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Sensitivity of Thoracic Digital Tomosynthesis (DTS) for the Identification of Lung Nodules

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Abstract Thoracic computed tomography (CT) is considered the gold standard for detection lung pathology, yet its efficacy as a screening tool in regards to cost and radiation dose continues to evolve. Chest radiography (CXR) remains a useful and ubiquitous tool for detection and characterization of pulmonary pathology, but reduced sensitivity and specificity compared to CT. This prospective, blinded study compares the sensitivity of digital tomosynthesis (DTS), to that of CT and CXR for the identification and characterization of lung nodules. Ninety-five outpatients received a posteroanterior (PA) and lateral CXR, DTS, and chest CT at one care episode. The CXR and DTS studies were independently interpreted by three thoracic radiologists. The CT studies were used as the gold standard and read by a fourth thoracic radiologist. Nodules were characterized by presence, location, size, and composition. The agreement between observers and the effective radiation dose for each modality was objectively calculated. One hundred forty-five nodules of greatest diameter larger than 4 mm and 215 nodules less than 4 mm were identified by CT. DTS identified significantly more >4 mm nodules than CXR (DTS 32 % vs. CXR 17 %). CXR and DTS showed no significant difference in the ability to identify the smaller nodules or central nodules within 3 cm of the hilum. DTS outperformed CXR in identifying pleural nodules and those nodules located greater than 3 cm from the hilum. Average radiation dose for CXR, DTS, and CT were 0.10, 0.21, and 6.8 mSv, respectively. Thoracic digital tomosynthesis requires significantly less radiation dose than CT and nearly doubles the sensitivity of that of CXR for the identification of lung nodules greater than 4 mm. However, sensitivity and specificity for detection and characterization of lung nodules remains substantially less than CT. The apparent benefits over CXR, low cost, rapid acquisition, and minimal radiation dose of thoracic DTS suggest that it may be a useful procedure. Work-up of a newly diagnosed nodule will likely require CT, given its superior cross-sectional characterization. Further investigation of DTS as a diagnostic, screening, and surveillance tool is warranted.

Keywords Digital tomosynthesis · Thoracic imaging · CT · Radiography · Pulmonary nodule · Chest

Background

The death rate for lung and bronchus cancer is currently higher than that of any other cancer among both men and women, accounting for 31 and 26 % of cancer deaths, respectively [1]. Metastases from many primary malignancies of other organs are also commonly found in the lungs. Thoracic computed tomography (CT) is considered the "gold standard" for nodule detection, given the current state of the art in imaging modalities for lung pathology. However, compared with standard chest radiography (CXR), CT is significantly more costly and even low-dose CT requires a higher radiation dose. While CXR continues to be commonly used as a tool in the evaluation of thoracic

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disease, it has a reduced sensitivity as compared with CT. For example, Henschke found that lung cancer (non-calcified lesions) was three times more likely to be identified on low-dose chest CT than with chest radiography [2]. This sensitivity loss is due in part to the superimposition of lesions on other structures such as the diaphragm, heart, ribs, and mediastinum as well as the greater ability of CT to accurately distinguish and quantify density of lesions. Accordingly, an imaging modality with a cost and radiation dose similar to that of chest x-ray, the ability to alleviate the problem of superimposition, and a sensitivity equivalent to that of chest CT would contribute to a more timely diagnosis of lesions within the lungs. Earlier diagnosis would, in turn, enable earlier intervention, thus potentially increasing survival rates.

Henschke and the Early Lung Cancer Action Program (ELCAP) reported in 2006 on the survival rates of Stage I lung cancer as detected by CT [3]. They concluded that "annual spiral CT scanning can detect lung cancer that is curable." Results from more recent large screening trials such as the National Lung Screening Trial have contributed to our current knowledge on the risk of lung cancer and have proven that there can be a benefit to overall survival in some high-risk populations [4]. Furthermore, these trials have clarified our understanding of the importance of nodule size and other morphological characteristics [5]. The implication is clear: a validated test of high sensitivity, high specificity, low cost, and low radiation dose—a test that is currently lacking—would be potentially useful in clinical practice and management of disease.

