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Review
The Role of Radiology in the Investigation and Management of Patients with Haemoptysis

T. J. MARSHALL, C. D. R. FLOWER and J. E. JACKSON*

*Department of Diagnostic Radiology, Addenbrookes Hospital, Cambridge, and *Department of Diagnostic Radiology, Royal Postgraduate Medical School, Hammersmith Hospital, London, UK*

Haemoptysis is a relatively common presenting symptom in clinical practice; it is frightening for patients and presents a diagnostic challenge to physicians and radiologists. Thirty years ago tuberculosis and bronchiectasis accounted for the majority of cases [1–3], but there has been a change in the spectrum of causes with a decline in tuberculosis and a relative increase in bronchial carcinoma which now accounts for a large proportion of cases in most studies [4,5]. A list of the causes of haemoptysis is given in Table 1. However, the relative frequency is dependent on a number of different factors including the criteria used for patient selection, the patient population and the techniques used for diagnosis. Investigation aims to establish a cause whilst recognizing that none will be found in a significant proportion of cases, so called 'cryptogenic haemoptysis'.

From a practical point of view it is appropriate to differentiate between haemoptysis which is of small volume and intermittent and that which is massive (usually defined as greater than 600 ml in 48 h) and potentially life threatening. The latter, which requires urgent bronchoscopy and possible radiological or surgical intervention is discussed later in the article. Most patients cough up small volumes of blood but are nevertheless alarmed and usually regard the symptom as an indication of a serious underlying disease.

The Role of Bronchoscopy in Haemoptysis

A careful history and clinical examination usually excludes non-pulmonary causes such as epistaxis or haematemesis and may give a clear indication of the presence with infection. The chest radiograph may reveal changes suggestive of a carcinoma or tuberculosis but frequently it is normal or only reveals non specific appearances. Regardless of the findings of the chest radiograph most clinicians consider haemoptysis to be an absolute indication for bronchoscopy [6] and this is usually performed with the fibre-optic bronchoscope, the rigid instrument being reserved for patients with massive haemoptysis. Fibre-optic bronchoscopy (FOB) is a relatively straightforward procedure, is usually well tolerated by the patient and provides excellent views of the bronchial tree and the means to obtain tissue for histology. For this reason its role in confirming or excluding malignancy in a patient with an abnormality on the chest radiograph suspicious of a bronchial neoplasm is well recognized. However, it is an invasive procedure not without complication [7] and there is debate about its role in investigating haemoptysis in the context of a normal or non-localizing chest radiograph, when the prevalence of carcinoma is small. For example in a retrospective study of 196 patients presenting to a community hospital over five years with haemoptysis and a normal or non localizing chest radiograph, only 12 (6%) had a bronchial carcinoma diagnosed by fibreoptic bronchoscopy [8]. This figure is comparable to the incidence reported in five other studies [9–13] in which the frequency ranged from 4% to 16%. In one review of 110 patients by Weaver *et al.* [14] there were no reported cases of malignancy.

Between 20% and 30% of patients presenting with haemoptysis have a normal chest radiograph and the justification for bronchoscopy when the yield is small is arguable in a climate of diminishing health care resources. Poe *et al.* [8] identified certain risk factors in patients presenting with small volume, recurrent haemoptysis which, if present, indicate a high probability of malignancy. These were aged greater than 50, male and had a smoking history of 40 pack-years or more (one packet of cigarettes per day for 40 years or an equivalent consumption). If these criteria were used to select patients with normal or non localizing chest radiographs for bronchoscopy these authors concluded that they could have reduced their use of the bronchoscope by 28%. Similar observations were made in retrospective studies by Weaver *et al.* [14] and Jackson *et al.* [15] who included haemoptysis lasting more than one week and an abnormality on the chest radiograph as additional risk factors and suggested an age cut-off of 40 years.

In a study by Adelman *et al.* [16] the clinical outcomes of 67 patients presenting with haemoptysis, who had a normal or non-localizing chest radiograph and a normal fibreoptic bronchoscopic examination were assessed by follow-up over a period which averaged three years. The prognosis for these patients with so-called cryptogenic haemoptysis was good; in only one patient did a carcinoma develop and that was 20 months after bronchoscopy when the haemoptysis had resolved. Overall, resolution of symptoms occurred within six months of presentation in the vast majority (90%). In contrast in the study by Lederle *et al.* [17] of 106 patients with haemoptysis and a non-localizing chest radiograph, five carcinomas were diagnosed by bronchoscopy but a further six were diagnosed at follow-up averaging 32 months. Two of the six additional malignancies were

Correspondence to: Dr C. D. R. Flower, Department of Diagnostic Radiology, Box 219, Addenbrookes Hospital, Cambridge CB2 2QQ, UK.

Table 1 – Causes of haemoptysis

	McGuinness et al. (*1994*) (n = *57*)	*Set* et al. (*1993*) (n = *91*)	*Naidich* et al. (*1990*) (n = *58*)	*Haponik* et al. (*1987*) (n = *32*)	*Santiago* et al. (*1991*) (n = *264*)	*Millar* et al. (*1990*)* (n = *40*)
Bronchiectasis	14 (25%)	14 (15%)	10 (17%)	0 (0%)	2 (1%)	7 (18%)
TB	9 (16%)	0 (0%)	1 (2%)	0 (0%)	15 (6%)	2 (5%)
Bronchial neoplasia	7 (12%)	34 (37%)	19 (33%)	14 (44%)	78 (29%)	2 (5%)
Fungal infection	7 (12%)	0 (0%)	1 (2%)	2 (6%)	8 (3%)	0 (0%)
Cryptogenic	11 (19%)	31 (34%)	19 (33%)	12 (37%)	57 (22%)	20 (50%)
Bronchitis	4 (7%)	4 (5%)	0 (0%)	3 (10%)	62 (23%)	0 (0%)
Miscellaneous	3 (5%)	8 (9%)	8 (10%)	1 (3%)	42 (16%)	9 (22%)
Multiple causes	2 (4%)	†	0 (0%)	0 (0%)	0 (0%)	‡

*All patients with a normal/non-localizing chest radiograph and a normal FOB. †Two cases of bronchial carcinoma also had bronchiectasis. ‡One case of bronchiectasis also had a peripheral mass, probably malignant.

considered to have been present at the time of the first FOB. This group differed from the previous group in that they were slightly older (average age of 61 years compared with 55 years) and they were exclusively male (compared with 36 males out of 67). Their smoking history was not significantly different.

