

# CONSIDERATIONS FOR STANDARD CHEST RADIOGRAPHY: THE LONG FILM-FOCUS DISTANCE TECHNIQUE

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## ABSTRACT

The possibility of using long film-focus distance radiography as a new screening method for lung cancer diagnosis was investigated. Long-film focus distance radiography produced exceptionally superior image sharpness suitable for use as clinical photographs, at a distance of about FFD (Film-Focus Distance) 20 m. The effective energy was increased by narrowing the radiation spectrum via an air-filter effect, which may prove useful in reducing radiation exposure dosage. Questionnaire results indicate good visualization of cardiac posterior and trachea shadow regions in the diaphragm.

Further study is required regarding methods for stabilizing patient position and synchronization with heart beat and respiration to improve reproducibility.

Key Words: Chest, Radiography, Long film-focus distance, Screening for lung cancer.

## INTRODUCTION

Recent advances in medical science have made it possible to effect radical cures of malignant tumors through early detection. However, prognosis of lung cancers shows a low five-year survival rate of 15% because most cases have metastasized before detection and curable early-stage lung cancers are difficult to detect by current chest radiological screening methods.<sup>1,2)</sup> Detection methods must be developed which are capable of detecting small lung cancers in the early stages to improve the prognosis.<sup>1)</sup>

Radiology is an effective method for the detection of small, localized lung cancers. Computed tomography (CT) is currently considered effective for detection. Conventional chest roentgenograms have been used, too, but they require improvement to detect small lung cancers. Therefore, we performed basic experiments of standardized radiological methods and found that penumbra is reduced when the X-ray cone approaches parallel, allowing the possibility of long film-focus distance radiography with minimal integral dislocation.

## MATERIALS AND METHODS

A Toshiba Diagnostic X-ray Generator Model KXO-1250A and Toshiba X-ray tube DXB-1024CH (focal spot: 1.2 mm, tube heat capacity: 1.500 KHU) were used with a film-focus distance (FFD) of up to 30 m with the X-ray cone passing through a hole in the wall of

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the radiography room. A laser pointer was used for positioning. Fuji HR-S and HR-8 models were used as film screening systems.

### 1. *Fundamental Examinations*

Experiment 1: The Graedel method was used for long film-focus distance radiography because of the lack of a suitable grid to eliminate scattering. A fluorometer conforming to Japan Industrial Standard was used to measure the scattered ray content with variable FFD and air gaps.<sup>3,4)</sup>

Experiment 2: The sharpness produced by the long film-focus distance radiography system was evaluated using a Kyokko type-1 chart attached to a polystyrene chest phantom on the X-ray tube side. Air gaps were set at 20, 40 and 60 cm, and the square wave responses were measured at FFD of 4, 10 and 60 cm, and the square wave responses were measured at FFD of 4, 10, 20 and 30 m.<sup>5)</sup>

Experiment 3: Changes in radiation quality in long film-focus distance radiography were investigated by measuring the half-value layer of a copper plate at FFD of 13 m, and by comparing filtered and unfiltered radiographs taken at FFD of 2 m. The radiographic conditions at FFD of 2 m were set at 140 kV, 50 mA and 0.06 seconds, and at FFD of 13 m were set at 140 kV, 100 mA and 0.32 seconds.

### 2. *Clinical Examinations*

Experiment 4: Fourteen volunteers were radiographed with artificial shadow circular acrylic materials (3 to 6 mm in diameter) attached to their chests to evaluate the effectiveness of long film-focus distance radiography. Radiographs were made at FFD of 2 m (using Bucky's radiographic device) and FFD of 13 m (with air gap of 60 cm). The films were read by 31 radiologists. An orientation film was used to discuss the visualization of the artificial shadows before the 28 photographs were read. The films were graded for reliability (reliable: 3; somewhat reliable: 2; unreliable: 1), and an Receiver Operating Characteristic curve was prepared.<sup>6)</sup>

A questionnaire was prepared in conjunction with the radiographic images. Sharpness, contrast, and artificial shadows were rated either good, fair, or poor, and the normal structures of the lungs, bronchi, pulmonary blood vessels, clavicle, shadow of subdiaphragm vessels, cardiac posterior shadow, trachea, mediastinal lines, thoracic vertebrae, etc. were rated as having good, fair, neither good nor difficult, somewhat hard, or difficult visualization. Statistical analysis was performed using the chi-square test.

Experiment 5: Radiation dosage on the skin surface was measured to establish standard exposure. When measurements were taken, conditions were the same as in Experiment 3.

In Experiments 3, 4 and 5, the equipment was at FFD of 13 m and air gap of 60 cm because of the geometric limitation for clinical use.

