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Clinical Application of a CT-Guided Lung Biopsy System: Core Needle Biopsy at the IVR Center

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Abstract

Prior reports of CT-guided lung biopsy of the small lung nodules of less than 2 cm have been unsatisfactory. In January 1998, we began a preliminary study of CT-guided lung biopsy in our conventional CT room. With the basic results achieved, we constructed a novel CT-guided lung biopsy system.

Together with Hitachi Corporation we have developed CT, the Radix Prima, exclusive for interventional procedures especially for CT-guided lung biopsy. As reconstruction delay time of the procedures has been shortened from 1.0 sec. to 0.6 sec. ,real time CT fluoroscopy monitoring is possible on the Cathode Ray Tube (CRT) monitor in the CT room, very closed to the patient. Multiple confirmations of the tip of the biopsy needle have been possible with this specially equipped CT. A semi-automatic-type needle have been selected for reliable biopsy, because the old fully-automatic-type needle was very heavy and easily misfired. Multiple punctures have been also used, because single punctures have a greater risk of obtaining inadequate specimens.

In our clinical study at our IVR center, the subjects comprised 41 patients (26 males, 15 females, ranging in age from 34 to 79, mean 64 years old). The mean nodule diameter was 1.9 cm, the mean distance from skin surface to lesion was 5.5 cm, and the mean number of punctures was 3.0. The biopsy results included 23 malignancies. In 13 patients the results were benign tumors or specific inflammation. In 4 patients the results were nonspecific inflammation. In only 1 patient was the specimen inadequate. There was no false negative. The correct rate of benign/malignant diagnoses was 98%. A complication of pneumothorax was observed in 22 patients, but all were improved by conservative treatment. Pulmonary hemorrhage was observed in 21 patients, 7 of whom also had hemoptysis. Each of these patients also responded to conservative treatment from specialist medical staff at the IVR center.

The 98% accuracy of our results indicates that multiple punctures using a semi-automatic-type biopsy needle and multiple confirmations of the needle tip on our method of real time CT fluoroscopy are extremely important for CT-guided lung biopsy of small lung nodules of less than 2 cm. (J Nippon Med Sch 2002; 69: 434–444)

Key words: Interventional procedures, technology CT, guidance Lung, biopsy Lung neoplasms

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Introduction

Recent widespread application of computed tomography (CT) has led to the detection of small nodular lesions in the lung, which were not easily spotted by the conventional thoracic plain X-ray method. The introduction of lung cancer screening using CT is also a likely factor[1,2]. It is also known that the prognosis of alveolar cell carcinomas, presenting ground-glass attenuation (GGA) within small nodular lesions, is influenced greatly by the quantity of fibrous tissue in the lesions[3]. Reliable diagnosis of such lesions is thus crucial, but the current image-based diagnosis alone has limitations and requires further histopathologic diagnoses[4]. Previous reports of CT-guided lung biopsy have addressed lesions with a mean size of 39.2 mm[5] or 34 mm[6]; successful biopsies were obtained with a size of approximately 24 mm, and failures were reported with a size of approximately 17 mm[7]. There are virtually no reports concerning lesions with a size of 2 cm or smaller, indicating actual demand for other suitable diagnoses. Even in the diagnosis of benign disease by biopsy, the reported specificity is not high, e.g., 52.4% and 81.7%[5,8], and its clinical application has been a vexing issue.

In January 1998, we began a preliminary study of lung field lesions with a mean nodular diameter of 1.9 mm in our conventional CT room. With the basic results obtained, we opened an IVR center as part of the Center for Advanced Medical Technology plan and constructed a novel CT-guided lung biopsy system. Here we report the demonstrated utility obtained in the clinical application of this system.

1. Preliminary Study

Subjects

The subjects comprised 34 patients (22 males, 12 females) with nodular lung field lesions who underwent CT-guided lung biopsy between January 1998 and February 1999 ("conventional CT room group", **Table 1A**).

