Differentiation of Pulmonary Embolism from Chronic Airways Obstruction by a Dual Isotope Technique

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Pulmonary embolism is a common disease that all too often eludes recognition. Diagnosis is difficult because the clinical manifestations are non-specific and there is no simple and early pathognomonic test. Although a normal perfusion scan excludes the presence of pulmonary emboli, the demonstration of occlusion of pulmonary arterial vessels by a standard perfusion lung scan using either \(^{99}\)technetium\(^{m}\) labelled macroaggregates \(^{99}\)Tc\(^{m}\)MAA or microspheres of human serum albumin does not finalise the diagnosis. Given an abnormal perfusion scan, particularly in a patient with a normal chest radiograph, the next stage is the differentiation between perfusion abnormalities arising from vascular obstruction, such as pulmonary embolism, and those secondary to abnormalities in ventilation, as with chronic airways obstruction. Experiments in animals have shown that whereas reduction in regional perfusion does not result in sustained reduction in ventilation, the reverse is not true, and reduction in lung ventilation may produce reflex hypoperfusion. To separate primary perfusion abnormalities from those secondary to hypoventilation, ventilation scanning agents must also be included, thus providing a combined ventilation-perfusion (V/Q) scan. In practical terms, much depends upon the choice of scanning agents and the methods of correlating the ventilation and perfusion scans, enabling a rapid and accurate clinical interpretation of the data presented.

The combination of perfusion scanning with \(^{99}\)Tc\(^{m}\)MAA and ventilation scanning with \(^{133}\)Xenon (Williams et al., 1974) has been used successfully in the diagnosis of pulmonary embolism but the use of \(^{133}\)Xenon is limited by its solubility and low energy. The introduction of \(^{81}\)Krypton\(^{m}\), an inert gaseous isotope of half-life 13 seconds and gamma energy of 190-keV, has permitted the production of high quality functional images of regional ventilation directly comparable with the \(^{99}\)Tc\(^{m}\)MAA perfusion scans (Fazio et al., 1975). We report the application of this procedure in three groups of adults: normal subjects, patients with pulmonary embolism, and patients with chronic airways obstruction.
PATIENTS
Twelve normal controls whose ages ranged from 20 to 58 years were volunteers from the medical and technical staff of the Nuclear Medicine Department. Their health was confirmed by physical examination and chest radiographs.

Thirty patients had been referred with a diagnosis of pulmonary embolism made on the basis of their history, clinical examination, and investigations such as chest X-rays, ECGs, biochemical reports and previous perfusion scans.

Ten patients had physiological evidence of chronic airways obstruction indicated by a forced expiratory volume (FEV$_{1.0}$) of less than 70 per cent of the forced vital capacity (FVC).

TECHNIQUE
All the subjects were seated upright and given an intravenous injection of 0.93 MBq/kg (25 µCi/kg) of $^{99}$Tc$^m$MAA. After five minutes, anterior, posterior, right and left lateral views of the lungs were recorded sequentially using a gamma camera (G.E. Radicamera or Nuclear Enterprises Mk III) set at the $^{99}$Tc$^m$ energy of 140 keV. Each image of approximately 300,000 counts was stored for one minute on a 64 x 64 matrix. After each projection, the subject remained in the same position in front of the gamma camera and, breathing as naturally as possible, inhaled $^{81}$Kr$^m$ in air through an Argyll nasal cannula, which was found more suitable than a face mask. $^{81}$Kr$^m$ was eluted continually from its generator by the passage of air at 70 kilo pascals (10 psi) over the cyclotron-produced parent $^{81}$Rubidium. After an interval of 30 seconds, ventilation scans were taken and stored from 5 minutes. The total time taken for each patient was 30 minutes. The interference due to $^{99}$Tc$^m$ in the $^{81}$Kr$^m$ channel was less than 2 per cent using the N.E. camera and 7 per cent using the G.E. camera. The results were corrected for these values. Using a 35 mm film, it was possible to obtain immediate visual comparison between ventilation and perfusion scans. A V/Q image for both lungs was generated after multiplication of the ventilation data frame by a factor rendering the total counts equal to those in the corresponding perfusion image. A profile of regional V/Q ratios down the lungs was then displayed.

RESULTS
Examples of perfusion and ventilation scans in a normal subject are shown in Fig. 1, together with a V/Q profile (Fig. 2). The highest V/Q ratios are found at the apices and the lowest at the bases, confirming the normal gradient in the upright position.

