Missed Lung Cancer on Chest Radiography and Computed Tomography

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Missed lung cancer raises an important medicolegal issue and contributes to one of the most common causes for malpractice actions against radiologists. Lung cancer may be missed on either chest radiography or computed tomography. Although most malpractice cases involve lesions overlooked on the former, a small and increasing portion of cases are related to chest computed tomography scan. Factors contributing to overlooked lung cancer can be attributed to observer performance, lesion characteristics, and technical considerations.

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Medicolegal Standpoint in Missed Lung Cancer

Of a total annual national medical expenditure of $800 billion, medical malpractice costs are estimated to be $9 billion.1 Median verdicts were in the $200,000-$300,000 range in the 1980s and exceeded $400,000 in the 1990s. According to a study by Physician Insurers Association of America (PIAA), in 1993, insurance payouts for radiology averaged $104,000, accounting for 6% of all medical malpractice claims paid.2,3 In a large malpractice database managed by PIAA reported from 1985 to 1995 (included approximately 130,000 cases), neoplasms of lung were cited as the sixth most common cause for medicolegal action against physicians. Approximately 45% of litigation resulting from missed lung cancer resulted in an indemnity payment, which averaged $150,000. The majority of medicolegal action regarding missed lung cancer involved chest radiographs (90%), whereas computed tomography (CT) and other studies attributed to the remaining 10%.4 In another study conducted by PIAA, radiologists were named as defendants in 40% of the cases (total of 218 patients) where a delay in diagnosis of lung cancer resulted in an indemnity payment. Throughout all specialties, a lack of communication with other physicians was observed in 10% of these cases; thus, the portion attributed to radiology might be even higher. Furthermore, the study reported that 39% of these patients had no initial symptoms of lung cancer, and that the most common diagnosis given to these patients was stage IV lung cancer.5 In a more recent study conducted by Schiff et al,6 lung cancer was listed as the third most frequently missed diagnosis, accounting for 3.9% of cases (pulmonary embolism and drug reaction or overdose were listed first and second place, respectively) among 583 physician-reported cases of diagnostic error. This was closely followed by colorectal cancer (3.3%) and breast cancer (3.1%). Furthermore, they reported that in a subgroup of major diagnostic errors (162 cases), 42% were related to radiology testing and 24% of these major diagnostic errors were the consequence of a failure or delay in considering the diagnosis. A study by Berlin et al, which focused on the prevalence and nature of malpractice litigation involving radiology over a 20-year period (1975-1994) in Cook County, IL, reported a 20-year average rate of 42% of the proportion of lawsuits claiming missed diagnosis to the total number of radiology-related cases. A look at the types of diagnoses missed (missed lung cancer, missed breast cancer, missed gastrointestinal lesions, and missed bone disease) showed that litigation related to missed bone disease accounted for the greatest percentage of cases of malpractice followed by breast and lung cancer. The rate for missed lung cancer reached a high in the years 1980-1984; this rate then decreased slightly and remained constant in the years 1985-1994.7,8

Reporting a missed radiologic diagnosis is a challenging task, which demonstrates both medicolegal and ethical dilemmas for the radiologists. Reports emphasize the importance of reporting missed diagnosis, both in written and oral form, by radiologists who discover a previous missed diagnosis committed either by themselves or by a colleague. Physicians who intentionally withhold reference to a previous...
missed finding not only violate the American College of Radiology standards of practice but also risk being sued for fraudulent concealment, and may conceivably be accused of unlawful conduct that could precipitate an investigation by their professional liability insurance carriers or state professional regulatory agencies. Potchen et al have stated that failure to detect a lung cancer under any conditions is considered negligent and refers to the phrase “res ipsa loquitur,” which means the facts speak for themselves. In other words, in their opinion, missed lung cancer on chest radiograph is sufficient evidence to count as negligence, without requiring someone to establish standards of care, and does not require an expert opinion in this setting. However, other evidence suggests that this is far too exacting a standard. In a study conducted by Muhm et al, 92 lung cancers were detected during a screening program using 4-month interval chest radiographs. Ninety percent of these lesions were visible in retrospect for months or even years. Interestingly, only 70% of the peripheral nodules (majority of nodules) were staged as American Joint Committee stage I lung cancer. Muhm et al further emphasized that it is difficult to detect abnormalities on chest radiographs and that some lesions will be overlooked even by an experienced radiologist with a high degree of suspicion. Thus, not all missed lung cancers represent a breach in standard of care and should not constitute negligence.