Methods

After completion of the routine scheduled examinations, biopsy was performed by two radiologists and two clinical radiology technicians using a Toshiba X-Vigor scanner (equipped for CT fluoroscopy). At the time of the procedure, the needle route was determined on the basis of previous thoracic CT, and patients were placed on the bed in a prone, supine, or side-recumbent position. A grid was then applied to the skin at the intended puncture site, CT imaging was exposed in 5 mm slices selected to include the lesion, and the needle route was established so as to allow puncture of one lobe only, with the images used to avoid inclusion of ribs or lung vessels. The software incorporated in the CT equipment was used to calculate the distance from the skin surface to the lesion and pleura, as well as the angle in the horizontal plane. A 23-gauge Cathelin needle was inserted in accordance with the calculated results, and after confirming by CT fluoroscopy that the needle tip was located very close to the pleura, 5 m*l* 1% Xylocaine was used for anesthesia.

For biopsy, a needle was inserted according to the calculated results, and the lesion was struck directly. During the procedure, the needle tip location was confirmed by CT fluoroscopy. If respiration was unsettled or the lesion was located very close to the vital organs, lead-lined gloves for radiation protection were worn, and the lesion was biopsied using real time CT fluoroscopy.

The cutting needle used in all patients was an 18-gauge Biopty needle (Bard, full-automatic-type). If the cutting needle did not collect an adequate specimen or when the nodular content was liquid, or in other unavailable circumstances, a 19-gauge Sure Cut needle (Cliny) was used for supplemental aspiration cytology. The needle was set to strike the target when the needle tip reached a point directly in front of the lesion or when it punctured the lesion itself.

Prior to the procedure, we provided a thorough explanation to the patient, including possible complications, and obtained informed consent.

Table 1A Lists of the patients. conventional CT room group

Patient	Age	Sex	Segment	Size (cm)	Distance (cm)	Needle passes (No.)
1	72	M	Rt. S^{9}	4	3.5	2
2	79	M	Lt. S^{1+2}	4	7	2
3	47	M	Rt. S^{6}	3	4.8	2
4	57	M	Rt. S^{2}	1	6.6	2
5	52	F	Rt. S^{2}	0.6	5.8	2
6	62	M	Lt. S^{6}	1.8	2.5	1
7	51	F	Rt. S^{4}	2.5	7.8	1
8	55	M	Rt. S^{9}	0.7	2.9	1
9	50	M	Lt. S^{9}	0.7	3.6	1
10	62	F	Rt. S^{3}	0.6	6.7	1
11	62	M	Rt. S^{6}	0.6	5.9	1
12	52	F	Lt. S^{6}	1	3.9	1
13	46	F	Lt. S^{5}	1	3	1
14	75	M	Lt. S^{9}	2.5	2.7	2
15	62	M	Rt. S^{6}	0.8	4.8	1
16	39	F	Rt. S^{1}	0.7	6.5	2
17	55	M	RT. S^{10}	1	4.9	2
18	68	M	Rt. S^{10}	1.2	3.2	1
19	59	F	Rt. S^{3}	2.8	8	4
20	62	M	Rt. S^{4}	1	5	1
21	65	M	Lt. S^{10}	3	5	2
22	64	F	Rt. S^{10}	4.2	4.6	3
23	63	F	Rt. S^{4}	1.8	4.8	1
24	73	M	Lt. S^{1+2}	4	3.9	2
25	65	M	Lt. S^{6}	3.2	3.4	2
26	72	M	Rt. S^{10}	1.2	4	1
27	39	M	Rt. S^{8}	1.2	7.3	2
28	55	M	Lt. S^{8}	1.2	7.2	2
29	61	F	Rt. S^{4}	1.5	7.4	2
30	57	M	RT. S^{4}	1.5	9.3	1
31	61	F	RT. S^{6}	2	5	3
32	52	F	Lt. S^{10}	3	4.4	2
33	55	M	Rt. S^{1}	3.2	6.3	2
34	79	M	Rt. S^{9}	1.5	6.5	1

Distance: Distance from skin surface to lesion, M: male, F: female, Rt.: right, Lt.: left, S: segment

Results

The mean age of the patients was 60 years, the mean nodule diameter was 1.9 cm, the mean distance from skin surface to lesion was 5.2 cm, and the mean number of punctures was 1.6.

