearing of the opacity showing ring shadows; arrow points to a 1·5 cm ring shadow.*
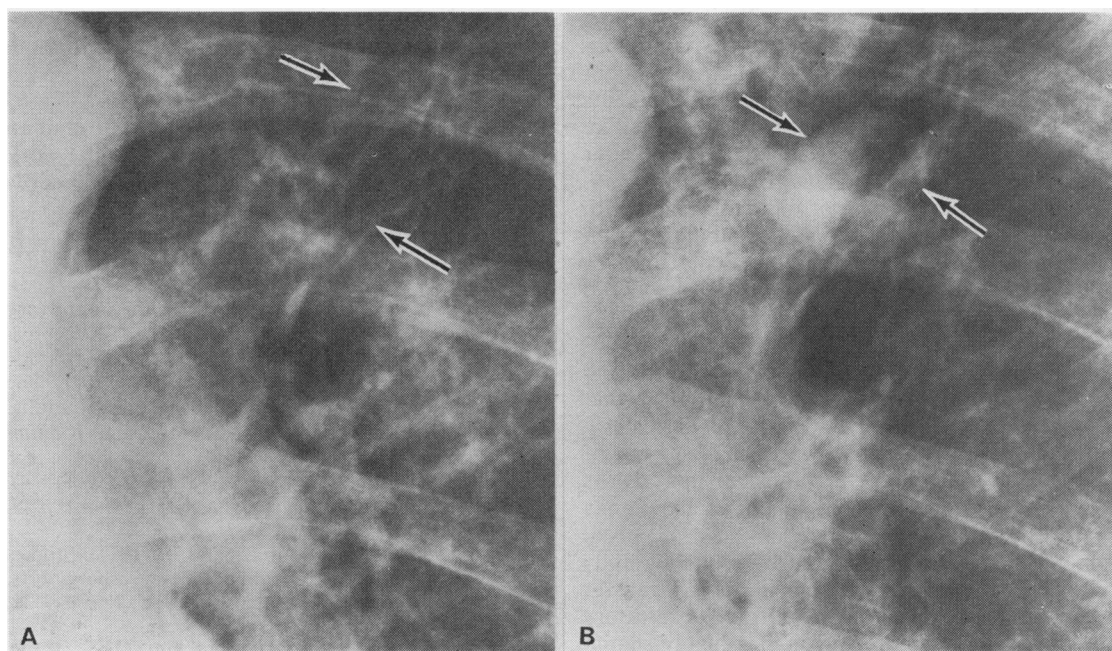
Fig. 5 Appearance of a band-like shadow at the site of a tubular shadow: (A) arrows point to one wall of tubular shadows; (B) arrows point to a band-like shadow.

Table 4 Correlation between clinical, physiological, and radiological features

	Age	Age at diagnosis of aspergillosis	Duration of aspergillosis	FEV_1	$\dot{V}_{50}air$	VC	DL_{CO}
No. of transient shadows	NS	NS	P < 0.01	NS	NS	NS	NS
Extent of tubular and ring shadows	NS	NS	P < 0.02	NS	NS	NS	P < 0.001
Total extent of permanent shadows	NS	NS	NS	NS	NS	NS	P < 0.01

Definitions of abbreviations: NS = statistically not significant; FEV_1 = forced expiratory volume in one second; $V_{50}air$ = maximal expiratory flow rate at 50% vital capacity; VC = vital capacity; DL_{CO} = gas transfer factor.

In the first radiograph 42% of them had two or more features of overinflation. It has been shown (Hodson et al., 1974) that radiological signs of overinflation are found only in patients who developed asthma before the age of 30 years. Of our 50 patients, 41 started having asthma before that age. Fewer patients (34%) had features of overinflation at the time of the last radiograph. This might be explained by the improvement of airways obstruction as the result of better treatment of the asthma. It might also suggest that bronchopulmonary aspergillosis had brought about more lobar shrinkage, thus masking the features of overinflation.

Only nine patients had no evidence of permanent changes due to aspergillosis in the first radiograph. The fact that these changes were already present at the time of diagnosis by us in most instances might be due to the fact that earlier radiographs were not made in the majority of patients. As found by others (Safirstein et al., 1973) and in our study a significant proportion of acute episodes appear to be asymptomatic, and this might explain the delay in making radiographs. From the time of the first radiograph to the last there was nevertheless progress in the extent of permanent changes, only one patient having a completely normal radiograph at the time of the last follow-up. In nine out of 33 patients who were seen for more than five years there was progress in the extent of the permanent shadows. The absence of radiological changes in 24 patients during the further period of four years suggests that the rate of deterioration is generally slow in

allergic bronchopulmonary aspergillosis.

About half of the acute episodes of consolidation were followed by demonstrable permanent changes, most often ring shadows. In some patients with earlier normal radiographs a band-like shadow was subsequently seen which was later replaced by a tubular shadow. This might be explained by transient filling of dilated bronchi with secretions and fungal material. The administration of oral corticosteroids to such patients may be followed by expectoration of sputum 'plugs' and the clearing of the band-like shadows (McCarthy *et al.*, 1970).

It has been reported (Andrus, 1940; Evans and Galinsky, 1944; Wynn-Williams, 1953) that bronchiectasis can be detected in a plain posteroanterior chest radiograph with a high degree of accuracy so that bronchography is not always necessary and was not used in our study. Pande *et al.* (1971) found the extent of the usual distal bronchiectasis as demonstrated by bronchography to be proportional to reductions in the gas transfer factor, the vital capacity, and the forced expiratory volume in one second. We found a highly significant statistical correlation only with the gas transfer factor and none with the other physiological measurements. Our study deals with a different form of bronchiectasis which is proximal and we did not use bronchography. This might account for the differences in the results.

In this study all the patients had a confirmed diagnosis of allergic aspergillosis and had had in the past at least one episode of a fleeting shadow in the chest radiograph. Permanent shadows may be found in patients with a positive prick skin test and positive precipitins to *Aspergillus fumigatus*. The presence of allergic aspergillosis in such cases is very probable, particularly if the permanent shadows affect the upper zones of the lung. The absence of evidence of transient shadows may explain why in some cases the diagnosis was not suspected. Acute episodes may also be asymptomatic, so that the need for a chest radiograph may not have been obvious.

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