Performance of trained radiographers in lung nodule detection: prospective comparison with experienced radiologists in lung cancer screening

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Purpose

A lung screening programme using low-dose CT (LDCT) requires a reading radiologist to dedicate a significant amount of time to the task. Should a national lung screening programme be launched, the number of radiologists reading lung screening CTs would - in terms of current working practices - need to increase, especially if the reading protocol involved more than one reader with consensus and arbitration, as is the case with many current or recently concluded lung cancer screening trials [1-4].

One possible method of circumventing the increase in radiologist-hours required for screening is to use radiographers as part of the CT reading process. The aim of this investigation was therefore to compare the performance of radiographers who had been given rudimentary training in CT lung nodule detection with radiologists in the UK Lung Screen (UKLS) trial.

Methods and Materials

Study design and case selection

The UK Lung Screen (UKLS) pilot trial is a randomised control trial that has been underway since 2011, randomising 4000 subjects (2000 in each arm) aged between 50 and 75 years to either screening with LDCT or no screening [5].

Over a 20-week period between November 2011 and April 2012, the LDCT studies of 290 consecutive participants in the LDCT arm of the UKLS were read prospectively for this study. All LDCT scans were performed at two participating sites.

Classification of nodules

Nodules were classified according to UKLS categories as summarised in Table 1 [5].
Table 1: UKLS categorisation of nodules.

**References:** Radiology, Royal Brompton Hospital - London/UK

A non-commercial database entry proforma (Artex VOF, Logiton, Netherlands) used for the UKLS study provided options for nodule categorisation, slice and segment location.

**LDCT reading by radiologists**

Each LDCT scan was read by a single thoracic radiologist at each of the two participating sites (Radiologist A at Site 1 and Radiologist B at Site 2). The scans were then transmitted to a central reading site for a second independent reading by Radiologist C.
A semi-automatic nodule segmentation package (Lungcare, Siemens Medical Solutions, Erlangen, Germany) was used for volumetric analysis. For pleural/ juxtapleural nodules or those with unreliable segmentation, maximal diameter was measured instead.

**Selection of reading radiographers**

Four radiographers were selected as readers. Radiographer 1 read scans at Local Site 1, and Radiographer 2 read scans at Local Site 2. Two radiographers (Radiographers 3 and 4) read scans at the central site. As such, each scan was read by two radiologists and between one and two radiographers (one local site radiographer and/or one central site radiographer).

All four radiographers had experience in thoracic CT scan acquisition, and had been trained and tested on 100 LDCT scans as part of a training evaluation study, using the same volumetric analysis software (Please see ECR 2013 Scientific Paper Control number 1964- "Feasibility of training radiographers to detect nodules in CT lung cancer screening").

**Reference standard**

Arbitration on discrepancies was provided at the central site by a thoracic radiologist with more than 20 years of experience, and the final consensus view was recorded on the database. All agreed category 2 to 4 nodules and intrapulmonary lymph nodes were considered positive in the reference standard.

**Classification of discrepancies**

For each LDCT study, a list of the consensus nodules and each reader's reading was generated. A nodule was considered to have been omitted by a reader if it was included in the reference standard but not recorded by that reader.

**Statistical analysis**

The sensitivity (the percentage of consensus nodules identified) and the average false-positive detection (FP) rate per case were calculated:

- for each reader, for all cases read by him or her;
- for each radiographer and radiologist within a particular radiographer-radiologist combination (10 combinations in total), taking into account only cases read by that combination, to enable direct comparison between that radiographer and radiologist (comparisons of sensitivity and average
FP rates performed using McNemar’s test and paired student's t-test, respectively); and

- for each reader in the first 10 weeks (P1), and compared to that in the second 10 weeks (P2) of the study (comparisons of sensitivity and average FP rates performed using the Chi-square test and independent samples student's t-test, respectively).

A p value of less than 0.05 was assumed to be statistically significant.

**Results**

**Reference standard**

Eighty-one (27.9%) of the 290 CT studies did not contain any nodules. The reference standard consisted of 599 nodules in the remaining 209 (72.1%) CT studies. Figure 1 illustrates the frequency of the number of reference standard nodules per scan. The majority of scans had one (74/209, 35.4%), two (48/209, 23.0%) or three (45/209, 21.5%) nodules. The median number of reference standard nodules per scan was one, with a range of 0 to 18 nodules.

567/599 (94.7%) of the reference standard nodules were solid. 260/599 (43.4%) nodules were Category 2, 135/599 (22.5%) were category 3, and 9/599 (1.5%) were Category 4. 195 nodules were classified as IPLNS (i.e. 34.4% of solid nodules, and 32.6% of the total number of reference nodules) (Figure 2).

**Overall performance of radiographers and radiologists**

Radiographers 1, 2, 3 and 4 had sensitivities of 67.6%, 77.8%, 79.4% and 61.6% respectively (mean sensitivity 71.6 ± 8.5%). Radiologists A, B and C had sensitivities of 88.9%, 87.0% and 74.0% (mean sensitivity 83.3 ± 8.1%).

