HIGH-RESOLUTION COMPUTED TOMOGRAPHY OF PNEUMOCONIOSIS

MASAMITSU KIDO,* M.D., Dr. Med. Sci. • Akira Kajiki,* M.D., Dr. Med. Sci.
• Hiroshi Yamazaki,* M.D. • Hajime Nakata,† M.D., Dr. Med. Sci.
• Kanji Egashira,† M.D.

*Pulmonary Division, University of Occupational and Environmental Health, JAPAN
†Department of Radiology, University of Occupational and Environmental Health
JAPAN 1-1, Iseigaoka,Yahatanishiku, Kitakyushu, 807 JAPAN

INTRODUCTION

The usefulness of high-resolution computed tomography (HRCT) was evaluated in 37 cases of pneumoconiosis and diagnostic accuracy was compared with those of conventional chest radiography concerning profusion, shape and size according to the ILO (1980) classification of radiographs of pneumoconiosis.

MATERIALS AND METHODS

37 patients of pneumoconiosis were all men with 39 to 86 years of age (mean 60.9±9.6). Except for 2 cases, they had history of cigarette smoking, and their smoking indices were 0 to 1980, with mean 655.8±398.0.

They had histories of occupational exposure to inorganic dusts in 17 of coalminers, 4 of tunnel drivers, 4 of coal and tunnel workers, 2 of welders and 2 had history of exposure to asbestos. Eight patients had history of exposure to miscellaneous dusts such as iron ore, zinc ore, silica brick, oven construction and their combination. Their radiographic findings were classified according to the ILO classification (1980).

The CT examination consisted of a series of high resolution 2mm thick sections scanned with a Siemens somatom II. A Siemens high resolution algorithm stressing the region of high spatial frequency with zooming model was used. The scanning was performed in 10 seconds, at 125kVp, 460mAs. The pixel size was 0.5mm with a magnification factor of 4.0. Six sections were scanned routinely from the level of the sternal notch caudad at 3cm intervals, grossly imaging the upper, middle, and lower lung fields (Figure 1). All scans were made in suspended moderate inspiration. No intravenous contrast materials was used. All images were observed and photographed with the window of 2024 Hounsfied units (HU) and the level of –600 HU, and additional settings were also used as needed.

Nodular and irregular opacities were graded according to the shape and size and profusion. Emphysema was evaluated separately according to their distribution (subpleural or parenchymal) and avascular area was graded to 4 classes as 1) (0–25%), 2) (26–50%), 3) (51–75), 4) (76–100%) respectively. Each conventional radiogram and CT was evaluated by 3 radiologists and 2 pulmonary specialists independently.

Dyspnea was graded to 1–5 according to Hugh-Jones criteria. Pulmonary function tests were performed using SRL M 100B,and FRC was measured by N_2 washout method and DL_{co} was measured by breath holding method (Forster). Arterial blood gas was obtained under air breathing by brachial artery puncture and analyzed using automatic blood gas analyzer IL813.

RESULTS

37 patients in the study were classified into 10 of category 1, 13 of category 2, 6 of category 3, and 8 of category 4 by plain chest X-P (Table I).

17 cases of coal workers pneumoconiosis were classified into 3 of category 1, 7 of category 2, 2 of category 3 and 5 of category 4. HRCT examination revealed marked parenchymal (central) emphysema from 50 to 100% of our criteria and nodular opacities was so attenuated that they were assessed as 0/1 p. All three cases showed marked obstructive ventilatory disturbance with 42 to 59% of $FEV_{1.0}$%. As compared with category 1 of coal workers pneumoconiosis, 7 of category 2 revealed milder emphysema score of 25% except for one case of 75%. Profusion of nodular opacities in HRCT are generally lower than conventional chest X-P in this group except for two cases which are complicated by tuberculosis. Among category 3, profusion of small opacities by HRCT was also lower than that of conventional X-P. Among category 4, evaluation of small opacities were very difficult because of destruction of intra-thoracic structure and emphysema.

3 of 4 tunnel drivers revealed dense nodular opacities higher than category 2 in conventional X-P and they are all graded as category 3 by HRCT. Three of four tunnel and coal workers also revealed marked nodular opacities by X-P and CT.