Computed Tomographic (CT) Imaging of the Airways

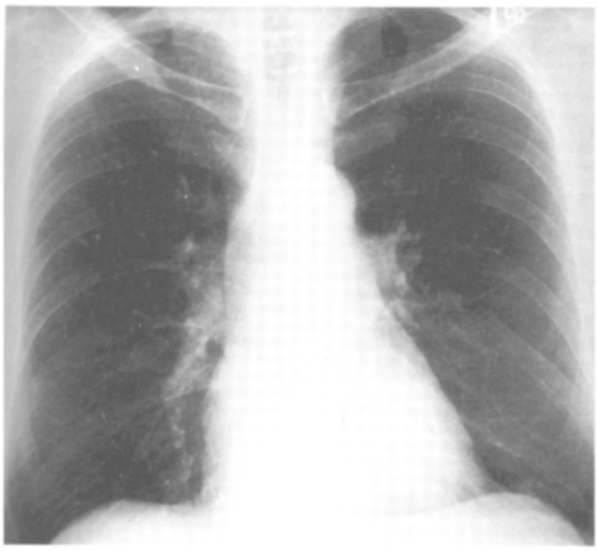
Computed tomography (CT) can be used as an adjunct to bronchoscopy in patients who are likely to have a carcinoma or as an alternative to it in patients in whom the likelihood of carcinoma is low. The value of CT in imaging the mediastinum and the central airways has been established for over a decade [18–24], as has its ability to delineate focal bronchial abnormalities such as bronchiectasis [25–27], blood clot [28], broncholithiasis [29,30] and endobronchial neoplasms [31]. Even in the early studies, using conventional techniques with early generation scanners, CT was shown to have a high sensitivity when compared to bronchoscopy for diagnosing bronchial abnormalities. In 1983 Webb *et al.* [32] demonstrated a good correlation between CT and bronchoscopy in 24 of 30 patients with abnormal chest radiographs and histologically proven bronchial neoplasms. Although CT failed to identify lesions discovered at bronchoscopy in three cases, in twelve other cases it demonstrated abnormalities not seen with bronchoscopy either because the abnormality was beyond the range of the bronchoscope (five cases) or in bronchi known to be difficult to visualize bronchoscopically (seven cases). In two of these cases subsequent bronchoscopic brushings of the segmental bronchus demonstrated to be abnormal at CT yielded positive diagnoses.

More recent studies have consistently demonstrated the accuracy of CT in depicting bronchial abnormalities detected bronchoscopically. In 1987 Henschke *et al.* [24] retrospectively assessed the value of CT as compared with FOB in 100 consecutive patients with suspected bronchial abnormalities who had been referred for both procedures. They demonstrated good correlation between the two techniques; four of 46 malignancies were missed by CT but five were also missed at initial bronchoscopy and later diagnosed (by repeat bronchoscopy in four cases) following their CT demonstration. This study was one of the first to illustrate the complementary role of the two techniques. In another study of 102 patients with both benign and malignant bronchial disease, Naidich *et al.* [33] had similar results with CT correctly identifying 59 of 64 lesions seen at FOB and six lesions (two of which were tumours) missed by bronchoscopy. In a study of 50 patients with lobar or segmental atelectasis, Woodring *et al.* [34] showed that CT correctly identified all 27 cases in which an obstructing tumour was the cause. The largest study to date is by Mayr *et al.* [35]. One hundred and forty-two patients requiring bronchoscopy for suspected endobronchial carcinoma also had CT; CT correctly identified a bronchial tumour in 120 of 121 patients. Thirty-eight patients in this study had a repeat bronchoscopy or surgery and in seven of these tumours were found; in all cases they had been identified by CT. These authors also evaluated CT vis a vis FOB in its assessment of individual bronchi of which 361 of 1413 were abnormal due to tumour involvement. CT sensitivities were 91% and 94% for two observers who each achieved a specificity for CT of 99%. These figures contrast with those in an earlier study by Colice *et al.* [36] who reported a sensitivity of 63% to 85% and a specificity of 61% to 77% for three observers, one of whom was a chest physician. The improved figures probably relate to a better scanning technique and an improved understanding of bronchial anatomy on CT.

CT Imaging in Haemoptysis

The role of CT when used specifically in the investigation of haemoptysis has also been evaluated [36–40]. Haponik *et al.* [37] compared the value of CT with chest radiography in 32 patients who presented with haemoptysis. Although CT demonstrated abnormalities more often than chest radiography and also correctly localized the source of bleeding in 23 (88.5%) of 26 patients who underwent bronchoscopy, the authors concluded that the additional information provided by CT influenced management in only six patients, that it did not obviate the need for bronchoscopy in any patient and that in only two patients did the information from CT supplement the information provided from the chest radiograph and bronchoscopy together. This is limited by being a retrospective study which assessed a small number of patients with a relatively high prevalence of tumours (14 of the 32 patients had carcinomas), using a 10 mm slice thickness and a 10 s exposure time, a technique which would now be considered inappropriate.

The optimal CT technique is based on the recommendations of Naidich *et al.* [38] and consists of 1–2 mm thick sections obtained every 10 mm from the thoracic inlet to the lung bases, with an additional spiral sequence



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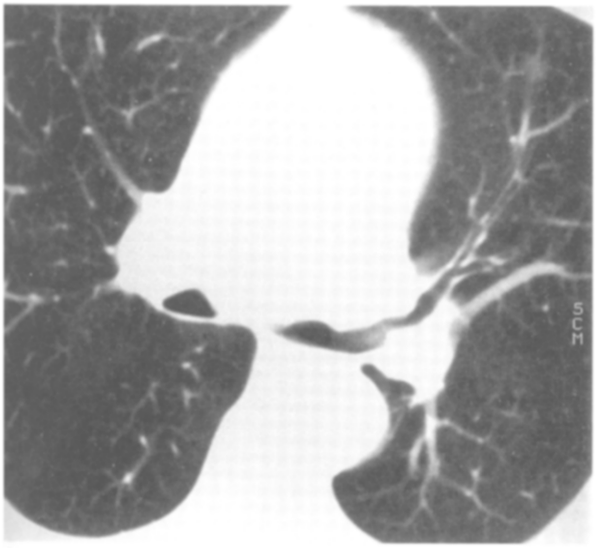

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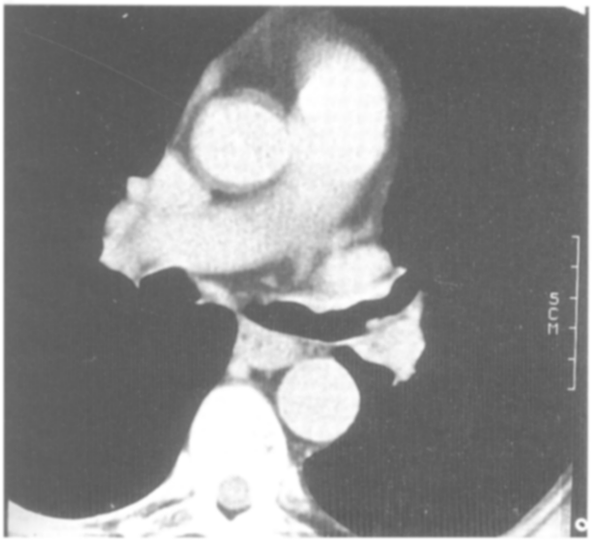

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Fig. 1 – A 74-year-old male with a single episode of haemoptysis. (*a*) Normal chest radiograph. (*b,c*) CT (at lung and soft tissue settings) reveals irregular narrowing of the distal main and proximal left upper lobe bronchi suggestive of a carcinoma. These findings were confirmed at bronchoscopy.

of 5 mm thick sections from the level of the aortic arch to just below the level of the inferior pulmonary veins. All images are reconstructed using a high spatial frequency algorithm. Such a protocol provides the best visualization of the airways and the lung parenchyma. Intravenous contrast enhancement may be required to further evaluate the mediastinum or hila.