The biopsy results included 10 malignancies, of which 9 were diagnosed as lung cancer. Out of these cancer cases, the biopsy allowed distinction of the tissue type and degree of differentiation in 6 and only the tissue type in 3. One patient had a metastatic lung tumor. Seven patients showed benign tumors or specific inflammation. In 13 patients the results were nonspecific inflammation, one of which was judged as a false negative. In 4 patients the specimens were inadequate (**Table 2**). The correct rate of benign/malignant diagnoses was 82% (**Table 3A**).

Core needle biopsy and aspiration cytology were performed simultaneously in 14 patients; in 2 patients the core needle biopsies showed malignant and the aspiration cytology showed Class 5; in 9 patients the core needle biopsies showed benign and aspiration cytology showed Class 1 or 2; in 2 patients the core needle biopsies showed malignant and the aspiration cytology showed Class 3; and in 1 patient the core needle biopsy showed malignant and the aspiration

Table 1B Lists of the patients. IVR center group

Patient	Age	Sex	Segment	Size (cm)	Distance (cm)	Needle passes (No.)
1	73	M	Rt. S^{10}	2	2.9	2
2	61	M	Rt. S^{2}	5	11.5	2
3	77	M	Rt. S^{9}	2.5	2	3
4	62	F	Rt. S^{9}	1.8	2.4	5
5	59	M	Rt. S^{3}	1.3	2.4	4
6	74	F	Rt. S^{7}	1.5	10	1
7	75	F	Rt. S^{9}	2	3	2
8	70	M	Rt. S^{2}	0.8	10	2
9	41	F	Rt. S^{6}	2	2.7	4
10	67	M	Rt. S^{9}	2.5	2	6
11	71	M	Rt. S^{9}	3.5	3.1	4
12	75	F	Rt. S^{3}	1	9.2	2
13	63	M	Rt. S^{5}	2	6.3	1
14	63	M	Rt. S^{8}	1.4	3.8	1
15	58	F	Lt. S^{3}	3.2	5.5	3
16	48	M	Lt. S^{4}	3	5.3	5
17	61	M	RT. S^{9}	4.2	5.7	5
18	79	M	Rt. S^{9}	2.7	4	3
19	79	M	Rt. S^{6}	0.7	4	4
20	44	F	Lt. S^{8}	1.2	2.7	2
21	78	M	Rt. S^{4}	2	7.7	3
22	74	F	Lt. S^{8}	0.8	4.1	4
23	72	F	Rt. S^{1}	1.8	11	2
24	50	F	Rt. S^{1}	1.2	7	4
25	61	F	Rt. S^{9}	1.2	5.8	5
26	71	M	Rt. S^{1}	2.5	3.2	4
27	59	M	Rt. S^{2}	1.5	4.5	4
28	69	F	Rt. S^{2}	0.8	5.2	3
29	48	F	Rt. S^{1}	1.5	8	4
30	69	M	RT. S^{1}	2	6.2	3
31	70	M	LT. S^{3}	1.8	2.6	3
32	74	F	Lt. S^{6}	1.8	5.6	2
33	65	M	Rt. S^{6}	1.8	3	4
34	59	M	Lt. S^{1+2}	2	5.9	1
35	45	M	Rt. S^{10}	2	5.5	1
36	75	M	Rt. S^{2}	1	9.9	2
37	34	M	Rt. S^{10}	2	3.1	4
38	67	M	Rt. S^{10}	1	5.8	3
39	56	M	Rt. S^{2}	0.8	6.1	2
40	72	M	Rt. S^{1}	2.3	7.4	3
41	59	F	Rt. S^{4}	1.2	7.9	1

Distance: Distance from skin surface to lesion

cytology showed Class 1 (**Table 4A**).

Complications of pneumothorax were observed in 14 patients, 2 of whom required insertion of a chest tube. Pulmonary hemorrhage was observed in 13 patients, one of whom also had hemoptysis. All complications responded to conservative treatments (**Table 5**).

The foregoing results successfully revealed the following points of improvement. The correct rate of diagnosis in the conventional CT room group was 82%, a non-satisfactory result compared to the 75.8–88%[5-7] in previous reports. Specimens were also poor in some patients, despite direct strikes as demonstrated by CT (**Fig. 1**), suggesting that the core needle of the fully automatic-type needle used did not actually pierce the lesion when fired.