In the United States, a standard of negligence applies. For negligence to be shown, 3 elements are necessary: (1) a breach in the standard of care as defined by actions of a reasonable physician practicing in a prudent manner, (2) that the injury can be related to the breach in care, and (3) that substantial harm was caused. Most often, litigation centers on the first consideration. As breach of the standard of care is a subjective measure, litigation frequently becomes a contest between expert witnesses on opposing sides of the case. In general, an adverse medicolegal outcome is best correlated with high conspicuity of the overlooked lesion.

There have been several reports on how practice guidelines could potentially reduce the number of malpractice cases and costs associated with them. These practice guidelines are defined as “systematically developed statements to assist practitioners and patient decisions about appropriate health care for specific clinical circumstances.” In answering the question “Can practice guidelines influence malpractice?” Gar nick et al emphasizes 4 assumptions in developing these guidelines. They must be matched to legal claims, be widely accepted, integrated into clinical practice, and readily interpreted.

Missed Lung Cancer on Chest Radiography

The detection of solitary pulmonary nodules (SPNs) has increased because of widespread use of CT; nevertheless, chest radiographs remain the basic routine examination. Given that chest radiographic images are 2-dimensional projections of 3-dimensional structures, the early detection of lung cancer by means of chest radiography can be a challenging task. Projection of pulmonary vessels, bones, and parts of the mediastinum on lung fields may partially or completely obscure pulmonary nodules on chest radiography. As a result, the interpreting radiologist may fail to detect lung lesions.

In a lung cancer screening study by the National Cancer Institute in New York, chest radiography was found to be best in detecting peripheral adenocarcinomas of the lung, the most common type of lung carcinoma. Previous studies have described several factors attributing to overlooked lung cancer. Observer error is probably the most important factor. A study by Kundel et al describes 3 types of observer errors (scanning error, recognition error, and decision-making error.) Scanning error and recognition error (Figs. 1 and 2) are referred to as a failure to perceive an abnormality, and decision-making error (most common error) describes mistaking a true lesion as a normal structure (Figs. 3 and 4). Another form of observer error that may contribute to overlooked lung cancer is satisfaction error (Fig. 5). This error is the result of diversion of the radiologist’s attention from a tumor by an eye-catching, but unrelated, finding. Another factor that may affect observer performance is intentional under-reading, that is, a conscious tendency to interpret equivocal radiographic shadows as negative.
also play a critical role in overlooked lung cancer. These characteristics include lesion size, density, and shape. Lesion size appears to be the most important factor. Even though the human eye is capable of detecting a pulmonary nodule as small as 3 mm, it is often difficult to detect pulmonary nodules that are <1 cm in diameter. Early studies have reported detection rates of 40%-87% for 1-cm lesions on screen-film systems. More recent studies with digital radiography reported an average size of 1.6 cm for missed lung cancer. Austin et al noted a mean diameter of 1.6 cm (0.6-3.4 cm). Heelan et al reported a 1.3-cm mean diameter in their 51 cases of missed lung cancer detected later on routine screening.

In a recent study by White et al examining the role of computer-aided detection (CAD) on missed lung cancer, the average overlooked lesion size was 1.8 cm. It appears that replacement of traditional screen films by digital radiography and application of CAD software does not seem to have significantly improved the detection rates for lesions <1 cm. Image density also plays an important role in missed lung cancer. Factors like low lesion density (Fig. 6) and complexity of the structures surrounding the lesion contribute to missed lung cancer. The term “lesion conspicuity” is used to denote this concept. Lesion conspicuity can be viewed intuitively as the obviousness of the lesion. In addition to lesion density, the shape and margin characteristics of a lesion also contribute to missed lung cancer. Technical considerations, such as image quality and patient positioning and movement, also contribute to the likelihood of missing lung cancer. The quality of chest radiographs plays an essential and basic role in diagnosis of SPNs and improvement of their delectability rate. All chest radiographs should use a high-kilovoltage technique and antiscattered grids. Good positioning and exposure are also required. Chest radiographs should be checked routinely, immediately after processing, for technique and quality and should be repeated if necessary.

Several studies have investigated the effect of selenium-based digital radiography on detection of pulmonary nodules. A study by Awai et al, which compared selenium-based digital radiography with high-resolution storage phosphor radiography for the detection of SPNs without calcification, demonstrated that the selenium-based technique was superior to high-resolution storage phosphor radiography in detecting such nodules.