Naidich *et al.* [38] retrospectively compared chest radiographic and CT findings with the appearances at FOB in 58 patients presenting with haemoptysis. Abnormalities involving the airways were depicted by CT in a total of 28 cases (48%) compared to 18 cases (31%) documented with fibre-optic bronchoscopy. Bronchiectasis was detected only by CT in 10 patients, in eight of whom the chest radiograph was normal or non-localizing, a prevalence of 17% which is in line with an earlier study by Jones *et al.* using bronchography at the time of FOB [39]. Malignancy was ultimately diagnosed in 24 patients in all of whom abnormalities were identified by CT. In six of these individuals the tumour was not visualized at bronchoscopy and the diagnosis of malignancy was made by CT (three cases) or by other means (three cases). In 10 of 21 cases of non small cell lung cancer CT had a definitive role in staging by documenting either direct mediastinal invasion and/or metastatic disease compared with only three cases in which bronchoscopy provided staging information. The authors recognized a number of significant limitations of the study, including the fact that it was retrospective and that the patient population may not have been truly represented but concluded that CT is useful for evaluating patients presenting with haemoptysis and has a potential role as a screening method in haemoptysis.

Similar conclusions were drawn by Millar *et al.* [40] in a study of 40 patients with a history of haemoptysis, normal chest radiographs and normal FOB examinations who subsequently had CT scans. Abnormalities, which were thought to be the likely cause of the bleeding, were seen at CT in 50% of the cases. They included bronchiectasis (seven patients), peripheral masses (two malignant and two tuberculous), alveolar consolidation (four patients) and abnormal enhancing vessels (three patients). The authors concluded that CT should precede FOB in patients with haemoptysis and a normal chest radiograph to optimize detection of abnormalities and direct cytological and microbiological sampling when no abnormality is detected at bronchoscopy.

The central role for CT in the investigation of haemoptysis is emphasised in two prospective studies in which patients underwent both CT and FOB and the results compared. In the study by Set *et al.* [41] the patients (91 in total) came from a largely rural population. Diagnoses which were regarded as the cause of the haemoptysis were obtained more often with CT (57 diagnoses in 55 patients) than by bronchoscopy (39 diagnoses in 39 patients). Thirty-four patients (37%) were found to have carcinomas; all were detected by CT, but seven were not diagnosed by bronchoscopy. Of these seven malignancies, five were beyond the visual range of the fibre optic bronchoscope but two were identified and biopsied at repeat bronchoscopy, following the road map which CT provided. As in Naidich's study [38] there were a significant number of cases of bronchiectasis (14 patients (15%)), the diagnosis of which was only made by CT. The main diagnosis made only by bronchoscopy

