The Value of Multislice Spiral Computed Tomography in Demonstrating the Relationship between Bronchial and Peripheral Lung Cancer

Jinwei Qiang
Kangrong Zhou
Yaping Jiang
Xuanguang Ye
Qun Wang
Songtao Xu
Lijie Tan

Department of Radiology, Jinshan Hospital of Fudan University, Shanghai 200540, China.

Correspondence to: Jinwei Qiang
E-mail: dr.jinweiqiang@163.com

OBJECITVE To investigate the value of multislice spiral computed tomography (MSCT) in demonstrating the relationship between bronchial and peripheral lung cancer.

METHODS MSCT was used to conduct volumetric targeted scans of 0.5 mm collimation for 53 cases of peripheral lung cancer and to demonstrate the relationship between bronchial and peripheral lung cancer by multiplanar reconstructions(MPR) images, curved multiplanar reformations(CMPR) and surface shaded display(SSD). The results were compared with macroscopic and microscopic specimens.

RESULTS 1) All the bronchi at the 3rd to 7th order were displayed clearly and completely with this CT protocol. The tumors that were related to the bronchus included 29 (96.7%) adenocarcinomas and 13 (76.5%) squamous-cell carcinomas. Statistical analysis showed that there was no significant difference between the two groups (χ^2=2.8, P>0.05). 2) The tumor-bronchus relationship was divided into four subtypes, i.e. type I: the bronchus was obstructed by a tumor, type II: the bronchus was obstructed when penetrated by a tumor with tapered narrowing; type III: the bronchial lumen shown within the tumor was unobstructed and intact, type IV: the bronchus ran at the periphery of a tumor, with an intact or narrowed lumen. 3) Type I occurred in 58.5% (31 cases), in which squamous-cell carcinoma was slightly more common than adenocarcinoma. Both type II and type III were seen in 15.1%(eight cases of each), of which all were adenocarcinomas. The incidence rate of type IV was 28.3% (15 cases), of which adenocarcinoma was slightly more frequent than squamous-cell carcinoma. 4) Squamous-cell carcinoma was more common than adenocarcinoma in the tumors in the fourth-order bronchus, whereas adenocarcinoma was more common than squamous-cell carcinoma in tumors with a relationship to the sixth-order bronchus.

CONCLUSION MSCT with volumetric targeted scans of ultra-thin sections were conducted followed by MPR,CMPR and SSD reconstruction. This procedure can accurately demonstrate the relationship between the nature of tumors and bronchus and thereby to some extent reflect pathological changes.

KEYWORDS: lung neoplasms/radiography, bronchus, tomography/X-ray computed.

Received November 18, 2004; accepted April 2, 2005.

The CT demonstrated tumor-bronchial relationships and their value have been reported abroad.[1,2] However, the research conducted was based on an axial transverse view, due to the limitation of equipment. There has been some limitations for morphological observations in using the technology, as it could only be applied for lung cancers at the subsegmental bronchus and above. Over the past two years, the postprocessing function of MSCT has shown broad application. [3] By applying MSCT and the methods such as the multi-planar reconstruction (MPR) or curved multi-planar reformation (CMPR), as well as surface shaded display (SSD), we have been able to show the relationship between peripheral lung cancer and the bronchi. In this report we discuss its value.

MATERIALS AND METHODS

Fifty-three patients with peripheral lung cancer, hospitalized during the period from November 2001 to August 2002, were confirmed by operation and pathology. Among them 36 patients were male and 17 female, ages ranging from 45 to 83 years, with a mean age of 62.4 ± 9.2. The diameter of the tumorous nodules ranged from 0.9 to 4.0 cm (mean diameter, 2.5 cm). The cell types were as follows: adenocarcinoma (n=30); squamous-cell carcinoma (n=17) and a group of six miscellaneous tumors including two adenosquamous carcinomas, and one each of bronchioloalveolar carcinoma, small-cell carcinoma, carcinoid and malignant mesothelioma. The mean nodule diameter was 2.4 cm in the adenocarcinoma group and 2.8 cm in the squamous-cell carcinoma group. No significant difference in tumor size between the two groups was found (Student *t* test, t=1.6, $P > 0.05$).

A Marconi Mx 8000 multslice CT scanner was used to perform scanning with 1, 2.5 or 5 mm of slice thickness on the whole lung. After localization of the tumor, the spiral targeted scan with FOV of 20 cm was conducted, with 0.5 mm collimation, 0.3 mm reconstruction increment, 1.75 Pitch and a high spatial frequency reconstruction algorithm. Breath-holding training was conducted for the patients before the scanning. A deep inspiration was taken when the scan was conducted.