In 2003, Quekel et al reported a 20% rate of missed lung cancer on chest x-rays. Furthermore, they reported that providing clinical information or previous chest x-rays for purposes of comparison did not improve the observer perfor-
mance. Separate evaluation by 2 readers also did not improve the results significantly. Simultaneous interpretation improved the sensitivity slightly (from 28% to 37%), but did not affect the specificity significantly (decreased slightly from 93% to 92%).

Austin et al.\textsuperscript{23} emphasized the need to compare the current radiograph with multiple prior radiographs, rather than the most recent examination, as being important in diagnosis of lung cancer. In a study of successful malpractice actions for delay in diagnosis of lung cancer conducted by PIAA, a prior radiograph was not compared with current radiograph in 16% of patients in whom it was obtained.\textsuperscript{5} This finding emphasizes the importance of prior radiographs for delay in diagnosis of lung cancer from a malpractice standpoint.

Woodring et al.\textsuperscript{30} showed that factors such as calm environment and proper lighting can affect optimal interpretation of the radiographs. Another practical method to reduce missed lung cancer is to avoid satisfaction of search error. Detecting an initial abnormality should not prevent the radiologist to look for possible further lesions. There have been recent reports on the effect of a double-exposure dual-energy subtraction (DES) technique on diagnostic performance of radiologists for detecting small pulmonary nodules on flat-panel detector chest radiographs. Using DES, Oda et al.\textsuperscript{31} reported significant statistical improvement in detecting part-solid pulmonary nodules and also for nodules with overlapping bone shadows (Fig. 7).

A massive training artificial neural network is another tool whose use has been evaluated for improving the performance of the radiologists in detecting pulmonary nodules. Oda et al.\textsuperscript{32} demonstrated a significant improvement in the performance of radiologists in detection of pulmonary nodules by using the effect of rib suppression with a massive training artificial neural network.

Recent software technology has the potential to assist radiologists to decrease the frequency of overlooked lung cancer. Some of these tools include CAD and the localized receiver operating characteristic methods. Recent reports suggest that these techniques can improve detection rates of missed lung cancer on primary interpretation.\textsuperscript{25,33,34}

White et al.\textsuperscript{25} reported the potential of CAD to detect nodules at chest radiography that were overlooked on initial interpretation by radiologists (Fig. 8). CAD was able to detect nodules that were overlooked at initial interpretation on 47% of radiographs and in more than 50% of patients. Moreover, no clear difference was observed between nodules detected with or without CAD system; however, there was a trend toward higher detection rates in more subtle nodules as subjectively scored by 2 radiologists. There was also a significant difference in detection of pulmonary nodules based on lobar

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**Figure 4** (A) Missed lung cancer (arrow) on portable chest radiograph presumably because of decision-making and satisfaction of search errors. (B) Corresponding axial CT imaging of the same patient outlining the missed lesion.

**Figure 5** (A) Anteroposterior chest radiograph shows a nodule in lingula (arrow) that was presumably missed because of satisfaction of search error. (B) Corresponding axial CT imaging of the same patient.
location. A somewhat high rate of false-positive results remains one of the limitations of CAD systems. Seamless integration of CAD technology into the workflow is another important challenge for which considerable progress has been made.

A recent study by Freedman et al34 investigated the application of a specific visualization algorithm (localized receiver operating characteristic) in detecting pulmonary nodules that are obscured by bony structures such as clavicles and the ribs. As a result of this method, they reported an increase of 16.8% in sensitivity for lung cancer detection (from 49.3% unaided to 66.3% aided by the software). Several studies have demonstrated the application of dual-energy radiography to improve detection rates for noncalcified pulmonary nodules. MacMahon et al35 showed that application of temporal subtraction chest radiography in combination with DES, a less widely used method, can also be a helpful tool for the radiologists in detecting pulmonary nodules. Both dual-energy and temporal subtraction can improve image quality and furthermore be integrated into the CAD system to improve detection rates for missed pulmonary nodules. Finally, CT scan can also be useful by producing a soft-tissue image devoid of overlapping skeletal structures, rendering an underlying parenchymal lesion more visible.