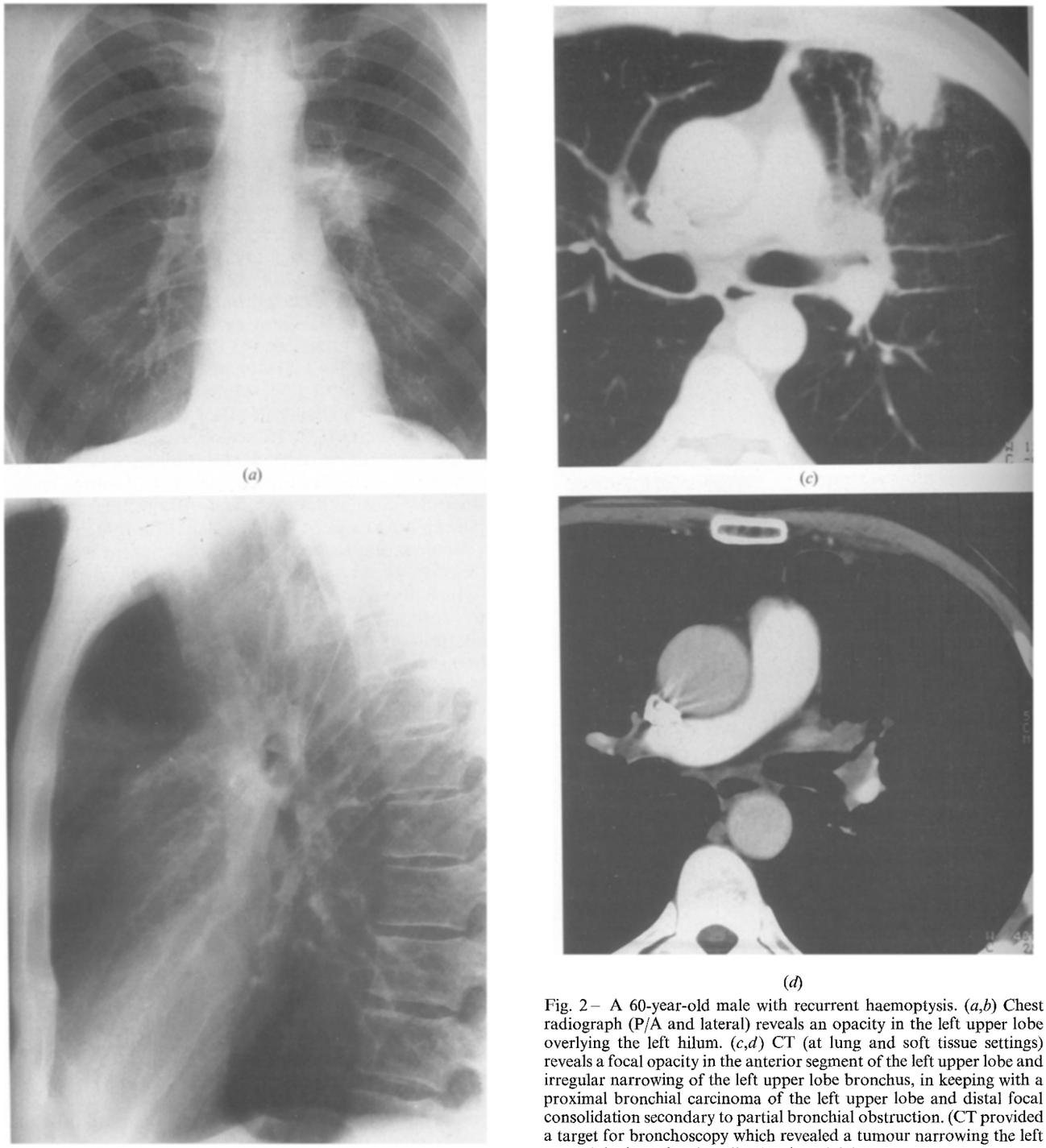


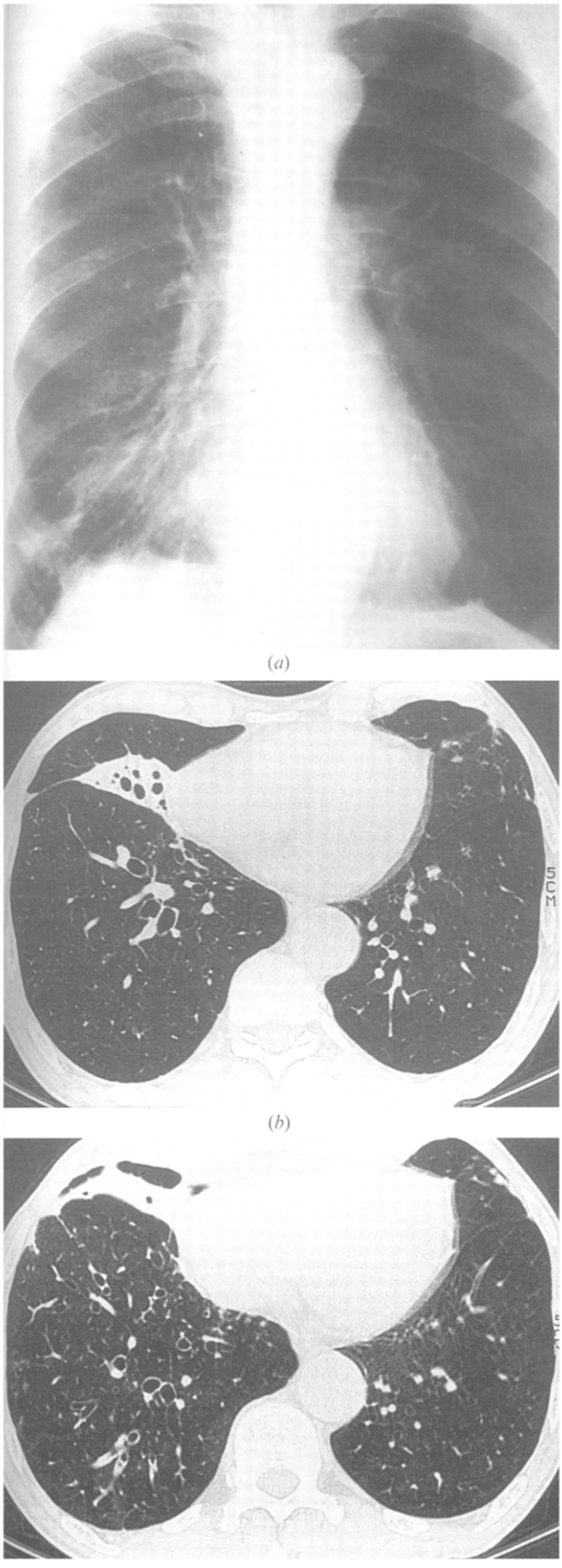
Fig. 2 – A 60-year-old male with recurrent haemoptysis. (*a*,*b*) Chest radiograph (P/A and lateral) reveals an opacity in the left upper lobe overlying the left hilum. (*c*,*d*) CT (at lung and soft tissue settings) reveals a focal opacity in the anterior segment of the left upper lobe and irregular narrowing of the left upper lobe bronchus, in keeping with a proximal bronchial carcinoma of the left upper lobe and distal focal consolidation secondary to partial bronchial obstruction. (CT provided a target for bronchoscopy which revealed a tumour narrowing the left upper lobe bronchus just distal to its origin).

was bronchitis. In 31 patients (34%) no cause was found by either technique, emphasising the relatively high proportion of cases which are cryptogenic.

In the other prospective study, McGuinness *et al.* [42] assessed 57 patients presenting with haemoptysis from a central city location (New York) and also compared CT with bronchoscopy. Again there was a significantly higher overall diagnostic yield from CT (61%) compared with bronchoscopy (43%) even though the prevalence of individual diseases differed from that in Set's study. Seven malignancies (12%) were diagnosed; all were detected by CT with one, peripheral tumour, missed by bronchoscopy. In concordance with the findings of Millar *et al.* [40] these authors observed that a specific diagnosis was made on the basis of the CT findings in 50% of those cases with non-diagnostic bronchoscopy, once again providing evidence that in selected cases in which a specific diagnosis has been made by CT the need for bronchoscopy is by no means mandatory.

Complementary Roles for Bronchoscopy and CT

The papers discussed above provide good evidence for the complementary roles of CT and FOB, although



(*a*)

(*b*)

(*c*)

Fig. 3 – A 77-year-old male with haemoptysis. (No history of recurrent sputum production to suggest bronchiectasis.) (*a*) Chest radiograph reveals patchy shadowing and slight loss of volume of the right lower lobe. (*b*,*c*) HRCT reveals extensive bronchiectasis in the right middle lobe, right lower lobe and to a lesser extent, the lingular segment of the left upper lobe. The right middle lobe is markedly reduced in volume.

further studies need to be performed to determine the impact of CT on patient management and outcome. In the meantime it is possible to suggest what the relative roles of CT and bronchoscopy should be in the management of patients with haemoptysis on the basis of available data. Firstly, a number of facts should be reemphasised: (1) in at least one third of cases of haemoptysis no cause is found; (2) in approximately 90% of these individuals haemoptysis will settle spontaneously within 6 months; (3) when the chest radiograph is normal or non localizing the prevalence of malignancy is very low (approximately 5%); (4) bronchiectasis accounts for approximately 15% of cases and is virtually impossible to diagnose by FOB but readily detected by CT; (5) if a carcinoma is the cause of haemoptysis it is unlikely to be missed by CT. This is probably because most tumours are relatively large by the time they bleed (of the 30 bronchial carcinomas diagnosed in the study by Set *et al.* [41], 25 (83%) were stage III or IV [39]); (6) bronchoscopy is required to obtain biopsies for histology or brushings and washings for cytology and microbiology. The diagnostic yield is improved, however, by a preliminary CT providing a road map both for bronchial and transbronchial biopsy. CT may also indicate that a percutaneous needle biopsy is a preferable approach in a small number of cases.

Based on the above evidence we would recommend that CT be used as the primary investigation in patients with normal or non-localizing chest radiographs. Fibreoptic bronchoscopy should only be performed if the CT is equivocal or reveals evidence of a tumour or when the haemoptysis does not settle within six months. This is an extension of the view that bronchoscopy may be unnecessary in a significant number of patients with haemoptysis [14,15]. This is likely to be preferable to patients who would be spared a bronchoscopy and be beneficial by being almost cost neutral. We would also recommend that CT be performed prior to bronchoscopy in patients in whom the chest radiograph is abnormal or suggestive of malignancy. The evidence indicates that such an approach optimises the results of biopsy and increases the number of cancers diagnosed. The financial implications of such a proposal might seem considerable. However, the majority of patients who are found to have a carcinoma would proceed to CT following bronchoscopy in any event, for the purpose of staging their tumour. The additional cost of CT is, therefore, unlikely to be significant.

Massive Haemoptysis

Massive haemoptysis is defined as the expectoration

Table 2 – Causes of massive haemoptysis

Active tuberculosis
Bronchiectasis (TB, cystic fibrosis, other)
Aspergilloma (with pre-existing chronic lung disease, e.g. sarcoid, TB)
Pneumoconiosis
Previous pulmonary infarction
Bronchogenic carcinoma
Pulmonary metastases
Pulmonary artery aneurysm (Rasmussen, mycotic, arteritis, e.g. Behcets)

of more than 600 ml of blood in 48 h [43,44]. Whilst chronic lung suppuration due to bronchiectasis or an asperigilloma within a chronic sarcoid or tuberculous cavity account for most cases of massive haemoptysis in the western world, active tuberculosis is probably the commonest cause, worldwide. A variety of other conditions may also be complicated by massive haemoptysis (see Table 2).