The postprocessing reconstruction was performed at the workstation. The MPR and/or CMPR images were conducted along the running direction of the bronchi to display the tumor-bronchi relationship. The order and shape of the bronchi with its relation to the tumor and the spatial relationship between the tumor and bronchi were determined by reconstructing the SSD images of the bronchus.

Fresh lung specimens were collected and the bronchus was cut open along the direction of the tumor's growth to observe the tumor-bronchus relationship, the shape of bronchial lumen within and next to the nodule and the manifestation of the mucosa, etc. The macroscopic tissue slices were drawn from the juncture between the bronchus and the tumor, and paraffin sections prepared for microscopic examination.

RESULTS

CT findings

All the bronchi at the 3rd to 7th order were displayed clearly and completely. CT showed that the tumors which had a pathological relationship with the bronchus amounted to 29 of 30 (96.7%) adeno-carcinomas, 13 of 17 (76.5%) squamous-cell carcinomas and 4 of 6 (66.7%) miscellaneous cancers. Statistical analysis showed that there was no significant difference between the adenocarcinoma and the squamous-cell cancer group (χ^2 =2.8, $P > 0.05$). The tumor-bronchus relationships were subtyped into four, i.e. type I: the bronchus was obstructed by the tumor (Fig.1); type II: the bronchus was blocked when penetrated by a tumor with tapered narrowing (Fig.2); type III: the bronchial lumen shown within the tumor was unobstructed and intact (Figs.3,4), type IV: the bronchus ran at the periphery of the tumor, with an intact or narrowed lumen (Figs.5, 6).

The relationship between the pathological types and the tumor-bronchus types can be seen in Table 1, where type I occurred most commonly, accounting for

58.5% (31 cases) of the tumors. The incidence for both type II and type III was 15.1% (in eight cases of each). Incidence of type IV was 28.3% (15 cases) of the tumors. There was no significant difference for type I and type IV between the adenocarcinoma and squamous-cell carcinoma groups (chi-square test, χ^2 =1.88, 0.50, $P > 0.05$). Between type II and type III, there was a significant difference (χ^2 =51.46, 4.65, $P <$ 0.05). In the group of miscellaneous cancers, one case of adenosquamous carcinoma was seen in type I, one case of small cell carcinoma in type I, one case of carcinoid in type I and type III and one malignant mesothelioma in type I and type IV.

The relationship between the pathological types and the tumor-bronchus orders can be seen in Table 2. Squamous-cell carcinoma was more common than adenocarcinoma in the tumors relating to the 4th-order bronchus, there being a statistically significant difference between the two cancers (χ^2 = 4.18, P = 0.05). Adenocarcinoma was a more common tumor compared to squamous-cell carcinoma relating to the 6th-order bronchus. The difference between the two cancers was highly significant (χ^2 =6.71, $P < 0.01$). Moreover, nine cases (31.0%), related to the bronchi at 2 or 3 orders, were found in the adenocarcinoma group but only one case (7.7%) was seen in the squamous-cell carcinoma group, but there was no statistically significant difference (χ^2 =2.68, $P > 0.05$) (Tables 1,2).

Pathological findings

The macropathological findings of the tumor-bronchus relationship were basically the same with the CT findings. In type I, the tumorous tissue was naked in the bronchial lumen and was blocked. In type II, the bronchial wall at the subulate segment within the tumor was stiff, the submucosa was invaded by the tumor, with no involvement in the mucous membrane. The gradual migration of the tumorous tissue was seen at a distal occlusive segment (Figs.7,8). In type III, the infiltration of the tumor was around the bronchus, with an incrusted and stiff tubal wall and a fibrotic reaction in it. The mucosa was laevis, with no invasion by the tumor. The bronchial lumen remained highly patent. It was smooth and unobstructed, even at the utmost end, or finally occluded. The type IV exist with other types concurrently, the infiltration of the tumor around the tubal wall allowed the wall to be incrassate and hard-shelled, and it kept the lumen unobstructed or slightly narrow (Fig.9).

Table 1. The relation between pathological types and patterns of tumor–bronchus relationship

	Type I		Type II		Type III		Type IV	
Groups	Cases	%	Cases	%	Cases	%	Cases	%
Adenocarcinoma	15	50.0	8	26.7	7	23.3	10	33.3
Squamous-cell carcinoma	12	70.6	0	0	0	0	4	23.5
Miscellaneous	4	66.7	0	0	1	16.7	1	16.7
Toal	31	58.5	8	15.1	8	15.1	15	28.3

Note: Counting was recorded separately when a case had more than one type.