## RESULTS

Experiment 1: A grid (12 : 1, 60 lines/cm) set at FFD of 2 m was used to measure scatter content. The scatter content measured with the grid was 5.5%. Scatter content rates at FFD of 2, 4, 10, 20 and 30 m with air gaps of 0–60 cm were estimated. The observed curves between scatter content rate and air gaps showed almost the same patterns (Fig. 1).

Experiment 2: Sharpness shown by modulation transfer function (MTF) was excellent at FFD of 4 m with an air gap of 20 cm, and at FFD of 10, 20 and 30 m with an air gap of 60 cm. The overall optimum sharpness was found at FFD of 20 m with an air gap of 60 cm, and a drop in

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sharpness was observed when the FFD was 30 m. This drop in sharpness may have been caused by poor conditions resulting from the limitations of the X-ray tube capacity (Fig. 2).

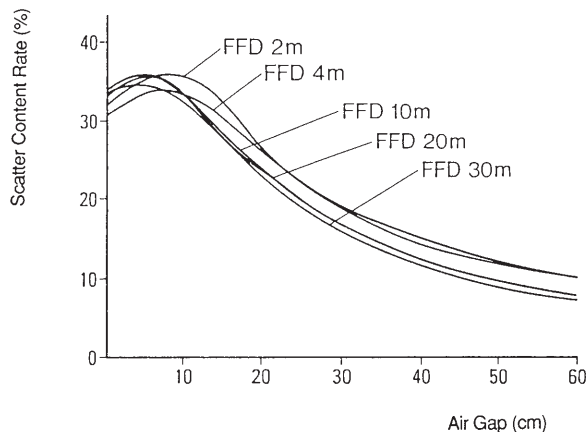


Fig. 1. Relationship between scatter content rate and air gap at different film-focus distances (FFD). The longer the air gap is, the lower the scatter content ratio is. When a grid (grid ratio 12 : 1,60 lines/cm) was used, the scatter content ratio was only 5.5%.

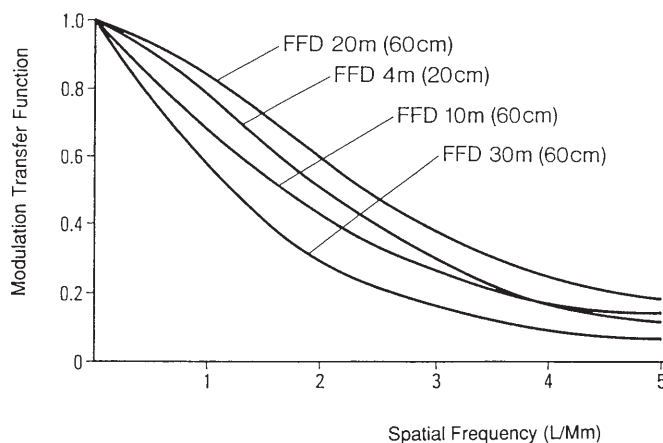


Fig. 2. Comparison of the spatial resolution between different film-focus distances (4, 10, 20, 30 m). The best air gap was chosen for each focus film distance. The spatial resolution for FFD 20 m and air gap 60 cm was best.

Experiment 3: First and second half-value layers of copper were measured at FFD of 2 m (with and without filter) and 13 m via a half-value layer logistic curve to determine the degree of heterogeneity. At FFD of 13 m the heterogeneity was close to unity at 0.494, and close to a single wave length compared with the heterogeneity of 0.387 and 0.346 at FFD of 2 m (with and without filter, respectively) (Fig. 3, Table 1). The measured effective energies were 48 KeV at FFD of 2m (without filter), 61 KeV at FFD of 2 m (with filter), and 67 KeV at FFD of 13 m. A rise in effective energy was observed via an air-filter effect (Fig. 4).

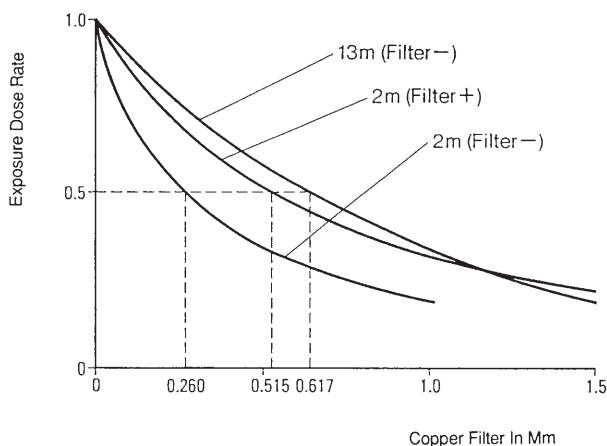


Fig. 3. Comparison of half-value layer at FFD 2 m (filter+, -) and at FFD 13 m (filter-). First and second half-value layers for FFD 13 m were 0.617 and 1.250 mm, respectively. For FFD 2 m (filter+) they were 0.515 and 1.330 mm, respectively. And for FFD 2 m (filter-) they were 0.260 and 0.750 mm, respectively.

