

Comparison of ^{99m}Tc -Technegas SPECT with ^{133}Xe dynamic SPECT in pulmonary emphysema

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This study was undertaken to compare axial images of ^{99m}Tc -Technegas SPECT (Technegas) with those of ^{133}Xe gas dynamic SPECT in patients with pulmonary emphysema. There were 20 patients, 19 males and 1 female. All patients except one ex-smoker were heavy smokers with a mean age of 68.1 years. For Technegas scintigraphy, the patients inhaled 505 MBq ^{99m}Tc -Technegas in several tidal volume breaths in the supine position without breath holding. For ^{133}Xe gas scintigraphy, the patients inhaled 370 MBq ^{133}Xe gas. ^{133}Xe gas dynamic SPECT was performed in the equilibrium phase for the last minute of the 3 minute inhalation in a closed circuit, and in the washout phase for 6 minutes of inhalation in a semi-closed circuit, by means of a gamma camera with dual detectors (Picker model Prism 2000). Abnormal findings included heterogeneity, defects and hot spots on Technegas images and on retention images taken 3 minutes after ^{133}Xe gas washout. In 2 of 20 patients, the degree of abnormal findings on Technegas images depended on the area of ^{133}Xe gas retention in the washout phase. In 3 patients, the degrees of abnormal findings on both Technegas SPECT and ^{133}Xe gas dynamic SPECT images were equivalent. In the remaining 15 patients, more detailed findings and a greater area were shown by Technegas SPECT than ^{133}Xe gas dynamic SPECT. We conclude that in patients with pulmonary emphysema Technegas SPECT can demonstrate ventilation impairment more easily than ^{133}Xe gas dynamic SPECT.

Key words: Technegas, ^{133}Xe gas, dynamic SPECT, pulmonary emphysema

INTRODUCTION

RECENTLY ultra fine ^{99m}Tc -labeled carbon particles are being used for ventilation scintigraphy including SPECT.^{1–10} Burch et al. reported that ^{99m}Tc -Technegas has considerably small particle size and can reach the peripheral parts of the lung.¹ ^{133}Xe gas is also used for dynamic SPECT in addition to planar images.¹¹ The present study was undertaken to compare axial images of ^{99m}Tc -Technegas (Technegas) SPECT with those of ^{133}Xe dynamic SPECT in patients with pulmonary emphysema.

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MATERIALS AND METHODS

Patients

Twenty patients were studied, 19 males and 1 female, with an age range of 49–78 years and a mean age of 68.1 years. All patients except one ex-smoker were heavy smokers and were diagnosed as having pulmonary emphysema on the basis of clinical symptoms, pulmonary function tests and CT (Table 1).

Technegas SPECT

Technegas was generated in a proprietary generator (Technegas Generator, Tetley Manufacturing Ltd., Sydney, Australia) by the resistive heating of a graphite crucible to 2,500°C in which a saline solution of 505 MBq of ^{99m}Tc -pertechnetate had been placed and dried. After generation of the aerosol, it was dispersed in a lead-lined chamber in an atmosphere of 100% argon. Following

Table 1 List of patients and pulmonary function test data

Case No.	Age Sex	Cigarette Index	Pulmonary function test			
			%FEV _{1.0}	%VC	RV/TLC	FEV _{1.0} %
1	62M	1140	101.20	95.80	35.40	76.40
2	61M	800	100.80	97.00	27.44	74.05
3	49M	1100	94.00	97.10	39.90	74.10
4	78M	1000	93.60	98.05	39.25	64.35
5	70M	600	92.59	100.91	30.65	77.64
6	71M	750	75.11	77.23	31.07	79.71
7	69M	1800	70.85	86.48	51.20	73.04
8	72M	800	60.70	54.30	47.60	75.50
9	78M	900	58.72	63.75	50.91	64.13
10	63M	700	54.69	92.58	30.85	56.97
11	72M	3000	51.04	80.07	46.97	51.60
12	76M	800	50.00	91.22	53.64	48.38
13	75M	1500	47.30	68.80	/	48.10
14	69M	1000	43.72	52.81	65.48	70.61
15	73F	1060	35.65	56.04	/	42.95
16	56M	1050	34.80	70.40	61.10	51.30
17	67M	1200	34.63	76.04	40.44	51.94
18	72M	900	31.48	57.46	58.98	54.21
19	74M	*	30.87	81.42	47.00	45.27
20	69M	900	27.83	67.39	73.08	47.56

