Dr R H Secker Walker and Miss Judy A Jackson
(Medical Unit, University College Hospital Medical School, London)

Scanning of the Lung

Automatic scintillation scanning of the lungs can be used either to demonstrate pulmonary arterial perfusion by giving radioactive macroaggregated human serum albumin intravenously (Taplin *et al.* 1964), or else to show the pattern of ventilation by inhaling radioactive aerosols or gases (Taplin *et al.* 1966, Quinn & Head 1966). In addition selective injection of radioactive macroaggregates into the bronchial arteries can demonstrate the extent of bronchial artery perfusion (Dr C Darke 1967, personal communication). This paper is concerned only with the use of scanning in the demonstration of pulmonary arterial perfusion.

Method

The preparation of technetium-99m-labelled macroaggregated human serum albumin (^{99m}Tc-MAA) and the scanning procedure, using a Picker Magnascanner III, have been described previously (Secker Walker 1968). A scan is started shortly after the intravenous injection of 1·5–2·0 mCi ^{99m}Tc-MAA. Anterior, posterior and sometimes lateral colourscans and photoscans are obtained.

After injection the particles become impacted in the small pulmonary arterioles and capillaries and their distribution is proportional to pulmonary arterial blood flow at the time of injection (Sabiston & Wagner 1964, Tauxe *et al.* 1967). The particles steadily disintegrate and pass through the lungs to be removed from the circulation by the liver and spleen. With 2·0 mCi ^{99m}Tc-MAA the radiation received by the lungs is approximately 300 mrads.

Table 1
Indications for lung scans

Indication	*No. of patients*	*Repeated scans*	*Total*
Suspected pulmonary embolus	266	115	381
Neoplasm of the bronchus	134	13	147
Other conditions ●	74	10	84
Total	474	138	612

●Other conditions include normal individuals, patients with chronic bronchitis and emphysema, bronchiectasis, asthma, pneumonia, pulmonary tuberculosis, thoracoplasties, pleural thickening, fibrosing alveolitis, post-irradiation pulmonary fibrosis, sarcoidosis, McLeod's syndrome, chronic rheumatic heart disease, congenital heart disease, cardiomyopathies, lymphoma and collagen diseases