Table 2 Results of biopsy diagnosis of conventional CT group and IVR center group

Biopsy diagnosis	Conventional CT room group (n = 34)	IVR center group (n = 41)
Adenocarcinoma	2	4
W/D Adenocarcinoma	2	7
M/D Adenocarcinoma		1
P/D Adenocarcinoma	2	
Squamous cell carcinoma	1	2
W/D Squamous cell carcinoma	1	
M/D Squamous cell carcinoma	1	
P/D Squamous cell carcinoma		1
Small cell carcinoma		1
Oat cell type		1
Malignant lymphoma		
B cell, large cell type		1
Metastatic tumor	1	5
Tuberculosis	5	7
Hamartoma		3
Organizing pneumonia		3
Lung abscess	1	
Cryptoccocosis	1	
Non spesific inflammation	13※	4
Inadequate specimen	4	1

W/D: Well differentiated, M/D: Moderate differentiated, P/D: Poor differentiated
※: Including one false negative case

Table 3A Results of CT guided Lung Biopsy of 34 Lesions at conventional CT room

Final diagnosis	Biopsy diagnosis			Total
	Malignant	Benign	Inadequate specimen	
Malignant	9 (True-positive)	1 (False-negative)	0	10
Benign	0 (False-positive)	20 (True-negative)	4	24
Total	9	21	4	34

Overall accuracy; 82%.

Table 3B Results of CT Guided Lung Biopsy of 41 Lesions at IVR Center

Final diagnosis	Biopsy diagnosis			Total
	Malignant	Benign	Inadequate specimen	
Malignant	23 (True-positive)	0 (False-negative)	0	23
Benign	0 (False-positive)	17 (True-negative)	1	14
Total	23	17	1	41

Overall accuracy; 98%.

Additionally, in the single false-negative case, CT clearly showed a direct strike (**Fig. 2**), but the diagnosis obtained was nonspecific inflammation (necrotic tissue). In this case, the number of punctures was only 1.

Based on these results, we concluded that improvements should be obtained by the use of a semi-automatic-type needle, firing after CT confirmation of lesion punctures by the core needle, and by multiple punctures rather than a single puncture. For these purposes, we decided to develop real time CT fluoroscopy with Hitachi Corporation. We then implemented these improvements in a clinical study at the IVR center.

Table 4 Results of biopsy: comparison between pathologic diagnosisi and cytologic diagnosis

A: Conventional CT room group			B: IVR center group		
Patient	Pathological Diagnosis	Cytological Diagnosis	Patient	Pathological Diagnosis	Cytological Diagnosis
1	tbc	class 1	1	M/D adeno ca	class 4
2	P/D adeno ca		2	P/D sq. c. ca	
3	tbc	class 1	3	tbc	inadequate specimen
4	tbc	class 1	4	W/D adeno ca	inadequate specimen
5	tbc	class 1	5	tbc	class 1
6	adeno ca		6	thyroidal ca meta	
7	W/D adeno ca		7	hamartoma	class 1
8	non specific inflammation		8	W/D adeno ca	class 3
9	non specific inflammation		9	tbc	class 2
10	non specific inflammation		10	small cell ca (oat cell type)	class 4
11	non specific inflammation		11	ML (B cell, Large cell type)	class 5
12	inadequate specimen		12	inadequate specimen	inadequate specimen
13	non specific inflammation		13	tbc	class 1
14	sq. c. ca	class1	14	organizing pneumonia	class 1
15	non specific inflammation		15	non specific inflammation	class 2
16	non specific inflammation		16	RCC meta	class 5
17	non specific inflammation	class 1	17	W/D adeno ca	class 5
18	non specific inflammation		18	colon ca meta	class 5
19	tbc	class 1	19	gastric ca meta	class 2
20	inadequate specimen		20	parotid ca meta	class 3
21	colon ca meta	class 3	21	adeno ca	class 3
22	abscess	class 2	22	adeno ca	class 5
23	W/D adeno ca		23	W/D adeno ca	class 5
24	adeno ca	class 5	24	hamartoma	class 1
25	W/D sq. c ca	class 5	25	W/D adeno ca	class 5
26	M/D sq. c. ca		26	W/D adeno ca	class 5
27	cryptococcosis		27	tbc	class 2
28	non specific inflammation		28	adeno ca	class 5
29	inadequate specimen	class 2	29	non specific inflammation	class 2
30	inadequate specimen		30	small cell ca	class 3b
31	non specific inflammation	class 2	31	tbc	class 1
32	non specific inflammation	class 1	32	sq. c. c	class 5
33	P/D adeno ca	class 3	33	sq. c. c	class 3
34	non specific inflammation		34	adeno ca	inadequate specimen
			35	tbc	class 1
			36	hamartoma	class 1
			37	non specific inflammation	class 1
			38	organizing pneumonia	class 2
			39	non specific inflammation	class 2
			40	papillary adeno ca	class 3b
			41	organizing pneumonia	