Massive haemoptysis is life threatening; when treated conservatively more than 50% of patients will die, usually from asphyxiation [43]. These patients should, therefore, be resuscitated and investigated with speed. Chest radiography occasionally reveals the cause of the bleeding but is more often non-localizing. Pulmonary consolidation usually reflects the presence of blood in the lung; its site is not a good indication of the origin of the bleeding as blood is aspirated throughout the bronchial tree. It is customary to perform bronchoscopy to localize the source of bleeding prior to intervention. This should be undertaken with the rigid bronchoscope under general anaesthesia as the narrow suction channel on the FOB is usually unable to clear the blood within the airway to enable clear views to be obtained [45]. Rigid bronchoscopy itself, has the disadvantage that it frequently cannot localize the bleeding more precisely than to one or other lung. In some centres the rigid bronchoscope is used to provide a bronchial toilet and the FOB, passed through the rigid bronchoscope, is used to localize the source of the bronchial haemorrhage. Unless active bleeding is taking place at the time of bronchoscopy, the source of bleeding may not be identified. In these circumstances alternative imaging techniques may be used. Radionuclide imaging with 99m Technetium (99m Tc) sulphur colloid has limited value because of its low spatial resolution [46]. If the chest radiograph is normal a high resolution CT may demonstrate a focal area of haemorrhage and thereby localize the source of bleeding.

In centres where aggressive surgical therapy is performed a considerable improvement in survival can be expected with a reported mortality of between and 1% [43] and 23% [47]. Many patients are not candidates for surgical resection, however, either because of bilateral disease or inadequate respiratory reserve. These patients can be managed by selective embolization of bronchial and other involved systemic arteries.

Selective bronchial angiography in man was originally described by Viamonte in 1964 [48] and the first case of successful control of massive haemoptysis by bronchial artery embolization was reported by Remy in 1973 [49]. In the intervening years a number of complications relating to bronchial arteriography were described in the literature, in particular a transverse myelitis [50,51] causing a certain degree of scepticism in the early stages. It has been well documented since these preliminary papers, however, that if the operator is fully aware of the potential complications of the technique and has a thorough understanding of bronchial arterial anatomy and of the pathophysiology of bronchial arterial bleeding, then successful control of haemoptysis can be obtained in a significant proportion of the patients without complication.

The Effect of Disease on the Pulmonary Systemic Arteries

Within chronically inflamed lungs abnormal bronchopulmonary shunts develop within peri-bronchial inflammatory tissue. The bronchial arteries and other non-bronchial systemic collateral vessels subsequently dilate because of the resultant increased blood flow and the small fragile vessels within the inflammatory tissue are therefore exposed to systemic arterial pressures and may subsequently rupture causing massive bleeding. The bronchial arterial abnormalities that may be seen during bronchial arteriography, reflecting these changes are:

(a) bronchial artery hypertrophy and tortuosity (bronchial artery diameter is normally 1–2 mm; in disease it may be 8 mm or more);
(b) areas of hypervascularity in the lung;
(c) pulmonary arterial and/or venous opacification (see Fig. 5). This is due to the enlargement of the normal systemic to pulmonary artery and pulmonary vein communications and is one of the most common findings in chronic suppurative lung disease complicated by haemoptysis).

Bronchial Artery Anatomy

The bronchial arteries vary considerably in their anatomical distribution. Most commonly they arise from the ascending thoracic aorta at a level between the superior end plate of T5 and the inferior end plate of T6 (approximately 70%). In approximately 45% of individuals there will be a single bronchial artery on one side, usually the right, and two bronchial arteries on the other. In a further 30% of individuals there will be single bronchial arteries arising bilaterally. A variety of other arterial configurations account for the remainder.

The most constant vessel to be seen at arteriography is right intercosto-bronchial trunk which is present in 80% of individuals and usually arises from the right posterolateral aspect of the thoracic aorta whereas individual right and left bronchial arteries arise from the anterior lateral aspect of the aorta. Bronchial arteries may also vary in their site of origin, occasionally arising from the inferior aspect of the aortic arch (seen in up to 15% of individuals) or from a separate systemic arterial branch such as the internal mammary artery, cervical trunk or inferior phrenic artery.

Bronchial arteries not only supply the bronchi but also contribute to the supply of numerous other structures including the middle third of the oesophagus, the diaphragmatic and mediastinal visceral pleura and the vasa vasorum of the aorta and pulmonary artery. Furthermore, there may occasionally be some supply to the myocardium and spinal cord.

In addition to bronchial arteries, chronically inflamed lungs are often supplied by other non-bronchial arteries via trans-pleural vessels [52]. Intercostal arteries are commonly involved (see Fig. 5) and in apical lung disease it is usual to see numerous thoracic arteries arising from the axillary artery supplying the abnormal lung tissue. In basal lung disease, an inferior phrenic arterial supply is common. Other possible contributory vessels include the internal mammary artery, branches of the thyro-cervical and costo-cervical trunks and the left gastric artery. Persistent haemoptysis after a technically successful bronchial artery embolization is usually due to a failure to recognize the involvement of these non-bronchial systemic vessels. They should, therefore,

