Can Radiological Technologists Serve as Primary Screeners in Low-dose Lung Cancer CT Screening? (Analysis Based on the Results of Certifying Examinations over a 10-year Period)

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Aims and objectives

Low-dose computed tomography (CT) screening for lung cancer was first reported in 1996 for early detection of lung cancer. In 2006, a study suggested that the 10-year survival rate of Stage 1 lung cancer cases, identified by lung cancer CT screenings, might approach 90%. Data indicating an approximately 20% decrease in mortality rate were reported in the lung cancer CT examination for a conventional chest radiograph image as a result of a randomized controlled trial by the NLST Team in 2011. Physicians and radiological technologists performing lung cancer CT screenings require education, and training and experience, and the screenings to be performed require certification to a certain level or higher to ensure accuracy of CT examination. In Japan, a joint examination meeting of six academic committee members was held in March 2007 to establish a CT examination certification system, and the purpose and forms of the projects were discussed. In April 2009, an organization for the "Accreditation Council for Lung Cancer CT Screening" was established, and accredited projects for doctors and radiological technologists began. In addition, to ensuring accuracy and consistency of CT scanner, a first reader (usually physician) of the "Double Reading system" involving two physicians, was demanded to radiological technologist. In about 10 years, approved 1243 lung cancer CT certified technologist (Fig. 1 on page 3). In this report, based on the 10 years data on accredited projects of lung cancer CT approved technologists, particularly analyzed changes in the exam passing rates and considered the future education requirements of certified technologists.
**Fig. 1:** Shown is the prefectural distribution of Japanese lung cancer CT certified technicians. Komazawa University (purple frame) and Shiga University of Medicine (blue frame) were used as test facilities.

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Methods and materials

2.1 Usage facilities for examination site

Komazawa University (1-23-1 Komazawa, Setagaya-ku, Tokyo, Japan) and Shiga University of Medicine (1-1-1 Banba Hikone, Shiga, Japan) were used as testing venues for certifying lung cancer CT technologists. The following three items were set as conditions for facility selection.

a. Possible to accommodate more than 100 people:

b. Setting a PC equivalent to corresponding to examinees (over 100 peoples):

and

c. When geographically divided Japan into two halves, it is located in the middle and the traffic access is good.

2.2 Study population and qualifications for examination

The present study analyzed data of 1593 examinees of the certification exam (exam of "1st to 17th"), performed by the lung cancer CT certification organization. The average number of years of experience of the examinees was 12.7 ± 7.11 years (Maximum, 38 years; minimum, 2 years). The basic requirements for technologists to perform the examination were as follows:

d. Have acquired a radiological technologist's license; and

e. Clinical practical experience as a radiological technologist for at least 2 years.

2.3 Examination method and system

The certification exam was conducted twice a year, but at different venues each time. The certification test consisted of two sections: a written test (25 questions, 60 min) (Fig. 2 on page 6) and an abnormal finding detection test (60 questions, 120 min) (Fig. 3 on page 6). Written test was conducted on the physics of CT and the clinical practice of lung cancer as the subject of examination. The abnormal findings detection test included normal cases. In the preliminary guidance established for this study, the detection point of abnormal findings was determined as "a nodule of 5 mm or more thought to be necessary for detailed examination". In the abnormal finding detection test, one server system was accessed by more than 100 client personal computers (PCs) (the number of clients corresponded to that of examinees). For the examination, a CT image viewer was installed on all PCs in advance. The image displayed in this viewer was altered by scrolling the mouse, and answers were recorded by marking (clicking) the...
area judged as an abnormal finding (Fig. 4 on page 7). Then, by clicking the "Next patient" tab for each case, the image of the next case was automatically loaded. It was possible to return to any case within the examination time and modify it. After completion of the detection test, answers were automatically collected and results were calculated.

2.4 Criteria of judgment (pass/fail)

The acceptance or rejection of the certification test was based on the sensitivity and Az value of the written test and the abnormal finding detection test result.

Conditions for certification were as follows:

f. The percentage of correct answers in the written examination must be >60%;

g. Detection sensitivity of "true positive" (TP) in the abnormal finding detection test must be >0.90; and

h. The Az value in the area under the Receiver Operating Characteristic curve of the abnormal finding detection test must be >0.90.

2.5 Statistical Analysis

A regression analysis using an ordinary least squares method was performed for the pass rate against the average number of years of experience with written test and abnormal finding detection test. The statistical significance of the TP and false positive (FP) values against the written test and abnormal finding detection test were explored using Welch’s t-test. A two-sided P-value <0.05 was considered to be statistically significant. All data were analyzed using the Tokei-Kaiseki version 2.0 and Tahenryo-Kaiseki version 2.0 for Mac software packages (Esumi Ltd, Tokyo, Japan).
Images for this section:

**Step 1: Written test**

![Image 1: Shiga University](image1)

![Image 2: Komazawa University](image2)

**Fig. 2:** To test the examinee’s knowledge of the safety management, dose management, and image quality management of a CT system. This knowledge is required in order to become a certified radiological technologist.

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Step 2: Abnormal findings detection test

**Fig. 3:** To test whether or not the examinee is able to detect lung nodules suspicious for lung cancer in CT images as a certified radiological technologist, the examinee’s ability to detect nodules is assessed within a specified time under controlled conditions.

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1. Display slices are changed by scrolling the mouse.
2. The mouse is also used to mark the locations showing abnormal findings.
3. Image data for the next patient is loaded by clicking [Next Patient] after image interpretation for the current patient is completed.

**Fig. 4:** CT image viewer for abnormal finding detection test using imitates the operation screen of the existing CT apparatus and is excellent in operability. Window adjustment function is also installed and can be arbitrarily adjusted.

