European Journal of Radiology 84 (2015) 1012–1018

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

The value of digital tomosynthesis of the chest as a problem-solving tool for suspected pulmonary nodules and hilar lesions detected on chest radiography

Angela Galea[a,*], Paul Dubbins[b,1], Richard Riordan[b,1], Tarig Adlan[b,1], Carl Roobottom[b,1], David Gay[b,1]

[a] Peninsula Radiology Academy, William Prance Road, Plymouth PL65WR, UK
[b] Plymouth Hospital NHS Trust, Plymouth PL68DH, UK

ARTICLE INFO

Article history:
Received 2 June 2014
Received in revised form
28 November 2014
Accepted 9 February 2015

Keywords:
Digital tomosynthesis
Chest radiology
Lung nodules
Hilar lesions

ABSTRACT

Objectives: To assess the capability of digital tomosynthesis (DTS) of the chest compared to a postero-anterior (PA) and lateral chest radiograph (CXR) in the diagnosis of suspected but unconfirmed pulmonary nodules and hilar lesions detected on a CXR. Computed tomography (CT) was used as the reference standard.

Materials and method: 78 patients with suspected non-calcified pulmonary nodules or hilar lesions on their CXR were included in the study. Two radiologists, blinded to the history and CT, prospectively analysed the CXR (PA and lateral) and the DTS images using a picture archiving and communication workstation and were asked to designate one of two outcomes: true intrapulmonary lesion or false intrapulmonary lesion. A CT of the chest performed within 4 weeks of the CXR was used as the reference standard. Inter-observer agreement and time to report the modalities were calculated for CXR and DTS.

Results: There were 34 true lesions confirmed on CT, 12 were hilar lesions and 22 were peripheral nodules. Of the 44 false lesions, 37 lesions were artefactual or due to composite shadow and 7 lesions were real but extrapulmonary simulating non-calcified intrapulmonary lesions. The PA and lateral CXR correctly classified 39/78 (50%) of the lesions, this improved to 75/78 (96%) with DTS. The sensitivity and specificity was 0.65 and 0.39 for CXR and 0.91 and 1 for DTS. Based on the DTS images, readers correctly classified all the false lesions but missed 3/34 true lesions. Two of the missed lesions were hilar in location and one was a peripheral nodule. All three missed lesions were incorrectly classified on DTS as composite shadow.

Conclusions: DTS improves diagnostic confidence when compared to a repeat PA and lateral CXR in the diagnosis of both suspected hilar lesions and pulmonary nodules detected on CXR. DTS is able to exclude most peripheral pulmonary nodules but caution and further studies are needed to assess its ability to exclude hilar lesions.

1. Introduction

Despite the inferior performance of chest radiography (CXR) to computed tomography (CT) scanning it remains the initial examination for the majority of pulmonary disease due to its low cost, easy access and low radiation dose. Obvious pulmonary lesions detected on CXR clearly need further investigation and CT scanning is recommended. Chest radiography however has a low sensitivity and specificity for the detection of early lung cancer [1]. Lung cancer is the leading cause of cancer globally and is associated with poor outcome [2–4]. However the 2011 US National Lung Screening Trial demonstrated that early detection reduces mortality and emphasizes the need to detect early cancer [5]. Small pulmonary nodules carry a low risk of lung cancer but may require further investigation and often patients with lung nodules undergo CT scanning for evaluation. Alternative investigations, without the high cost or radiation dose of CT scanning that offer increased accuracy in pulmonary and hilar lesions suspicious for cancer would be useful in the investigation of pulmonary disease.

* Corresponding author. Tel.: +44 7800511681.
E-mail addresses: galeaangie@gmail.com (A. Galea), Paul.dubbins@nhs.net (P. Dubbins), richardriordan@nhs.net (R. Riordan), tarig.adlan@nhs.net (T. Adlan), carl.roobotoom@nhs.net (C. Roobottom), davegay@nhs.net (D. Gay).
[1] Tel.: +44 1752437437.

http://dx.doi.org/10.1016/j.ejrad.2015.02.007
0720-048X/

Table 1
The various indications for referral for a chest radiograph. Some patients were referred for more than one symptom.

Indication	In-patient *N* = number of patients	Out-patient *N* = number of patients
Cough	3	29
Shortness of breath	3	21
Chest pain	4	8
Infection	1	3
Arrythmia	2	2
Other (e.g. weight loss, arthritis)	4	10

A radiologist will frequently identify a small group of CXRs that are equivocal either because of an inability to correctly characterise a visualised abnormality as soft tissue or calcified and therefore likely benign or an inability to determine the location of the lesion as intra- or extrapulmonary. The radiologist may be unsure whether a lesion is real or composite especially if it lies in a region of heavy anatomical noise such as the lung hila or apices. Patients with equivocal CXRs due to one of the above findings were included in the study to assess the role of digital tomosynthesis (DTS) in confirming or excluding a potentially significant abnormality.