As a whole, except for category 4 and asbestos cases, 23 of 31 cases showed lower profusion score in CT than in conventional X-P. This may reflect the effect of summation in postero-anterior projection of plain X-P compared with the horizontal thin slice in CT. Subpleural curvilinear opacities were observed in three cases of coal workers pneumoconiosis and one case of asbestosis.

Two cases of asbestosis showed marked irregular opacities in the middle and lower lung field in plain X-P. One of them

Figure 1. Tomogram showing the levels of the six routine sections.

also revealed calcified pleural plaques along the crura of the bilateral diaphragm. CT revealed more clearly the calcified plaques along the thoracic wall with varying thickness. Another case showed intense irregular opacities with honey comb appearance. The CT scan demonstrated marked interstitial changes with subpleural curvilinear opacities whicb could not be demonstrated by plain X-P. In the upper lung field, CT also revealed marked emphysematous changes which may explain the marked obstructive ventilatory disturbance (VC 116% of predicted, $FEV_{1.0\%}$ 55%). Dyspnea score was 2.5 ± 1.0. No clear correlation was found between the radiographic category and dyspnea score.

Studies on pulmonary function were VC 95.7 ± 17.9 percent (mean SD) of predicted value,$FEV_{1.0}$/FVC 64.2 ± 15.6 percent, flow at 75% FVC(V25) divided by height (meter) 0.38 ± 0.24 L/sec/m, RV/TLC 37.4 ± 10.3, $\%DL_{co}$ 106.2 ± 27.5%, PaO_2 ± 78.7, 6.8 torr, A $-aDO_2$ 24.0 ± 7.4 torr (Table I).

No clear correlation was found between conventional radiographic findings nor HR-CT findings and pulmonary function parameters except emphysema score by CT and $FEV_{1.0\%}$ which showed mild inverse relationship.

Nodular opacities, interstitial fibrosis, bullae and emphysema were more clearly and specifically demonstrated on HR-CT scans than on conventional chest radiographs in most patients.

Radiologic-pathologic correlation was performed on the specimens of transbronchial lung biopsy in 4 patients. One case was illustrated in Figure 2. This 54-year-old retired silica brick factory worker showed combined restrictive and obstructive ventilatory disturbance with VC of 57%, $FEV_{1.0\%}$ of 42%, flow at 75% FVC of 0.13L/sec/m. Plain X-P (Figure 2a) was categorized as PRlp. HRCT also revealed dense nodular opacities in upper and middle level of slice (Figure 2b). Subpleural thickening of interlobular septum was also observed. Specimen of transbronchial biopsy revealed well defined pneumoconiotic nodules and mild thickening of alveolar septum (Figure 2c). Small opacities in HRCT may well reflect these small pneumoconiotic nodules seen in TBLB.

Figure 3a shows plain X-P of 88-year-old retired coal miner with an occupational history of 37 years. His autopsied lungs were fixed, dried and, scanned by HRCT and compared with radiograph by soft X-ray or macroscopic findings (Figure 3). Excellent spatial resolution of HRCT was clearly demonstrated from their comparison.

DISCUSSION

HRCT examination of the lung using an extended scale and three-to-four fold magnification imaging format presented the most recent improvement in CT. It has excellent spatial resolution in high-contrast regions which have been expected

Table I

Age, Smoking Index, Duration of Occupational Exposure, RRCT, and Pulmonary Function Parameters According to Radiographic Categories (mean ±SD)