W/D: Well differentiated, M/D: Moderate differentiated, P/D: Poor differentiated, adeno ca: Adenocarcinoma, sq. c. ca: Squamous cell carcinoma, small cell ca: Small cell carcinoma, meta: Metastasis, colon ca: Colon cancer, thyroidal ca: Thyroidal cancer, gastric ca: Gastric cancer, parotid ca: Parotid cancer, RCC: Renal cell carcinoma, tbc: Tuberculosis

Table 5 Complications of conventional CT room group and IVR center group

Complication	Conventional CT room group (n=34)	IVR center group (n=41)
Pneumothorax	14	22
needed for chest drainage	2	0
Pulmonary bleeding	13	21
with hemoptysis	1	7

2. Clinical Study

Subjects

The subjects comprised 41 patients (26 male, 15 female) with pulmonary nodular lesions who underwent CT-guided lung biopsy between March 1999 and March 2000 ("IVR center group", **Table 1B**).

Table 6 Characterization of conventional CT room group and IVR center group

Characteristic	conventional CT room group (n = 34)	IVR center group (n = 41)	p
Age (yr)	60	64	NS
Diameter of lesion (cm)	1.9	1.9	NS
Lesion depth from skin (cm)	5.2	5.5	NS
Needle passes (No.)	1.6	3	< 0.01

NS: not significant, p: Student's t test

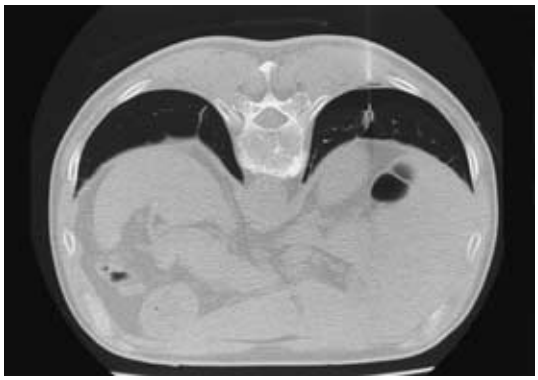

Fig. 1 CT scan of a 1.2 cm nodule in right lower lobe (S^{10}) in a 68-year-old male in the prone position. The tip of the full-automatic-type biopsy needle reaches the nodule on CT, the specimen is inadequate.

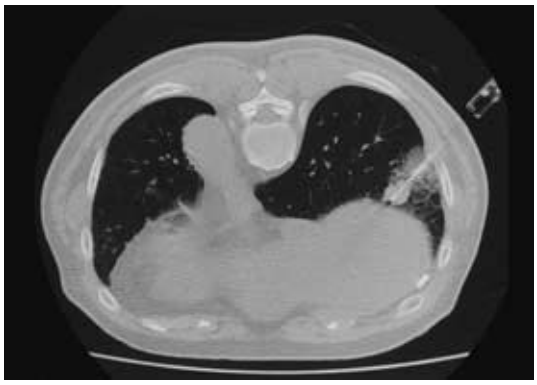

Fig. 2 CT scan of a 1.5 cm nodule in right lower lobe (S^{9}) in a 79-year-old male. Post surgical operation state of colon cancer. The tip of the full-automatic-type biopsy needle is confirmed in the nodule, the specimen is necrotic tissue. After 6 months observation, the nodule increases in size, and re-biopsy is performed at the IVR center. The biopsy diagnosis is metastasis of colon cancer.

