

Thorax

Editorials

Continuous volume computed tomography in pulmonary embolism: the answer, or just another test?

Few exercises in clinical medicine are more troublesome than securing a diagnosis of pulmonary embolism. Because of the protean clinical features of pulmonary embolism, much reliance has been placed on the direct and indirect imaging of clot within the pulmonary arteries and/or peripheral venous system. This has prompted the cynical observation that radiologists and other imagers devise tests of dubious value faster than clinicians can discard them. Increasingly elaborate diagnostic algorithms have been recommended, which in reality are seldom followed. The ideal diagnostic test would reliably and safely show clot within the pulmonary arteries. Pulmonary arteriography is regarded as the final arbiter, simply because it directly images embolus within the pulmonary arteries. The assumption that life threatening emboli are not missed by pulmonary arteriography seems to hold true.^{1,2} However, it is worth assaying this gold standard from time to time; although false positives are difficult to prove and probably scarce, false negatives can occur despite extensive intravascular thrombus.³

In the UK ventilation-perfusion (\dot{V}/\dot{Q}) scanning is more widely available than pulmonary arteriography. The PLOPED study² has shown that, when the suspicion of pulmonary embolism is high, based on clinical and laboratory findings, and the \dot{V}/\dot{Q} scan is in the high probability category, the chance of a positive pulmonary arteriogram exceeds 95%. At the opposite extreme, a low suspicion of pulmonary embolism and a normal \dot{V}/\dot{Q} scan is associated with a normal arteriogram in 95% of cases. Unfortunately, most patients do not fall into these convenient categories and the problem of establishing which patients require anticoagulation without resort to pulmonary arteriography remains unresolved. It has recently been argued that patients with indeterminate \dot{V}/\dot{Q} scan or high \dot{V}/\dot{Q} probability with discordant clinical probability should undergo compression ultrasonography of the lower limbs⁴ with a view to empirical treatment if deep venous thrombosis is shown. However, a negative ultrasonographic test results in the common dilemma of whether to proceed to pulmonary arteriography or to treat with anticoagulation without confirmation of the diagnosis.

The recent recognition that modern computed tomography (CT) scanners are able to detect pulmonary emboli complicates the diagnostic algorithm. Advances in CT technology have allowed a gradual increase in the speed of data acquisition and image reconstruction. In the early 1970s each slice required up to five minutes to acquire, but by the end of the 1980s this had reduced to about two seconds. However, a complete examination of the thorax still required a breath hold for each slice, often resulting

in misregistration of anatomy due to an inconstant depth of inspiration. Indeed, a pulmonary nodule, easily visible on a chest radiograph, might not be represented on any of an apparently continuous series of CT slices. Although it was appreciated that pulmonary emboli could sometimes be seen by conventional contrast-enhanced CT scanning,^{5,6} this was often serendipitous⁷ and depended on catching the bolus of contrast at the right time.

Current CT scanners equipped with increased computing power can capture data at an astonishing rate. With a constantly moving table top and continuous radiation output from the rotating X-ray tube, most of the thorax can be scanned during the phase of maximal intravenous contrast enhancement within a single breath hold. The resultant data set may then be reconstructed into apparently contiguous or even overlapping individual CT images. The technique has been termed spiral CT (pedantically, "helical" is a preferable term as "spiral" implies a change in diameter with each turn) or generically as continuous volume CT (CVCT) scanning. CVCT and fast scanning has allowed the detection of pulmonary emboli from the level of the pulmonary trunk out to segmental or even subsegmental pulmonary arteries.⁸⁻¹⁰

In this issue of *Thorax* van Rossum and coworkers suggest a place for CVCT scanning in patients with suspected pulmonary embolism and an abnormal \dot{V}/\dot{Q} scan.¹¹ Their study is a logical development of the earlier observations of Remy-Jardin *et al.*⁸ In this new study 249 patients with a clinical suspicion of pulmonary embolism underwent \dot{V}/\dot{Q} scanning and, in the 77 patients with an abnormal \dot{V}/\dot{Q} scan, CT scanning and compression ultrasonography of the legs were performed. Pulmonary embolism was detected in 32 of the 35 patients with a high probability \dot{V}/\dot{Q} scan. Forty two patients who had a non-diagnostic \dot{V}/\dot{Q} scan (defined as neither normal nor high probability) also underwent pulmonary arteriography in addition to the three patients who had a high probability \dot{V}/\dot{Q} scan but no evidence of emboli on the CVCT scan. Patients who had a normal \dot{V}/\dot{Q} scan were not investigated further. In the group of patients with non-diagnostic \dot{V}/\dot{Q} scans and the three patients with high probability \dot{V}/\dot{Q} scans but no confirmation of embolism by CT scanning, CVCT scanning (using pulmonary arteriography as the gold standard) had a sensitivity of 83% and a specificity of 97%. There was one false positive and one false negative CVCT scan. Two patients had both a negative CVCT scan and negative arteriogram. Replacing the pulmonary arteriogram with CVCT scanning in this group of patients would have resulted in failure to diagnose pulmonary embolism in two patients and an erroneous positive diagnosis in one.