X-P category	No	Age	Smoking Index	Duration of Expo. (year)	Dyspnea	CT			VC (%)	RV/TLC (%)	$FEV_{1.0}$% (%)	V_{max}/RI L/sec/m	%DLco (%)	DLco/VA	P_{aO_2} (torr)	$A\text{-}aDO_2$ (torr)
						Nodular Profusion	Subpl. Emphy.	Central Emphy.								
I	10	58.5 ± 9.3	805.0 ± 350.7	27.2 ± 8.6	2.4 ± 1.2	0.3 ± 0.5	12.5 ± 24.3	37.5 ± 33.8	93.4 ± 17.5	42.5 ± 13.2	59.1 ± 19.8	0.33 ± 0.29	106.8 ± 19.5	4.74 ± 1.15	80.1 ± 6.2	21.2 ± 6.2
2	13	62.0 ± 8.0	654.2 ± 541.3	22.2 ± 8.3	2.0 ± 0.9	1.3 ± 1.3	20.5 ± 27.0	32.7 ± 27.7	97.6 ± 13.2	35.0 ± 6.5	65.3 ± 9.9	0.30 ± 0.12	106.3 ± 25.7	4.91 ± 1.29	79.0 ± 5.6	24.4 ± 7.9
3	6	58.8 ± 9.7	615.0 ± 145.8	21.0 ± 12.9	2.8 ± 0.8	1.2 ± 1.2	45.0 ± 27.4	55.0 ± 32.6	96.7 ± 28.0	33.9 ± 9.9	76.7 ± 6.7	0.57 ± 0.21	91.3 ± 41.2	4.21 ± 0.79	74.5 ± 7.2	28.2 ± 10.3
4	8	64.0 ± 12.8	417.5 ± 238.0	24.8 ± 7.6	3.4 ± 0.9	1.7 ± 1.3	12.5 ± 20.9	20.8 ± 10.2	92.1 ± 19.6	35.8 ± 11.3	60.8 ± 17.9	0.40 ± 0.33	112.4 ± 30.1	5.05 ± 0.96	79.5 ± 9.1	23.5 ± 7.1
Total	37	60.9 ± 9.6	655.8 ± 388.0	23.5 ± 8.9	2.5 ± 1.0	1.1 ± 1.2	22.4 ± 27.0	35.3 ± 28.9	95.7 ± 17.9	37.4 ± 10.4	64.2 ± 15.6	0.38 ± 0.24	106.3 ± 27.5	4.80 ± 1.00	78.7 ± 6.8	24.0 ± 7.4

to give the advantages in evaluating interstitial diseases such as pneumoconiosis. Several investigators have already reported the value of HRCT in evaluating pneumoconiosis.

We compared HRCT with conventional chest radiograph and pulmonary function studies.

Contrary to our expectation there are substantial discrepancies between radiological and CT evaluation. Concerning nodular opacities, HRCT showed good spatial resolution but lower profusion score than conventional chest radiographs. This may reflect the effect of summation in postero-anterior profection of plain X-P compared with the horizontal thin slice in CT. Attenuation of nodular opacities by emphysema also may contribute to this emphysematous cases because it is speculated that progress of emphysema may attenuate the nodular opacities.

Interstitial fibrosis, bullae, and emphysema were more clearly and specifically demonstrated on CT scan than conventional chest radiographs in most patients. The subpleural distributions of bullae were particularly well demonstrated in CT which may not be reflected in pulmonary function studies.

HRCT is useful for performing detailed morphological analyses of abnormalities of the peripheral portions of the lung, but no clear correlation was found between HRCT findings and pulmonary function parameters.

REFERENCES

1. Todo, G., Ito, H., Nakano, Y., et al.: High-resolution CT(HR-CT) for the evaluation of pulmonary peripheral disorders. Rinshohosyasen. 27:1319-1326 (1982) (In Japanese).
2. Fiore, D., Biondetti, P.R., Sartori, F., Calabro, F.: The role of computed tomography in the evaluation of bullous lung disease. *J. Comput. Assist. Tomogr.* 6:105-108 (1982).
3. Kreel, L.: Computed tomography of interstitial pulmonary disease. *J. Comput. Tomogr.* 6:181-199(1982).
4. Muhm, J.R., Brown, L.R., Crowe, J.K. et al.: Comparison of whole lung tompgraphy and computed tomography for detecting pulmonary nodules. *Am. J. Roentgenol.* 131:981-984(1978).
5. Eakata, H., Kimoto, T., Nakayama, T. et al.: Diffuse peripheral lung disease: Evaluation by high-resolution computed tomography. *Radiology* 157:181-185(1985).
6. Examination of the fine interstitial changes of pneumoconiosis with high resolution computed tomography (HR-CT). *J. UOEH* 8 (suppl):363-367 (1986).
7. Aberle, D.R., Gamusu, G., Ray, C.S. et al.: Asbestos-related pleural and parenchymal fibrosis. Detecton with high-resolution CT. *Radiology* 166:729-734 (1988).
8. Begin, R., Bergeron, D., Samson, L. et al.: CT assessment of silicosis in exposed workers. *Am. J. Roentgenol.* 148:509-514 (1987).
9. Bergin, C.J., Muller, N.L., Vedal, S. et al.: CT in silicosis: Correlation with plain films and pulmonary function tests. *Am. J. Roentgenol.* 146:477-488 (1986).