In patients with pulmonary embolism (Fig. 3) reduced perfusion in the embolised segments is not matched by a reduction in ventilation. The V/Q ratio in the embolised region is increased.

In patients with chronic airways obstruction, there is greater reduction in ventilation than in perfusion. The areas of diminished ventilation do not always
Fig. 1. $^{99}\text{Tc}^{m}$MAA perfusion scan (top) and $^{81}\text{Kr}^{m}$ ventilation scan (bottom) in normal subject. (Anterior view.)
correspond with the area of diminished perfusion (Fig. 4). The normal $V/Q$ gradient is completely distorted with reduced values giving a flattened $V/Q$ profile. Typical distributions of regional $V/Q$ ratios in normal subjects, in patients with pulmonary embolism and in chronic airways obstruction are shown in Fig. 5.

**DISCUSSION**

There is no pattern of abnormal perfusion that is specific for pulmonary embolism. Non-embolic lung disease such as asthma and emphysema may be
Fig. 3. $^{99}\text{Tc}^{m}$MAA perfusion scan (top) in pulmonary embolism showing impaired perfusion but normal $^{81}\text{Kr}^{m}$ ventilation scan, (bottom). (Anterior view.)
Fig. 4. $^{99}\text{Tc}^m\text{MAA}$ perfusion scan (top) in chronic airways obstruction and $^{81}\text{Kr}^m$ ventilation scan (bottom). Impaired perfusion and ventilation. (Anterior view.)
normal radiographically and yet produce regional ischaemia. The perfusion scan can be repeated after 10 days, allowing some degree of differentiation between evolving patterns of embolic ischaemia and the more static hypoperfusion of chronic airways obstruction, but at the price of a further delay in diagnosis and after needless anticoagulation. Simultaneous perfusion and ventilation scanning enables a more accurate differentiation to be made between the ischaemia of chronic airways obstruction and that of pulmonary embolism, with the minimum of delay.

Our results confirm those of other workers (Williams et al., 1974). In pulmonary embolism, the reduction in perfusion is unaccompanied by reduction of ventilation, whereas in chronic airways obstruction there is a greater deficit in ventilation than in perfusion. In dubious cases a $V/\bar{Q}$ profile may help to clarify the diagnosis.

The method is undemanding of the patient and easy to operate. Since the subjects breathe at tidal volume throughout, the ventilation scans are ‘physiological’ and patients with dyspnoea, who are unable to undergo breath-holding procedures, can co-operate fully.

The advantages of $^{81}$Kr over $^{133}$Xe have been stressed (Fazio et al., 1975).

Fig. 5. Typical distribution of regional $\dot{V}/\bar{Q}$ ratios from apex to base in erect lungs of normal subject, patient with pulmonary embolism and patient with chronic airways obstruction.
The great disadvantage of $^{81}\text{Kr}$ at present is its restricted availability; we depend upon a once-weekly delivery. In our initial series of 52 patients we have found it valuable to use combined ventilation-perfusion scanning. A more ‘dynamic’ approach might be possible when $^{81}\text{Kr}$ becomes available in both gaseous and dissolved states, yielding a more direct comparison between ventilation and perfusion by means of the same isotope.

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References
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WHATEVER HAPPENED TO THE POUND?

Even recent College Cash-books throw up sociologically interesting information. A simple funeral, in the 1870s, cost £3.10s.0d. In September 1876, the College paid the Wenham Lake Ice Co. £1.1s.0d. and George Cockerell & Co. £25 for twenty tons of the best Wallsend coal: Cockerell’s coal carts used to be a regular feature of London streets before the First World War; he was the father of Sir Sidney, the secretary of William Morris and the ‘Dictator’ of the Fitzwilliam Museum, and of Douglas Cockerell, the great book-binder. And Wenham is reminiscent of Macaulay’s son-in-law’s fragment on ‘Our Ancestors’, who ‘burned their coals at home, and fetched their ice from Wenham: they played the man before Quebec and stormed the heights of Blenheim’. The College bought a dozen claret, alas, it does not say what, but it was presumably pre-phylloxera, for 24s, and five dozen sherry also at 24s. This was before the days when the Prince of Wales refused a glass of sherry and made it unfashionable (‘decent people do not drink sherry’). Before the First World War there was a house in the country where there was a pipe (about 860 bottles) of George Horne, 1832, twice round the world in cask in a sailing-ship, which no one would drink, and a cask of about the same date was found in the cellars of the Athenaeum in the 1930s, probably forgotten for the same reason.