Table 2. The relationship between the pathological types and the related bronchi orders

	The 4th-order		The 5th-order		The 6th-order		The 7th-order	
Groups	Cases	%	Cases	%	Cases	%	Cases	%
Adenocarcinoma	2	6.9	10	34.5	23	79.3	5	17.2
Squamous-cell carcinoma	4	30.8	3	23.1	5	38.5	2	15.4

Note: The data were recorded separately when a case was related to different orders of the bronchi

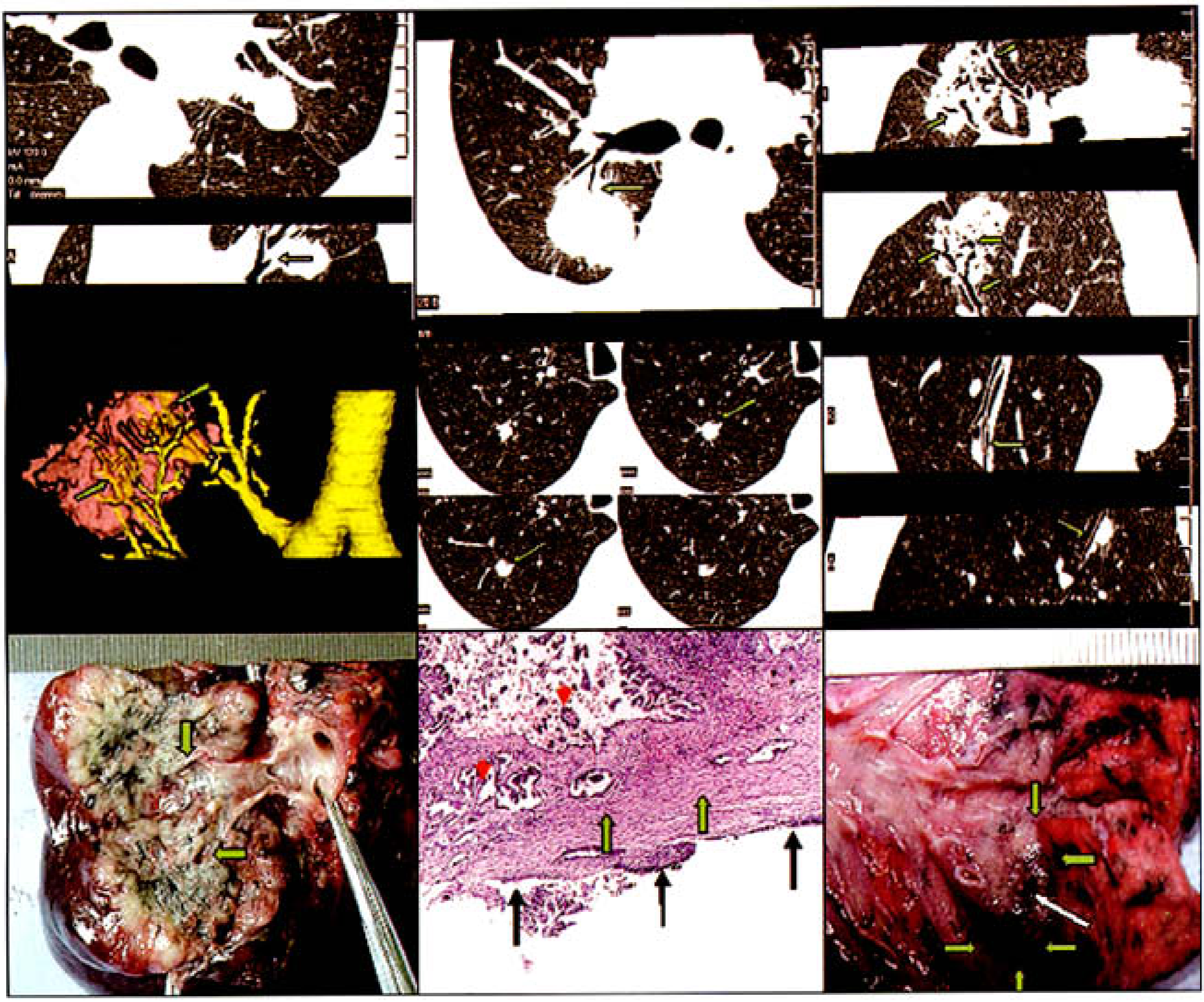

Fig.1. The tumor-bronchus relationship in type I: Axial and sagittal MPR images of a squamous-cell carcinoma at the posterior segment of the left upper lobe of the lung indicate the 5th-order bronchus leading to the margin of the nodule and being obstructed.