Figure 2a. 54-year-old man with a history of silica-brick factory worker for 35 years. Chest radiograph showing small round opacities.

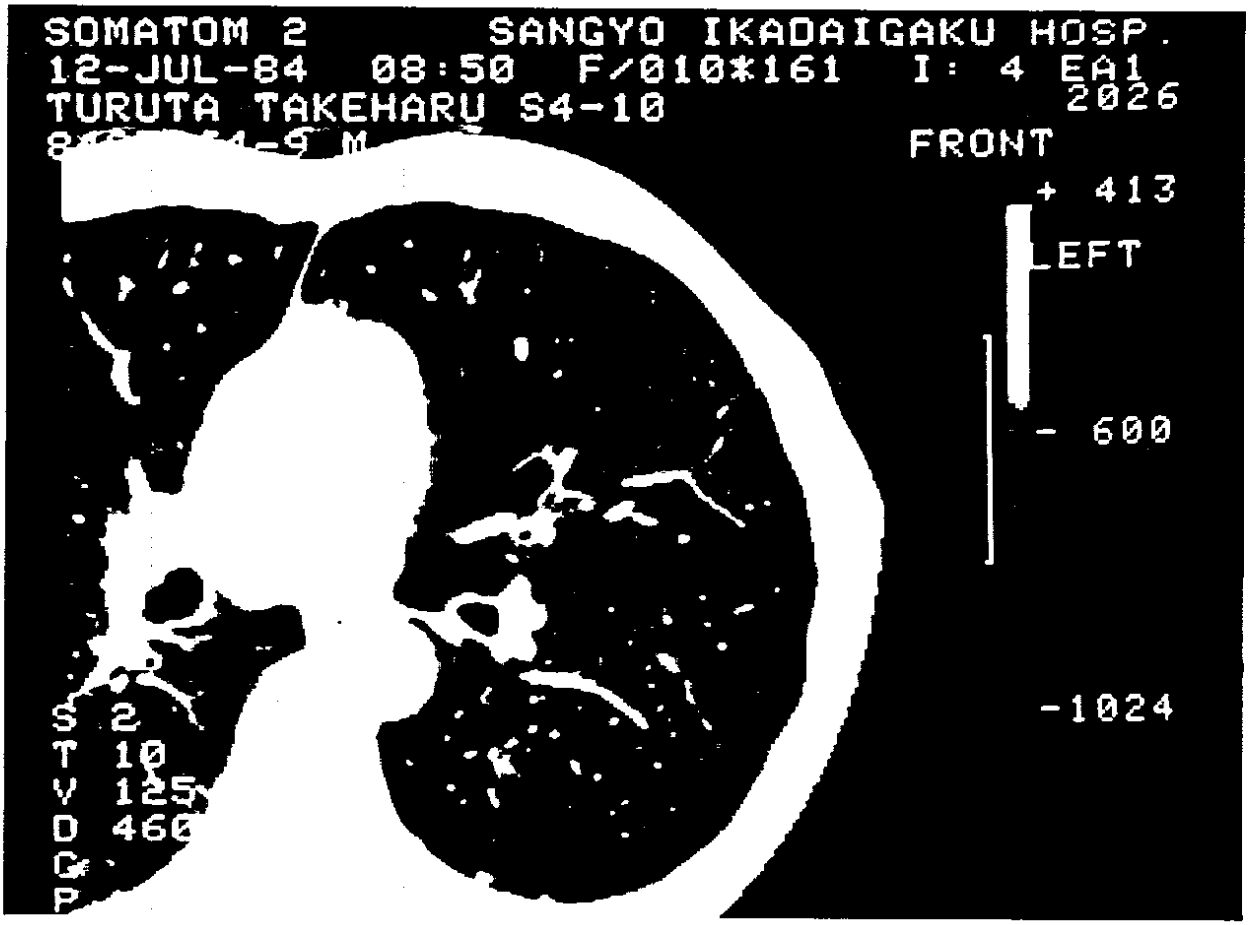

Figure 2b. HRCT. Diffuse well-defined small opacities in the middle lung fields.