Ultrasonography of the lower limbs revealed deep vein thrombosis in 12 patients, all of whom had had high probability \dot{V}/\dot{Q} scans and positive CVCT scans. Thus compression ultrasonography as the next investigation in all patients with abnormal \dot{V}/\dot{Q} scans would have made further investigation unnecessary in only 12 out of 77 (16%) cases.

In this study the performance of CVCT scanning compared with pulmonary arteriography, particularly its low false negative rate, appears impressive. The false positive rate of CVCT scanning remains unknown and inter-observer variation is also uncertain, but since a positive diagnosis relies simply on the identification of an intravascular filling defect, it is likely to be similar to pulmonary arteriography. The overall agreement between CVCT scanning and pulmonary arteriography in making the diagnosis of pulmonary embolism was good, but it would be reassuring to know that the filling defects representing pulmonary embolus correlated, defect for defect, between the two techniques. It is interesting that the authors felt it necessary to give pulmonary arteriography (the gold standard) a helping hand by interpreting the arteriograms in conjunction with the CVCT and \dot{V}/\dot{Q} scans.

The idea that CVCT scanning can be interposed between an indeterminate perfusion scan and pulmonary arteriography and so cut out the need for a ventilation scan raises the spectre of yet another unwieldy diagnostic flow chart. The most important question is in which situations, if any, can CVCT replace \dot{V}/\dot{Q} scanning and/or pulmonary arteriography. In a recent small series¹² the sensitivity of CVCT scanning for the presence of clot in the central pulmonary arteries was 86% and the specificity was 92%, in line with other series.^{8,13} However, when subsegmental vessels were included in the analysis these values fell to 63% and 89%, respectively. The conclusion was that clot in the subsegmental vessels demonstrated on pulmonary arteriography is not always reliably detected by CVCT scanning. The clinical importance of clot confined to subsegmental vessels is unknown. Whether refinements in CVCT technique can significantly improve the detection of emboli in small pulmonary arteries remains to be seen.

CVCT scanning offers two major advantages over all other non-invasive imaging tests. Firstly, it directly images intra-arterial clot whereas other tests (plain chest radiography, \dot{V}/\dot{Q} scanning, compression ultrasonography of the lower limb) mentioned in a recent review⁴ supply only indirect evidence of pulmonary embolism. Secondly, in contrast to pulmonary arteriography, CVCT scanning gives a bigger picture than the inside of the pulmonary arteries; as van Rossum *et al* have shown, this is not a diagnostic luxury. In the group with non-diagnostic \dot{V}/\dot{Q} scans, CVCT scanning showed other abnormalities in 24 of 42 patients which, in most cases, were likely to account for the patients' symptoms and signs. Even in patients with high probability \dot{V}/\dot{Q} scans the diagnosis of pulmonary embolism was refuted by CVCT scanning in two of 35 cases (both with subsequent negative pulmonary arteriograms). Interestingly, signs of pulmonary infarction were present in nearly one third of the patients with high probability \dot{V}/\dot{Q} scans.

The ability to scan a large part of the pulmonary arterial tree in a single breath hold, with optimal contrast opacification, is crucial to the success of CVCT scanning in detecting pulmonary emboli. Further potential improve-

ments include targeted reconstruction which would increase the spatial resolution of small areas of the pulmonary arterial tree, multiplanar reformations which might aid interpretation, and larger single breath hold scan volumes.