Missed Lung Cancer on CT

The use of CT imaging allows a more uniform radiographic exposure. However, it is not clear that this innovation has reduced the frequency of missed lung cancer because it allows identification of smaller lung lesions, and these lesions may be overlooked. CT is often used to determine whether a subtle shadow found on chest radiography is a parenchymal nodule, as well as for numerous other reasons. Lesions can be overlooked in either instance. An important consideration with respect to chest CT is its use for early detection of lung cancer. Previously, chest radiography and sputum cytology have not demonstrated a convincing mortality benefit for lung cancer screening. As a result, CT screening for early detection of lung cancer has gained considerable attention. Over the past decade, there have been conflicting reports on the effectiveness of CT screening in early detection of lung cancer.

Figure 6 (A) PA chest radiograph shows a nodule (arrow) that was presumably missed because of low density with overlapping ribs. (B) Axial CT imaging of the same patient.

Figure 7 (A) PA chest radiograph imaging of a patient with missed pulmonary nodule (arrow) presumably because of overlap with rib and corresponding digital subtraction imaging with improved visualization of the lesion (B).
Lung cancer can be missed on either routine clinical imaging or chest CT screening protocols. In the clinical setting, missed lung cancer demonstrates a mixture of central and peripheral lesions. Small diameter nodules often are more associated with overlooked lung cancer in this setting. Naidich et al demonstrated that the average detection rates for nodules smaller than 7 mm, 4.5 mm, 3 mm, and 1.5 mm were 91%, 32%, 48%, and 1%, respectively, using simulated nodules. Distractions like aortic aneurysm and old tuberculous scarring can factor into missed lung cancer.

Malpractice cases involving missing lung cancer on chest CT are well demonstrated. One notable case involved a lawsuit in a patient with advanced lung cancer whose 8-mm left lower lobe lung lesion had been overlooked on a lung cancer screening CT scan. A settlement of $1,000,000 was made, of which the radiologist assumed 90%.

Missed lung cancer in association with chest CT screening protocols has been reported predominantly on lesions in peripheral location and early stage. A study by Li et al demonstrated that the bulk of misidentified lesions was stage IA. The average size on reported missed lesions was approximately 16 mm and often associated with severe underlying disease.

CAD software applications in assessing lung nodules on CT scan have been reported in several studies. In developing a clinically useful automated system for detection of pulmonary nodules, an increased true-positive rate and a decreased false-positive rate, with a sufficient balance between the 2 values, are necessary. A study by Awai et al showed that the use of the CAD system did not significantly enhance the diagnostic abilities of board-certified radiologists; however, it did have a significant positive effect on diagnostic capability of radiology residents. The ultimate goal is to develop a CAD system with a true-positive rate of 90% or greater and a false-positive rate of 0.1 or less. There are currently reports of true-positive rates ranging from 72% to 95% and false-positive results between 1.0 and 4.6 per CT quadrant or section with the CAD system. A recent study by Godoy et al evaluated the performance of CAD in a series of pathologically proven lung cancers, showed sensitivities of 87.7% and 95.4% for solid and semisolid lesions measuring ≥4 mm and ≥11 mm in size, respectively. CAD sensitivity was found to be affected by low nodule density; ground-glass nodules demonstrated sensitivity rates as low as 30%. Furthermore, they reported that lesions located peripherally were better detected with CAD than those in central or subpleural locations. Using thinner axial data (1-2 mm) leads to improved sensitivity of the CAD and decrease in false-positive rate. Thin-section CT, however, is associated with an increased amount of radiation exposure to the patients. Yuan et al investigated the performance of CAD system for pulmonary nodule detection using a low-dose (120 kVp, 80 mA) protocol with a 1.25-mm slice (thin slice) screening CT. They reported an increase in detection rate of pulmonary nodules by 21.2% when using CAD detection system in combination with thin-slice (1.25 mm) CT as compared with a medium-slice thickness (2.5 mm) CT imaging. CAD software can be applied as a second reader in detection of small pulmonary nodules. Preliminary recent reports of NLST outlined the significant advantage of CT in early detection of lung cancer. Application and integration of the CAD software with con-

**Figure 8** PA chest x-ray demonstrating 3 pulmonary nodules (circles) detected by computer-aided detection software, some of which could have been missed if not detected with computer-aided detection.
Conclusions

Lung cancer can be overlooked either on chest radiography or chest CT. Various factors contribute to the pitfalls of chest radiography and CT, but often these factors are very similar in nature. This can lead to medicolegal ramifications and litigation against radiologists. A variety of strategies can be directed toward minimizing missed lung cancer.

References


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