Table 1. Heterogeneity Ratios for FFD by Measurement of Half-Value Layers of Copper

| Technique         | First half-value layer H1 | Second half-value layer H2 | Heterogeneity $h=H1/H2$ |
|-------------------|---------------------------|----------------------------|-------------------------|
| FFD 13 m          | 0.617                     | 1.250                      | 0.494                   |
| FFD 2 m (filter+) | 0.515                     | 1.330                      | 0.387                   |
| FFD 2 m (filter-) | 0.260                     | 0.750                      | 0.346                   |

The heterogeneity ratio for the long distance method (FFD 13 m) was 0.494. This means that the X-ray spectrum by the long distance method is narrowed and that the effective energy is increased.

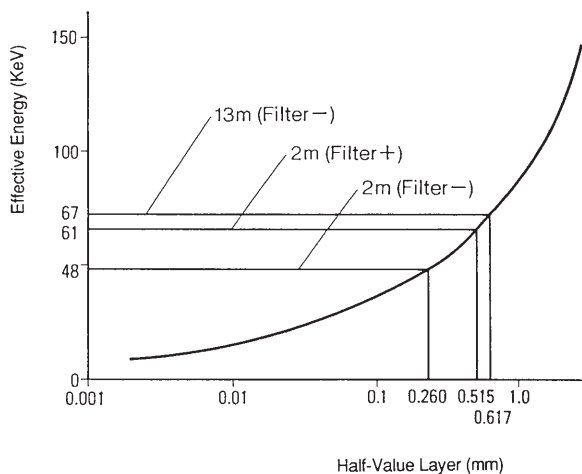


Fig. 4. Relationship between effective energy and half-value layer in the copper filter. Effective energies for FFD 13 m (filter-) and FFD 2 m (filter+, -) were 67, 61, 48 keV, respectively.

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Experiment 4: Although improved sharpness was observed in long film-focus distance radiography, no significant difference was found in the detection rates of the artificial shadows (Fig. 5). The results of the questionnaire show that, in the respondents' opinions, long film-focus distance radiography offered good visualization of the shadow of the cardiac posterior shadow ( $0.05 < p < 0.1$ ), trachea ( $p < 0.001$ ), mediastinal lines ( $p < 0.05$ ), and thoracic vertebrae ( $p < 0.001$ ) (Table 2).

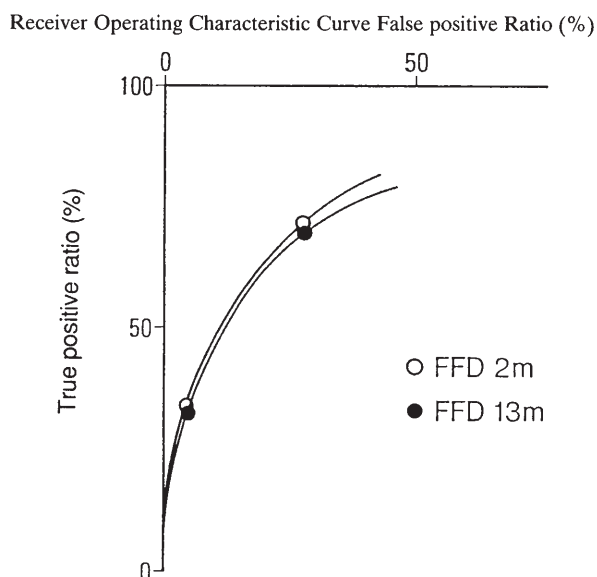


Fig. 5. Although improved sharpness was observed in long film-focus distance radiography, no significant difference was found in detection of the artificial shadows.

