Computer-Aided Nodule Detection System:

Results in an Unselected Series of Consecutive Chest Radiographs

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Rationale and Objectives: To evaluate the performance of a computer-aided detection (CAD) system with bone suppression imaging when applied to unselected consecutive chest radiographs (CXRs) with computed tomography (CT) correlation.

Materials and Methods: This study included 586 consecutive patients with standard or portable CXRs who had a chest CT scan on the same day. Among the 586 CXRs, 438 had various abnormalities, including 46 CXRs with 66 lung nodules, and 148 CXRs had no significant abnormalities. A commercially available CAD system was applied to all 586 CXRs. True nodules and false positives (FPs) marked on CXRs by the CAD system were evaluated based on the corresponding chest CT findings.

Results: The CAD system marked 47 of 66 (71%) lung nodules in this consecutive series of CXRs. The mean FP rate per image was 1.3 across all 586 CXRs, with 1.5 FPs per image on the 438 abnormal CXRs and 0.8 FPs per image on the 148 normal CXRs. A total of 41% of the 752 FP marks were related to non-nodule pathologic findings.

Conclusions: A currently available CAD system marked 71% of radiologist-identified lung nodules in a large consecutive series of CXRs, and 41% of "false" marks were caused by pathologic findings.

Key Words: Lung nodule; lung abnormality; computer-aided detection (CAD); chest radiography (CXR); chest computed tomography (CT).

Potentially resectable lung cancers missed by radiologists on conventional chest radiographs (CXRs) in clinical practice are mostly located in the lung periphery and have a median diameter of about 20 mm (1,2). Even under the constrained conditions of an observer performance study, where observers are specifically focused on nodule detection, about 40% of all subtle cancers remain undetected by radiologists (2). However, advances in radiographic chest imaging such as dual–energy subtraction (DES), temporal subtraction, and computer-aided detection (CAD) have the potential to improve radiologists' performance in the detection of subtle, obscured, or otherwise potentially overlooked lung cancers (3–5).

Previous reports of a Food and Drug Administration–approved chest CAD system (OnGuard, Riverain Medical) applied to the detection of radiologist-missed lung cancers on CXRs described relatively low sensitivity and a high number of false-positive (FP) detections (35% sensitivity with 5.9 FPs per radiograph with OnGuard 1.0 [6] and 50% sensitivity with 3.9 FPs per radiograph with OnGuard 3.0 [7]). Over the past few years, however, newer versions of the same nodule detection system have achieved higher lung nodule detection sensitivities with markedly improved specificity compared to these earlier versions (8). This CAD system recently incorporated bone suppression imaging (BSI) (9–11), which, in addition to impacting CAD system performance, can improve radiologists' accuracy in the detection of lung nodules and discrimination between true-positive and FP CAD marks on CXRs (9–11) through direct visualization of the BSI images.

Until now, the performance of CAD systems applied to CXRs has been evaluated almost exclusively with small numbers of highly selected cases, which typically included a limited number of nodules in otherwise abnormality-free lungs (6–13). To simulate the effect of using CAD in routine clinical practice, this study investigated CXRs from patients with and without lung diseases in an otherwise unselected series. Rather than relying on the consensus of radiologists interpreting the CXRs as the "truth" for the CAD evaluation, another more sensitive and more specific imaging modality, computed tomography (CT), was used to verify the presence of nodules on each CXR.

MATERIALS AND METHODS

Chest Radiographs and Chest CT Scans

This retrospective study consisted of 586 consecutive patients (270 men and 316 women; median age, 59 years; age range,

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18–96 years) during a 6-month period who had a chest CT scan obtained on the same day as a standard posteroanterior (PA) CXR (n = 248) or portable anteroposterior (AP) CXR (n = 338) at the University of Chicago Medical Center. Among these 586 otherwise unselected patients, 50 patients had two or more CXRs on the same day as a CT scan; however, only the first CXR on the day of the CT scan was used in the present study. Standard PA radiographs were obtained using a computed radiography system (Fujifilm Medical Systems, Stamford, CT) at 110 kVp with a 10:1 antiscatter grid and variable milliamperes depending on patient size. Bedside portable radiographs were obtained using a computed radiography system (Fujifilm Medical Systems, Stamford, CT) at 110 kVp with an 8:1 antiscatter grid and variable milliamperes depending on patient size. The chest CT scans were obtained on 16- and 64-slice scanners, and reconstructed with contiguous 1- and 3-mm axial sections, as well as 10-mm overlapping maximum intensity axials, and 4-mm coronal and sagittal slab sections.

