

Acta Medica Okayama

Volume 52, Issue 2

1998

Article 5

APRIL 1998

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Abstract

X-ray computed tomography (CT) has been used for diagnosis of pulmonary emphysema because it can reveal the morphology of low attenuation areas. Recently, ^{99m}Tc -Technegas imaging, one of several types of scintigraphic techniques, has been used for ventilation scintigraphy. Technegas scintigraphy was performed on 15 patients with pulmonary emphysema, and we compared the extent and degree of abnormal findings on Technegas scintigraphy with the extent of low attenuation areas shown by CT. We classified the findings of Technegas imaging into three grades, from mild to severe, according to the extent of peripheral irregularity and central hot spot formation. We also classified the findings of CT as centrilobular emphysema into three grades from mild to severe according to the extent of low attenuation areas in the peripheral lung fields. In 5 cases, CT and Technegas assessment resulted in equivalent diagnoses. In eight cases, Technegas images showed more detailed findings than CT images. In the two remaining cases, which were diagnosed as panlobular emphysema on CT, Technegas images showed the severe stage. Technegas scintigraphy was useful for diagnostic assessment of pulmonary emphysema, especially for panlobular emphysema, which is difficult to distinguish from the normal lung condition by CT assessment.

KEYWORDS: ^{99m}Tc -Technetium-Technegas, single photon emission computed tomography, computed tomography, centrilobular emphysema, panlobular emphysema

*PMID: 9588225 [PubMed - indexed for MEDLINE]

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The Usefulness of ^{99m}Tc-Technegas Scintigraphy for Diagnosing Pulmonary Impairment Caused by Pulmonary Emphysema

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X-ray computed tomography (CT) has been used for diagnosis of pulmonary emphysema because it can reveal the morphology of low attenuation areas. Recently, ^{99m}Tc-Technegas imaging, one of several types of scintigraphic techniques, has been used for ventilation scintigraphy. Technegas scintigraphy was performed on 15 patients with pulmonary emphysema, and we compared the extent and degree of abnormal findings on Technegas scintigraphy with the extent of low attenuation areas shown by CT. We classified the findings of Technegas imaging into three grades, from mild to severe, according to the extent of peripheral irregularity and central hot spot formation. We also classified the findings of CT as centrilobular emphysema into three grades from mild to severe according to the extent of low attenuation areas in the peripheral lung fields. In 5 cases, CT and Technegas assessment resulted in equivalent diagnoses. In eight cases, Technegas images showed more detailed findings than CT images. In the two remaining cases, which were diagnosed as panlobular emphysema on CT, Technegas images showed the severe stage. Technegas scintigraphy was useful for diagnostic assessment of pulmonary emphysema, especially for panlobular emphysema, which is difficult to distinguish from the normal lung condition by CT assessment.

Key words: ^{99m}Technetium-Technegas, single photon emission computed tomography, computed tomography, centrilobular emphysema, panlobular emphysema

Pulmonary emphysema, as defined by the National Heart, Lung and Blood Institute, is "an abnor-

mal permanent enlargement of the air spaces distal to the terminal bronchioles, accompanied by destruction of the alveolar walls, and without obvious fibrosis" (1). Chest radiographs, X-ray computed tomography (CT) and several types of scintigraphs have been used for assessment of the condition. CT can morphologically depict pulmonary emphysema as small low attenuation areas (LAAs) (2-4). Recently ^{99m}Technetium (^{99m}Tc) -Technegas, which is comprised of ultrafine ^{99m}Tc labeled carbon particles, has been used for ventilation scintigraphy (5). We studied the diagnostic potential of ^{99m}Tc-Technegas scintigraphy for assessment of pulmonary emphysema.

Patients and Methods

Patients. Fifteen patients (ranging in age from 32 to 78 years, all male smokers, cigarette index 240-3000) underwent CT and ^{99m}Tc-Technegas scintigraphy. All patients were diagnosed as having pulmonary emphysema by clinical symptoms, LAA on CT, and pulmonary function tests. The patients were ranked from 1-15 by percent forced expiratory volume in one second (% FEV 1.0) in order of increasing severity of impairment (Table 1). Pulmonary function tests were performed using a Chestac-35K and Chestac-55V (Chest MI, Tokyo, Japan).