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Results

Fig. 5 on page 11 shows the results of evaluating the correlation between average number of years of experience and pass rates in the written test (Left) and the abnormal finding detection test (Right). The results of the regression analysis were as follows: Slope value, -0.004; intercept, 0.965; and correlation coefficient R = 0.105 (P-value = 0.71) in the written test; and slope value, 0.039; intercept, 0.355; and correlation coefficient R = 0.558 (P-value = 0.03) in the abnormal finding detection test.

In Fig. 6 on page 11, the results of the written test were classified into four groups of years of experience: 2-5 years, 6-10 years, 11-20 years and 21 years or more. The average score value of each was: 2-5 years: 77.1, 6-10 years: 76.4, 11-20 years: 74.2, over 20 years: 73.0. The combinations other than "2-5 years" - "6-10 years" and "11 to 20" - "over 20 years", there were significant difference (p <0.01).

In Fig. 7 on page 12, as in Figure 6, the results of the abnormal finding detection test were classified according to the years of experience, and the accuracy of the TP values was evaluated. The average TP value of each group was: 2-5 years, 0.922; 6-10 years, 0.930; 11-20 years, 0.937; and over 20 years, 0.937. In the combinations of "2-5 year" - "11-20 year" and "over 20 year", "6-10 year" - "11 -20 year", the differences were observed to be statistically significant (P < 0.01, P < 0.01, and P < 0.05, respectively).

In Fig. 8 on page 13, the accuracy of the FP value was evaluated in the same way. The average FP value of each group was: 2-5 years, 0.465; 6-10 years, 0.430; 11-20 years; 0.484; and over 21 years, 0.365. In all results, the mean FP value decreased significantly (P < 0.05) in the group with over 20 years of experience.

Discussions

This study examines the data from a 10-year record possessed by the Accreditation Council for Lung Cancer CT Screening. The philosophy of the Accreditation Council for Lung Cancer CT Screening is "to guarantee lung cancer CT screening at a certain accuracy or higher anytime anywhere in Japan". The certification exam is the level least able to achieve this philosophy. In this study, the score of the written test, TP value, and FP value of the examinees will be considered from the viewpoint of the years of experience. There was a weak correlation between the years of experience in the written exam and the passing rate (Fig. 5 on page 11, Left). Currently, the certification organization discloses the publication of dedicated text as part of the preliminary learning and previous test questions, without answers, on the website of the Accreditation Council for Lung Cancer CT Screening. By using these resources, it is inferred that the examinees have obtained a learning effect that exceeds the acceptance level by 10 points or more,
regardless of the number of years of experience. In addition, aggregated results were classified into 4 groups of years of experience: 2-5 years; 6-10 years; 11-20 years; and 21 years or more. When evaluated, the written test scores decreased significantly with an increase in years of experience (Fig. 6 on page 11). We suggest that this indicates a decline in knowledge of "academic knowledge" with an increase in number of years of experience. In other words, finishing school education, biasing academic knowledge such as engineering knowledge, image quality and dose evaluation of CT scanner for a long time in clinical seems to have affected the decrease in average score.

In the abnormal finding detection test, the passing rate improved as the years of experience increased (Figure 5, Right). As shown by Figure 7.8, both TP and FP values improved significantly as the years of experience increased. The style and contents of the CT work of the radiological technologist has changed significantly, due to shorter photographing time caused by multiple rows of CT detectors, and higher picture quality due to the development of the sequential approximation application reconstruction method. Single-slice CT scans, the lesion was recognized from the thick-slice image, and the thin-slice photographing was performed again. Also, The spread of "Picture Archiving and Communications" system was inadequate, and the necessary range was outputted by "film". These works have brought automatically improved the reading ability of the "radiological technologists". In the era of 16-row multidetector CT scans, there was a process of recognizing the lesion from the thick-slice image and reconstructing the thin-slice image from the same raw data. However, since the era of 64-row detectors, the images provided by the thin slices has become the standard practice; consequently, the role of image confirmation by the radiological technologist has markedly decreased, and consequently the ability to detect abnormal findings has decreased.

The Accreditation Council for Lung Cancer needs to pay close attention to these data trends and issues. The responsibilities of certified technologists will change because of changes in medical technology. In order to maintain the standard of certified technologists, it is always necessary to eliminate biases in knowledge, to assess the balance between the foundation and clinical knowledge, and to review the educational method.

For example, in order to detect abnormal findings, research and development of Computer-Aided Detection (CAD) has been promoted, and some facilities have already adopted it. In the future, further improvements in accuracy can be expected by developing diagnostic support software equipped with artificial intelligence, or deep learning. In particular, Deep Neural Networks have been designed to model cognitive patterns of human and animal cranial nerve circuits based on previous data, and have been reported to be applied in clinical settings. We believe that training and practice using CAD is indispensable for maintaining the standard of certified technologists.
Fig. 5: Figure 5 shows the results of evaluating the correlation between average number of years of experience and pass rates in the written test (Left) and the abnormal finding detection test (Right).

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**Result of Written TEST**

**Fig. 6:** In Figure 6, the results of written test were classified according to the years of experience: 2-5 years, 6-10 years, 11-20 years and 21 years or more, and the score was evaluated.

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Fig. 7: In Figure 7, the results of the abnormal finding detection test were classified according to the years of experience, and the accuracy of the TP values was evaluated.

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Fig. 8: In Figure 8, the results of the abnormal finding detection test were classified according to the years of experience, and the accuracy of the FP values was evaluated.
Conclusion

According to the results of the certification exam, the average score of the written test tended to be high when the experience was low. The TP and FP values of the abnormal finding detection test were better as the number of years of experience increased. In order to guarantee and maintain the abnormal findings detection ability of accredited technologists, it is important to revise the educational system according to current standard practices. In future, combined use of CAD is expected to be a practical choice.
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