Digital tomosynthesis (DTS) is a mathematical technique by which tomographic planes are reconstructed using multiple projections of an object obtained at differing angles. DTS images appear similar to traditional mechanical tomograms; however, as a digital process, tomosynthesis creates an entire 3D field using a set of images detected from one curvilinear pass of an x-ray tube. The multiple images received on one stationary detector are digitally processed and the results are displayed in coronal sections comparable to CT reconstructions, but with higher resolution images than CT and with the qualities of a digital radiograph. Research for this modality began more than 30 years ago and has since moved from the experimental stage to one of clinically significant uses [6]. The most significant improvements in DTS have been realized with recent advances in digital detector technology, allowing multiple rapidly acquired projections at high resolution. The utility of this technique has been demonstrated for source localization in brachytherapy, orthopedic hardware visualization, and dental imaging, as well as being an exciting new technique in mammographic imaging, especially when coupled with PET. For thoracic imaging, full-size 17×17 in. digital tomographic radiography equipment is relatively new, creating thin-section coronal tomographic images that can be displayed and read on a PACS workstation. Although DTS equipment is available for clinical practice, there is little existing research available to demonstrate the sensitivity, specificity, and utility of this technique.

Vikgren and colleagues reported on the sensitivity and specificity of DTS as compared with CXR in a similar study completed in 2008 [7]. Analyzing 80 clinically relevant nodules greater than 4 mm, along with 51 smaller nodules, they found that DTS was 56 % sensitive while CXR found only 17 % of the nodules [7]. In a retrospective analysis, 92 and 28 % of the nodules could be visualized on DTS and CXR, respectively [7]. Of note, observers in the study had 6 months of clinical experience with thoracic DTS imaging [7]. The same group analyzed the effective radiation dose of DTS using the Monte Carlo technique and a standardized phantom and found that the technique offers considerably less dose then CT for similar sensitivity [8].

The aim of the current study was to determine sensitivity and specificity data for DTS imaging of the chest, specifically regarding its ability to identify and further characterize lung nodules. The nodules found by CXR, DTS, and the gold standard, CT, were recorded and analyzed based on size, type, composition, and location within the chest. The study was designed to test four hypotheses:

1. The sensitivity of DTS for the identification of lung nodules is clinically superior to that of standard PA and lateral CXR.
2. The increased sensitivity of DTS when compared to that of CXR is more apparent for small nodules and for nodules in those locations of the chest in which anatomical superimposition obscures the lung field on a standard chest radiograph.
3. The sensitivity of chest DTS for the identification of lung nodules greater than 4 mm is clinically equivalent to that of CT.
4. The sensitivity and specificity of DTS to detect calcifications in nodules is superior to CXR and similar to CT.

Materials and Methods

The IRB approved study enrolled 95 patients scheduled to receive a PA and lateral CXR and chest CT for a clinical indication, including potential malignancy. Those patients who were unwilling to give consent, physically unable to endure the radiological studies, pregnant or suspected to be pregnant, and less than 18 years of age were excluded from the

study. After the data were analyzed, it was decided to also exclude those patients with more than 20 pulmonary nodules seen on chest CT or excessive disease in order to facilitate accurate correlation between nodules from one imaging modality to the next.

A DTS imaging study was added to each patient's scheduled exams within their respective single-care episode (no greater than 4 weeks between exams). The CXR and DTS exams were performed on the same imaging equipment (General Electric Definium 8000 Chest System). It should be noted that there is some setup required when switching between standard CXR and DTS imaging at our institution, due to differences in x-ray tube to image detector distance. Acquiring the DTS images takes less than 10 s, during which time the patient is required to hold his or her breath. The DTS acquisition was set at a slice thickness of 5 mm, a sampling factor of 1, and a dose mode of 10X. The data processing was left at its default settings: Look:Custom1:MOD3DVR, contrast adjust 130 %, brightness adjust 155 %, tissue contrast 0.1, and edge of 1-. The CT was performed with our institution's standard lung CT protocol and interpreted by the board-certified radiologist designated on the clinical schedule.

The DTS studies were de-identified and their order randomized. They were then analyzed by board-certified radiologists and lesions were categorized by the following: presence, size, shape, composition, and location. The largest dimension of each lesion was recorded and composition data included specifically whether or not the lesion was calcified. Similar to another work, the location of the lesion was reported by lobe and distance from the hilum [9]. The presence of several other common chest radiograph and CT findings such as atelectasis, emphysema, pulmonary venous hypertension, enlarged pulmonary arteries, hyperinflation, and adenopathy were also recorded as simply "yes" or "no" entities.