* Ex-smoker (Stopped smoking 15 years ago)

/ not examined

inhalation of 100% oxygen at 5 l/min for 3 minutes, all patients were given 505 MBq ^{99m}Tc-Technegas by inhalation in several tidal volume breaths without breath holding through a mouthpiece while wearing a nose clip and lying in the supine position. The SPECT system was a gamma camera with dual detectors (Picker model Prism 2000, Northford, Connecticut, USA) equipped with a low-energy, high-resolution collimator. Seventy-two images were acquired for 40 seconds each at 5° intervals. Each image was stored in a 128 × 128 pixel matrix. Reconstruction of images was performed by means of Butterworth and Ramp filters with no correction for attenuation.⁹

Xe-133 dynamic SPECT

Following inhalation of 100% oxygen at 5 l/min for 3 minutes, the patients also inhaled 370 MBq ¹³³Xe gas through a mask over the nose and mouth connected to the ¹³³Xe gas ventilation system (Xe-VSS set, Nippon Mediphysics, Osaka, Japan), as a single breath planar image and held their breath for 15 seconds. ¹³³Xe dynamic SPECT was performed in the equilibrium phase for the last minute of the 3 minute breathing in a closed circuit, and in the washout phase for 6 minute breathing in semi-closed circuit, by means of a Picker model Prism 2000 equipped with a low energy general all purpose parallel collimator. Dynamic SPECT data acquisition by each detector was performed for 1.5 seconds per projection with 20 views encompassing a 180° arc. Each detector was rotated in clockwise and counterclockwise directions

across the same projection arc for 30 sec. Each image was stored in a 64 × 64 pixel matrix. Reconstruction of images was performed with no correction for attenuation, by means of Butterworth and Ramp filters. Two sequential 30 second images were added to obtain one 1 minute image.

Interpretation of SPECT images

All SPECT images were interpreted independently by three radiologists. Abnormal findings on Technegas imaging were classified according to the extent of heterogeneity, defect, and hot spot formation as follows: peripheral heterogeneity in mild cases, additional hot spot formation in moderate cases, and additional regional defects in severe cases.¹² Abnormal findings on ¹³³Xe imaging were heterogeneity and defects on single breath images and on retention images 3 minutes after washout.¹⁵

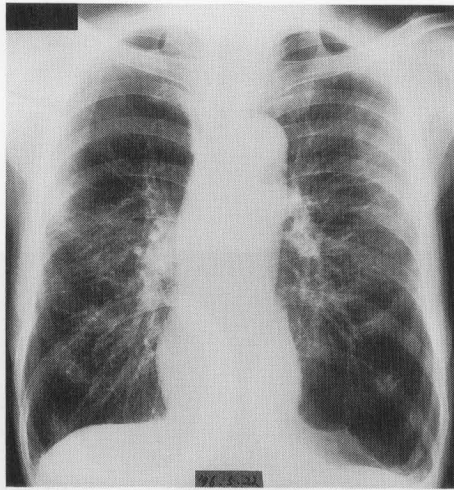
RESULTS

According to the severity on Technegas planar images, there were 6 mild, 1 moderate and 13 severe cases, whereas on SPECT images there were 3 mild and 17 severe cases. Among these patients, there were 13 with equivalent severity in planar and SPECT images in which the degree of the severity was severe in all patients. In the remaining 7 patients, the severity in SPECT images was greater than on planar images: severe on SPECT and mild on planar in 2; severe on SPECT and moderate on planar in 1; and moderate on SPECT and mild on planar in 4 patients.

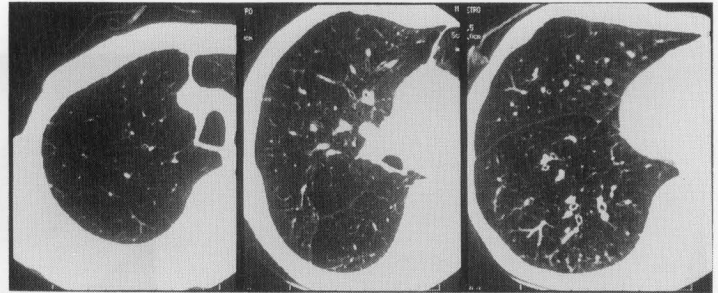
On ¹³³Xe dynamic SPECT, there were heterogeneity and peripheral defects in single breath and retention images in different segments in one or both lungs in all cases.

