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II Potential Usefulness of Computed Nodule Detection in Screening Programs for Lung Cancer

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Abstract The potential usefulness of computer-aided diagnosis (CAD) in mass survey for lung cancer were investigated. When the sensitivity of the computer output was adjusted nearly equal to that of the mass survey in our database which contained 198 photofluorogaraphic films, some shadows detected by the computer outout were different from those detected by human observers. Therefore, the best estimated sensitivity of an observer using the computer output was equal to or greater than the sensitivity of double reading. It is expected that CAD may have a role in mass survey for lung cancer using photofluorographic films

Key Words : Photofluorographic film, Mass survey, Lung cancer, Pulmonary nodules, Computer-aided diagnosis (CAD)

Introduction

It is wellknown that radiologist can fail to diagnose pulmonary nodules from chest radiographs in as many as 30% of patients with positive findings[1)2)]. Muhm et al reported that 90% of peripheral lung cancers were visible in retrospect on previous films in their study. To reduce the number of false-negative diagnoses, we are developing a computer aided diagnosis scheme for detection of lung nodules in digital chest images. Computer output would be used to alert radiologists to locations of possible nodules[4)-7)]. In Japan, approximately 12.5 million people are examined by annual mass survey with photofluorographic chest radiographs for the detection of asymptmatic heart and pulmonary diseases. One of the purposes of this mass survey is to screen for lung cancer. Approximately 20% of all lung canceers in Japan are detected by these surveys[8)]. Despite careful readings, however, more than 50% of lung cancers detected by radiographic mass survey were visible in retrospect previously on films[9)10)11)]. We applied a computerized method for detection of lung nodules in photofluorographic chest images and evaluated the potential usefulness of the CAD scheme in the lung cancer-screening program[9)].

Method

With the photofluorographic chest system used commonly for the mass survey, posterior-anteerior chest image are recorded on a 100mm roll film using a mirror film using a mirror camera. A rare-earth phospher screen is used at 90 to 140 kVp with 5 : 1 to 10 : 1 grid. The image quality of photofluorographic film is inferior to that of conventional screen-film system due to the low resolution of optical system and also the high noise level caused by film grainness.

We used photofluorographic film from the

mass survey in Yamaguchi Prefecture (Yamaguchi, Japan). In 1985 to 1989, approximately 250,000 persons were examined, and 355 lung cansers were detected by this mass survey. We used films of 95 patients with abnormal test results, who had primary and metastatic lung cancers, and 103 patients with normal test results selected by four radiologists from all films, which we were able to obtain from the central office of the mass survey in July 1990. All patients with abnormal test results who were selected had lung nodules that were less than approximately 4 cm in size, and the nodules with secondary shadows, such as obstructive pnneumonitis and atelectasis, were excluded, because our computerized scheme is aimed at the detection of lung nodules. In the 103 patients with normal results, absence of mass lesions was confirmed by the review of the films as well as the subsequent year's in retrospect by four radiologists. Of the 95 patients with abnormal results we included 36 films with false-negative findings that did not initially detect mass lesions in survey; however, lung cancer subsequently developed. In retrospect, the lesions were confirmed as possible malignant tomours by four radiologists. Therefore, the sensitivity rate of the physicians detecting lesions in the patients selected for this study was 62.1%.

Photographic chest films were digitized into 512 × 512 matrix of 10 bits depth using a Konica laser scanner (Konica Corporation, Tokyo, Japan) with 0.175-mm sampling distance. It should be noted that the 512 × 512 matrix may be adequate for the detection of lung nodules. The pixel size of digitized chest images was approximately 0.6 mm in the object plane. Digitized images were analysed on a DEC Micro VAX 3500 computer (Digital Equipment Corporation, Maynard, MA) with the automated detection scheme.

Our computerized scheme is on a difference -image technique with which the camoflaging anatomic background in the chest is reduced initially[4)-7)]. The difference image is obtained by subtraction of a "nodule supressed" from a "nodule-enhanced" image. Each of these images is produced using linear filter and ring -shaped averaging filter for enhancement and suppression, respectively.

Three feature-extraction techniques are applied to any suspicious densities in the difference image to reduce false-positive detections arising from normal anatomic background[4)-7)] Fig. 1. The central processing unit time is approximately 3minutes per chst image.

It was evaluated whether the detecting lung cancers using computer output for mass survey was really useful; 1) Estimated sensitivity of detecting lung cancers using computer output for mass survey. 2) Estimated sensitivity of double reading and single reading with computer-aided diagnosis (CAD) 3) Performance of identifying nodules from candidates obtained with computerized scheme.