The study included three experimental arms: a PA and lateral CXR, a DTS exam, and a CT. Independent, blind, and randomized interpretations of chest radiographs and DTS images were completed by three board-certified radiologists proficient with CXR and new to DTS imaging. CT served as the control arm of the study. Each CT study was read by a fourth board-certified radiologist who was unblinded to the results of the CXR and DTS data, as well as the clinical history. This fourth analysis served as a consensus read for comparison purposes between each modality.

Sensitivity was estimated on a per nodule basis (considering each nodule within a patient as an independent observation). Specificity was estimated on per patient basis. Estimates of sensitivity for radiography and DTS were compared using McNemar's test, a test of paired proportions. Comparison between the estimates of sensitivities for radiography and DTS among the true negatives were also made using McNemar's test. A p value less than 0.05 was considered statistically significant. Among the true positive nodules, univariate and multivariable logistic regression with findings from DTS (yes, no) as a response variable was used to assess the association with lesion size, location, and composition determined by CT as potential predictor variables. Agreement of findings among the three readers regarding presence or absence of a nodule was estimated using kappa statistic for radiography and DTS separately.

As a companion study to nodule identification, the effective radiation dose for each CXR and DTS was objectively calculated by calculating the dose area product. As established by the National Radiological Protection Board, the effective dose conversion factor from the dose area product is 0.22 and 0.14 for PA and lateral CXR, respectively [10]. Similarly, 0.014 was used as the conversion factor for effective dose from dose length product ratio for each CT acquisition as established by the American Association of Physicists in Medicine [11].

Results

Of the 95 enrolled participants, 13 were excluded leaving the results for 82 individuals to be analyzed. There were 11 studies in which no nodules were found. DTS and CXR each correctly identified two of these studies for a specificity of 18.2 %. Three hundred sixty nodules were found among the remaining participants. Using 4 mm as the cutoff, 145 of the nodules found were clinically relevant [12]. Another 215 nodules were identified that measured less than 4 mm in diameter. Figure 1 shows the sensitivity data for DTS and CXR by nodule size.

DTS outperformed CXR for clinically significant nodules greater than 4 mm; its sensitivity was 32 % as compared to 17 % (p value <0.001). DTS continued to outperform CXR as the nodules increased in size up to 1 cm in diameter. Given the statistical significance and adequate number of nodules, the remainder of the analysis was completed on only the clinically relevant nodules greater than 4 mm. To more fully understand

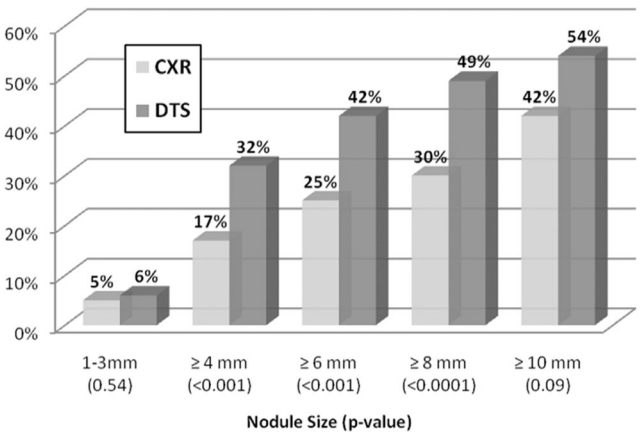

Fig. 1 Sensitivity (y-axis) of DTS and CXR for identification of lung nodules grouped by nodule diameter (x-axis). The p value for each comparison is in *parenthesis*

the underlying benefits and limitations of DTS according to location, the sensitivity results were divided into their respective lobes and distance from the hilum (Table 1).