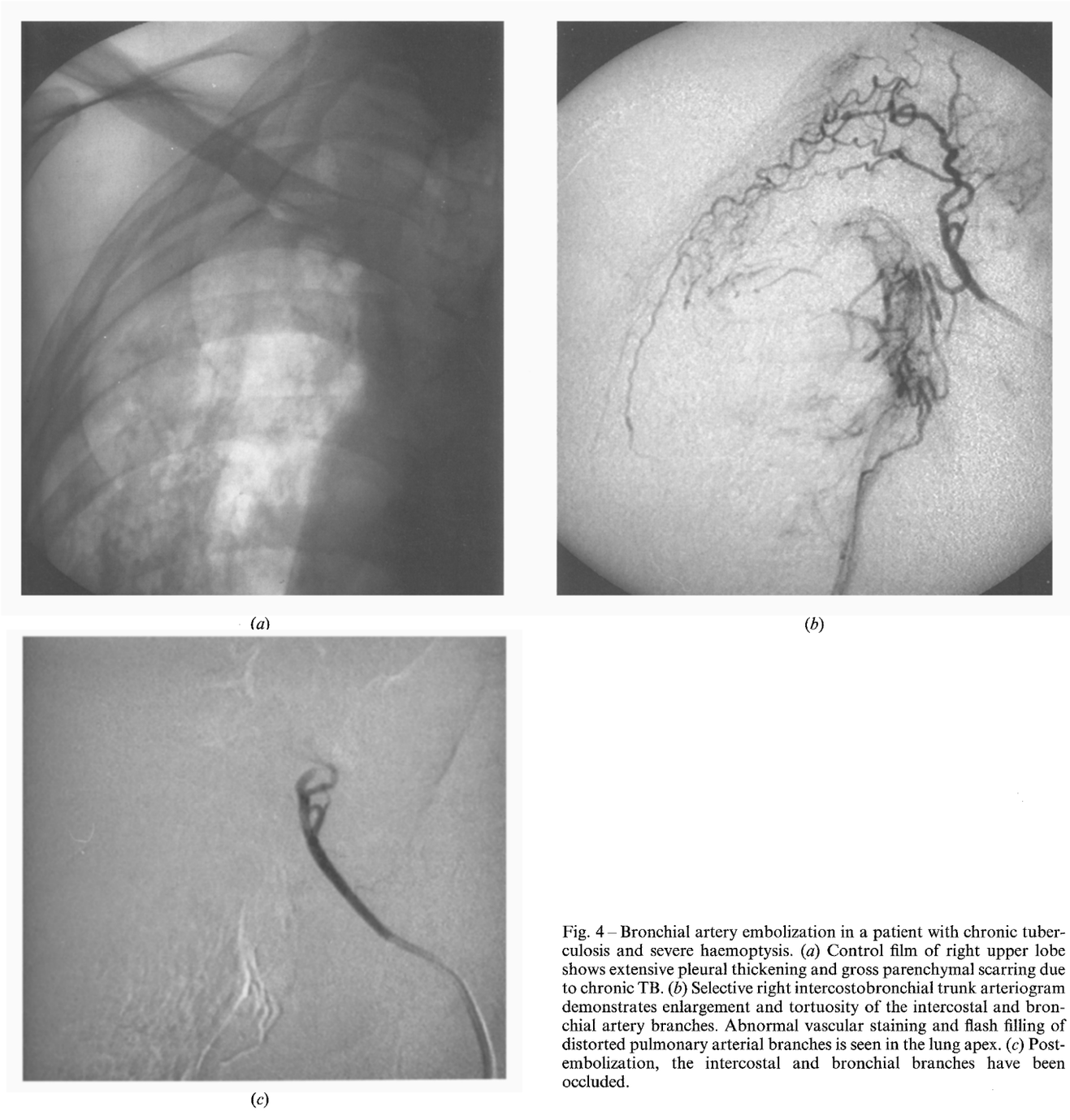


Fig. 4 – Bronchial artery embolization in a patient with chronic tuberculosis and severe haemoptysis. (*a*) Control film of right upper lobe shows extensive pleural thickening and gross parenchymal scarring due to chronic TB. (*b*) Selective right intercostobronchial trunk arteriogram demonstrates enlargement and tortuosity of the intercostal and bronchial artery branches. Abnormal vascular staining and flash filling of distorted pulmonary arterial branches is seen in the lung apex. (*c*) Post-embolization, the intercostal and bronchial branches have been occluded.

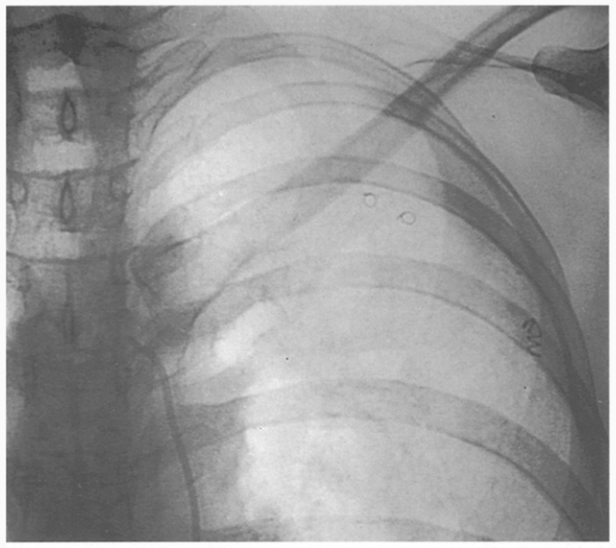
always be looked for at the time of the first aortogram and if of sufficient size should be selectively embolized together with any hypertrophied bronchial arteries [53,54].

In a minority of cases (about 5%) haemoptysis may result from a pulmonary arterial source [55,56], the most common of which is the so-called Rasmussen's aneurysm. Originally described in association with active TB [57], this is a false aneurysm of the pulmonary artery due to erosion of a pulmonary arterial branch by chronic inflammation; it is seen particularly in chronic pulmonary tuberculosis. Pulmonary angiography should, therefore, be performed in patients who return with continued haemoptysis after previous systemic arterial embolization, particularly if there is evidence of fibrocavitatary TB.

Angiographic Technique

Prior to selective catheterization of the bronchial artery, a thoracic aortogram should be performed to provide a clear road map of the bronchial arterial anatomy and to identify other systemic feeding vessels. Although not essential, digital subtraction equipment is useful throughout the procedure because it allows rapid acquisition of images and easy access to images when embolization is being performed.

A variety of different catheters should be available for optimal selective bronchial arterial catheterizations; these should be chosen according to individual anatomy of the bronchial arteries and aorta. When embolization is planned, end hole only catheters are mandatory because catheters with both end and side holes are more prone to



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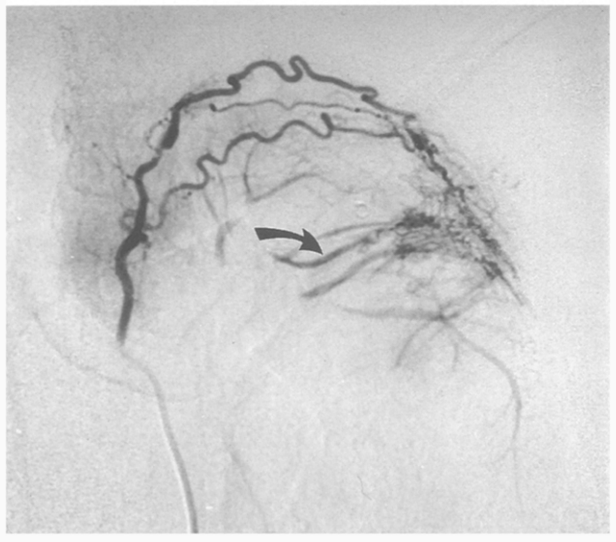

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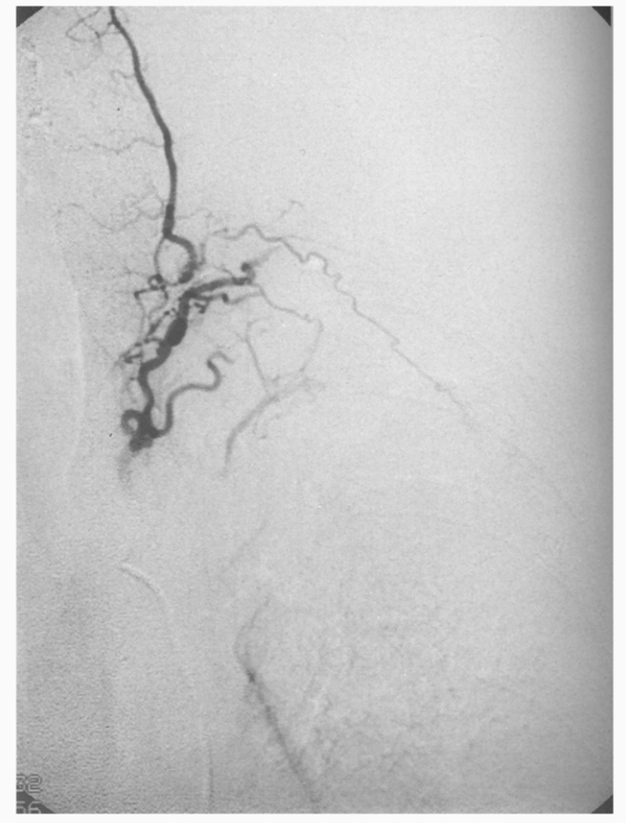

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Fig. 5 – Bronchial artery embolization in a patient with left upper zone mycetoma and chronic sarcoidosis. (*a*) Control film of the left upper zone demonstrates several coils from a previous embolization of the axillary artery branches. (*b*) Left highest intercostal arteriogram demonstrates marked hypertropy and tortuosity of the intercostal branches supplying an area of increased vascularity in the upper zone laterally at the site of the known mycetoma. There is filling of the pulmonary arterial branches medially (arrow). (*c*) Post-embolization arteriogram demonstrates occlusion of the intercostal arterial branches. Note that the deep cervical branch of the costocervical trunk is now opacified via the highest intercostal artery through small communicating vessels. This vessel was not filled on the pre-embolization arteriogram due to the 'steal effect' of the hypertrophied intercostal arteries.

occlusion with embolic material and may allow escape of embolic material through side holes into other vessels causing unwanted embolic complications. Co-axial catheters may be required for super-selective catheterization in some cases where a secure catheter position cannot be achieved for embolization with a conventional catheter. Satisfactory opacification of bronchial arteries during selective arteriography can be achieved by hand injection of contrast medium; the rate and volume of injection vary depending on the real size of the bronchial arteries and are judged by the angiographer according to the 'real-time' images obtained during the acquisition.