CT. CT was performed by obtaining 12 slices from above the aortic arch to the diaphragm with 1.5 or 5mm collimation in a bone detail algorithm during moderate inhalation using two CT scanners, the CT9800 and HiSpeed Advantage (General Electric, Milwaukee, WI, USA). CT images from each lung were displayed with a window level of -600 and window width of 1,500.

We classified the findings of CT as centrilobular

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Table 1 Clinical and pulmonary function test data in 15 cases with pulmonary emphysema

Case number	Age & Sex	Cigarette index	Pulmonary function test				Severity		
			% FEV 1.0	% VC	RV/TLC	FEV 1.0%	CT		Technegas SPECT
1	58M	750	98.80	67.00	21.12	52.20	Mild	<	Mild
2	32M	240	95.05	95.10	31.90	68.10	Mild	<	Mild
3	78M	1000	93.60	98.05	39.25	64.35	Moderate	<	Severe
4	70M	600	82.32	100.91	30.65	77.64	Severe	=	Severe
5	71M	750	75.11	77.23	32.17	68.71	Mild	<	Moderate
6	69M	1600	72.63	76.48	50.22	69.14	Mild	<	Mild
7	72M	800	60.70	54.30	47.60	71.10	Moderate	<	Mild
8	78M	900	56.53	63.75	50.91	64.13	—	<	Severe
9	63M	700	53.25	92.58	30.85	56.97	Moderate	=	Moderate
10	72M	3000	51.04	80.07	46.97	51.60	Severe	<	Severe
11	76M	800	47.65	91.22	53.64	48.38	Severe	=	Severe
12	67M	1200	34.63	76.04	40.44	51.94	Severe	<	Severe
13	72M	900	31.48	57.46	58.98	54.21	Severe	=	Severe
14	74M	700	30.87	81.42	47.00	45.27	—	<	Severe
15	69M	900	27.83	67.39	73.08	47.56	Severe	=	Severe

% FEV 1.0: Percent forced expiratory volumes in one second; VC: Vital capacity; RV/TLC: Residual volume/total lung capacity; CT: Computed tomography; SPECT: Single photon emission computed tomography.

—: Unclassified

< Technegas SPECT showed greater changes than CT.

= Technegas SPECT and CT showed the same degree and range.

emphysema into three grades from mild to severe according to the extent of LAAs in the peripheral lung fields: mild, small LAAs up to 5mm in diameter scattered sparsely; moderate, medium-sized LAAs up to 10mm in diameter next to each other; and severe, large LAAs of more than 10mm next to or fused with each other or no normal lung parenchyma due to emphysema (6, 7).

^{99m}Tc-Technegas scintigraphy. Technegas is generated in a proprietary generator (Technegas Generator, Tetley Technologies, Sydney, Australia) by electrostatic heating to 2,500°C of a graphite crucible in which a saline solution of 505MBq of ^{99m}Tc pertechnetate has been placed. After generation of the aerosol, it is dispersed in a lead-lined chamber in an atmosphere of 100% argon. Following the inhalation of 100% oxygen at 5l/min for 3min all patients were given Technegas by inhalation through a mouthpiece while wearing a nose clip and lying in the supine position. Inhalation took place in several tidal volume breaths without breath holding. The penetration of inhaled Technegas to the alveoli in the peripheral lung is excellent. The distribution of Technegas is homogeneous in normal cases, and in cases with peripheral ventilatory impairment, the distribution is het-

erogeneous. In more advanced cases, central hot spots and surrounding regional defects caused by central hot spots occur due to increased ventilatory turbulence and the the existence of bronchial hypersecretions which favor the coalescence of microparticles and their subsequent impaction in the proximal bronchial trunks (8-10).