Fig.2. The tumor-bronchus relationship in type II: MPR image of an adenocarcinoma on the posterior segment of right upper lobe of the lung shows a subsegmental bronchus extending into the mass 1 cm long with distal obstruction, its two secondary subsegments tapered narrowing and interruption.

Figs.3,4. The tumor-bronchus relationship in type III: The coronary and sagittal MPR (Fig.3) and SSD image (Fig.4) of an adenocarcinoma at right upper lobe of the lung show the well-expanded apical and posterior segmental bronchus and their branches of the 5th to 7th order.

Figs.5,6. The tumor-bronchus relationship in type IV: The axial (Fig.5), coronal and sagittal MPR images (Fig.6) of a 0.9 cm adenocarcnoma at the posterior segment of right upper lobe of the lung show 180-degree encasement of the tumor for the 6th-order bronchus, with a normal luminal shape.

Fig.7. The same macroscopic specimen as the case in Fig. 2 shows that the intratumoral bronchus (green arrow) is in accordance with MPR image.

Fig.8. The same pathological section (H&E× 40) as the case in Fig. 2 shows the intact bronchial mucosa (balck arrow), the overt fibrotic reaction (green arrow) and the tumor cells infiltration within the bronchial wall, with gradual transmigration at the far end (red arrow).

Fig.9. The same macroscopic specimen as the cases in Fig.5 and 6 shows that the neoplasm invades the bronchial wall (green arrow), but the mucosa remaining intact (white arrow).

DISCUSSION

The value of MSCT in demonstrating the tumor-bronchus relationship

Restricted by the speed and thickness of the scanning and influenced by the orientation of the bronchus, common CT, including single-slice helical CT, is only applicable for displaying the large bronchus above the segment of the bronchus and is unable to display the bronchus under the subsegment. [1,2] So it can not be used to demonstrate the relation between peripheral lung cancer and the bronchus. Multislice CT scanning can accomplish a wide-ranging thin slice scanning very quickly and can thoroughly eliminate slice misregistration and partial volume effect. Its isotropic characteristics obviously enhances the resolution of the Z axis and can display the bronchus at lesser orders. Our study indicated that the bronchus at the 3rd to 7th order can be clearly displayed by using the technology of the 0.5 mm ultrathin, volumetric targeted scan, the high spatial frequency reconstruction algorithm, and with MPR, CMPR and SSD reconstruction. The quality of the images for MPR and CMPR was nearly the same as the primitive image of the cross section, which was favorable to display the tumor-bronchus relationship. The image of SSD had a three-dimensional effect and was applied to determine the order and spatial relationship of the bronchus.

The CT bronchus sign means that as the tubular bronchus with low-density reached the tumor, it may or not enter the tumor. An air bronchogram sign will occur if the bronchus enters the tumor.[4] The sign can thoroughly reflect the tumor-bronchus relation. Choi et al.[2] confused the two signs, resulting in a misleading conclusion. In fact, the air bronchogram sign has a narrow sense, which can only relate to the nodules in part of the bronchi (type II and type III); the CT bronchus sign is a much broader sign, which includes the bronchi in the nodule and at the nodule-interface (type I to type IV). For evaluation of the tumor-bronchial relationship, the air bronchogram sign is much limited, while the CT bronchus sign covers all the types of tumor-bronchial relationships and has much wider value in clinical applications. With the research on a CT bronchus sign, Gaeta et al.[1] directed the bronchoscopic biopsy and obtained good results, which markedly improved the positive rate for the biopsy of the bronchial lesions at the 4th and 5th order. Choi et al.[2] used a CT bronchial sign to predict the types of tumor cells. Their results showed that squamous-cell carcinoma was the most common cancer seen in type I, followed by type IV, but it was not seen in type III. Adenocarcinoma and bronchioloalveolar carcinoma were most frequently seen in type III, accounting for 35% and 78%, respectively. But the specificity of the study was not clear, because the focus of the study included all the central and peripheral lung cancers and tumors of various sizes. Our results indicated that the incidence of peripheral lung cancer was 58.5% in type I, 15.1% in both type II and type III and 28.3% in type IV. Squamous-cell carcinoma was slightly more prevalent than adenocarcinoma in type I, adenocarcinoma was seen in type II, III and IV, and adenocarcinoma was slightly more common than squamous-cell carcinoma. In the tumors with relationship to the 4th-order bronchus, there was more squamous-cell carcinoma compared to adenocarcinoma. In the tumors with a relationship to the 6th-order bronchus, there was more adenocarcinoma than squamous-cell carcinoma.

