Digital tomosynthesis in lung cancer: state of the art

Luca Bertolaccini[1], Andrea Viti[2], Alberto Terzi[1]

[1]Thoracic Surgery Unit, Sacro Cuore-Don Calabria Research Hospital, Negrar Verona, Italy; [2]Thoracic Surgery Unit, S. Croce e Carle Hospital, Cuneo, Italy

Correspondence to: Luca Bertolaccini, MD, PhD, FCCP. Thoracic Surgery Unit, Sacro Cuore-Don Calabria Research Hospital, Via Don Angelo Sempreboni 5, 37024 Negrar Verona, Italy. Email: luca.bertolaccini@gmail.com.

Abstract: Chest digital tomosynthesis (CDT) is a limited angle image tomography, which improves the visibility of anatomy compared with radiographic imaging. Due to the limited acquisition angle of CDT, it has the potential to significantly increase the temporal resolution of patient surveillance at the cost of reduced resolution in one direction. CDT is 3 times more effective in identifying pulmonary nodules compared to conventional radiography and at lower doses and cost compared with routine chest computed tomography (CT) examinations. There is only one report in which CDT was used in a single-arm observational study for lung cancer detection in at-risk population while a few studies suggested that CDT sensitivity is superior to radiography but inferior to CT in detecting lung nodules, other studies on the accuracy of CDT suggest that the specificity is much closer to CT than radiography. Therefore, large-scale randomized controlled trial would be needed to confirm benefits of CDT and identify where it is best used in the clinical setting. CDT seems to be a cost-effectiveness first-line lung cancer screening tool to detect potential lung cancer nodule.

Keywords: Chest digital tomosynthesis (CDT); lung cancer; early diagnosis; screening

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Introduction

Lung cancer is the current leading cause of cancer death worldwide. Because of its high sensitivity, low dose helical computed tomography (CT) is currently considered the gold standard for lung cancer detection (1). One of CT scan advantages is the non-susceptibility to reduced accuracy caused by overlapping anatomy typical of chest standard roentgenograms. Nevertheless, CT has some drawbacks such as the high radiation dose, the costs, the motion artifacts, and the variation in reconstruction algorithms used by different scanners (2). Recent advances in digital X-ray detector technology have renovated interest in tomography and its clinical applications. Conventional tomography provides planar information about an object from its projection images; a roentgen tube and an X-ray film receptor are placed on either side of the object, the relative motions of the tube and film are predetermined based on the desired location of the in-focus plane. A single image plane is generated by a scan, whereas multiple scans may be required to provide a sufficient number of planes to cover the selected structure in the object (3).

Chest digital tomosynthesis (CDT) is the evolution of the technique of geometric tomography, which was used extensively prior to the advent of chest CT scans but that was no more used for chest imaging owing to the positioning difficulty, high radiation dose, and residual blur caused by out of plane structure. The increasing concern about radiation dose to the patient from CT has resulted in the rebirth of new tomographic techniques such as CDT because of the associated low radiation dose (4).

Characteristics of CDT

CDT is a limited angle image reconstruction method from two dimension cone-beam projections, which improves the visibility of anatomy compared with radiographic imaging. CDT images are acquired using a high-quality digital detector with rapid read-out. Many current flat-panel detectors can provide this hardware requirement. The only additional requirements are a motorized tube mover and additional software to perform tomosynthesis reconstructions. No extra radiographer time is required for tomosynthesis, as projections may be acquire without repositioning the patient immediately after acquiring a standard chest radiograph. The coronal images are reconstructed in a few minutes, but this has not required longer appointment times than for a standard chest radiographs in our department (5). The patient needs to be able to stand (albeit supported) and must be able to hold breath for 10 seconds to avoid movement artifact (4,6). Due to the limited acquisition angle of CDT, it has the potential to significantly increase the temporal resolution of patient surveillance at the cost of reduced resolution (7). Recent reports have shown that the use of tomosynthesis, as an alternative of conventional chest radiography, leads to considerable improvement in diagnostic information with no increase in radiation dose compared to that of a standard two-view chest radiograph (posterior-anterior and lateral projections) (8,9).

Compared to standard radiography, CDT has several advantages like improved lesion detection due to a reduction in anatomical noise or composite artifact, better depth localization and contrast resolution (10). The advantages of CDT when compared to CT relate to cost and reduced radiation dose to patients (10).

CDT has a few limitations: patients undergoing this procedure are required to stand still and hold their breath firmly; it has a limited depth resolution, which may explain the difficulty in detecting nodules in the sub-pleural region and the occurrence of artifacts from medical devices (11). Advanced algorithms for detecting pulmonary nodules are increasingly described but the potential application of CDT in other areas of the thorax should not be underestimated. A unique characteristic of CDT is its capability to reconstruct tomograms from multiple layers of the object under study by utilizing the image data obtained during a single tomographic exposure. Compared with CT, CDT utilizes an area detector system and a flat-panel detector, enabling acquisition of a set of tomographic image data from the entire field of view in a short exposure time. Ideally, structures in a given plane of interest should be clearly displayed in the corresponding CDT reconstruction plane, whereas those located outside that plane should not be visible (12). As a result, out-of-plane structures cannot be completely removed from the reconstruction plane and are always present in such planes (12). CDT has potential clinical application, mainly for lung nodule detection to varying degrees, but at present is confined mainly to research studies (10).