Figure 2c. Photomicrograph of transbronchial lung biopsy showing well-defined pneumoconiotic nodule. Hematoxylin and eosin stain, x40.

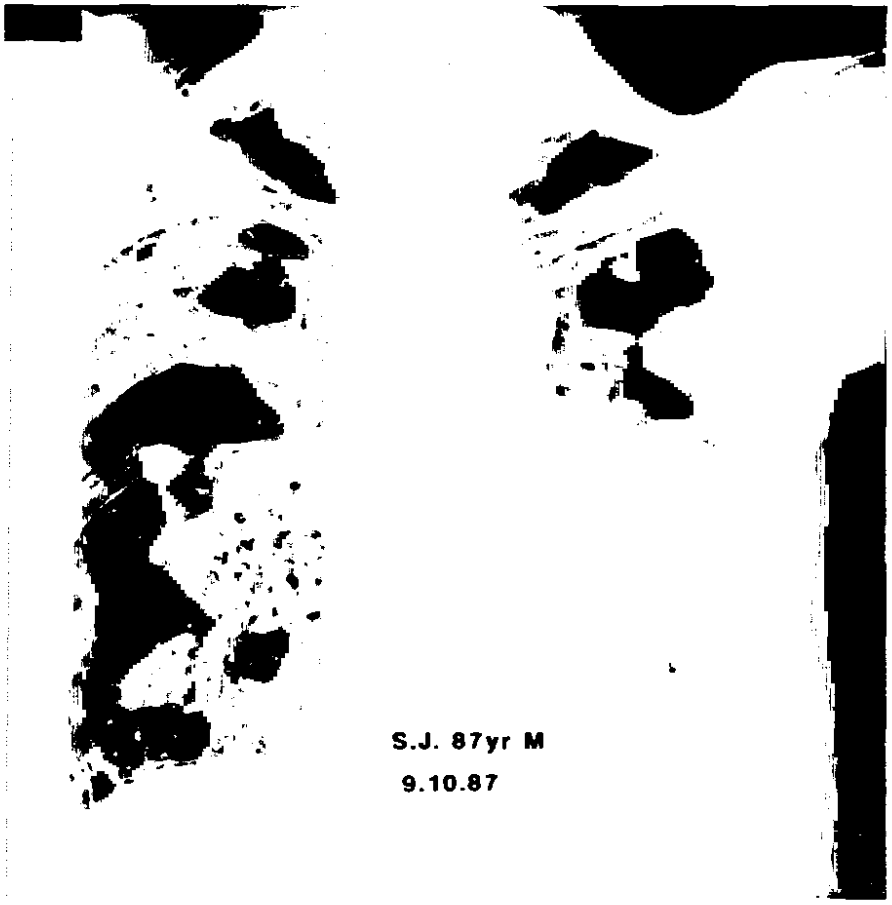

Figure 3a. 88-year-old man with a history of coal miner for 37 years.
Chest radiograph eight month prior to his death shows large opacities and fibrocalcified tuberculous change with few nodular opacities.