DTS showed more than double the sensitivity of CXR in the right upper lobe (RUL), right middle lobe (RML), and left lower lobe (LLL). The increase in sensitivity was the least apparent in the right lower lobe (RLL). Regarding the distance from the hilum, there was no significant difference between the two modalities for nodules within 3 cm of the hilum (study included only nine nodules in this region). DTS outperformed CXR in those nodules abutting the pleura and those located within the periphery. The composition of each nodule was documented on the radiologist data sheet as either calcified, solid/soft tissue, ground glass opacity/subsolid, mixed/semi-solid, or indeterminate. For the purpose of analysis, these results were reported as either calcified, or non-calcified. CT revealed that 25 of the 145 nodules greater than 4 mm were calcified. The sensitivity of CXR and DTS by composition is also reported in Table 1. Both modalities were more sensitive for calcified than for non-calcified nodules. The advantage of DTS was slightly more apparent for non-calcified nodules. The sensitivity of each modality to classify the calcification in identified nodules was also investigated (Table 2). Only true positives were included. Accordingly, the number that was available to analyze was low. There was not a significant difference between the ability of CXR and DTS to correctly characterize the nodule composition.

Table 1 Sensitivity of DTS and CXR for identification of lung nodules greater than 4 mm in diameter grouped by their respective lung lobe, distance from the hilum, and composition. The "% increase" represents the sensitivity advantage of DTS over that of CXR. The *p* value for each comparison is listed in the last column

	Nodules	DTS (%)	CXR (%)	% Increase	*p* value
Lobe					
RUL	41	26	10	160	0.0001
RML	11	39	18	117	0.04
RLL	39	37	25	48	0.049
LUL	21	37	22	68	0.049
LLL	33	27	13	108	0.004
Total	145	32	17	88	<0.001
Centrality					
Abuts hilum	5	0	20	NA	0.25
<3 cm	4	8	0	NA	1
>3 cm	111	32	16	100	<0.001
Abuts pleura	25	39	24	63	0.027
Total	145	32	17	88	<0.001
Composition					
Calcified	25	41	24	71	0.011
Non-Calcified	120	30	16	88	<0.0001
Total	145	32	17	88	<0.001

Table 2 Sensitivity of DTS and CXR for characterization of lung nodule composition for nodules greater than 4 mm. Only those nodules that were identified by each modality were included (reflection of overall sensitivity)

Composition	DTS		CXR	
	Nodules	Correct (%)	Nodules	Correct (%)
Calcified	10	83	6	63
Non-calcified	36	88	19	89

The sensitivities reported in Tables 1 and 2 indirectly correlate to false negatives. The false positives results were investigated separately and are tabulated in Table 3 by composition, as determined by each modality. Chest x-ray had a total of 53 false positives reported over the 246 studies read; DTS recorded 23.

When the three observers disagreed, an attempt was made at comparing their data using a kappa statistic (Table 4). There was substantial agreement between the observers when reading DTS studies, and fair to moderate agreement for CXR.

The additional findings data is binary in nature, recording simply the presence or absence of a finding as determined by CT. The number of positive findings was low and accordingly reduced the power of the results. CT reported emphysema in 18 of the 82 participants. CXR was 3.5 % sensitive to these findings while DTS identified 6.9 %. DTS had a slightly higher false positive rate with a positive predictive value (PPV) of 57 % as compared to 66 % in CXR. There were 35 studies that demonstrated linear atelectasis or fibrosis on CT. DTS and CXR correctly identified 55 and 41 % of these, respectively. The two modalities had a similar PPV, near 53 %. Pulmonary venous hypertension was only present in 1 of the 82 participants. All observers correctly identified this participant in both modalities. The PPV was similar at 23 and 19 %. DTS and CXR performed almost identically in identifying enlarged pulmonary arteries. With 15 participants having enlarged pulmonary arteries as reported by CT, both modalities had a sensitivity of 13 % and PPV of 75 %. Adenopathy was identified by CT in only five studies. DTS had a sensitivity of 20 % and CXR 13 %, with similar PPV near 28 %. The last finding analyzed was hyperinflation. This is traditionally recorded only by CXR and therefore as such

Table 3 False positive nodules reported for each modality. This includes the total false positives for all 82 patients across three observers (246 studies)

Composition	DTS	CXR
Calcified	2	9
Non-Calcified	21	44
Total	23	53

Table 4 Kappa statistics for agreement between the three observers in the study. There was substantial agreement between the three observers when reading DTS studies. The agreement of the CXR data was fair to moderate

Reviewers	DTS	CXR
Agreement of 1 and 2	0.54 (0.41, 0.66)	0.39 (0.23, 0.56)
Agreement of 1 and 3	0.52 (0.40, 0.63)	0.23 (0.09, 0.37)
Agreement of 2 and 3	0.56 (0.45, 0.67)	0.39 (0.25, 0.54)

was not assessed by CT. DTS reported hyperinflation at only 25 % of the frequency of CXR.