The value of the air bronchogram sign has already been established,[5-8] and its incidence in lung cancer was 26.9% to 65%, while in benign tumors, it was only 0% to 5.9%. So the incidence of the air bronchogram sign was obviously higher than that of CT bronchial sign. This sign had a close relationship with bronchioloalveolar cell carcinoma and adenocarcinoma.[2,6-9] Yoshino et al.[10] proposed that the air bronchogram sign was a positive prognosis indicator following adenocarcinoma resection.

The pathological basis for the types of tumor-bronchial relationship

Peripheral lung cancers have two patterns of growth form, hilic growth and lepidic growth. The hilic growth is seen as the proliferation and accumulation of the tumor cells, forming a solid mass that compresses and replaces the neighbouring lung tissue. Since these tumors were bronchogenic, the bronchus was blocked at the border of the tumor, which resulted in the tumor entering the bronchial lumen, or the bronchus to be obstructed after being penetrated by a short segment of tumor with tapered narrowing. The reason was that because of the pressure of the tumors and the intratumoral fibrotic contracture, all the macroscopic specimens and the pathological sections displayed the intact mucosa at the pyramidal segment of the bronchus. There was no tumorous tissue in the lumen but a gradual transmigration of the tumorous tissue at the blocking area.

In lepidic growth, tumor cells crawl along the alveolar wall and interalveolar septum and can extend from one alveolus to the another through alveolar pores. At the same time, tumor cells can also extend from one pulmonary lobule to the another, through a lymphatic tract and small airway, or by direct infiltration, while the bronchus still remains unobstructed, thus forming the air bronchogram sign. In addition, the tumorous infiltration from the outer tubal wall of the bronchus to the inner, the desmoplastic response provoked on the wall caused the bronchial wall to be thick and stiff. The fibrotic retraction in the tumor failed to compress the intra-tumoral bronchus, on the contrary, it kept the bronchus highly patent and even slightly dilated to form the malignant tumor-specific air bronchogram sign. Based on the same reason the bronchus on the borderline of a tumor can also extend widely. By contrast, if the tumor is benign, the bronchus on the tumor's border will not be affected by the invasion of the tumor and the fibrotic reaction, and the bronchus is still soft, which is prone to the pressure of the nodule with the expanding growth and will result in wall compression, even flattening.

In summary, ultra-thin volumetric targeted scanning with MSCT and MPR, CMPR and SSD reconstruction can clearly and completely display the bronchi at the 3rd to 7th order, precisely demonstrate the tumor-bronchus relationship and reflect some pathological changes.

REFERENCES

1 Gaeta M, Barone M, Russi EG, et al. Carcinomatous solitary pulmonary nodules: evaluation of the tumor-bronchi relationship with thin-section CT. Radiology. 1993; 187: 535–539.

2 Choi JA, Kim JH, Hong KT, et al. CT bronchus sign in malignant solitary pulmonary lesions: value in the prediction of cell type. Eur Radiol. 2000; 10:1304–1309.

3 Schoepf UJ, Bruening RD, Hong C, et al. Multislice helical CT of focal and diffuse lung disease: comprehensive diagnosis with reconstruction of contiguous and high-resolution CT sections from a single thin-collimation scan. AJR Am J Roentgenol. 2001; 177:179–184.

4 Singh SP. The positive bronchus sign. Radiology. 1998; 209:251–252.

5 Jiang T, Shi ML, Lu N, et al. High resolution CT scanning of solitary pulmonary nodule. Chin J Oncol. 1998; 20:216–217.

6 Zhang YQ, Wang KQ, Cao DQ, et al. Air bronchogram in differential diagnosis of small peripheral lung cancers on CT image. Chin Med J. 1993; 106:357–360.

7 Kui M, Templeton PA, White CS, et al. Evaluation of the air bronchogram sign on CT in solitary pulmonary lesions. J Comput Assist Tomogr. 1996; 20:983–986.

8 Kushihashi T, Munechika H, Ri K, et al. Bronchioloalveolar adenoma of the lung: CT-pathologic correlation. Radiology. 1994; 193: 789–793.

9 Kuriyama K, Tateishi R, Doi O, et al. Prevalence of air bronchograms in small peripheral carcinomas of the lung on thin-section CT: comparison with benign tumors. AJR Am J Roentgenol. 1991; 156:921–924.

10 Yoshino I, Nakanishi R, Kodate M, et al. Pleural retraction and intra-tumoral air-bronchogram as prognostic factors for stage I pulmonary adenocarcinoma follow complete resection. Int Surg. 2000; 85:105–112.