Following the administration of Technegas, single photon emission computed tomography (SPECT) imaging was performed. The SPECT system used was a Picker model Prism 2,000 (Northford, CT, USA) with a low-energy, high-resolution collimator. SPECT was circular throughout 360°. Seventy-two images were collected at 5° intervals for 40sec, each with a 128 × 128 matrix size. A low-pass filter and Ramp filter were used. No correction was made for attenuation. SPECT was performed in axial imaging with a 4.95mm thickness for comparison with CT.

We classified the findings of Technegas imaging into three grades, from mild to severe, according to the extent of peripheral irregularity and central hot spot formation: mild, peripheral heterogeneity; moderate, additional hot-spot formation; and severe, further regional defects (Fig. 1)(8).

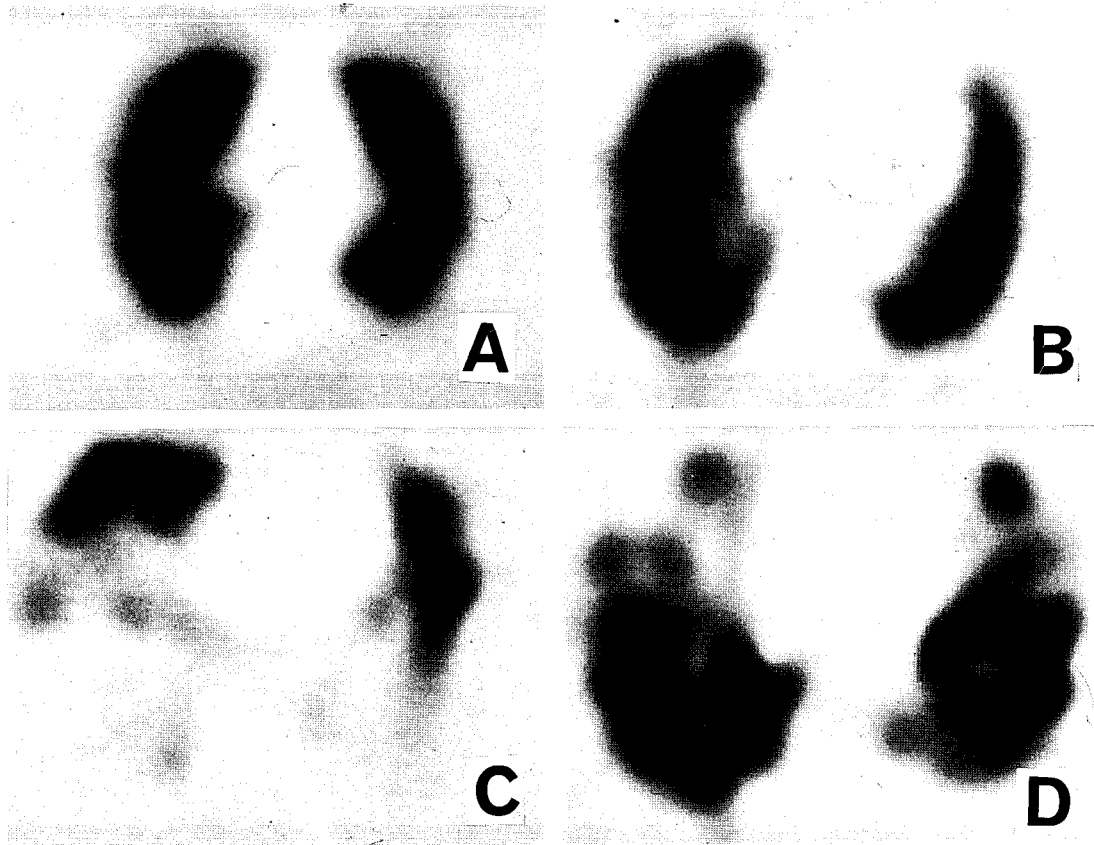


Fig. 1 The classification of Technegas images. A: Normal; B: Mild; C: Moderate; D: Severe.