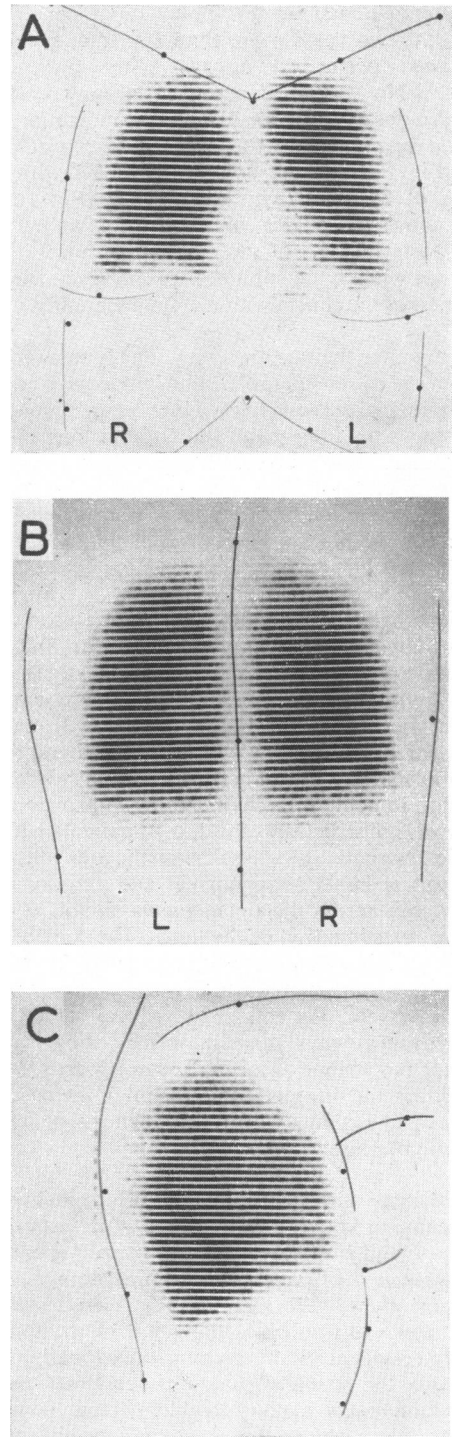


Fig 1 *Normal lung scan. Healthy female volunteer aged 29.* A, *anterior scan.* B, *posterior scan.* C, *right lateral scan, showing increased activity posteriorly as the injection was given while lying supine*

Results and Discussion

In the last two years more than 600 lung scans have been performed at University College Hospital. No untoward reactions of any kind have been observed. Table 1 shows the indications for lung scanning and the number of repeated scans. Fig 1 shows the lung scans of a healthy woman of 29. The right lateral view (Fig 1c) clearly shows the greater concentration of activity in the posterior part of the lung as the injection was given while lying supine. Figs 2–5 give some indication of the clinical value of lung scanning.

Shortly after their introduction lung scans were shown to be of considerable value in the diagnosis of pulmonary embolism (Wagner *et al.* 1964). Fig 2 shows the lung scans and chest radiograph of a woman of 60 who had a moderately severe pulmonary embolus. The combination of several large defects in perfusion and a normal chest radiograph is highly suggestive of pulmonary embolism.

Unfortunately pulmonary arterial perfusion is disturbed by most lung diseases, many heart and a few subdiaphragmatic conditions. In particular, patients with chronic bronchitis and emphysema (*see* Fig 4), or bronchial asthma (*see* Fig 3) may have clear lung fields on their chest radiographs but abnormal patterns of perfusion. The disturbed perfusion in acute bronchial asthma improves as the airways obstruction subsides. In patients with chronic obstructive airways disease the area of the lung scan is larger than normal and activity is usually seen across the upper mediastinum, as a result of over-inflation of the lungs. The distribution of activity within each lung is usually markedly irregular although the lung outlines are often well preserved. Patients with severe chronic obstructive airways disease often show an apparent redistribution of perfusion towards the upper lobes and diminished perfusion of the bases as is seen in patients with mitral stenosis or left ventricular failure.

In patients with carcinoma of the bronchus, lung scanning shows a wide range of defects in perfusion, and is of some value in the pre-operative assessment of patients for thoracotomy. At operation the defects are usually seen to be related to distortion or compression of the pulmonary vessels at the hilum, and occasionally to invasion of the vessels by tumour tissue. Bronchial obstruction plays a considerable part in some patients. Fig 5 shows the chest radiograph and lung scan of a woman of 53 with an oat cell carcinoma of the bronchus. At bronchoscopy (Dr H Nicholson) the tumour was seen arising from, and obstructing, the right lower lobe bronchus. It was judged to be operable, but at thoracotomy (Miss D Nightingale) there was a large mass of tumour surrounding and attached to the superior vena cava and spreading into the pericardium. The growth was clearly inoperable.

Sometimes a lung scan will suggest that a hilar shadow is malignant because there is a large associated defect in perfusion, and sometimes it will suggest the likely site of a bronchial carcinoma in those patients with malignant cells in their sputum but normal chest radiographs and bronchoscopies.

At present much of the information contained in a scan is ignored. Digital computer analysis of scan data is being used with increasing frequency (Brown 1966, Tauxe *et al.* 1966). Handling the data in digital form allows correction for the physical decay of short-lived isotopes, background subtraction, statistical analyses and reproduction of the scans in a variety of ways. Resolution can be improved by eliminating scalloping at the scan edges, smoothing the unevenness at low count rates, and correcting the data to correspond with the response characteristic of the collimator used (Sprau *et al.* 1966). The distribution of activity at any level of the maximum count rate can be displayed, so offering a means of contrast enhancement over much smaller ranges than is possible with either colourscans or photoscans. In addition a comparison of the total counts in each lung, of the profiles of the counts per row, and of the areas of each lung at different levels of the maximum count rate can be made. Fig 6 shows a small part of the output from a lung scan processed in this way. The program was run on the University of London Atlas computer.