The effective dose for each single study was calculated and then averaged across modalities. The mean effective doses for CXR, DTS, and CT were 0.10 (range of 0.03–0.54), 0.21 (0.10–0.81), and 6.8 (3.9–12) mSv, respectively. The mean ratio of DTS to CXR was 2.4, and CT to DTS was 37.

Discussion

DTS's performance was superior to that of CXR throughout the study. Specifically, DTS was 88 % more sensitive than CXR for clinically relevant nodules. This increased sensitivity was equally apparent for smaller nodules or for those nodules in locations prone to superimposition. The ability of DTS to detect calcification was no greater than that of CXR. Unfortunately, given their respective sensitivities, the number of nodules to analyze for composition purposes was low in both DTS and CXR. As expected, neither modality approached the sensitivity or specificity of CT for identification or characterization of lung nodules.

Thirteen participants were excluded from the study. The first seven exclusions were noncompliant to the study protocol: CTs that did not traverse the entire lung, missing studies, and studies that were separated by more than 4 weeks. The remaining six participants were excluded because they were found to have numerous nodules at data collection (>20). Interestingly, adding these cases to the study would have significantly increased the sensitivity of DTS. One patient in particular had multiple, diffuse, bilateral calcified granulomas measuring between 2 and 4 mm in diameter. All three observing radiologists read the CXR as negative, yet the DTS study revealed between 40 and 80 granulomas—too numerous to count (Fig. 2a). DTS and CXR studies with significant artifact were included in the study. The bases of the lung with DTS are partially obscured by reconstruction artifacts of the abdominal contents. Similar artifacts were also apparent with foreign bodies such as defibrillators within the chest. Given the angle at which the original images are captured, even a small artifact will project through the entire chest and obscure the lung fields. Motion artifact was also apparent in some studies.

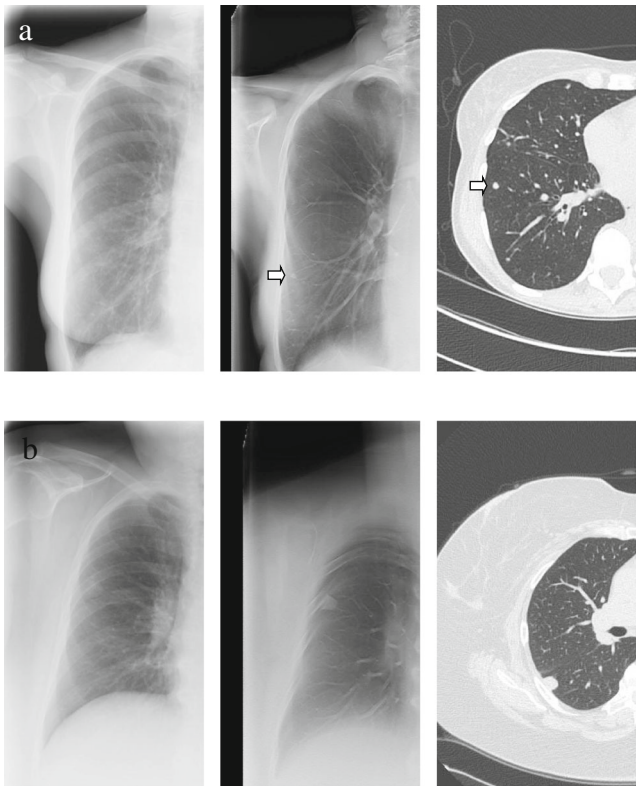

Fig. 2 **a** DTS and CT image demonstrating multiple nodules throughout the lung (*arrowheads* show one nodule). The CXR on the far left was read as negative. **b** CXR, DTS image, and CT image demonstrating a pleural nodule in the superior segment of the RLL that abuts the major fissure and chest wall

