In the investigation of suspected lung cancer bleomycin labelled with cobalt-57 and gallium-67 labelled with citrate are currently used to detect the primary tumour and to establish the presence of metastases in the lung hilum and mediastinum. A comparative study of these radiopharmaceuticals was performed in 63 patients with proved lung cancer. $^{57}$Co-bleomycin showed the primary tumour in 58 patients (92%) and $^{67}$Ga-citrate in 34 (54%) ($p < 0.01$). The average tumour-to-lung ratio was 3.4 with $^{57}$Co-bleomycin and 1.5 with $^{67}$Ga-citrate. Proved metastases in the hilum or the mediastinum were visualised with $^{57}$Co-bleomycin scintigraphy in 16 out of 18 patients (89%) and with $^{67}$Ga-citrate scintigraphy in only eight (45%) ($p < 0.01$). These results indicate that $^{57}$Co-bleomycin scintigraphy is more suitable for detecting and staging lung cancer than is $^{67}$Ga-citrate. $^{57}$Co-bleomycin is valuable in the detection of peripheral lesions, in which a pathological diagnosis is difficult to achieve, since a positive scintigram indicates malignancy. When $^{57}$Co-bleomycin scintigraphy suggests hilar or mediastinal metastases mediastinoscopy should be carried out; but when no metastases are apparent it is reasonable to proceed directly to thoracotomy without mediastinoscopy.

Methods

The criteria for selection of patients included (a) the need to investigate a peripheral lesion of unknown origin seen on the chest radiograph and (b) the need to detect possible metastases in the hilum and mediastinum. Most patients were referred because of a small symptomless lesion on a chest radiograph from a mass screening programme.

Scintigraphy was performed in 93 patients. Informed consent was obtained. Of these patients, 23 were excluded because of lack of histological confirmation. Of the remaining 70 patients, 63 were


**57**Co-bleomycin and **67**Ga-citrate in detecting and staging lung cancer

men and seven were women. The age range was 44–83 years (mean 63 years). In 63 patients a diagnosis of malignant lung tumour was made. There were 41 patients with squamous-cell carcinoma, 11 with large-cell anaplastic carcinoma, seven with adeno carcinoma, two with small-cell anaplastic carcinoma, and one with basal-cell carcinoma. A patient with carcinoid tumour was also included. In eight patients a benign lesion was found at operation or after careful follow-up; one of these had both a benign and a malignant lesion. In all patients with a malignant tumour the hilum and the mediastinum were evaluated by a surgical procedure or at necropsy within 10 weeks of scintigraphy.

**57**Co-bleomycin was prepared as follows. Into 3 mCi (111 MBq) **57**Co-chloride in 1 ml HCl (0·1 mol/l) was stirred 7·5 mg bleomycin or the bleomycin-A2 fraction (supplied by Lundbeck) in 1·0 ml 1·8% NaCl solution and subsequently 2 ml 0·1 mol/l Na-acetate (pH 5·6). The pH of the product was 4–6. Filtration (0·22 μm pore size) was performed under aseptic conditions. The radiopharmaceutical was injected only when the amount of free **57**Co**+** was less than 3%, measured with instant thin-layer chromatography.

All patients were first injected intravenously with 1 mCi (37 MBq) **57**Co-bleomycin. Scintiphotos were made 24 hours later. Subsequently 3 mCi (111 MBq) **67**Ga-citrate (obtained from New England Nuclear and Byk Mallinckrodt CIL BV) was injected intravenously and usually 48 hours later scintiphotos were obtained.

Scintigraphy was performed with a large-field gamma camera. During the **57**Co-scintigraphy a low-energy, parallel-hole collimator was used. A preset count of 50 k and a preset time of 10 minutes were used. During the **67**Ga-scintigraphy a medium-energy parallel-hole collimator was used. The 296-keV and 184-keV photopeaks were used. A preset count of 400 k and a preset time of 10 minutes were selected. Anterior and posterior views of the thorax were obtained and other views if necessary.

All scintigrams were reviewed as unprocessed analogue pictures by several of the authors without knowledge of the pathological diagnosis and a consensus interpretation was made. The results of the scans were expressed as positive, equivocal, or negative. Scintigrams were also accumulated in a computer system in 64 × 64 frame mode. Tumour-to-lung uptake ratios were calculated from the digital pictures with the following technique. A rectangular region of interest was chosen around the tumour. A lower display level was set to visualise the tumour only and the mean count per channel in the visible part of the region was calculated. This was divided by the mean count per channel of a similar rectangular region of interest in the corresponding area of the opposite lung.

**Results**

**PRIMARY TUMOUR**

**57**Co-bleomycin was clearly superior in detecting primary tumours (table 1). There was a sensitivity of 92% with **57**Co-bleomycin scintigraphy and of 54% with **67**Ga-citrate scintigraphy (equivocal scintigrams are considered negative). This difference is significant (sign test, *p* < 0·01). In 55 patients tumour-to-lung ratios were calculated. The tumour-to-lung ratio with **57**Co-bleomycin scintigraphy was 3·4 ± 1·7 (mean ± SD) and with **67**Ga-citrate scintigraphy 1·5 ± 0·9. The mean difference between these ratios in individual patients is significant (Student’s *t* test, *p* < 0·01).