To assess the clinical value of lung scanning these scans have been classified into four groups: (1) A normal lung scan showed a distribution of activity matching that seen in the lung scans of healthy volunteers. (2) Slightly abnormal scans showed minor defects in the distribution of activity of doubtful significance. (3) Pulmonary hypertension: if there was a redistribution of

Table 2

Results of pulmonary scintillation scanning

	Lung scan				
Indication	*Abnormal*	*Slightly abnormal*	*Pulmonary hypertension*	*Normal*	*Total*
Suspected pulmonary embolus	141	69	21	35	266
Neoplasm of the bronchus	102	25	5	2	134
Other conditions	40	17	5	12	74

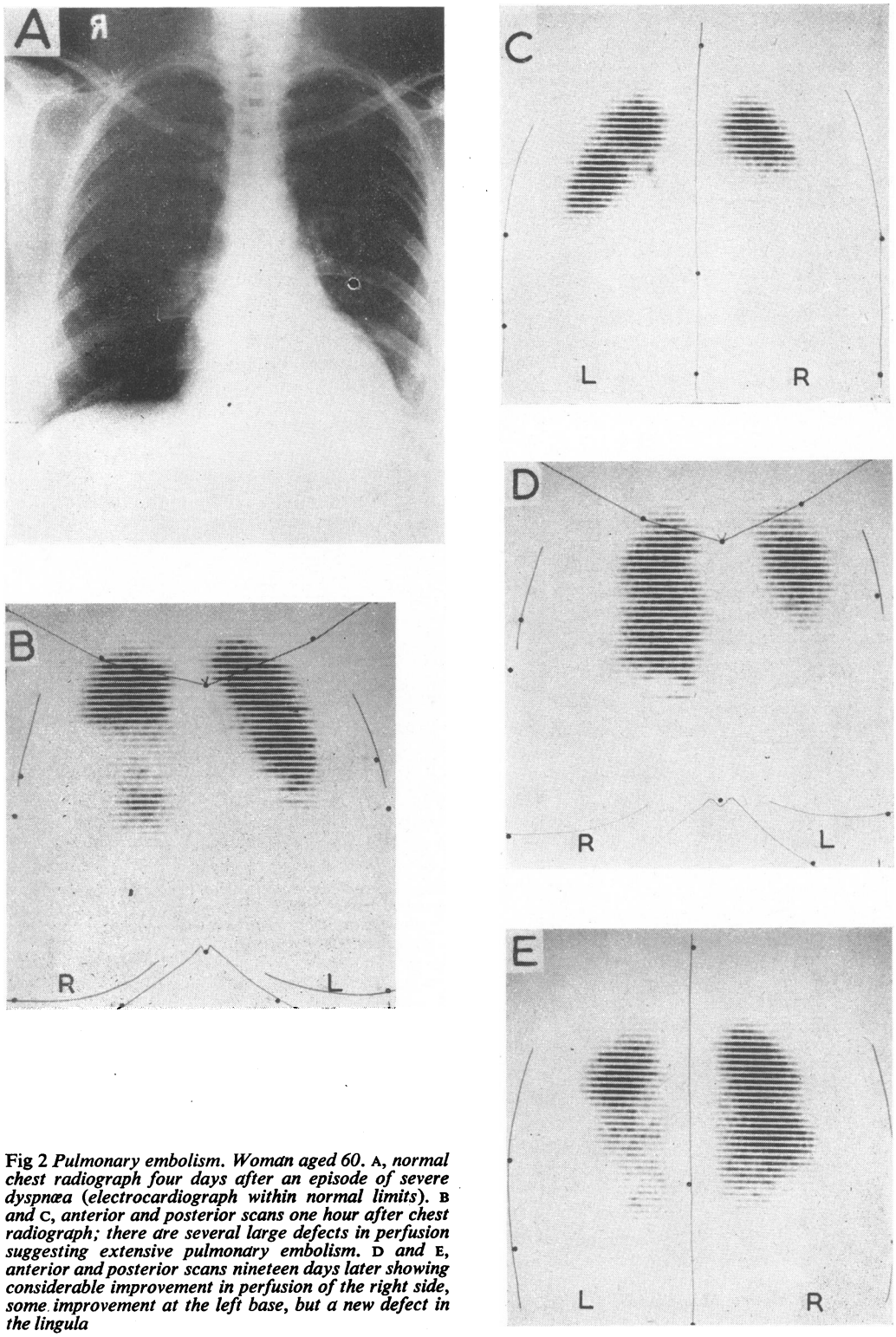
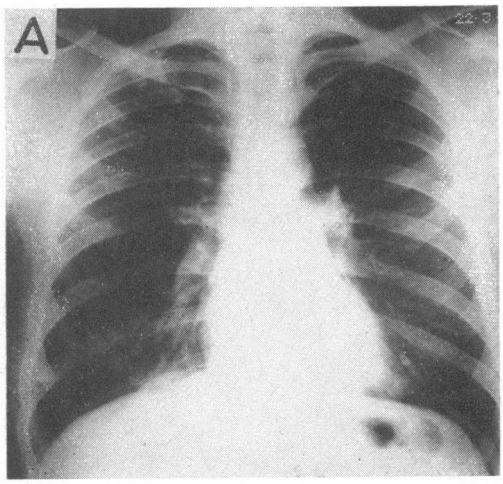
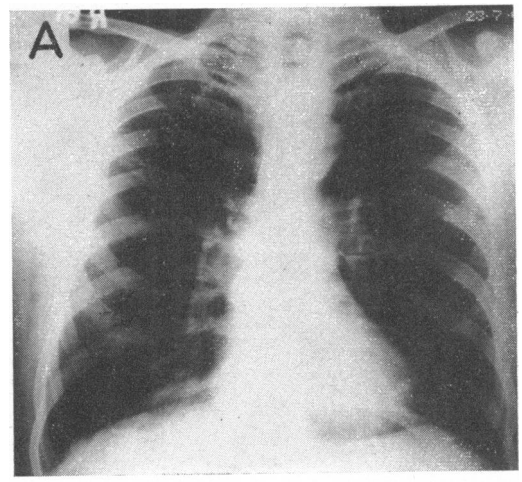
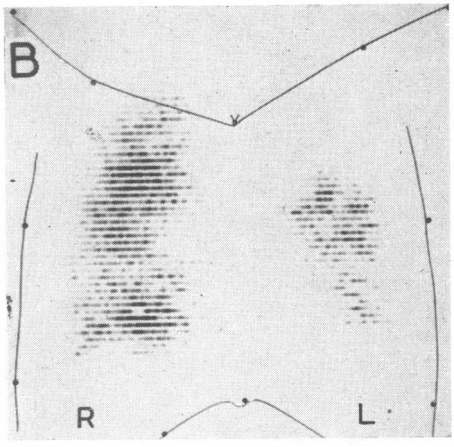


Fig 2 *Pulmonary embolism. Woman aged 60.* A, *normal chest radiograph four days after an episode of severe dyspnœa (electrocardiograph within normal limits).* B *and* C, *anterior and posterior scans one hour after chest radiograph; there are several large defects in perfusion suggesting extensive pulmonary embolism.* D *and* E, *anterior and posterior scans nineteen days later showing considerable improvement in perfusion of the right side, some improvement at the left base, but a new defect in the lingula*