Result

The computer output of the nodule detection scheme applied on the photofluorographic chest images of two different subjects included a variety of outcomes as illustrated in Fig. 2. Notice that the correct location of the nodule is indicated by a circle, and the

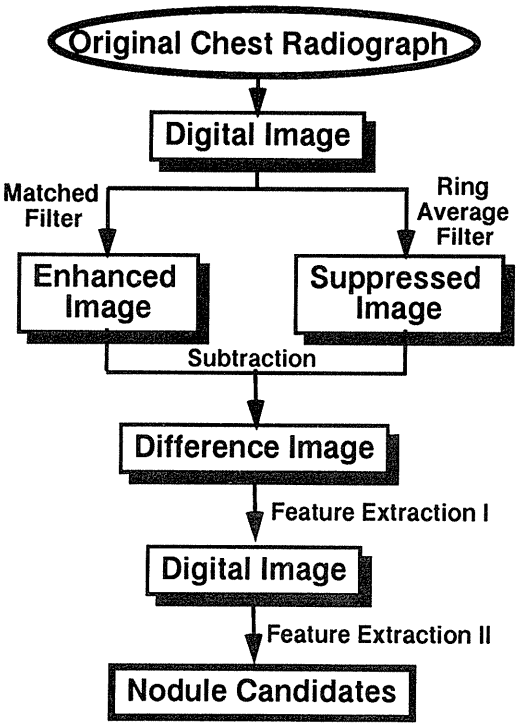


Fig. 1 Our computerized scheme

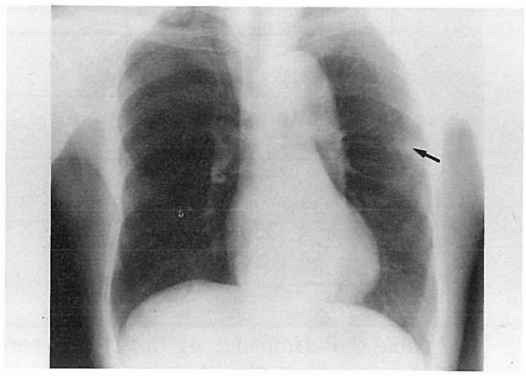
locations identified by the computer as potential nodule sites are marked by arrows.

This nodule failed to be detected in the left middle lung field in Fig. 2 a, on mass survey, whereas the computer was successful in detection of the nodule, although the computer output included seven false positive detections in Fig. 2 b. The overall performance of computerized detection scheme for lung detection scheme for lung nodules in the 198 photofluorographic chest images is shown in Table 1. The CAD scheme provided similar sensitivity to mass screening (63% versus 62%), respectively.

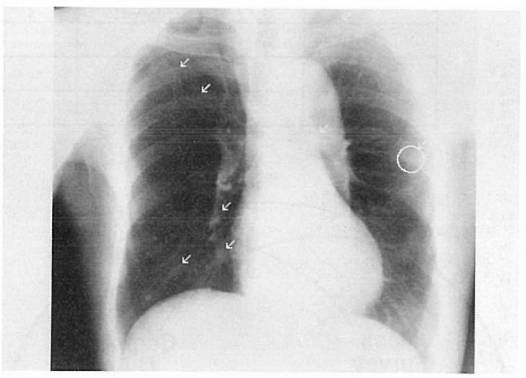
The estimated sensitivity of double reading and single reading with computer-output were compared. Five observers with more than for ten years experiences were selected, and they observed the nodules which lung cancers were included over half of all nodules, by an ordinary method. The results, the best estimated sensitivity of observer using the computer out put was equal to or greater than the sensitivity of double reading in Table 2. Next, on performance of three observers for identifying nodules from 280 candidates (included 7 false negative lung cancers with mass survey) obtained with computerized scheme, observers picked 8 or 9 nodules and obtained the better sensitivity and specificity in Table 3.

Discussion

It has been demonstrated that early detection of lung cancer followed by surgical resection provides the best opportunity for cure. The clinical stage of lung cancer detected by mass survey is earlier than that of symptomatic lung cancer[12)13)]. These results suggest the potential usefulness of mass surveys for early detection of asymptomatic lung cancers. Although it has not been conclusively demonstrated that lung cancer screening



(a)



(b)

Fig. 2 An example of false negative cases from the mass survey. the faint (arrow) overlapped with the rib is seen in the left middle fields (Fig. 2-a). The computer output (cross) correctly identified the shadow with seven false positives (Fig. 2-b).

Table 1 Estimated sensitivity of detecting lung cancers using computer output for mass survey.

Shadow type	Mass survey	Computer output (CO)*	Combination (best estimate)
All	59/95(62.1%)	60/95(63.2%)	74/95(77.9%)
Small**	4/13(30.8%)	5/13(38.4%)	6/13(46.1%)
Faint	8/26(30.8%)	14/26(53.8%)	16/26(61.5%)
Overlapping	6/15(40.0%)	11/15(73.3%)	11/15(73.3%)

*Computer output: 63% sensitivity at 11.7 false positives positives per image

**less than approximately 10 mm in diameter

Table 2 Estimated sensitivity of double reading and single reading with CAD in 198 cases.