Bronchial Artery Embolization

The aim of embolization is to reduce the systemic arterial perfusion pressures to the fragile vessels within inflammatory tissue and to try to prevent the development and enlargement of non-bronchial systemic arterial collaterals. It is essential to avoid using an embolic agent with will pass through abnormal bronchial arteries to pulmonary artery/vein shunts with resultant pulmonary arterial or even systemic arterial embolization. In addition, it is important to avoid using embolic agents which produce such distal occlusion that normal peripheral branches supplying the bronchi, oesophagus or vasa vasorum of the pulmonary artery or aorta are occluded with potentially disastrous consequences such as oesophageal, pulmonary arterial or aortic wall necrosis. Currently the best agent for bronchial arterial embolization is polyvinyl alcohol, a particulate agent which is available in a variety of sizes. Choice of particle size is made on the basis of the appearances of the selective bronchial arteriograms. In general, embolization with coils should be avoided as there is no evidence that their use is associated with an improved result in terms of control of haemoptysis. In particular, their deployment serves only to prevent recatheterization of the occluded bronchial artery should the patient return at a later date with a further bleed. They may be used, however, to occlude pulmonary artery aneurysms and occasionally they may be utilised in certain vessels to protect a vascular territory from embolization, e.g. the internal mammary artery.

Good embolization technique is important with care

being taken to check on the progress of the vessel occlusion with frequent angiographic 'runs'. As distal vascular occlusion occurs previously unopacified vessels (such as the spinal artery) may be visualized as the 'steal' effect by the hypertrophied bronchial arterial branches diminishes. The end point of embolization is when there is contrast stasis within the bronchial artery (see Figs 4 & 5).

RESULTS

Immediate control of haemoptysis will be achieved in between 75% and 90% of patients by bronchial artery embolization but up to 20% of patients will rebleed within 6 months [58–61] and approximately 50% of patients will have further significant haemoptyses on longer term follow-up [62]. Early rebleeding is usually due to incomplete embolization either because one of the bronchial arteries was not catheterized or because non-bronchial systemic arteries were not identified and occluded. Late rebleeding is generally due to disease progression and such patients may be successfully treated by repeat embolization. Patients with haemoptysis due to an aspergilloma tend not to respond well to embolization and better results can be achieved by combining embolization with percutaneous intracavitatary instillation of anti-fungal agents [63–66].

REFERENCES

1 Abbott OA. The clinical significance of pulmonary haemorrhage: a study of 1316 patients with chest disease. *Diseases of the Chest* 1948;14:824–842.
2 Heller R. The significance of haemoptysis. *Tubercle* 1946;26:70–74.
3 Soulders CR, Smith AT. The clinical significance of haemoptysis. *New England Journal of Medicine* 1952;247:790–793.
4 Johnston H, Reisz G. Changing spectrum of haemoptysis: underlying causes in 148 patients undergoing diagnostic fibroptic bronchoscopy. *Archives of International Medicine* 1989;149: 1666–1668.
5 Santiago S, Tobias J, Williams AJ. A reappraisal of the causes of haemoptysis. *Archives of Internation Medicine* 1991;151:2449–2451.
6 American Thoracic Society. A statement of the management of haemoptysis. *American Review of Respiratory Diseases* 1966;93:471.
7 Suratt PM, Smiddy JF, Gruber B. Deaths and complications associated with fibreoptic bronchoscopy. *Chest* 1976;69:747–751.
8 Poe RH, Israel RH, Marin MC *et al.* Utility of fibreoptic bronchoscopy in patients with haemoptysis and a non-localizing chest roentgenogram. *Chest* 1988;93:70–75.
9 Rath GS, Schaff JT, Schneider GL. Flexible fibreoptic bronchoscopy techniques and review of 100 bronchoscopies. *Chest* 1973;63:689–693.
10 Zavala DC. Diagnostic fibreoptic bronchoscopy: Techniques and results of biopsy in 600 patients. *Chest* 1975;68:12–19.
11 Dreisen RB, Albert RK, Talley PA *et al.* Flexible fibreoptic bronchoscopy in the teaching hospital: yield and complications. *Chest* 1978;74:144–149.
12 Gong H Jr, Salvateirra C. Clinical efficacy of early and delayed fibreoptic bronchoscopy in patients with haemoptysis. *American Review of Respiratory Diseases* 1981;124:221–225.
13 Jackson CV, Savage PJ, Quinn DL. Role of fibreoptic bronchoscopy in patients with haemoptysis and a normal chest radiograph. *Chest* 1985;87:142–144.
14 Weaver LF, Solliday N, Cugell DW. Selection of patients with haemoptysis for bronchoscopy. *Chest* 1979;76:7–10.
15 Snider GL. When not to use the bronchoscope for haemoptysis. *Chest* 1979;76:1–2.
16 Adelman M, Haponik EF, Bleeker ER *et al.* Cryptogenic haemoptysis: clinical features, bronchoscopic findings and natural history in 67 patients. *Annals of International Medicine* 1985;102:829–834.
17 Lederle FA, Nichol KL, Parenti CM. Bronchoscopy to evaluate haemoptysis in older men with nonsuspicious chest roentgenograms. *Chest* 1989;5:1043–1047.
18 Shepard JAO. Computed tomography of the mediastinum. *Clinics in Chest Medicine* 1984;5:291–305.
19 Faling LJ, Pugatch RD, Jung-legg Y *et al.* Computed tomographic scanning of the mediastinum in the staging of bronchogenic carcinoma. *American Review of Respiratory Diseases* 1981; 124:690–695.
20 Staples CA, Muller NL, Miller RR *et al.* Mediastinal nodes in bronchogenic carcinoma: comparison between CT and mediastinoscopy. *Radiology* 1988;167:367–372.
21 McLoud TC, Bourguin PM, Greenburg RW. Bronchogenic carcinoma: analysis of staging in the mediastinum with CT by correlative lymph node mapping and sampling. *Radiology* 1992;182:319–323.
22 Naidich DP, Terry PB, Stitik FP *et al.* Computed tomography of the bronchi: 1. Normal anatomy. *Journal of Computer Assisted Tomography* 1980;4:746–753.
23 Jardin M, Remy J. Segmental bronchovascular anatomy of the lower lobes: CT analysis. *American Journal of Roentgenology* 1986;147:457–468.
24 Henschke CI, Davis SD, Auh PR *et al.* Detection of bronchial abnormalities: comparison of CT and bronchoscopy. *Journal of Computer Assisted Tomography* 1987;11:432–435.
25 Naidich DP, McCauley DI, Khouri NF *et al.* Computed tomography of bronchiectasis. *Journal of Computer Assisted Tomography* 1982;6:437–444.
26 Muller NL, Bergin CJ, Ostrow DN *et al.* Role of computed tomography in the recognition of bronchiectasis. *American Journal of Roentgenology* 1984;143:971–976.
27 Grenier P, Maurice F, Musset D *et al.* Bronchiectasis: assessment by thin-cut CT. *Radiology* 1986;161:95–99.
28 Fishman EK, Freeland HS, Wang KP *et al.* Intrabronchial lesion on computed tomography secondary to blood clot. *Journal of Computer Assisted Tomography* 1984;8:547–549.
29 Shin MS, Kiang-Jey H. Broncholithiasis: its detection by computed tomography in patients with recurrent haemoptysis of unknown origin. *Journal of Computer Assisted Tomography* 1983; 7:189–193.
30 Kowal LE, Goodman LR, Zarro VJ *et al.* CT diagnosis of broncholithiasis. *Journal of Computer Assisted Tomography* 1983;7:321–323.
31 Naidich DP, McCauley DI, Siegelman SS. Computed tomography of bronchial adenomas. *Journal of Computer Assisted Tomography* 1982;6: 725–732.
32 Webb WR, Gamsu G, Speckman JM. Computed tomography of the pulmonary hilum in patients with bronchogenic carcinoma. *Journal of Computer Assisted Tomography* 1983;7:219–225.
33 Naidich DP, Lee JJ, Garay SM *et al.* Comparison of CT and fibreoptic bronchoscopy in the evaluation of bronchial disease. *American Journal of Roentgenology* 1987;148:1–7.
34 Woodring JH. Determining the cause of pulmonary atelectasis: a comparison of plain radiography and CT. *American Journal of Roentgenology* 1988;150:757–763.
35 Mayr B, Ingrisch H, Haussinger K, Huber RM. Tumours of the bronchi: role of evaluation with CT. *Radiology* 1989;172:647–652.
36 Colice GL, Chappel GJ, Frenchman SM, Solomon DA. Comparison of computerized tomography with fibreoptic bronchoscopy in identifying endobronchial abnormalities in patients with known or suspected lung cancer. *American Review of Respiratory Diseases* 1985;131:397–400.
37 Haponik EF, Britt EJ, Smith PL *et al.* Computed chest tomography in the evaluation of haemoptysis: impact on diagnosis and treatment. *Chest* 1987;91:80–85.
38 Naidich DP, Funt S, Ettenger NA *et al.* Haemoptysis: CT-Bronchoscopic correlations in 58 cases. *Radiology* 1990;177:357–362.
39 Jones DK, Cavanagh P, Schneerson JM, Flower CDR. Does bronchography have a role in the assessment of patients with haemoptysis? *Thorax* 1985;40:668–670.
40 Millar AB, Boothroyd AE, Edwards D *et al.* The role of computed tomography (CT) in the investigation of unexplained haemoptysis *Respiratory Medicine* 1992;86:39–44.
41 Set PAK, Flower CDR, Smith IE *et al.* Haemoptysis: Comparative study of the role of CT and fibreoptic bronchoscopy. *Radiology* 1993;189:677–680.
42 McGuiness G, Beacher JR, Harkin TJ *et al.* Haemoptysis: Prospective high-resolution CT/Bronchoscopic correlation. *Chest* 1994; 105:1155–1162.
43 Crocco JA, Rooney JJ, Fankushen DS *et al.* Massive haemoptysis *Archives of International Medicine* 1968;121:495–498.
44 Conlan AA, Hurwitz SS Krige L *et al.* Massive haemoptysis: review