The increase in sensitivity of DTS peaked at the 4-mm nodule size and then waned as the size of the nodules approached 1 cm. At 1 cm and above, DTS held no significant advantage. It was assumed that the sensitivity of DTS would be greater in regions more prone to superimposition on a PA CXR, such as the LLL. While this was not perfectly confirmed in the data there were likely multiple factors at play. The lung bases were obscured by diaphragm artifact. Thus, the decreased sensitivity in the RLL was anticipated. This was not reflected in the numbers for the LLL. It is possible that the advantage in sensitivity in the LLL due to improved retrocardiac resolution balanced the basal sensitivity loss. It is also possible that these results were all affected by the centrality of the nodules within the study population for each lobe, as the data shows that sensitivity near the hilum was not ideal for either modality. Pleural nodules were much better characterized by DTS, both by the data and anecdotally across the three observers. Figure 2b demonstrates a pleural nodule abutting the major fissure in the superior segment of the RLL.

DTS did not demonstrate improved soft tissue resolution over that of CXR, with DTS and CXR both correctly characterizing over 80 % of those nodules that were identified. This was examined by assessing the ability of each modality to identify calcification. While there was no significant

difference between the abilities of the modalities to characterize nodules, the composition did have an effect on sensitivity. Both modalities were better able to identify nodules that were calcified, and DTS showed a slight advantage in identifying non-calcified lesions. This is likely again due to the reduced influence of superimposing structures on subtle lesions. Accordingly, the majority of the false positive nodules throughout the study were classified as non-calcified, most likely a result of their subtle appearance.

Additional findings from the study serve to illuminate clinical relevance and suggest directions for future investigation. DTS performed slightly better than CXR in identifying emphysema and linear atelectasis, and performed almost identically for adenopathy and the size of the vessels within the lung. The ability to call hyperinflation on DTS was less than that of CXR and likely due to the segmental display of the lung, as the in-focus plane includes only a specific portion of the data. Anecdotally, the three observers remarked that while they still tend to under-call findings such as emphysema and fibrosis with DTS as compared to CT, the ability to characterize the parenchyma and associated pathology with DTS is superior to that of CXR. DTS was also superior to CXR for the characterization of musculoskeletal (MSK) lesions. The depth of field especially helped identify rib lesions. Unsurprisingly, the observers found that adenopathy and soft tissue resolution with DTS was much inferior to that of CT.

Despite the novelty of the DTS modality at our institution, the correlation between the results of the three observers was substantial. This speaks to the intuitiveness of the displayed results; namely, a stack of digital CXR quality images in the coronal plane that can be scrolled through on a standard PACS workstation.

The radiation dose results from the study were as expected—and encouraging. While DTS doubles the dose of that of a PA and Lat CXR combined, it is still 37 times less than that of the radiation dose received during the thoracic CT. The minimal dose increase seems acceptable given the distinct increment in clinically relevant information.

The study was limited in various respects. The patient population, by design, had a low number of negatives. As a result, the specificity data lacks power. Similarly, each modality's sensitivity limited the number of true positives. Accordingly, the ability to analyze nodule density characterization data was restricted. The study also only imaged each participant once. As a result, the reproducibility of nodule measurements was not assessed. This may be an important aspect of lung nodule surveillance over time and a promising area for future research. In addition, there is some slice-to-slice blurring and projection overlap even on the "slices" of a reconstructed DTS that make the specific nodule morphology and density characteristics less precise than CT where edge characteristics and internal structure/density are exquisitely demonstrated and calibrated to actual density with Houndsfield units. Therefore, DTS can be considered superior to CXR for detection and perhaps some characterization, but CT would be required for accurate morphological assessment or densitometry of a nodule. Thus, we would not consider DTS to be a replacement of CT for this and as with CXR, CT would likely be needed for further characterization. The characterization of other lung pathologies was anecdotally superior to the abilities of CXR, although the current study was not designed to capture data on a level significant enough for objective analysis.

No ground glass density nodules were identified in the study population. Given the imaging characteristics and appearance of other abnormalities, it is likely that larger ground glass and subsolid nodules would be apparent. Some phantom studies performed elsewhere also confirm this, but it appears that detection sensitivity for predominantly ground glass density and smaller nodules is less than CT (but greater than radiography). DTS is clearly not as good at characterization of density as CT. Significant calcification in a nodule can be seen, but the specific degree of soft tissue vs. subsolid vs. ground glass is not as apparent in DTS [13].

