Solitary Pulmonary Nodules*  
CT-Bronchoscopic Correlation  
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The possible contribution of computed tomography (CT) in the management of patients with solitary pulmonary nodules (SPNs) or masses was reviewed retrospectively in 65 patients undergoing fiberoptic bronchoscopy (FOB). Nodules were evaluated by size, location, surface contour, and the presence in cross-section of a bronchus leading to or contained within the nodule or mass, a "positive bronchus sign." Thirty-five lesions were associated with a positive bronchus sign; 21 of 35 (60 percent) were diagnosed endoscopically, ($p = .027$); of 30 cases with a negative bronchus sign, only ten (30 percent) had a diagnosis made by FOB ($p = .034$). It is concluded that CT may be of use in the routine evaluation of pulmonary nodules, prior to bronchoscopy, especially in cases for which histologic evaluation is essential, especially to determine the presence or absence of a CT bronchus sign.

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tandardization in the approach to patients with solitary pulmonary nodules (SPNs) or masses remains elusive. This is especially problematic when tissue sampling is required. Whether patients should be evaluated preferentially by fiberoptic bronchoscopy (FOB), or rather by transthoracic needle aspiration and/or biopsy, or even surgically, remains controversial. While previous reports have described in detail factors likely to predict bronchoscopic success, including roentgenographic criteria, to date, the potential role of computed tomography (CT) has not been analyzed. It is the purpose of this report to evaluate the possible contribution of CT specifically in patients with solitary parenchymal lesions to determine the likely yield from flexible fiberoptic bronchoscopy.

MATERIAL AND METHODS

Sixty five cases of SPNs were reviewed retrospectively in patients who underwent both FOB and CT in order to identify findings on CT scans that might predict bronchoscopic yield. Nodules were evaluated by size, location (central vs peripheral, as determined by CT), surface contour (smooth, lobulated, or spiculated), and the presence or absence of a "bronchus sign" (the finding on cross-section of a bronchus leading directly to or contained within the nodule or mass).

Scans were obtained utilizing state-of-the-art scanners. The shortest possible scan times were used (between 2 and 4.8 seconds). Images were acquired with patients in suspended deep inspiration. Intravenous contrast was utilized as indicated, usually to clarify mediastinal or hilar anatomy. Ten millimeter thick sections every 10 mm were obtained routinely through the thorax. In 43 cases, 1.5 mm thick sections additionally were obtained specifically through nodules in order to derive quantitative densitometric measurements. All patients shown by this technique, or complementary techniques to have diffusely or centrally calcified nodules were deleted from the study.

Biopsies were performed endoscopically, utilizing standard biopsy forceps; washings were obtained as well in all cases.

The significance of both the presence and absence of airways in association with masses in relation to bronchoscopic yield was evaluated using standard 2 x 2 chi square analysis.

RESULTS

In 55 of 65 cases, histologic confirmation was obtained either bronchoscopically or surgically (Table 1). Fifty malignancies were documented, including 23 adenocarcinomas; 18 squamous cell carcinomas; five small cell carcinomas; and four undifferentiated carcinomas. Five cases proved benign, including one hamartoma; one carcinoid tumor; and three granulomas. In ten cases, bronchoscopy was nondiagnostic; these patients subsequently were lost to follow-up. In four cases, the diagnosis was only made cytologically, including three cases of adenocarcinoma and one case of squamous cell carcinoma.

For SPNs less than 2 cm in diameter, the histologic diagnosis was made bronchoscopically in four of 15

Table 1—CT-Bronchoscopic Correlation in the Evaluation of SPNs: Correlation with Cell Type in 55 Cases

<table>
<thead>
<tr>
<th>Bronchus Sign Present</th>
<th>Bronchus Sign Not Present</th>
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<tbody>
<tr>
<td>Adeno</td>
<td>10/18</td>
</tr>
<tr>
<td>Squamous</td>
<td>6/8</td>
</tr>
<tr>
<td>Undifferent</td>
<td>2/2</td>
</tr>
<tr>
<td>Small</td>
<td>2/2</td>
</tr>
<tr>
<td>Other</td>
<td>1/3</td>
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</tbody>
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| (1 carcinoid, 1 hamartoma, 3 granulomas) |

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Manuscript received June 22; revision accepted August 12.

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cases (21 percent), while for lesions greater than 2 cm, the diagnosis was established in 26 of 46 cases (57 percent). Central lesions, defined by CT as localized to the inner one-third of the pulmonary parenchyma, were successfully diagnosed in ten of 14 cases (71 percent), while peripheral lesions were accurately identified in 21 of 51 cases (41 percent). No significant difference in yield was found based on lobar distribution, or surface contour.

Thirty five cases (54 percent) were associated with a positive bronchus sign (Fig 1). Twenty-one of 35 (60 percent) of these had a diagnosis established bronchoscopically (p = .027). Thirty cases (46 percent) were unassociated with airways, a negative bronchus sign. Of these, only ten (30 percent) had a diagnosis made by FOB (p = .034) (Table 2). If only cases in which 1.5 mm thick sections were obtained, a negative bronchus sign was associated with a positive biopsy in only one of seven cases (14 percent).