Results

Table 1 shows the severity of cases as assessed by ^{99m}Tc-Technegas scintigraphy and CT imaging. On Technegas scintigraphy, three cases were diagnosed as mild, three as moderate, and nine as severe. On comparison of the degree of severity between CT and Technegas imaging, in the four cases judged as severe and one case judged as mild, both images were equivalent. In the three cases judged as severe by Technegas imaging, of which two were severe and one mild on CT, Technegas scintigraphy showed more detailed findings than CT. In the two moderate and three mild cases assessed by Technegas imaging, all of which were mild on CT, Technegas scintigraphy also showed more detailed findings than CT. In the remaining two cases, Technegas imaging showed findings judged as severe, whereas on CT, classification

as centrilobular emphysema was not applicable. In these two cases, CT showed diffuse LAAs in both lower lobes and no septal structures such as are present in the severe stage of centrilobular emphysema. It was difficult to distinguish LAAs from normal lung parenchyma. These lesions were assessed as panlobular emphysema (6, 11, 12). Concerning the degree and severity assessed by CT and Technegas imaging, there were no cases which CT revealed more detail or a greater extent of abnormal findings than Technegas scintigraphy. Fig. 2 (Case #13) shows the CT and scintigraph of a typical case of centrilobular emphysema and Fig. 3 (Case #8) shows those of panlobular emphysema. In centrilobular emphysema, as shown in Fig. 2, tiny LAAs, even though they are only a few millimeters in diameter, can be easily detected in the normal lung field. Both CT and Technegas images show an equivalent degree of severity. On the other hand, in panlobular emphysema as shown in

Fig. 3, uniform LAAs are difficult to recognize as abnormal due to a lack of contrast with normal parenchyma.

Technegas imaging shows a greater extent of abnormal findings and a greater degree of severity than CT.