Other areas of research that will be important to clinical utility include a cost analysis and efficiency study. The cost of DTS is expected to be less than that of CT and roughly equivalent to that of CXR. The clinical throughput for DTS was anecdotally faster than that of CT and similar to CXR; however, the data processing for DTS following each study took a moderate amount of time. The time needed to analytically read each of the modalities will be of significance as well. It is expected that with the increased size and quality of the DTS data set, the time needed to read a study will fall somewhere between that of CXR and CT; this warrants further study. Along these lines, it should be noted that the Centers for Medicare and Medicaid Services (CMS) has recently issued a national coverage determination (NCD) for Medicare coverage of screening for lung cancer with low-dose computed tomography (LDCT) based on the evidence that LDCT can reduce overall mortality in a high-risk population. A standard chest radiograph does not reduce overall mortality. DTS might be considered as an alternative to CXR at reduced cost and radiation dose to CT since it appears more sensitive than CXR. However, there are several potential issues. Firstly, it is unclear if DTS could fill a role or have performance similar to LDCT for screening purposes since large-scale use of DTS in a screening setting has not been studied. Also, the reimbursement of thoracic DTS for screening purposes is not approved by CMS and generally not at the same level as CT by third-party payers even though the technology is a bit more expensive than a typical digital chest x-ray modality and the interpretation process is considerably more time consuming than a 2-view chest x-ray. Finally, advances in CT technology in the last few years have allowed for improved image quality at lower dose than previously achievable. These advances include improved detector technology in the CT scanners,

scanners that automatically adjust the x-ray dose based on patient size and the anatomy being imaged, the use of lower energy x-rays, special x-ray filters made of tin or other materials, and more sophisticated mathematical algorithms to build the CT images. Now, a "low dose" chest CT can be performed with 5–10 times less radiation than a typical scan 10 years ago. A low-dose chest CT can be around 1–2 mSv. With other advances currently in development by CT manufacturers, it is likely in the near future that a chest CT might be acquired with a dose nearly equivalent to a standard radiograph. Specifically, with ultra-low-dose chest CT currently under development combining a flat tin filter with new detector technology and the latest reconstruction techniques a next-generation CT scanner is able to make diagnostic images with a mere 0.06-mSv effective dose [14].

Overall, the specific role that DTS imaging will have in clinical practice is yet to be determined. This study revealed that the sensitivity is greater than that of CXR, with a radiation dose much less than that of CT, but the clinical impact of these improvements is unknown. It is not apparent that this level of increased sensitivity over CXR justifies the consideration of a general screening program using DTS. However, those patients who are currently being followed by chest x-ray alone could benefit by a solution with many CT-like benefits at less dose. The reproducibility of nodule measurements over time has not been assessed. The role of CT and the interplay between DTS and CT also poses a clinical dilemma. Additional imaging beyond that of CXR could advance immediately to CT, although, for some problem-solving situations, such as further characterization of bony abnormalities or localizing known abnormalities found on CXR, progression to DTS would already be warranted. Going forward, the major role of DTS imaging will likely be an alternative primary imaging study to CXR.

Conclusions

Thoracic digital tomosynthesis has the potential to provide a practical method for thoracic imaging at a higher sensitivity for lung lesions as compared to traditional radiography, with a minimal increase in radiation, exam time, and cost. This technique has the potential to provide earlier diagnosis of lung lesions in patients who would not typically go to CT for initial work-up and therefore could significantly decrease the radiation dose for screening, follow-up, and surveillance in patients at high risk for or with known pulmonary disease. However, the specific role of DTS in clinical imaging has yet to be determined. DTS allows for better visualization through reduction in overlap of structures, as does CT, but detection of focal abnormalities such as lung cancer in a patient with pulmonary fibrosis can still be difficult. Given greater slice-to-slice blurring artifacts with DTS compared to CT reconstruction, it would appear that CT is superior for detection and characterization of complex anatomy or focal disease within an area of architectural distortion and increased density such as fibrotic parenchymal disease. Further research is needed to answer a number of questions before significant claims regarding its utility can be made with confidence.

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