The size of the lesions, measurable on the chest radiographs in 57 patients, influenced the scintigraphy results. The mean diameter of the lesions measured was 3·7 cm (range 1·0–8·3 cm). The diameters of the tumours in the patients with false negative **57**Co-bleomycin scintigrams were 3·7, 1·7, 1·8, 1·9, 1·7, 1·6, and 1·8 cm. The mean diameter of the tumours in the patients with equivocal results was 3·4 cm (range 2·0–8·3 cm). The diameters of the tumours in the patients with positive results were 4·7, 5·7, 4·6, 3·7, 3·6, 4·7, and 4·8 cm. The mean diameters of the tumours in the positive group was 3·7 cm (range 2·0–5·0 cm). The mean diameters of the tumours in the equivocal group was 3·4 cm (range 1·0–5·0 cm).

**Table 1** Detection of primary tumours in 63 patients with proved lung cancer

<table>
<thead>
<tr>
<th>Scintigraphy result</th>
<th><strong>57</strong>Co-bleomycin</th>
<th><strong>67</strong>Ga-citrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>58</td>
<td>34</td>
</tr>
<tr>
<td>Equivocal</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Negative</td>
<td>4</td>
<td>20</td>
</tr>
</tbody>
</table>

![Fig 1](relation_between_diameters_of_the_primary_tumours_and_negative_equivocal_and_positive_results_of_67Ga-citrate_scintigraphy.png)

Fig 1 Relation between diameters of the primary tumours and negative, equivocal, and positive results of **67**Ga-citrate scintigraphy.
Tumours smaller than 3 cm were seldom visualised with $^{67}$Ga-citrate. An example of a small tumour seen on a chest radiograph and on the $^{57}$Co-bleomycin but not the $^{67}$Ga-citrate scintigram is illustrated in figs 2 and 3.

The pathological diagnoses of the tumours in the four patients with false-negative $^{57}$Co-bleomycin scans were carcinoid tumour, squamous-cell carcinoma, adenocarcinoma, and large-cell anaplastic carcinoma. No relation between the histological type of the tumour and the scintigraphy results was noted for either radiopharmaceutical.

**HILUM AND MEDIASTINUM**

Eighteen patients proved to have metastases in hilum or mediastinum. The results of scintigraphy in this group and in the 45 patients without metastases are presented in table 2. In the detection of these metastases the sensitivity of the $^{57}$Co-bleomycin scintigraphy was 89% and of the $^{67}$Ga-citrate scintigraphy 44%, a significant difference (sign test, $p < 0.01$). The specificity of the $^{57}$Co-bleomycin scintigraphy was 98% and of $^{67}$Ga-citrate scintigraphy 91% (equivocal scintigrams are considered false positive). This difference is not significant (sign test).

**BENIGN LESIONS**

Eight patients proved to have a benign lesion. The nature of their lesions and the scintigraphy results are presented in table 3. Three had false-positive results from $^{57}$Co-bleomycin scintigraphy but none from $^{67}$Ga-citrate scintigraphy.

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**Fig 2** Chest radiograph of a 66-year-old man presented with a coin lesion (diameter 1.7 cm) in the right lung, discovered at a routine chest x-ray examination; cytological examination of the sputum was suggestive of squamous-cell carcinoma (Papanicolaou grade 4). The lesion could not be seen at bronchoscopy.

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1.2, and 1.0 cm. The diameter of the tumour in the patient with an equivocal $^{57}$Co-bleomycin scintigram was 2.5 cm. The relation between tumour size and the results of the $^{67}$Ga-citrate scintigrams is shown in fig 1.

---

**Fig 3** Negative $^{67}$Ga-citrate scintigram (left) and positive $^{57}$Co-bleomycin scintigram (right) with tumour-to-lung ratio of 2.4 and appreciable uptake of radioisotope also in the mediastinum (same patient as in fig 2). Both are posterior views. At mediastinoscopy enlarged lymph nodes were found, and the biopsy specimen showed squamous-cell carcinoma.
Table 2  Detection of metastases in hilum and mediastinum with $^{57}$Co-bleomycin and $^{67}$Ga-citrate scintigraphy

<table>
<thead>
<tr>
<th>Group</th>
<th>No of patients</th>
<th>$^{57}$Co-bleomycin scintigraphy</th>
<th>$^{67}$Ga-citrate scintigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>Equivocal</td>
<td>Negative</td>
</tr>
<tr>
<td>With hilar tumour</td>
<td>18</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Without hilar tumour</td>
<td>45</td>
<td>1</td>
<td>44</td>
</tr>
</tbody>
</table>

Table 3  Diagnoses and scintigraphy results* of eight patients with benign lesions

<table>
<thead>
<tr>
<th>Patient No</th>
<th>Diagnosis</th>
<th>$^{57}$Co-bleomycin</th>
<th>$^{67}$Ga-citrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Active tuberculosis</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Pneumonia</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Lung infarction</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Chondroma</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Scar tissue</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Metaplasia</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Pneumonia</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Bronchopatia osteoplastica</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* + indicates positive scintigram and - negative scintigram.
† This patient had two different benign lesions.
‡ This patient also had squamous-cell carcinoma.