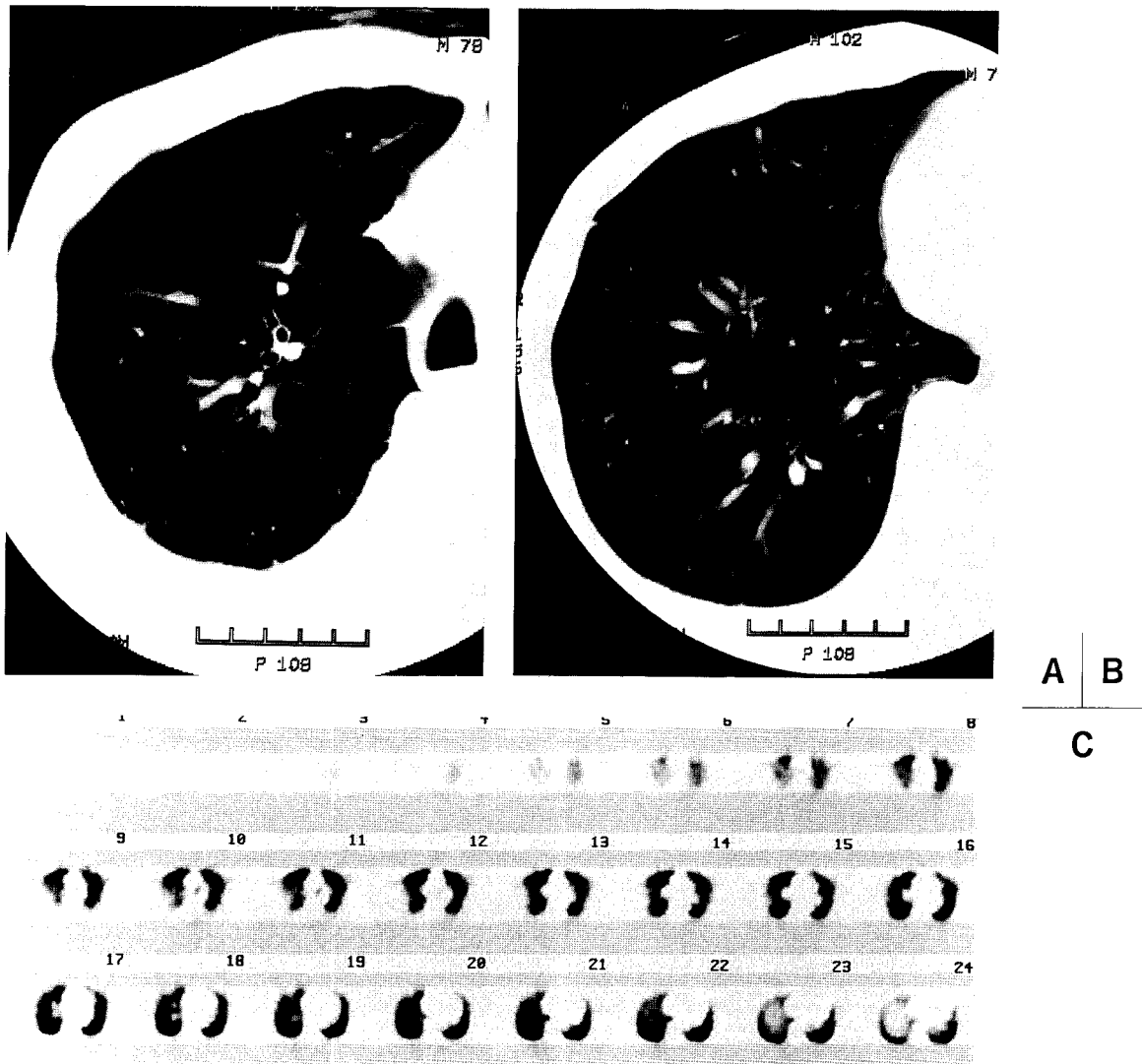
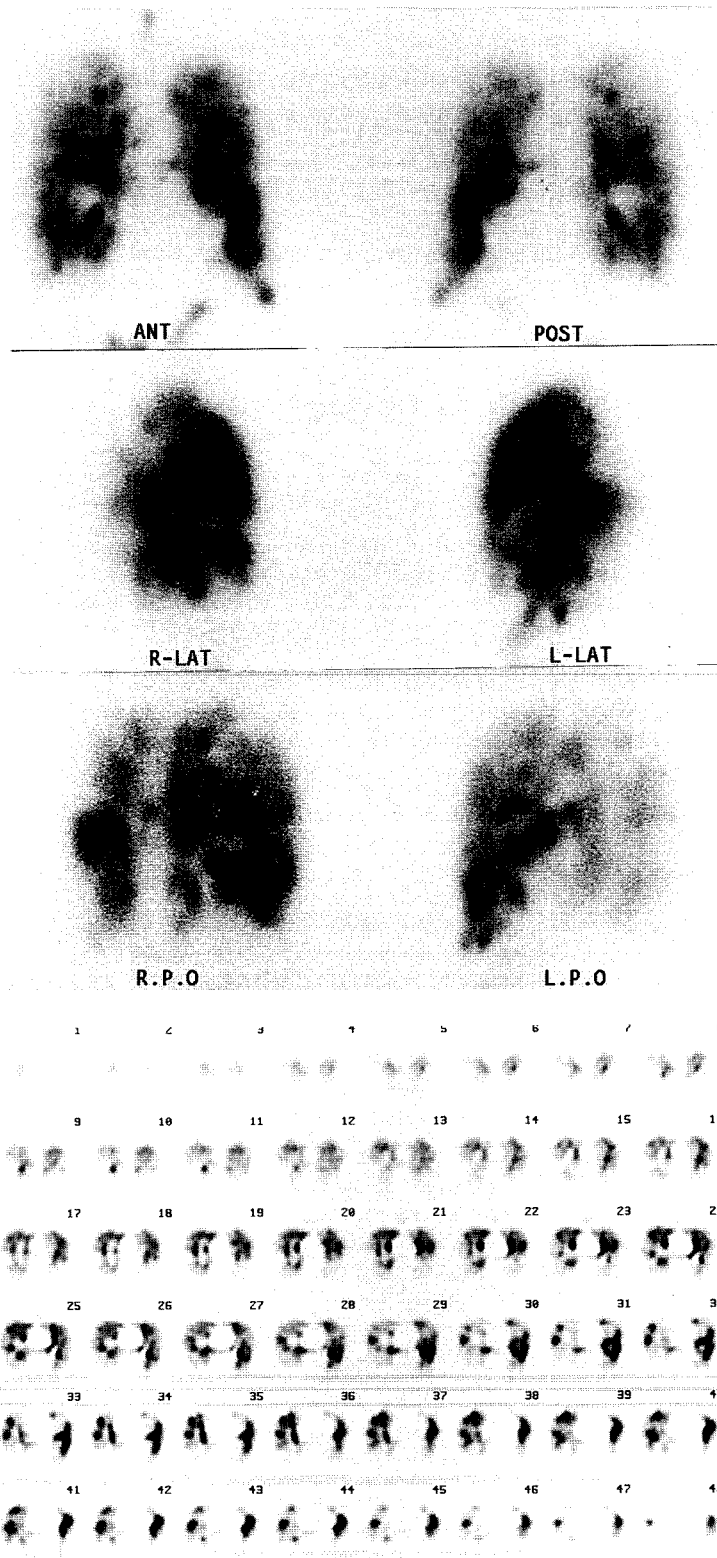