The average FP rate per case for radiographers 1, 2, 3 and 4 were 1.2 ± 2.1, 2.9 ± 2.8, 0.6 ± 1.0 and 1.1 ± 1.3 respectively, while that of radiologists A, B and C were 0.5 ± 0.8, 0.7 ± 1.0 and 0.2 ± 0.5 respectively.

**Comparison of radiographer and radiologist performance**
The sensitivities of each radiographer compared to those of the corresponding radiologists within a particular radiographer-radiologist combination are illustrated in Figures 3-6. Radiographers 1 and 2 could only be compared with their corresponding local site radiologists (i.e. radiologists A and B respectively) and the central site radiologist (radiologist C). Radiographer sensitivity was significantly lower than radiologist sensitivity in 7 of 10 radiographer-radiologist combinations (range of difference, 9.7%-32.8%, p<0.05), and not significantly different in 3/10 combinations.

The average FP rates per case for each reader in each radiographer-radiologist combination are illustrated in Table 2. Radiographers had significantly higher false-positive rates than radiologists in 8/10 combinations (range of difference, 0.4-2.6, p<0.05), and there was no significant difference in the remaining two combinations.

![Table 2](image)

**Table 2**: Average false-positive detection (FP) rates per case for radiographers and radiologists in each radiographer-radiologist combination.

**References**: Radiology, Royal Brompton Hospital - London/UK

**Reader performance in P1 compared to P2**
The two radiographers with the lowest overall sensitivity (Radiographers 1 and 4) showed a significant improvement in sensitivity between P1 and P2 (sensitivity 50.0% in P1 versus 74.1% in P2 for Radiographer 1, 41.8% in P1 versus 67.2% in P2 for Radiographer 4, p<0.005), but their sensitivity in P2 still did not reach the level of Radiographers 2 and 3, who showed no significant difference in their sensitivity between the two periods. Radiologists' sensitivity did not significantly differ between the two periods.

No radiographer or radiologist demonstrated a significant difference in their average FP rates per case between the two periods. As such, the improved sensitivity of Radiographers 1 and 4 in P2 did not come at the expense of an increased average FP rate.

**Images for this section:**

![Frequency distribution of the number of nodules per CT study.](image)

**Fig. 1:** Frequency distribution of the number of nodules per CT study.
Fig. 2: Breakdown of reference nodules according to category and nodule type. Numbers within columns are absolute numbers of nodules.

Fig. 3: Sensitivity of radiographer 1 compared to Radiologists A (n=130) and C (n=130).
Fig. 4: Sensitivity of radiographer 2 compared to Radiologists B (n=139) and C (n=139).

Fig. 5: Sensitivity of radiographer 3 compared to Radiologists A (n=68), B (n=87) and C (n=155).
Fig. 6: Sensitivity of radiographer 4 compared to Radiologists A (n=64), B (n=49) and C (n=113).
Conclusion

The importance of a high rate of nodule detection—i.e. high sensitivity—is underscored by the fact that most failures in lung cancer diagnosis are due to errors of detection rather than interpretation [6,7]. Considering this in isolation, any CT screening programme would want readers with the highest possible sensitivity. In this context, data from our study suggests that radiographers cannot be considered ideal first readers for lung screening, since their performance in the majority of cases was statistically significantly lower than that of the radiologists.

However, a radiographer can act as an aid to nodule detection rather than a first reader, in the same way that computer-aided detection (CAD) does. The advantage of having a radiographer rather than a computer as a detection aid is that interaction and discussion regarding missed or incorrect findings is possible with the radiographer, whereas learning and "tuning" of a CAD system depends on artificial neural networks and algorithms that the radiologist is not privy to, and has no influence over.

Caution should always be exercised when comparing sensitivities between nodule detection studies, as differences in the method of reading, derivation and stringency of the reference standard [8], and in the types of patients undergoing CT scans (e.g. patients with multiple metastases versus lung screening studies) can profoundly affect sensitivity. Nevertheless, it is reassuring that the mean performance of the radiographers and radiologists in our study was comparable to radiologists in the published literature [9-15].

Intuitively, it might be expected that radiographers, who have no experience in pulmonary nodule evaluation, would tend to falsely interpret any abnormal pulmonary opacity as a pulmonary nodule, and so increase their false positive rates. As such, it is not surprising that in the majority of cases, radiographers had higher average false-positive rates than radiologists. However, these rates were comparable to, and for the majority of radiographers lower than, current CAD systems.

It is also noteworthy that the two radiographers with the lowest performance showed an improvement in their sensitivity between the first and second 10 weeks of the study, and perhaps more importantly that this increased sensitivity did not carry the penalty of an increased false-positive rate. It can be speculated that (a) the nodule detection ability of a radiographer relies on his or her inherent perceptual ability once some level of basic training has been provided, and (b) it may be possible to improve suboptimal sensitivity with time and reading experience, but this improvement will probably still be limited by the individual’s aforementioned inherent ability.
In summary, this study demonstrates that radiographers’ performance in lung nodule detection is comparable to radiologists in the published literature but lower than that of radiologists reading the same scans, and with higher false-positive rates. Radiographers are thus not sensitive enough to be used as first readers in CT lung screening.

References


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