Considering the extent of impairment, in 2 of 20 patients (10.0%), the extent of abnormal findings on Technegas was inferior to the area of ¹³³Xe retention in the washout phase. In these patients, Technegas could not enter the emphysematous area in which there were peripheral defects and which showed remarkable retention images on ¹³³Xe gas SPECT. In 3 of 20 patients (15.0%), the degree of abnormal findings in both Technegas and ¹³³Xe dynamic SPECT were equivalent. In the above 5 patients, both planar and SPECT images of Technegas were equivalent with respect to severity but in the remaining 15 patients (75.0%), more detailed findings and a greater area of abnormality were shown on Technegas SPECT than on ¹³³Xe dynamic SPECT.

Two typical cases are shown in Figs. 1 and 2. In the case shown in Fig. 1, ¹³³Xe dynamic SPECT was estimated to be superior to Technegas SPECT. On the other hand, in the case shown in Fig. 2, Technegas SPECT was estimated to be superior to ¹³³Xe dynamic SPECT.



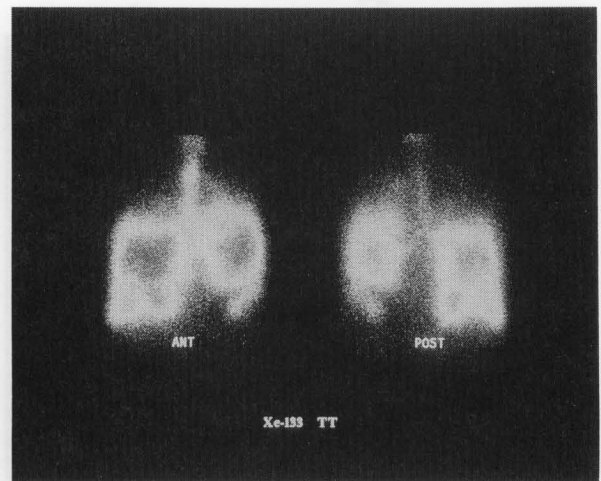
1-a



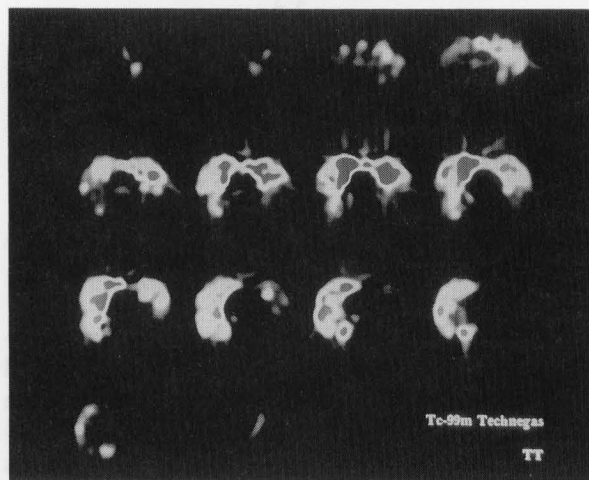
1-b



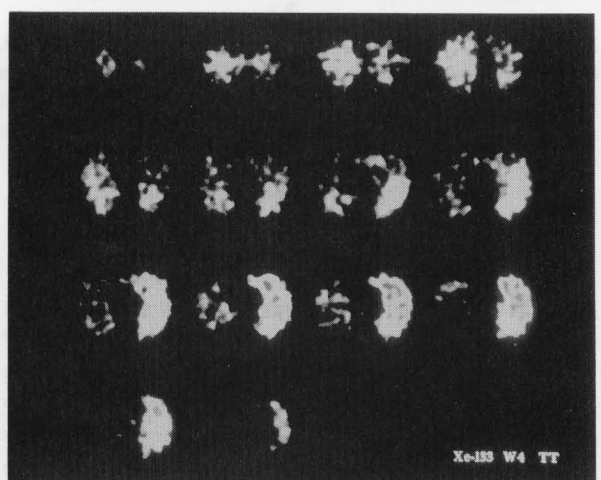
1-c



1-d

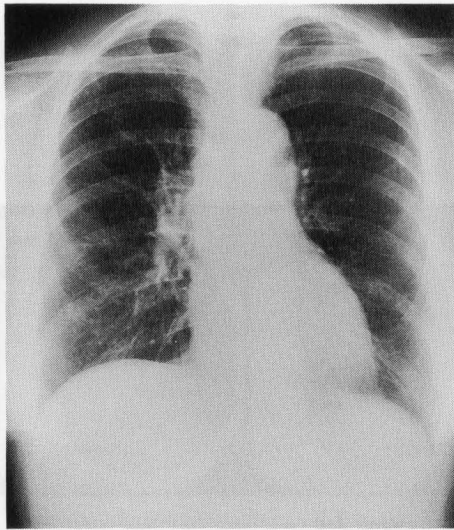


1-e



1-f

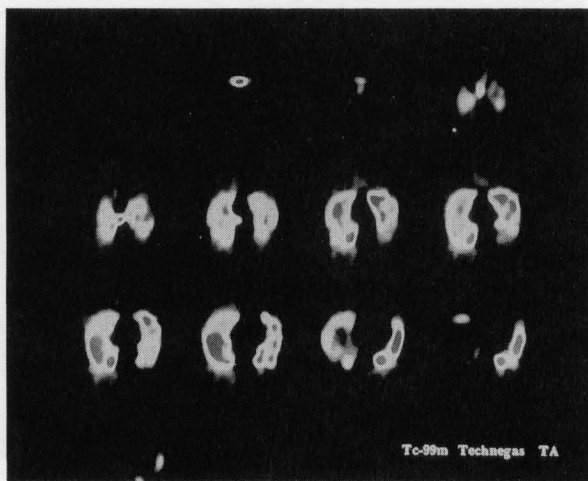