Methods

The scheduled examinations were performed by three radiologists, two clinical radiology technicians, and one nurse using a Hitachi Radix Prima (equipped for CT fluoroscopy) with full equipment for vital sign monitoring. The Radix Prima was developed by us and Hitachi Corporation for the real time interventional radiology (IVR) system especially for lung biopsy. As the reconstruction delay time of the procedure has been shortened from 1.0 sec. to 0.6 sec., real time CT fluoroscopy monitoring was available on the CRT monitor in the CT room at the IVR center, and we could confirm the needle tip very close to the patients.

The procedure itself was basically akin to that performed on the "conventional CT room group", but the cutting needle used was an 18-gauge TEMNO needle (Allegiance, semi-automatic-type). The cutting needle is supposed to strike the target when the core needle pierces the lesion.

The age, nodule diameter, distance from the skin surface to the lesion, number of punctures, biopsy results, and complications were studied comparatively between the conventional CT room group and the IVR center group.

Results

The mean age was 64 years, the mean nodule diameter was 1.9 cm, the mean distance from the skin surface to the lesion was 5.5 cm, and the mean number of punctures was 3.0.

The biopsy results included 23 malignancies, of which 18 cases were lung cancer. Out of the 18 cancer cases, the biopsy allowed distinction of the tissue type and the degree of differentiation in 11 cases and only the tissue type in 7. Five patients had metastatic lung tumors. Thirteen patients had benign tumors or specific inflammation. Four

patients showed nonspecific inflammation. In one patient the specimen was poor (**Table 2**). There was no false negative. The correct rate of benign/malignant diagnoses was 98% (**Table 3B**).

Core needle biopsy and aspiration cytology were performed simultaneously in 34 patients; in 12 patients the core needle biopsy specimens showed malignant and the aspiration cytology showed Class 4 or 5; in 15 patients the core needle biopsies showed benign and the aspiration cytology showed Class 1 or 2; in 6 patients the core needle biopsies showed malignant and the aspiration cytology showed Class 3; and in one patient the core needle biopsy showed malignant and the aspiration cytology showed Class 2 (**Table 4B**).

Complications of pneumothorax were observed in 22 patients, but all were improved by conservative treatments. Pulmonary hemorrhage was observed in 21 patients, 7 of whom also had hemoptysis. Each of these patients also responded to conservative treatments (**Table 5**).

No statistically significant differences between the two groups were observed in the age, nodule diameter, or distance from the skin surface to the lesion. The number of punctures increased significantly in the IVR center group (**Table 6**). Nonspecific inflammation diagnosed by biopsy was given a final diagnosis only when the nodule diameter had not increased in the 6-month or longer observation period.

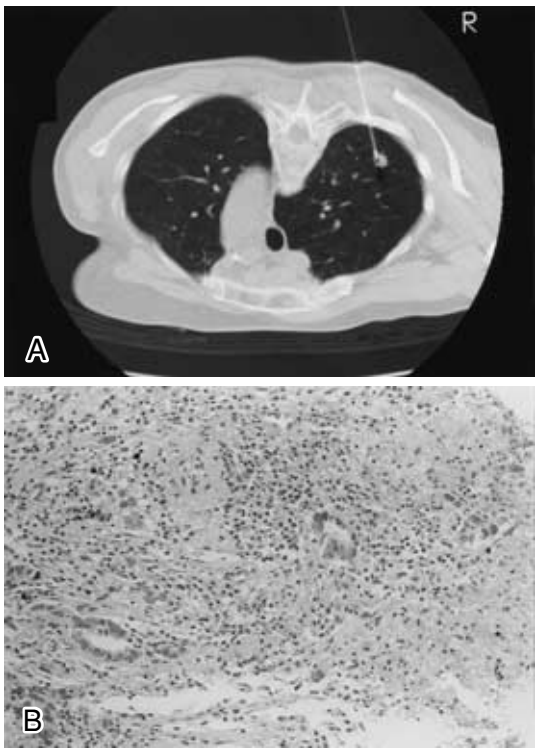

Fig. 3 Pulmonary adenocarcinoma in a 69-year-old female.
A: CT scan shows 0.8 cm nodule in right S^2.
B: Biopsy specimen shows increase in fibrous tissue and atypical cells forming irregular tubular structures (H-E stain, ×500).