First, a research radiologist (F.L., combined research and clinical experience >15 years) reviewed all 586 CXRs along with their same-day chest CT scans and also reviewed radiology and pathology reports for these patients before applying the CAD system. Second, a chest radiologist (H.M., 39 years experience) reviewed the 586 CXRs together with the CT findings provided by the research radiologist. The nature of all abnormalities present on the CXRs and corresponding CT scans as noted by these two radiologists was recorded, along with whether an abnormality occupied >50% of the lung area as projected on the CXR. Subtlety ratings (from "extremely subtle" to "extremely obvious" on a 1–10 scale) were assessed for each lung nodule (if identified on the CXR with the CT scan as a reference) by consensus of the two radiologists. The bi-dimensional measurements of lung nodules on the CXRs were obtained through a computer interface by the research radiologist. The nodule exclusion criteria included the following: 1) calcified or scar-like opacities and 2) opacities that were visible on CT but completely invisible on CXR (even with prior CT-based knowledge of their presence and location) such as CT-detected micronodules, small nonsolid nodules, and faint nodules that projected over the mediastinum or diaphragm in the CXR.

CAD System

A newer nodule detection CAD system (ClearRead +Detect 5.2, formerly OnGuard, Riverain Technologies) with BSI (SoftView, version 2.4) was applied to all 586 CXRs. This system is a postacquisition software approach that uses image processing to simulate a bone image from a standard CXR and then uses the simulated bone image to form a BSI image. The details of the CAD system are proprietary, but it incorporates information from both standard CXR and BSI images. No operator-controlled adjustments are available for this system. The marks generated by the CAD system (circles of variable size) are shown on the standard image, and the radiologist can toggle to the BSI image (with or without CAD marks) to benefit from the appearance of the processed image. In this study, the CAD system was evaluated in a standalone manner.

The purpose of this CAD system is to identify noncalcified nodules that are visible (although sometimes subtle and potentially overlooked by radiologists) on CXRs; the system was not applied to the CT scans, which were only used by the authors in this study to confirm the presence or absence of nodules or other diseases in the CXRs. Thus, the CT scans were used to establish "truth" for the CXRs. Although most CT scans in this unselected series had various small opacities, CXRs are simply not sensitive enough to capture any visible signal for such abnormalities. The authors identified noncalcified nodules before application of the CAD system and thereby categorized marks subsequently generated by the CAD system as true positives or FPs. A calcified nodule or scar was considered an FP if marked by the CAD system.

Data Analysis

A lung nodule was considered as marked by the CAD system if its center (intersection of the length and width diameter segments that comprised the bi-dimensional measurements by the research radiologist) was manually determined to be located within the circular CAD mark. The CAD detection rate (sensitivity) was computed as the number of lung nodules with centers located inside the CAD marks divided by the total number of lung nodules. The CAD FP rate was calculated as the number of CAD marks determined to be FPs ("FP marks") divided by the total number of CXRs. FP marks were analyzed based on the main imaging findings located within the CAD mark; FP marks were classified into three groups as follows: 1) normal anatomic structure, 2) abnormal pathologic change, or 3) medical device.

An additional CAD detection metric was computed as the fraction of CXRs with at least one nodule marked by the CAD system. The corresponding CAD specificity metric was computed as the fraction of CXRs with no significant abnormality that had no CAD marks.

A chi-square test for independence was used to compare CAD FP rates 1) between standard PA CXRs and portable CXRs, 2) between CXRs with and without abnormal imaging findings, and 3) between CXRs with abnormal lung area <50% and ≥50% for the 586 CXRs.

Institutional review board approval was obtained, and the requirement for informed patient consent was waived. Our study was compliant with the Health Insurance Portability and Accountability Act.

RESULTS

Imaging Findings on Chest Radiographs and Chest CT Scans

Among the 586 consecutive patients, 148 patients (25%) had no significant abnormal findings, and 438 patients