Fig. 1 Case 19. A 74-year-old male. Ex-smoker. Chest X-ray film (Fig. 1-a) shows vascular narrowing and hyperinflation. X-ray CT (Fig. 1-b) shows severe stage with many low attenuation areas in the entire lung field. Both planar images of Technegas (Fig. 1-c), and single breath images of ^{133}Xe gas (Fig. 1-d) show heterogeneity in the entire lung, and large defects in left lower lung field. Technegas SPECT (Fig. 1-e) shows severe stage with heterogeneity, hot spot formation and the peripheral defects, especially almost complete defect in left lower lobe. ^{133}Xe dynamic SPECT (Fig. 1-f) shows retention in the images taken for 1 minute after 3 minutes washout. Remarkable retention is seen in the left lower lobe. In this case, ^{133}Xe dynamic SPECT is estimated to be superior to Technegas SPECT.



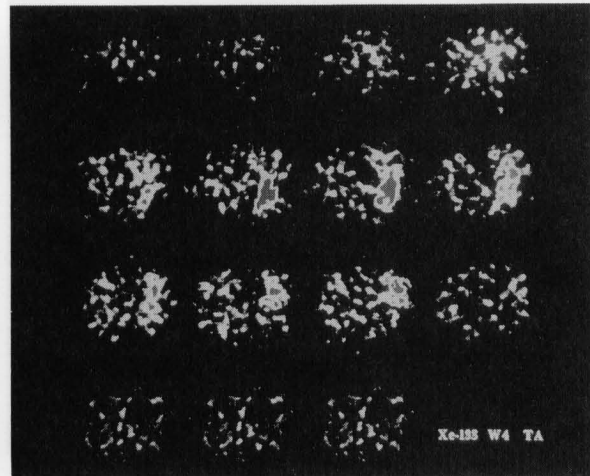
2-a



2-b



2-c



2-d

Fig. 2 Case 15. A 73-year-old female. Cigarette index: 1060. Chest X-ray film (Fig. 2-a) shows no vascular narrowing. X-ray CT (Fig. 2-b) shows moderate stage with a few low attenuation areas in the upper and middle, but not in lower lung fields. Technegas SPECT (Fig. 2-c) shows heterogeneity and defects of the peripheral lung fields. On ^{133}Xe dynamic SPECT (Fig. 2-d), retention areas are smaller than abnormal areas on Technegas images (Fig. 2-c). In this case, Technegas SPECT is estimated to be superior to ^{133}Xe dynamic SPECT.