Discussion

CT provides better detection of small nodular lesions in the lung field than the conventional thoracic plain X-ray. However, these images alone present limitations in qualitative diagnosis that would necessitate histopathologic diagnosis[4]. Since Haaga et al. first reported a method for CT-guided biopsy of small nodular lesions in the lung field, CT-guided lung biopsy has come into widespread use[9]. Previous reports on correct rate of diagnosis in CT-guided lung biopsy include 75.8% by Arakawa et al. (mean diameter 39.2 mm)[5], 88% by Lucidarme et al. (mean diameter 33.6 mm)[6], and 82.6% by Tsukada et al. (24.1 mm mean diameter in successful biopsies, 17.6 mm mean diameter in unsuccessful biopsies)[7]. Thus our results are characterized as having an extremely high correct rate of diagnosis for the smallest lesions addressed (**Fig. 3, 4**). The prognosis of lung cancer changes at a cutoff of 2 cm diameter lesions[10], necessitating reliable diagnosis of 2 cm or smaller lesions, and our results are satisfactory to meet this need.

CT-guided lung biopsy is still frequently performed to fill the gaps left by ordinary everyday CT scanning in a short time and with inadequate staff. Pursuant to the opening of the IVR center, we constructed a novel system for CT-guided lung biopsy and began clinical applications as part of the Center for Advanced Medical Technology plan aimed at creating next-generation, novel health care technologies. The concept in the creation of the IVR center was to bring about more advanced IVR through installation of cutting-edge image-based diagnostic equipment providing rapid and accurate

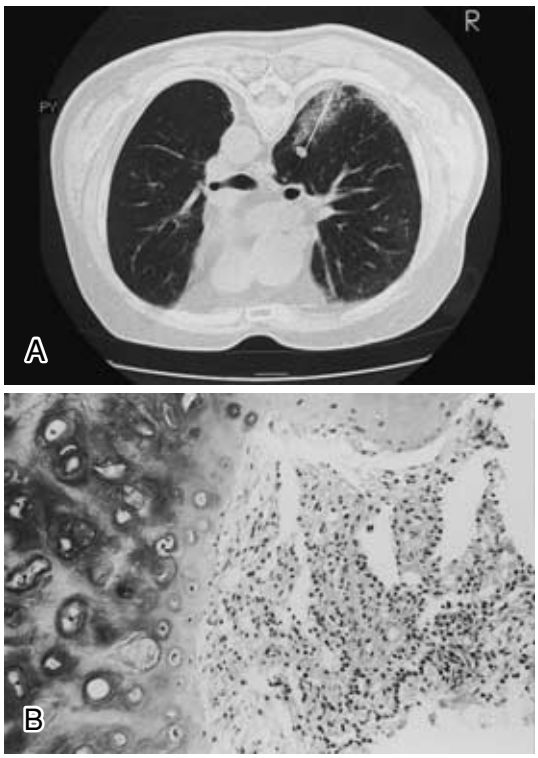

Fig. 4 Pulmonary hamartoma in a 75-year-old male.
A: CT scan shows 1.0 cm nodule in right S^2.
B: Biopsy specimen shows edematous matrix connected with matured cartilagenous tissue. In the matrix, alveolus like tubular structures are confirmed (H-E stain, ×500).

interventions. In addition to high speed spiral CT, the rotational digital angiography system, open type MRI equipment, and high-resolution Doppler ultrasound equipment have been installed. The Radix Prima is an apparatus jointly developed by us and Hitachi Corporation exclusively for CT in IVR, especially for CT-guided lung biopsy. The unit has a 3.5 MHU-capacity X-ray tube and is equipped for CT fluoroscopy. CT fluoroscopy is displayed in real time with a 0.6-second delay, and the unit allows 100-second continuous use. The needle tip was easily confirmed by this CT fluoroscopy mode. As a result, we are now able to perform CT-guided lung biopsy in a reasonable time and with an adequate staff including specified interventional radiologists and nursing staff. As the procedure time has also been shortened, the burden on the patient has been reduced.

There are few reports concerning the factors governing correct diagnosis rates in CT-guided lung biopsy, but a report by Wescott et al. states that increasing the number of punctures had the effect of raising the correct diagnosis rate[11]. The mean number of punctures in our study was 1.6 in the conventional CT room group and 3.0 in the IVR center group, significantly greater in the latter group. In other respects, we observed no statistically significant differences between the two groups in the mean age, mean nodule diameter, or distance from the skin surface to the lesion, but the correct rate of benign/malignant diagnosis rose from 82% in the conventional CT room group to 98% in the IVR Center group. These results suggest that multiple punctures raise the correct diagnosis rate.