Observers	CAD (63.2%)	E	D	C	B
A (72.6%)	84.2%	81.1%	77.9%	75.8%	80.0%
B (68.4%)	80.0%	80.0%	78.9%	80.0%	
C (68.4%)	84.2%	81.1%	77.9%		
D (66.3%)	78.9%	78.9%			
E (71.6%)	85.3%				

Table 3 Perfomance of three observers for identifying nodules from candidates obtained with computerized scheme.

Observers	No. of candidates (True nodules)	No. of shadows picked up	Sensitivity	Specificity
F	280 (7)	9	5/7	269/273
G	280 (7)	8	5/7	270/273
H	280 (7)	8	5/7	270/273

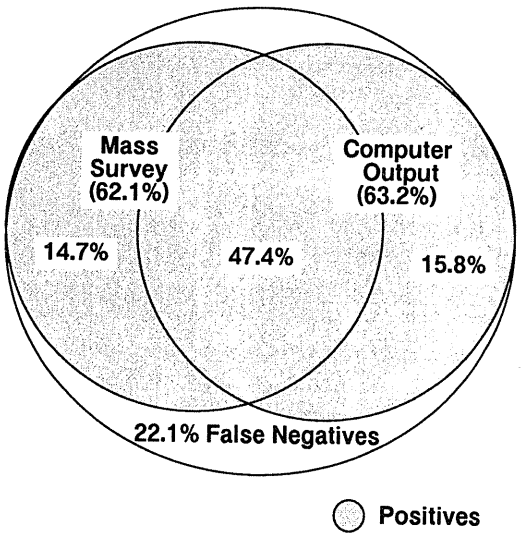


Fig. 3 Relationship between the sensitivities of the mass survey and the computer output.

leads to a reduction in mortality in a screened group, it is possible that more accurate screening techniques would provide improved results. As stated ealier, more than 50% of lung cancers detected by radiographic mass survey were visible in retrospect on previous films[9)10)]. Obviousy, this is one of the problems to be addressed in screening programs. In Japan, photofluorography is used for mass surveys, because of its low cost and high throughput compared with conventional radiography. However, the image quality of photofluorographic chest films is not as goood as that of conventional screen-film systems, although it is believed that the image quality of survey films is adeauate for nodule detection compared with conventional radiographs. However, the fact that physicians read many low-quality films at a very high rate (200-300films/hour) is a problem. In general, computer can be expected to be more accurate than humans. Therefore, in principle, computer may have a role in solving this problem. Digital processing of low-quality photofluorographic image by the computer might facilitate the computerized detection of lung nodules. In addition, it may be possible to use "diffeerence images" produced as a by-product of the CAD scheme for visual detection of nodules by radiologists. In fact, in receiving difference images for photofluorographic chest films,

the nodules were identifiable in approximately 80% of the patients with abnormal results. Those identified included nodules missed by both mass survey and the computer.

To gain an insight into the potential usefulness of the computerized scheme in lung nodule detection, we attempted to compare the nodules detected by the computer with those of the mass survey when the sensitivity of the computer output was adjusted to be nearly equal to the sensitivity of the mass survey as shown in Table 1.

In the mass survey, small, faint, and/or overlapping shadows tend to be overlooked. These shadows are extremely difficult for radiologists to detect, even if, multiple readings are performed. However, our results indicate that the computer might be able to detect some of these shadows. Therefore, theoretically, the use of the computer output could improve the sensitivity rate from 62.1% to 77.9%.

It is assumed that a radiologist would use all of the computer generated true positive detections. We assume that the radiologist can take advantage of the computer output to correct errors when the missed nodules were detected by the computer. This is a high hypothetical situation, with which one can predict the maximam possible sensitivity. Realistically, however, it is likely that the sensitivity attainable would be lower than the maximam sensitivity, and the false positive findings would increase. It is sometimes said that the CAD false-positive results are easily recognized by the human observer. However, further investigation is needed to understand more clearly the effect of the CAD false-positive results on observer performances in the detection of lung nodules.

In summary, our results show the potential usefulness of the computer out-output to alert radiologist to possible nodule locations and thus reduce the number of false negative diagnoses in mass survey[11].

However, the number of false-positive diagnoses in the current output is relatively high, and the sensitivity may have to be improved before actual use in clinical situations. The computerized scheme is still in its infancy, and it expected that the filterling and feature-extraction technique will continue to be improved to the point where false-positive results are reduced to an accetable level for application in chest screening programs.

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