No matter how accurate a test is, it will be used in clinical practice only if it is readily available. In this respect, pulmonary arteriography is wanting in the UK, being available in only about one third of acute hospitals.¹⁴ Even if the earlier promises of magnetic resonance pulmonary arteriography are fulfilled,^{15,16} the severe shortage of magnetic resonance machine time in the UK rules out this technique for the time being. CT scanners are widely available and an increasing number of machines have continuous volume scanning capability. For this reason alone, further evaluation of the accuracy and economics of CVCT scanning in pulmonary embolism is needed. It would be premature to predict how CVCT scanning will be used in the diagnosis of pulmonary embolism, but a multicentre European trial just underway should help to establish whether it is the imaging technique of choice or just another imperfect test.

Correspondence to: Dr D M Hansell.

Department of Radiology,
Royal Brompton Hospital,
London SW3 6NP, UK

DAVID M HANSELL

Department of Radiology,
Chelsea and Westminster Hospital,
London SW10 9NH, UK

SIMON P G PADLEY

- Novelline RA, Baltarowich OH, Athanasoulis CA, Waltman AC, Greenfield AJ, McKusick AK. The clinical course of patients with suspected pulmonary embolism and a negative pulmonary arteriogram. *Radiology* 1978; 126:561-7.
- PIOPED investigators. Value of ventilation/perfusion scan in acute pulmonary embolism. *JAMA* 1990;263:2653-9.
- Brown KT, Bach AM. Paucity of angiographic findings despite extensive organized thrombus in chronic thromboembolic pulmonary hypertension. *J Vasc Intervent Radiol* 1992;3:99-102.
- Hyers TH. Diagnosis of pulmonary embolism. *Thorax* 1995;50:930-2.
- Godwin JD, Webb WR, Gamsu G, Ovenfors CO. Computed tomography of pulmonary embolism. *AJR* 1980;135:691-5.
- Webb WR, Gamsu G, Wall SD, Cann CE, Proctor E. CT of a bronchial phantom. Factors affecting appearance and size measurements. *Invest Radiol* 1984;19:394-8.
- Verschakelen JA, Vanwijck E, Bogaert J, Baert AL. Detection of unsuspected central pulmonary embolism with conventional contrast-enhanced CT. *Radiology* 1993;188:847-50.
- Remy-Jardin M, Remy J, Wattinne L, Giraud F. Central pulmonary thromboembolism: diagnosis with spiral volumetric CT with the single breath-hold technique - comparison with pulmonary angiography. *Radiology* 1992;185:381-7.
- Teigen CL, Maus TP, Sheedy PF, Stanson AW, Johnson CM, Breen JF, *et al*. Pulmonary embolism: diagnosis with contrast enhanced electron-beam CT and comparison with pulmonary angiography. *Radiology* 1995;194: 313-9.
- Blum AG, Delfan F, Grignon B, Beurrier D, Chabot F, Clandon M, *et al*. Spiral-computed tomography versus pulmonary angiography in the diagnosis of acute massive pulmonary embolism. *Am J Cardiol* 1994;74: 96-8.
- van Rossum AB, Treurniet FEE, Kieft GJ, Smith SJ, Schepers-Bok R. Role of spiral volumetric computed tomographic scanning in the assessment of patients with clinical suspicion of pulmonary embolism and an abnormal ventilation-perfusion lung scan. *Thorax* 1996;51:23-8.
- Goodman LR, Curtin JR, Mewissen MW, Foley WD, Lipchik RJ, Crain MK, *et al*. Detection of pulmonary embolism in patients with unresolved clinical and scintigraphic diagnosis: helical CT versus angiography. *AJR* 1995;164:1369-74.
- Teigen CL, Maus TP, Sheedy PF, Johnson CM, Stanson AW, Welch TJ. Pulmonary embolism: diagnosis with electron-beam CT. *Radiology* 1994; 188:39-45.
- Cooper TJ, Hayward MW, Hartog M. Survey on the use of pulmonary scintigraphy and angiography for suspected pulmonary thromboembolism in the UK. *Clin Radiol* 1991;43:243-5.
- Geffer WB, Hatabu H, Dinsmore BJ, Axel L, Palevsky HI, Reichek N, *et al*. Pulmonary vascular cine MR imaging: a noninvasive approach to dynamic imaging of the pulmonary circulation. *Radiology* 1990;176:761-70.
- Sostman HD, Debatin JF, Spritzer CE, Coleman RE, Grist TM, McFall JR. MRI in venous thromboembolic disease. *Eur Radiol* 1993;3:53-61.