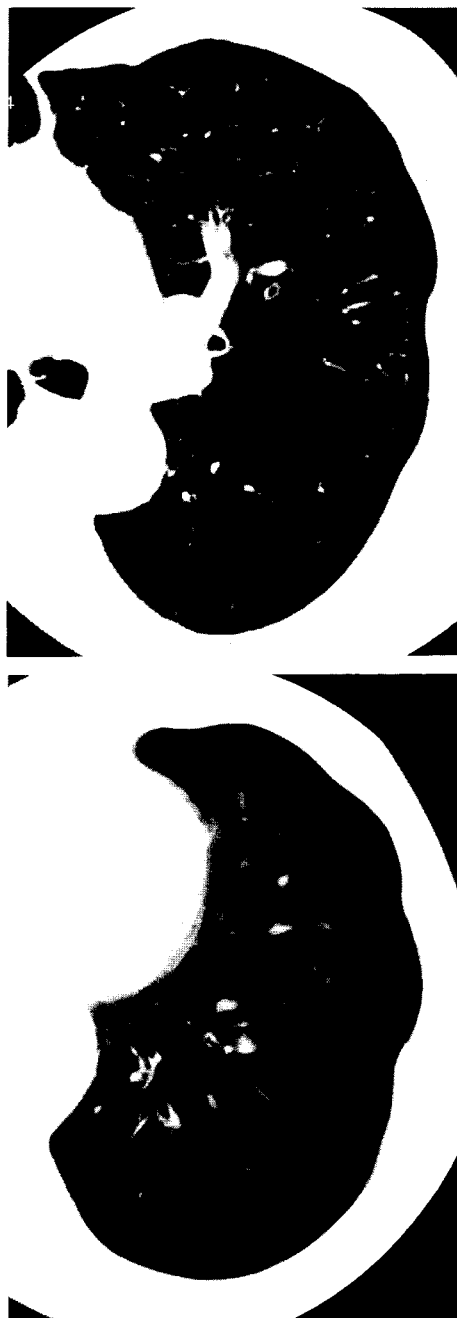