Table 2. Questionnaire Results

| IMPRESSION               | CONVENTIONAL METHOD |    |    |    |    | LONG DISTANCE METHOD |    |    |    |    |
|--------------------------|---------------------|----|----|----|----|----------------------|----|----|----|----|
|                          | A                   | B  | C  | D  | E  | A                    | B  | C  | D  | E  |
| Sharpness                | 12                  | 62 | 26 |    |    | 11                   | 56 | 33 |    |    |
| Contrast                 | 10                  | 63 | 27 |    |    | 13                   | 58 | 29 |    |    |
| Artificial shadows       | 9                   | 55 | 36 |    |    | 9                    | 52 | 39 |    |    |
| Lung field               | 7                   | 40 | 29 | 21 | 3  | 6                    | 41 | 25 | 23 | 6  |
| Bronchus                 | 7                   | 39 | 25 | 26 | 3  | 5                    | 38 | 25 | 27 | 4  |
| Pulmonary vessels        | 6                   | 41 | 29 | 26 | 3  | 7                    | 36 | 26 | 24 | 7  |
| Clavicular bone          | 25                  | 45 | 20 | 7  | 0  | 26                   | 46 | 18 | 8  | 1  |
| Subdiaphragm shadow      | 1                   | 22 | 20 | 33 | 24 | 4                    | 24 | 21 | 34 | 17 |
| Cardiac posterior shadow | 1                   | 21 | 23 | 38 | 17 | 3                    | 32 | 26 | 31 | 9  |
| Trachea                  | 2                   | 31 | 26 | 36 | 5  | 10                   | 49 | 20 | 19 | 2  |
| Mediastinal lines        | 0                   | 20 | 25 | 31 | 24 | 4                    | 30 | 27 | 24 | 15 |
| Thoracic vertebrae       | 0                   | 12 | 21 | 33 | 34 | 4                    | 26 | 22 | 28 | 21 |

Image quality: A, good; B, fair; C, poor.

Visualization of normal tissues: A, good; B, fair; C, neither good nor difficult; D, somewhat hard; E, difficult.

Experiment 5: When the filter was set at FFD of 2 m, the measured skin exposure was 2.63 mR (678.54 nC/kg). At FFD of 13 m without a filter, the exposure was 1.73 mR (446.34 nC/kg).

## DISCUSSION

Shadows of pulmonary vessels and bronchial tubes must have good enough definition to be differentiated from anomalous shadows in order to detect treatable small lung cancers; therefore, radiographs of great sharpness are necessary. Various efforts have been made to reduce the penumbra and scattered rays of X-ray radiography. Long film-focus distance radiography is excellent in this respect, although there are few reports of its practical improvements. This lack of improvement is thought to result from problems linked to the X-ray generator and X-ray tube capacity. In recent years, however, long film-focus distance radiography has been made possible by improvements in X-ray diagnostic equipment. The characteristics of long film-focus distance radiography are as follows:

(1) Sharpness is increased by minimizing penumbra. Sharpness increases overall, particularly on the focus point side, as the sharpness of the dorsal shadow of chest P-A images approaches the sharpness of the image portions near the film.

(2) Images with relatively slight distortion are obtained as the difference in the rate of enlargement is eliminated between the image on the tube side and the image on the film side.

(3) X-ray radiation quality is improved by rendering the cone more parallel, and the low voltage portion is cut via the air-filter effect to narrow the X-ray wavelength band. This raises the effective energy and reduces scattering.<sup>7,8)</sup>

(4) When the proportion of the exit dose to the incident dose is increased, the dosage is reduced in comparison with conventional radiographs.<sup>9)</sup>

The Graedel effect was used to eliminate scattering; however, the ability to eliminate scattering of the conventional grid was superior. Thus, the creation of a suitable grid used in conjunction with the Graedel effect should produce sharper images. These are important elements in achieving the early stage detection of small lung cancers.

The reasons why significant differences were not found in detection of artificial shadows by long film-focus distance radiography on ROC analysis were considered to be the prevalence of false negative responses, cardiac movement resulting from prolonged exposure time, and the reduced contrast attributable to the elevation of effective energy and the narrowing of the X-ray spectrum width. The questionnaire results suggest that, in the respondents' opinions, long film-focus distance radiography offered good visualization of the shadow of the cardiac posterior shadow and trachea, which may be an advantage of changing radiation quality.

Long film-focus distance radiography must incorporate shorter exposure time and be synchronized with the heart beat via electrocardiograph to eliminate artifacts. To obtain reproducible radiographs the electrocardiographic synchronization, respiratory synchronization and means for stabilizing the position of the patient must be investigated further.

## CONCLUSIONS

The possibility of using long film-focus distance radiography as a new screening method for lung cancer diagnosis was investigated. Long film-focus distance radiography produced exceptionally superior image sharpness suitable for use as clinical radiographs, at distances of about

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FFD 20 m. Long film-focus distance radiography is also useful in reducing radiation exposure dosage, although exposure time remains a problem. Finally, methods for stabilizing patient position and synchronization with heart beat and respiration must be studied to improve reproducibility. These problems must be solved to adapt long film-focus distance radiography as a screening method for lung cancers.

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