Clinical applications of CDT

Standard chest roentgenogram is still the first examination for suspected lung lesions, and chest CT scans is usually used to confirm the diagnosis (13). By reducing composite artifacts, CDT has a superior sensitivity when compared to plain radiography for the detection of lung nodules. The sensitivities of chest roentgenogram and CDT for the detection of lung nodules are 27-49% and 60-92%, respectively (8,14).

CDT as case-solving technique

CDT can be used as case-solving technique in the diagnosis of equivocal or suspected pulmonary lesions on chest radiography. Once CDT identifies chest opacity as being a pulmonary lesion, a CT scan for further evaluation, classification, and staging is required. The use of CDT would entail less waiting time and radiation dose than sending patients directly to CT for the workup of the suspected lung lesion that then turns out to be benign, non-pulmonary, or a false positive nodule. Prospectively, CDT could spare further chest radiography and could replace CT scan in the characterization of incidental chest lesions identified by conventional chest radiography (2).

CDT in metastasis surveillance programs

CDT could be a tool for the metastasis surveillance program, in patients with extra-thoracic malignancy. Alternating CT scan and CDT interval examinations could reduce costs and radiation risk. A follow up program using CDT in patients with colorectal malignancy has shown a high sensitivity (4,14).

CDT in follow-up of pulmonary nodules

A further field of application of tomosynthesis could be the follow-up of pulmonary nodules previously identified on chest radiography or CT scan. Although tomosynthesis might possibly miss nodules <4 mm in diameter (8), and it does not allow three-dimensional volumetric nodule measurement, as CT does (15). Dobbins *et al*. reported 71% detection sensitivity for >5 mm nodules (6). Vikgren *et al*. reported near 100% sensitivity for nodules above 5 mm (8). These results both show a relatively low detection rate for nodules of less than 4 mm. In a clinical setting however, detection of nodules less than 4 mm is of no importance according to the Fleischner Society criteria (16). Misinterpretation at CDT is possible for sub-pleural nodules or for those located in the region of the lung in the proximity of the chest wall, where the limited depth resolution of CDT may hamper the correct spatial location of the findings. This limitation is related to the geometric frontal plane acquisition by CDT (acquisition in the sagittal plane is not recommended because of the higher radiation dose exposure). In a paper evaluating the diagnostic performance of chest radiography, CDT, and low dose CT scan for the detection of small pulmonary ground-glass opacity nodules using an anthropomorphic chest phantom, the diagnostic performance of CDT in the detection of pulmonary small ground glass nodules was not significantly different from that of chest radiography but CT scan performed significantly better. For ground glass opacity nodule, detection results are controversial. According to Gomi *et al*. (11), CDT ability to detect ground glass opacity in a phantom was similar to CT; while others don't consider CDT a suitable alternative to CT scan (17). In a phantom study, comparing CDT and chest CT scan in terms of assessing the sizes of nodules CDT and chest CT were comparable, even for the nodules located in areas where size measurement is limited on simple radiograph. Therefore, CDT and CT could be used interchangeably even for nodules located in blind area on simple chest roentgenogram (18).

CDT in lung cancer screening detection and its possible use as a screening tool

In an observational study involving nearly 2,000 subjects, the percentage of lung nodules and lung cancer detected with tomosynthesis was comparable to that reported for low-dosage CT. The detection rate of lung cancer was 0.9% (early stage disease in 55%), these results are encouraging since the specificity of CDT was very high and only 2% of cases were false positive at baseline and only 0.6% (one lesion) detected by CDT was not confirmed at CT scan at first round. Most of the health risks of screening would remain also with a wider use of tomosynthesis for cancer screening, the same reported by the National Lung Screening Trial (1) but with the advantage of a reduction in radiation exposure and costs as only 7% of patients who underwent CDT later underwent to CT of the chest (5).

Conclusions

CDT is an imaging tool with a wide and growing range of clinical applications. Its position in the chest radiologist's armamentarium lies halfway between radiography and CT scan. CDT improves diagnostic accuracy and confidence in the diagnosis of suspected pulmonary lesions on chest radiography. Its sensitivity is superior to radiography but inferior to CT, whereas the few studies on the accuracy of DTS suggest that the specificity is much closer to CT than radiography. For the radiologist, CDT studies took longer to read than chest X-rays because of multiple images scrolling, but the overall interpretation time is lower than CT because of the lower number of images evaluated. CDT is gaining popularity for the evaluation of the equivocal radiograph and in the right clinical context. One of its most promising roles may be to refine patient selection for low-dose CT screening with lower cost and radiation dose. Ideally, CDT could replace chest CT for the detection of early stage lung cancer. Furthermore, CDT examinations can discover other pathological finding not visible on standard chest radiography. Therefore, the hope is that the CDT have a wider clinical use in the near future.

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