When analyzed by location, all 14 central lesions proved to have a positive bronchus sign; bronchoscopy was positive in ten of 14 cases. Of the 51 peripheral lesions, 20 of 51 cases (39 percent) had a positive bronchus sign; 11 of these (55 percent) were diagnosed bronchoscopically. Of the 31 cases of peripheral lesions with a negative bronchus sign, biopsy specimens were positive in ten of 31 cases (32 percent) (Table 3).

**DISCUSSION**

Radiologic criteria predicting the diagnostic accuracy of bronchoscopy in the evaluation of solitary pulmonary nodules and masses have been reviewed extensively. While the overall yield of FOB for endoscopically visible lesions exceeds 90 percent, reports of diagnostic yields for fluoroscopically-guided transbronchial biopsies of peripheral nodules is more variable, ranging from approximately 40 to 60 percent. Size and location, in particular, are critical determinants. As documented by Radke et al., in their series of 97 cases evaluated with biplane fluoroscopy, the bronchoscopic yield when lesions were smaller than 2 cm in size was 28 percent as compared with 64 percent if the diameter was greater than 2 cm. These findings are consistent with those reported in this series.

Proximity to the central airways is also significant, although less critical than size, with lesions located in the central or inner one-third of the lung generally easier to biopsy. This factor has led to various, often elaborate methodologies for evaluating the precise location of nodules relative to the carina and hilum on chest roentgenograms.

The potential significance of the relationship between pulmonary lesions and airways has been discussed. Tsuibo et al. correlated bronchography with surgically resected tumors in 47 cases and found a significant relationship between the size of tumors and the number of involved airways. Approximately 60 percent of lesions under 3 cm in size were supplied by only one bronchus, while for tumors greater than 3 cm, three or more bronchi could be identified in 60 percent. This bronchus-tumor relationship has been cited as a possible explanation for the high bronchoscopic yield for larger tumors.

Ono et al. also have studied bronchial-tumor relationships by prior mapping of the location of pulmonary masses with selective peripheral bronchography. A positive cytologic diagnosis for lung cancer was made in 45 of 46 patients (97.8 percent), leading these authors to advocate routine use of selective bronchography in evaluating peripheral lung lesions.

To date, the potential role of CT in delineating bronchial-tumor relationships has not been examined. Because of the advantages inherent in cross-sectional

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**Table 3—CT-Bronchoscopic Correlation: Results by Location**

<table>
<thead>
<tr>
<th></th>
<th>Peripheral</th>
<th>Central</th>
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<tbody>
<tr>
<td>Pos bronchus</td>
<td>20 cases</td>
<td>14 cases</td>
</tr>
<tr>
<td>sign</td>
<td>Bronchoscopy +</td>
<td>Bronchoscopy +</td>
</tr>
<tr>
<td></td>
<td>11/20 (55%)</td>
<td>10/14 (71%)</td>
</tr>
<tr>
<td>Neg bronchus</td>
<td>31 cases</td>
<td>None</td>
</tr>
<tr>
<td>sign</td>
<td>Bronchoscopy +</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>10/31 (32%)</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td>51 cases</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bronchoscopy +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21/51 (41%)</td>
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</table>
negative bronchus sign, especially when care is taken to obtain thin sections through the region of interest. Significantly, only one of seven patients (14 percent) with a negative bronchus-sign, evaluated with thin (1.5 mm) sections, yielded positive biopsy specimens.

The potential role of CT in enhancing bronchoscopic yield has yet to be evaluated. While no systematic attempt was made prospectively to utilize CT findings as a guide for bronchoscopy, the potential value of CT as a roadmap may prove significant. CT-guided bronchoscopy may be especially useful in those cases for which transbronchial needle aspiration (TBNA), and/or biopsy is planned. As reported by Shure et al., this technique is especially efficacious in the diagnosis of submucosal or peribronchial tumors. In their study of 31 patients presenting with submucosal or peribronchial abnormalities, routine forceps biopsy was positive in 55 percent of cases, while TBNA yielded positive results in 71 percent. The combination of those two techniques yielded positive results in nearly 90 percent. Similar results have been reported by Wang et al. As shown in Figure 2, by providing a detailed outline of the exact relationship between airways and tumor, both centrally and peripherally, CT may allow more confident and widespread use of these techniques.

It is concluded that CT may be of use in the routine evaluation of pulmonary nodules and masses as a means to determine the best diagnostic approach particularly in cases for which histology is required, especially when sequential 1.5 mm thick sections are obtained. The potential of CT to augment the diagnostic yield of FOB by providing a bronchoscopic roadmap remains to be determined in a large, prospective series.

ACKNOWLEDGMENTS: The authors wish to express their appreciation to Dr. Marilyn E. Noz for her considerable assistance in the statistical analysis of data; and to Jane Crafts for her invaluable help in the preparation of this manuscript.

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