Reasons why suitable samples are not obtained may include a partial volume phenomenon in CT, where the biopsy needle has not actually struck the target, even though the lesion appears to have been pierced, and only necrotic tissue is collected (**Fig. 2**). We believe that multiple punctures and confirmation of the needle tip may reduce the frequency of such occurrences. Based on the fact that the correct diagnosis rate in the IVR center group was a satisfactory 98% with a mean of 3.0 punctures, we believe that 3 is an appropriate number of punctures. However, an adequate time interval is needed for multiple punctures, and in this respect, performance of the procedure at the IVR center is essential.

When CT-guided lung biopsy was introduced, aspiration cytology was prevalent[12]. Recently, reports of the utility of core needle biopsy have begun to appear[5-7]. We believe that core needle biopsy is useful for determination of the tissue type and degree of differentiation and for treatment planning and the prognosis of malignant lesions. Very recent findings have shown that prognosis of alveolar cell carcinomas is influenced by accumulation of fibrous tissue independent of the lesion size[3], which makes accurate knowledge of the tissue type necessary. Specificity diagnosis is also required to eliminate false negative results when the result of biopsy diagnosis is benign. The report of Greif et al. states that the rate of specific diagnosis in the biopsy of benign pulmonary lesions rose from 16.7% with

aspiration cytology to 81.7% with core needle biopsy[8]. Our results from 48 patients who underwent simultaneous core needle biopsy and aspiration cytology also indicate the low utility of aspiration cytology in that 2 patients demonstrated Class 1 or 2 and 8 patients demonstrated Class 3 by aspiration cytology despite their malignant core needle biopsy specimens. Distinction of the tissue type and degree of differentiation in malignancy diagnosis and judgment of the specificity in benign specimens were both good in the IVR center group, results which we attribute to the reliable collection of adequate specimens by multiple puncturing using a core needle biopsy needle. Most reports concerning biopsy needles also involve the use of fully-automatic-type needles[5-7], which are disadvantageous in that the automatic biopsy equipment is heavy, the needle tip may become mis-aligned to the lesion during attachment, and entry of the core needle into the lesion at the time of firing prevents confirmation by CT. In efforts to eliminate these drawbacks, we selected a semi-automatic-type biopsy needle at the IVR center. A semi-automatic-type needle is light-weight and has excellent maneuverability; it also allows CT determination prior to the time of firing when the core needle pierces the lesion. We therefore believe that the use of a semi-automatic-type needle allows completion of more reliable biopsy.

The complications of CT-guided lung biopsy include pneumothorax, pulmonary hemorrhage, hemoptysis, air embolism, and seeding of malignant cells[13-16]. In our results, we observed pneumothorax, pulmonary hemorrhage, and hemoptysis, but we observed neither air embolism nor seeding of malignant cells. According to a report by Sinner et al, a certain deal of matrix in the specimen is needed to disseminate malignant cells to the tract[17]. Therefore it is hard to disseminate malignant cells to the tract with an 18 to 20 gauge fine needle. We think it is necessary to follow up for seeding of malignant cells for a longer time. Various reports implicate the lesion size, number of punctures, and needle thickness as factors governing the frequency of occurrence of pneumothorax[14,18]. From our results, we believe that an increased number of punctures increases the incidences of pneumothorax, pulmonary hemorrhage, and hemoptysis. However, each incidence was taken care of swiftly by staff members and responded to conservative treatments before reaching a serious state.

In conclusion, our results indicate that multiple puncturing, using a semi-automatic-type biopsy needle and multiple confirmation of the needle tip by our method of real time CT fluoroscopy is extremely useful in CT-guided lung biopsy for nodular lung field lesions of less than 2 cm, even if CT visualization appears to reflect a direct strike on the lesion. Though multiple puncturing increases the frequency of complications, we believe that rapid countermeasures can lessen the severity of complications. In terms of personnel and time, we believe that CT-guided lung biopsy at IVR center is useful for achieving the goals.

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