DISCUSSION

A washout study with ^{133}Xe gas is widely used to detect regional ventilation impairment in airways diseases.¹³⁻¹⁸ The late phases of these regional ventilation studies are helpful in evaluating cases of mild to moderate airway obstruction which would otherwise be misdiagnosed by radiographs.^{15,16} ^{133}Xe retention has been reported to be characterized as mild if retention is beyond three minutes but less than six minutes, moderate if between six and ten minutes, and severe if persisting longer than ten minutes.¹⁵ Nevertheless, the planar image has a two-dimensional character and has inherent limitations because of superimposition of the diseased and normal parts of the lung, and the background effect in the chest wall.¹³ Three-

dimensional SPECT images, on the other hand, can more precisely assess the location or involvement in pulmonary disease.⁹⁻¹¹

With respect to recent ventilation studies, some advantages of the clinical use of Technegas has been reported and has an appropriate energy level.^{3,4,9} Previously the ideal size for aerosol droplets in order to get good uniformity in the lungs during deep tidal volume breathing was considered to be between 0.1 and 0.5 μm .¹⁹ Because particles larger than 2 μm are likely to be deposited in the proximal bronchial trunci, $^{99\text{m}}\text{Tc}$ -phytate aerosol images had a limitation due to intense bronchial foci or hot spot formation in cases with severe chronic obstructive pulmonary disease.⁷ Technegas is ultra fine carbon particles of the order of 0.005 μm .¹ Technegas imaging also gives

similar or better diagnostic information on lung ventilation imaging in quantitative comparison with ^{133}Xe and $^{81\text{m}}\text{Kr}$ due to the necessity for preparation in advance and the latter two gases and a high cost.^{3,4} No need for a ventilation system in the case of Technegas is also an advantage over ^{133}Xe scintigraphy. Technegas SPECT images assessed the pulmonary diseases better than planar images.^{9,10}

In 2 of 20 cases in the present study, ^{133}Xe dynamic SPECT was estimated to be superior to and more prominent than Technegas SPECT in spite of the equivalent size of the abnormal area. These areas were of such a character that ^{133}Xe gas could not enter in a single breath but could enter in the equilibrium phase following remarkable retention in the washout in contrast to the inability of Technegas to enter, suggesting that Technegas has the character of an aerosol in spite of its ultra fine particles. If rebreathing time is not long enough to allow ^{133}Xe to accumulate in regions with poor air exchange, then ^{133}Xe retention will not be seen during washout.¹⁶

Although ^{133}Xe scintigraphy is sensitive enough to detect the emphysematous regions due to its retention during washout, Technegas SPECT detected more detailed findings in areas where retention was not seen on ^{133}Xe dynamic SPECT. In 15 cases, more detailed findings and greater area were provided by Technegas SPECT than by ^{133}Xe dynamic SPECT. In our study, because of the short time, we could not assess SPECT images during a single breath but only planar images which cannot be compared with SPECT images during equilibrium and the washout phase. If these comparisons can be studied, more precise location or the nature of impairment will be assessed.

X-ray CT can morphologically depict very tiny low attenuation as emphysematous areas,^{20,21} but ventilation study including SPECT can reveal more extensive or detailed findings, even very mild abnormalities, than the X-ray CT.^{9,11} Localized pulmonary emphysema, even if it is severe on X-ray CT or scintigraphy, may not influence the overall pulmonary function. Zhang et al. showed that the distribution of Technegas images became heterogeneous with the degree of severity of silicosis on SPECT images, which correlated to X-ray CT.¹⁰

^{133}Xe dynamic SPECT has the advantage of assessing severity by means of parameters such as $T_{1/2}$ and mean transit time (MTT).¹¹ On the other hand, although Technegas images are static, they have an advantage over ^{133}Xe dynamic SPECT images since the former do not require a ventilation system and there is no dyspnea in patients during examination. Technegas images may reveal not only emphysematous lesions but also other impairments. Morphological examination by means of radiologic-pathologic correlative studies may be necessary in cases with abnormal findings on Technegas SPECT even if there is no abnormality on ^{133}Xe dynamic SPECT.

In conclusion, in the present study Technegas SPECT

provided more detailed findings of ventilation impairment than ^{133}Xe dynamic SPECT in patients with pulmonary emphysema.

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