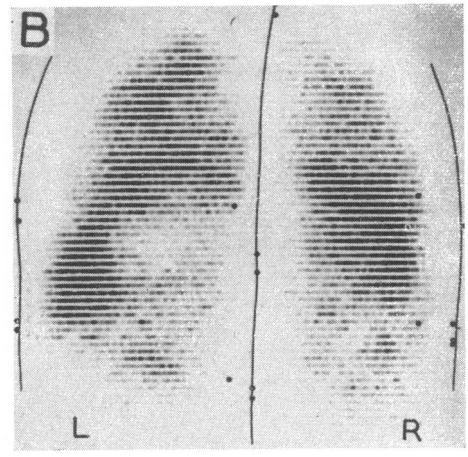


Fig 4 *Chronic bronchitis. Man aged 53 with a history of chronic bronchitis for twenty years.* A, *chest radiograph.* B, *posterior lung scan showing irregular perfusion throughout both lung fields*

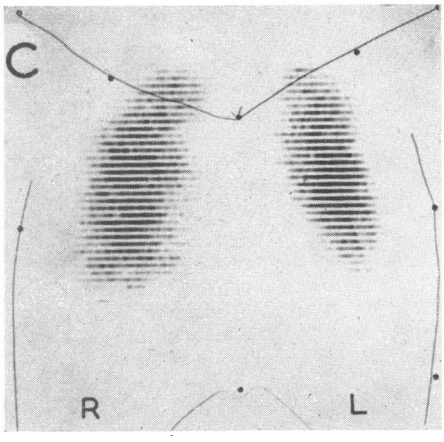
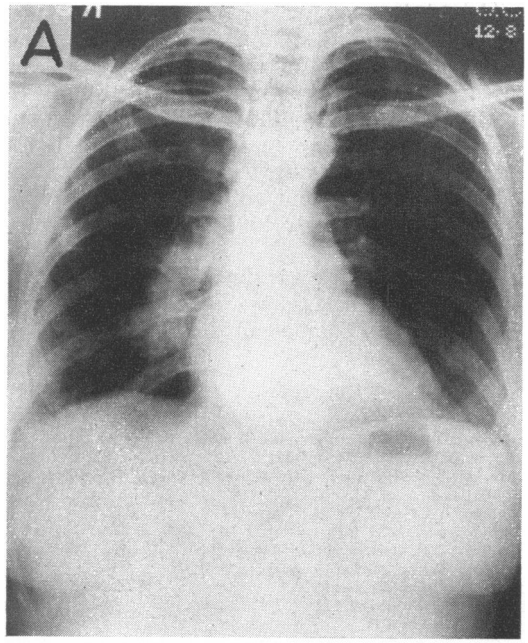


Fig 3 *Bronchial asthma. Man aged 39.* A, *chest radiograph shortly after the onset of an attack of status asthmaticus.* B, *anterior lung scan four days later showing numerous patchy defects in perfusion; he still had signs of severe bronchospasm.* C, *anterior lung scan seven days after recovery; pulmonary perfusion is much improved and the area of each lung is smaller*



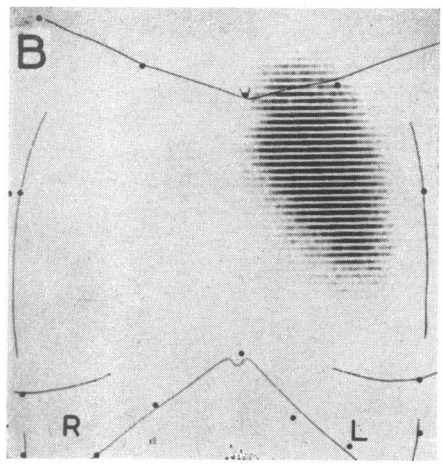


Fig 5 *Carcinoma of the bronchus. Woman aged 53 with an oat cell carcinoma arising in the right lower lobe bronchus. Bronchoscopically operable.* A, *chest radiograph showing prominent right hilum.* B, *anterior lung scan showing very little perfusion of right lung and normal perfusion on the left side*

activity towards the upper lobes with the lung outlines relatively well preserved the scans were classified as showing 'pulmonary hypertension'. (4) Abnormal scans showed obvious defects in the pattern of perfusion ranging in size from segmental to almost no pulmonary arterial perfusion at all. The results of the scans are shown in Table 2.