Fig. 2 CT and Technegas images of a 72-year-old male patient with centrilobular emphysema (Case #13).

A: CT showing the severe grade with large low attenuation areas (LAAs) of more than 10mm fused with each other predominantly in the upper lobe; B: Small LAAs of up to 5mm in diameter scattered sparsely in the lower lobe; C: Technegas SPECT shows the severe stage with heterogeneity, hot spot formation and peripheral defects in the entire lung field, especially almost complete defects in the posterior segment in the upper lobe and lateral areas in the middle lung field in the right lung. CT; SPECT: See legend to Table I.

Fig. 3 CT and Technegas images of a 78-year-old male patient with panlobular emphysema (Case #8).

A: CT clearly shows diffuse low attenuation in the lower lobe in contrast to the upper lobe with normal attenuation bordered by a major fissure in the left lung; B: CT shows diffuse low attenuation in the entire lower lobe in the left lung; C: Planar images of Technegas show heterogeneity, hot spot formation and regional defects, especially in the lower lobe of the left lung in a left posterior oblique view. ANT: Anterior; POST: Posterior; R: Right; L: Left; LAT: Lateral; R.P.O: Right posterior oblique; L.P.O: Left posterior oblique; D: Technegas SPECT shows hot spot formation in the hilar region and remarkable heterogeneity in both lower lobes. CT; SPECT: See legend to Table I.



A | C
B | D

Fig. 3

Discussion

Localized pulmonary emphysema, even if it is shown as severe on CT or Technegas images, does not influence the overall pulmonary function. Even a case with normal pulmonary function tests may show tiny LAAs on CT. CT has been shown to be useful for diagnostic evaluation of pulmonary emphysema (1-3). On the contrary, although the spatial resolution of scintigraphy is inferior to CT, nuclear medicine can depict the physiological kinetic movement and assess the regional pulmonary function in contrast with overall function (13, 14). The results of the present study indicate that ^{99m}Tc -Technegas scintigraphy reveals more detail and a larger extent of abnormalities than CT in cases of pulmonary emphysema.

Aerosol labeled ^{99m}Tc inhalation scintigraphs have previously been used for the assessment of ventilation impairment because they require no special equipment or ventilation systems. ^{99m}Tc -phytate used as one of the aerosol-labeled ^{99m}Tc , however, has a limitation due to intense bronchial foci or hot spot formation in cases with severe chronic obstructive pulmonary disease. Particles larger than $2\mu\text{m}$ are likely to be deposited in the proximal bronchial trunks (9). Although particle size of Technegas is in the order of $0.005\mu\text{m}$ (15), different investigators agree that the size is more likely to be less than $0.2\mu\text{m}$ (10, 16). So particle size less than $1\mu\text{m}$ can be reach to the alveoli, Technegas images can reveal the imaging in the area of the alveoli not in the proximal airway. Technegas is reported to be superior to or equivalent to ^{133}Xe scintigraphy (15, 17) which is used to assess ventilation. Because ^{133}Xe gas has lower energy than ^{99m}Tc , it would be difficult to delineate the outline of the lung in multiple projections and ^{133}Xe ventilation images were taken from a posterior projection due to requirements of the ventilation system.

CT can morphologically depict centrilobular emphysema as small LAAs (2, 3). These areas are revealed as centrilobular emphysema in contrast to the surrounding normal parenchyma. However, the parenchymal destruction seen on CT scans in patients with panlobular emphysema is distinctly different from that seen in patients with mild and moderate centrilobular emphysema, both in appearance and distribution (6). Panlobular emphysema appears as large and extensive areas of uniform low attenuation, characteristically with a lower-lobe distribution, and associated with a reduction in the size of

pulmonary vessels. No peripheral preservation of the lobule occurs, and therefore no striking density differences exists between the affected lobules and the homogeneous background of the normal pulmonary parenchyma (11). The sensitivity of CT for diagnosing panlobular emphysema has been reported to be lower than that for the diagnosis of centrilobular emphysema, although the extent of underestimation dose not differ significantly between CT and high resolution CT (12). In the two cases of panlobular emphysema in the present study, Technegas images clearly showed ventilation impairment. Technegas scintigraphy appears to be useful for the assessment of ventilation impairment of not only panlobular emphysema which is difficult to differentiate from the normal lung condition on CT but also centrilobular emphysema.

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Received April 4, 1997; accepted December 22, 1997.