DTS is a type of limited angle tomography whereby about sixty low dose images are acquired over a limited range of X-ray tube movement in the cranio-caudal axis. The raw images are used to reconstruct contiguous coronal images in the antero-posterior axis through the area of interest. Tomosynthesis evolved from the technique of tomography, which was used to evaluate, inter alia the lung hila, the kidneys and the petrous temporal bones. Increasing concern about the patient dose from CT has resulted in a resurgence of interest in tomographic techniques such as tomosynthesis because of the associated low radiation dose.

Digital tomosynthesis reduces composite artefact due to anatomical noise by providing better depth resolution thus separating the structures in the antero-posterior dimension. DTS can correctly differentiate between lesions of the rib cage, pleurally based lesions and intrapulmonary lesions [6–13]. Improved contrast resolution of DTS when compared to CXR results in better calcium detection [13]. Advantages when compared to CT relate to cost and dose reduction.

The role of DTS in the evaluation of pulmonary nodules has been explored in previous studies [14–16]. In this study we chose a more pragmatic approach by assessing both non-calcified intrapulmonary nodules and hilar masses using CT as the gold standard. The purpose of this study is to assess whether DTS can be used instead of a repeat PA and lateral chest radiograph in the evaluation of an equivocal chest radiograph.

2. Method

2.1. Patients

The study was approved by the regional ethics committee. This was a single centre, prospective observational study. All inpatients and outpatients with an equivocal finding on chest radiograph were included. The indications for the initial chest radiograph were varied so as to simulate clinical practice and are shown in Table 1. All patients included in the study consented to have a repeat PA and lateral CXR, a DTS and a CT chest within 4 weeks of their initial CXR.

2.2. Digital tomosynthesis

A General Electric (GE, Buc, France) VolumeRAD system with a high-quality digital detector with rapid read-out was used, which relies on the GE Definium 8000 digital X-ray system to acquire the projection images necessary for tomosynthesis reconstruction. A scout image of the chest is first obtained to confirm a correct position. The patient is then instructed to hold his/her breath for 10 s whilst 60 discrete images are acquired over an angular range of 35° to produce 50–60 coronal reconstructions of the chest. The tube voltage was set at 120 kVp. Each raw image delivers an average effective dose of 2 μSv resulting in a cumulative effective dose of 0.15 mSv for the average 70 kg male patient (this effective dose includes both the scout and raw images).

2.3. Computed tomography

The CT examinations were performed using a 64 slice multidetector (HD750, GE Healthcare) scanner. The scan parameters used were: a set noise index of 39.68; 120 kV and a range of 100–750 mA. The CT slice thickness was 0.625 mm for all patients. The effective dose (based on an unenhanced scan) was calculated using a conversion factor from dose–length product (DLP) to E (E_{DLP}) of 0.017 mSv/(mGy cm) and was 4 mSv[17].

Thirty-two patients with suspected hilar lesions were scanned following an additional 100 mL intravenous bolus injection of iodinated contrast at a rate of 3.5 mL/s. All other patients had an unenhanced scan of the chest.

2.4. Image interpretation

A nodule was defined according to the Fleischner Society Glossary of Terms as a rounded opacity, well or poorly defined measuring up to 3 cm in diameter [18]. A hilar lesion for the purpose of this study was defined as a lesion of any size but within 3 cm of the hilar point measured in the coronal/antero-posterior (AP) direction. Hilar lesions included hilar carcinomas, lung nodules within 3 cm of the hilar point and hilar adenopathy. The hilar point is formed as the descending superior pulmonary vein crosses anterior to the interlobar pulmonary artery [19,20].

2.5. Data analysis

Three radiologists with 30, 15 and 10 years experience participated in the study. Two radiologists with 30 and 10 years experience (reviewers 1 and 2) blinded to the patient history evaluated two series for each patient; one series contained a PA and lateral CXR whereas the second series contained a DTS of the chest. The series were randomly allocated with 4 weeks between each series to minimise recall bias. The time to report both series was recorded. For those patients with more than one lesion detected on their CXR and DTS only the most obvious abnormality that was initially raised as equivocal on their index CXR was analysed. All other incidental abnormalities were not included in the analysis.

The readers were instructed to classify all intrapulmonary non-calcified peripheral nodules and hilar lesions as true lesions. Artefactual, calcified, pleural or extrapulmonary lesions were classified as false lesions as shown in Table 2. Readers were allowed to use processing tools such as windowing and zooming as they would in clinical practice. When there was a discrepancy amongst the readers, a third reader with 15 years experience was asked to arbitrate the findings.

The CT images were analysed by a 4th radiologist with 6 years experience. 0.625 mm CT axial slices, 5 mm maximum intensity projection (MIP) axial, coronal and sagittal CT reformats were used to maximise lesion detection. The axial images were used to measure the largest diameter of the detected lesion for analysis. Coronal CT images were reconstructed for all lesions detected on CT and these were compared subjectively to the CXR and DTS findings. Any lesions detected on CXR and DTS were correlated with the reference standard CT into true positive and negative and false positive and