Discussion

Clinical staging of lung cancer is important for several reasons—firstly, to aid the selection of the most effective treatment; secondly, to assist in determining prognosis; and, thirdly, to allow comparison of the results reported from different sources.

$^{67}$Ga-citrate is widely used for this purpose; $^{57}$Co-bleomycin is used on a smaller scale. After the first paper on the use of $^{67}$Ga-citrate as a tumour-seeking agent,16 initially encouraging results in detecting lung cancer were reported. In 1217 patients, collected from different publications, a sensitivity of 91% was found.17 Later it became evident that a negative scan could not be relied on in the case of lesions less than 3 cm in diameter. The detection of mediastinal metastases proved disappointing, possibly because of the high uptake normally seen in this region.18 Recently it was stated that the detection of hilar and mediastinal tumour extension with $^{67}$Ga-citrate is still highly controversial.19 A considerable number of false-positive19 and false-negative scintigrams has been reported.20 Possibly a higher dose, up to 10 mCi (370 MBq),21 more refined equipment such as a tomographic system,22 injection of iron,23 24 or injection of desferoxamine mesylate after $^{67}$Ga-citrate injection25 would improve the sensitivity. Another disadvantage of $^{67}$Ga-citrate is its rather poor specificity—it is concentrated in benign lesions such as inflammation26 and sarcoidosis lesions.27

$^{57}$Co-bleomycin has proved to be useful in the detection of lung cancer. A sensitivity of 98% was found in one series8 and in another 96%.28 In 112 patients with mediastinal tumour invasion no false negatives were encountered.8 The specificity of $^{57}$Co-bleomycin has not been investigated thoroughly. The long half life of $^{57}$Co (270 days) has restricted its use largely to those patients suspected of having a neoplasm. It is known, however, that in inflammatory conditions, especially active tuberculosis, positive scintigrams are sometimes seen.8 28 Now that $^{55}$Co, a positron-emitting radioisotope with a half life of 18 hours, is available as a label for bleomycin,29 a prospective study in non-neoplastic diseases should be carried out to determine the specificity of Co-bleomycin.

The results of the present study lead to the conclusion that $^{57}$Co-bleomycin is superior to $^{67}$Ga-citrate in the detection and staging of lung cancer. More primary tumours were visualised and the sensitivity was 92%, compared with 54% for $^{67}$Ga-citrate. In comparative studies Grove et al11 and Poulose et al12 found a sensitivity of 91% with $^{57}$Co-bleomycin and 76% with $^{67}$Ga-citrate in patients with lung cancer. The latter figure is better than our results. In the present study tumour-to-lung ratios for $^{57}$Co-bleomycin were clearly better: 3·4 compared with 1·5 for $^{67}$Ga-citrate. Bertrand et al compared tumour-to-lung ratios in 21 patients with lung cancer and found a ratio of 5·2 for $^{57}$Co-bleomycin and of 2·1 for $^{67}$Ga-citrate.13 Detection of hilar and mediastinal metastases proved more reliable with $^{57}$Co-bleomycin in our study. In none of the few comparative studies that we know of were the hilum and mediastinum evaluated, yet these areas are of great clinical importance.

The size of the lesion plays an important part in its detection with radiopharmaceuticals. Patients with a large primary tumour, in whom a diagnosis could easily be established by other means, were excluded from this study. Patients with obvious clinical or radiological signs of hilar or mediastinal metastases were also excluded. They were subjected to mediastinoscopy without prior scintigraphy. In most of our patients the lesion was discovered on mass screening radiographs, when symptoms had not yet developed. As a result most of the patients studied had a small tumour. This may explain our unfavourable results with $^{67}$Ga-scintigraphy. The
importance of the tumour size for the scintigraphy results is shown in fig 1.

The major drawback of \(^{57}\)Co, its long half life, poses no threat to the patient since \(^{57}\)Co-bleomycin is quickly excreted by the kidneys; but the urine should be collected for at least 24 hours and stored to prevent environmental contamination. Using \(^{64}\)Co as label for bleomycin solves this problem. Our first results with \(^{55}\)Co-bleomycin in the detection of lung cancer, with a positron camera, are promising. 29

We do not advocate that \(^{57}\)Co-bleomycin should replace biopsy and histological diagnosis of the primary tumour; but in peripheral lesions, in which a pathological diagnosis is difficult to obtain, a positive scintigram is an indication of a malignancy. When hilar or mediastinal metastases are suggested by scintigraphy, mediastinoscopy is carried out. If mediastinoscopy provides histological evidence of metastases thoracotomy is not indicated. When no hilar or mediastinal metastases are shown on the scintigram (and in the absence of distant metastases) we consider that mediastinoscopy is not needed. We then proceed directly to thoracotomy.

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Co-bleomycin and ⁶⁷Ga-citrate in detecting and staging lung cancer


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