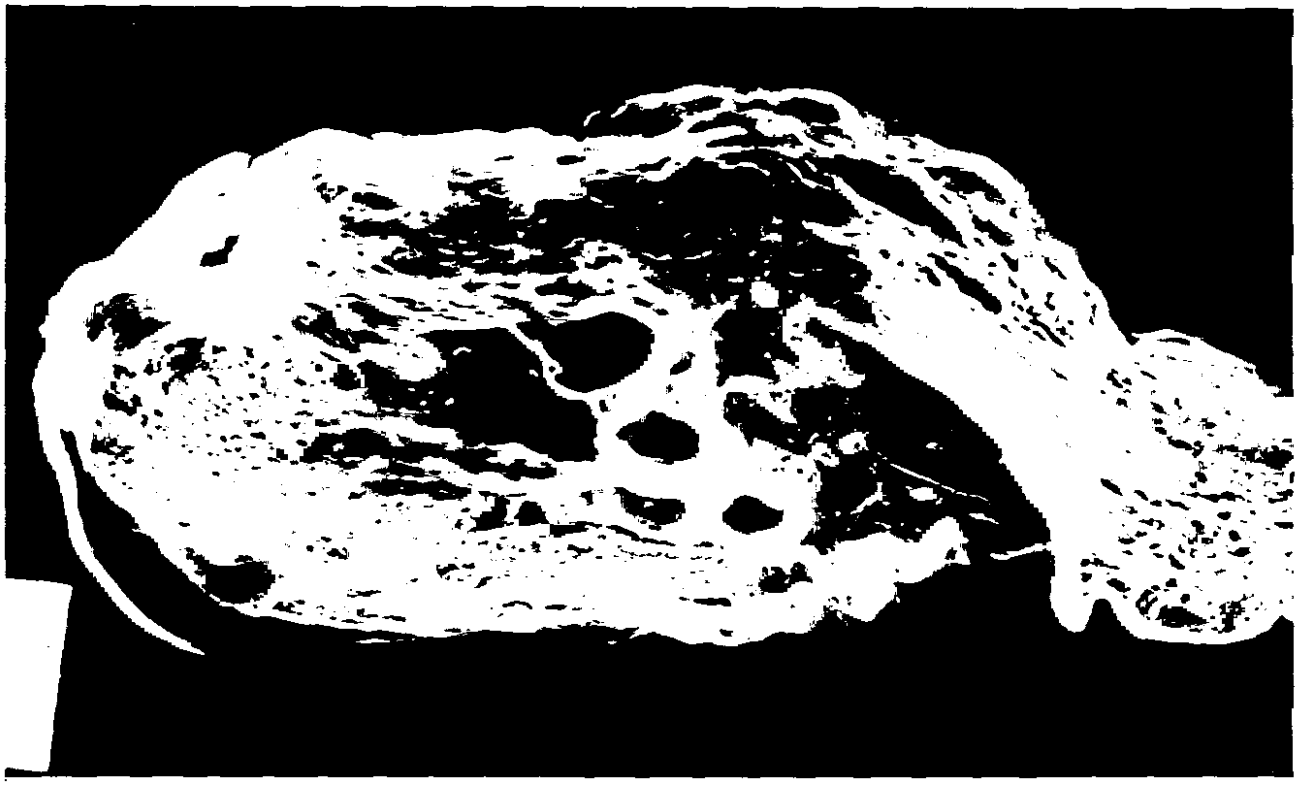

Figure 3b. HRCT of autopsied lung after fixation at the level of middle lung field.

Figure 3c. Post-fixation radiograph of lung in the horizontal slice at the same level as HRCT.

Figure 3d. Macroscopic view of lung at the same level.

Proceedings of the VIIth International Pneumoconioses Conference *Part*
Transactions de la VIIe Conférence Internationale sur les Pneumoconioses *Tome*
Transaciones de la VIIa Conferencia Internacional sobre las Neumoconiosis *Parte*

II

Pittsburgh, Pennsylvania, USA—August 23–26, 1988
Pittsburgh, Pennsylvanie, Etats-Unis—23–26 aout 1988
Pittsburgh, Pennsylvania EE. UU—23–26 de agosto de 1988

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

CDC
CENTERS FOR DISEASE CONTROL

Sponsors

International Labour Office (ILO)
National Institute for Occupational Safety and Health (NIOSH)
Mine Safety and Health Administration (MSHA)
Occupational Safety and Health Administration (OSHA)
Bureau of Mines (BOM)

November 1990

DISCLAIMER

Sponsorship of this conference and these proceedings by the sponsoring organizations does not constitute endorsement of the views expressed or recommendation for the use of any commercial product, commodity, or service mentioned.

The opinions and conclusions expressed herein are those of the authors and not the sponsoring organizations.

DHHS (NIOSH) Publication No. 90-108 Part II