In the patients with suspected bronchial carcinoma abnormal lung scans were common. Neoplasms close to the hilum usually give rise to large defects in perfusion, and the size of the defect gives some indication of the operability of the tumour – the larger the defect the less chance of successful removal. The converse is not true. A small tumour may, for instance, be inoperable because it involves the spine or ribs without disturbing pulmonary arterial perfusion to any extent.

Areas of consolidation due to pneumonia have diminished perfusion, but the defect is rarely so marked as that seen when the consolidation is due to pulmonary infarction or when there is an underlying neoplasm. Areas of bronchiectasis have virtually no pulmonary arterial perfusion.

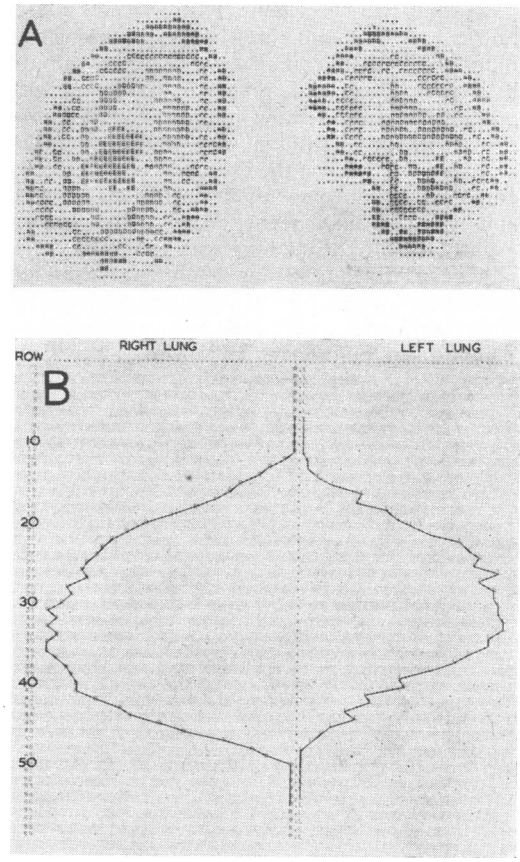


Fig 6 *Part of the computer output from a program run on the University of London Atlas computer.* A, *10 level lung scan with 20% background subtraction; each 10% level of the maximum count rate is represented by either a letter or dots;* E=*maximum.* B, *profile of counts per row as a percentage of maximum row counts in each lung from apex to base*

A large proportion of the lung scans for suspected pulmonary embolism were clearly abnormal – but not all of these patients had pulmonary emboli. After the age of 60, up to 20% of the scans were abnormal because of chronic bronchitis and emphysema (Secker Walker 1969).

Selective pulmonary angiography is the most accurate method of demonstrating pulmonary emboli, but is not without danger (Sabiston *et al.* 1965, Goodwin 1965) and may be deceptive (Marable *et al.* 1966). Lung scanning is considerably safer and simpler but the results are less reliably interpreted.

Provided there is no history of chronic bronchitis or asthma in patients with suspected pulmonary embolism, the combination of an abnormal lung scan with several areas of poor perfusion and a normal or almost normal chest radiograph makes the diagnosis almost certain. Even when there is evidence of pulmonary infarction, a lung scan will almost always demonstrate other areas where emboli have occurred without infarction. Repeated scans in patients with pulmonary emboli show improvement in most areas with an occasional new defect, and this sequence will suggest the diagnosis of pulmonary embolism in patients with chronic bronchitis and emphysema whose scans usually change only slightly. Failure of the lung scan to improve in a patient suspected of having a pulmonary embolus should cast doubt on the diagnosis. If both the chest radiograph and lung scan are normal the diagnosis of pulmonary embolism is most unlikely.

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