of 123 cases. *Journal of Thoracic Cardiovascular Surgery* 1983; 85:120–124.
45 Imgrund SP, Goldberg SK, Walkenstein MD *et al.* Clinical diagnosis of massive haemoptysis using the fibre-optic bonchoscopic. *Critical Care in Medicine* 1985;13:438–443.
46 Haponik EF, Rothfeld B, Britt EJ *et al.* Radionuclide localisation of massive pulmonary haemorrage. *Chest* 1984;86:208–211.
47 Sehat S, Oreizie M, Moinedine K. Massive pulmonary haemorrhage: surgical approach as choice of treatment. *Annals of Thoracic Cardiovascular Surgery* 1978;25:12–15.
48 Viamonte M Jr. Selective bronchial arteriography in man. Preliminary report. *Radiology* 1964;83:830–839.
49 Remy J, Voisin C, Dupuis C *et al.* Traitement des hemoptysies par embolization de la circulation systemique. *Annals of Radiology* (Paris) 1974;17:5–16.
50 Feigelson HH, Ravin HA. Transverse myelitis following selective bronchial arteriography. *Radiology* 1965;65:663–665.
51 Di Chiro G. Unintentional spinal cord arteriography: a warning. *Radiology* 1974;112:231–233.
52 Parke WW, Michels NA. The non-bronchial systemic arteries of the lung. *Thoracic Cardiovascular Surgery* 1965;49:694–727.
53 Keller FS, Rosch F, Loflin TG *et al.* Non-bronchial systemic collateral arteries: significance in percutaneous embolotherapy for haemoptysis. *Radiology* 1987;164:687–692.
54 Jardin M, Remy J. Control of haemoptysis: systemic angiograpy and anastomoses of the internal mammary artery. *Radiology* 1988;168:377–383.
55 Remy J, Lemaitre L, Lafitte JJ *et al.* Massive haemoptysis of pulmonary arterial origin: diagnosis and treatment. *American Journal of Roentgenology* 1984;143:963–969.
56 Rabkin JE, Astafjev VI, Gothman LN *et al.* Transcatheter embolization in the management of pulmonary haemorrhage. *Radiology* 1987;163:361–365.
57 Calmette A. *L'infection Bacillaire et la Tuberculose chez l'homme et chez les animaux* 4th ed. Paris, Masson et Cie, 1936:327.
58 Remy J, Arnaud A, Fardow H *et al.* Treatment of haemoptysis by embolization of bronchial arteries. *Radiology* 1977;122:33–37.
59 Uflacker R, Kaemmerer A, Picon PD *et al.* Bronchial artery embolization in the management of haemoptysis: technical aspects and long-term results. *Radiology* 1985;157:637–644.
60 Stoll JF, Bettman MA. Bronchial artery embolization to control haemoptysis: a review. *Cardiovascular Interventional Radiology* 1988;11:263–269.
61 Cohen AM, Doershuk CF, Stern RC. Bronchial artery embolization to control haemoptysis in cystic fibrosis. *Radiology* 1990; 175:401–405.
62 Remy J, Jardin M. In: Dondelinger RF, Rossi P, Kurdziel JC, Wallace S, eds. *Interventional Radiology*. New York: Thieme Medical Publishers, Inc., 1990:325–341.
63 Stiksa G, Edlundh G, Riebe I *et al.* Bilateral pulmonary aspergillomas in ankylosing spondylitis treated with transthoracic intracavitary instillations of antifungal agents. *Scandinavian Journal of Resporatory Diseases* 1976;57:163–170.
64 Hargis JL, Bone RC, Stewart J *et al.* Intracavitary amphotericin B in the treatment of symptomatic pulmonary aspergillomas. *American Journal of Medicine* 1980;68:389–394.
65 Shapiro MJ, Albeda SM, Mayock RL *et al.* Severe haemoptysis associated with pulmonary aspergillomas. Percutaneous intracavitary treatment. *Chest* 1988;94:1225–1231.
66 Lee KS, Kim YH, Bae WK. Percutaneous intracavitary treatment of a giant aspergilloma (letter). *American Journal of Roentgenology* 1990;154:1346.