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Review article

Digital tomosynthesis of the chest: A literature review

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ABSTRACT

Digital tomosynthesis is a relatively novel imaging modality using limited angle tomography to provide 3D imaging. The purpose of this review is to compare the sensitivity of digital tomosynthesis of the chest and plain film chest imaging in accurately identifying pulmonary nodules and to compare the effective dose between standard chest examinations using digital tomosynthesis and CT. A review of current literature has shown that small scale studies found digital tomosynthesis to be three times more effective in identifying pulmonary nodules compared to conventional radiography and at lower doses compared with routine chest CT examinations. This indicates that tomosynthesis could potentially be a beneficial imaging modality and could be used in a number of ways to detect and monitor pulmonary nodules for cancer. However with limited research, large-scale studies would need to be performed to confirm its benefits and identify where it is best used in the clinical setting.

Introduction

Digital tomosynthesis is a newly evolving imaging modality recently made clinically possible by advances in digital flat panel detector technology. It is a type of limited angle tomography providing the benefits of 3D imaging. Currently this new technology is being tested for mostly for breast and chest examinations. This literature review will be focusing on digital tomosynthesis of the chest where it is suggested to be beneficial in the detection of lung nodules.[1,2] The sensitivity of tomosynthesis, this being how well tomosynthesis can correctly identify pulmonary nodules in patients who have pulmonary nodules and the specificity, being how well tomosynthesis performs in correctly determining the absence of pulmonary nodules, needs to be assessed before it's use in clinical practice. Pulmonary nodules can easily be missed or misinterpreted on conventional X-rays, when a 3D object, the chest, is displayed as a 2D image resulting in overlap of anatomy. Tomosynthesis, much like CT, allows greater detection of pulmonary nodules by viewing one slice at a time. This is achieved by blurring out structures above and below the selected slice thereby eliminating much of the overlying anatomy. Not only is chest tomosynthesis meant to provide greater sensitivity of nodules but it is also intended to have a lower dose and cost compared to CT.[3,4]

Digital tomosynthesis uses a single linear sweep of the X-ray tube while the flat panel detector remains stationary. A number of low dose projections are taken over a limited sweep angle. These projections are then reconstructed into a set of 2D slices parallel to the detector using an algorithm. Patients are positioned similar to routine radiographic projections and may be upright or supine. Like any modality it is essential that radiologists and radiographers are aware of the acquisition parameters and potential artifact that may arise from them.[5] The basic acquisition parameters include sweep direction, sweep angle, the number of projections and the radiation dose. The resulting potential artifacts that can occur are Blurring-ripple, ghost artifact distortion, poor depth resolution, metallic artifact and image noise.[5] These artifacts as well as the physics and parameters to optimize tomosynthesis imaging are describe in detail by Machida et al.[5] (Fig. 1).

Aims

The aims of this literature review are to compare the sensitivity of digital tomosynthesis of the chest and plain film chest imaging in accurately identifying pulmonary nodules and to compare the radiation dose to the patient between standard chest examinations using digital tomosynthesis and CT.

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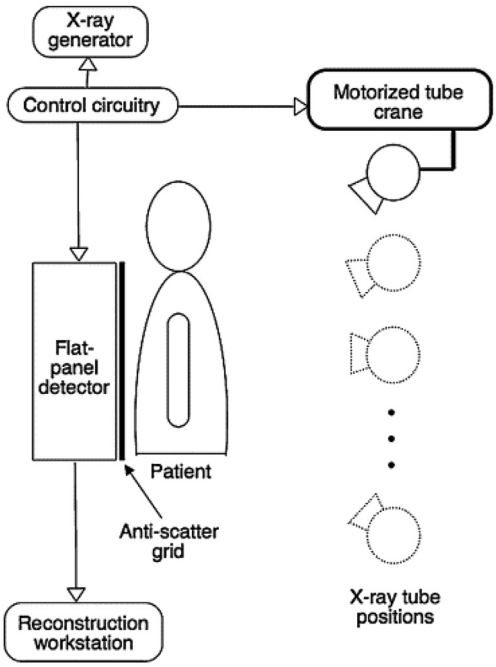

Figure 1. The flat panel detector remains stationary while the motorized tube crane moves through a linear sweep taking a number of projections. Reprinted with permission from Elsevier, European Journal of Radiology. Dobbins JT, McAdams H. Chest tomosynthesis: technical principles and clinical update. *Eur J Radiol* 2009; 72(2):244–51.

Methods

An initial search of the databases EMBASE, Ovid MEDLINE, Scopus and PubMed were performed. The key terms consisted of: chest tomosynthesis, pulmonary nodules, conventional radiography, chest X-ray, chest CT, radiation dose, CT radiation dose and effective dose. These terms were used in a number of various combinations. A subsequent search of the world-class Radiology journals, such as *Radiology*, *Radiographics* and the *American Journal of Roentgenology* was performed as well. Articles not in English were excluded. As tomosynthesis is a relatively newly evolving technique, the search was limited to articles published within the last six years. The articles were used to collect information on the sensitivity of pulmonary nodule detection and the related dose.

Discussion

Sensitivity of digital chest tomosynthesis

A number of clinical trials suggests that digital chest tomosynthesis has a higher sensitivity in the detection of pulmonary nodules when compared to conventional chest radiography. Pulmonary nodules are often difficult to identify on plain film with many being missed by experienced radiologists.[6,7] Missed pulmonary nodules may be seen in hindsight after CT but remain difficult to identify prospectively.[8,9] Conventional radiography in comparison to CT has a much lower sensitivity and specificity in nodule detection. Theoretically nodules as small as 3 mm should be detected on plain film due to their X-ray absorbing properties and the amount of attenuation.[10] However on conventional radiographs pulmonary nodules often go unnoticed until they reach at least 8 mm in diameter.[10] Noise from scatter radiation and anatomical overlap in radiography examinations can result in decreased contrast making small features like pulmonary nodules difficult to detect.[6] However the main reason conventional radiography has limited sensitivity is due to presenting a 3D chest as a 2D image.[11,12] This produces anatomical overlap and clutter from the lung markings, pulmonary vessels, thorax, mediastinum, heart, diaphragms and ribs.[13] Overlying anatomy not only decreases conspicuity of nodules but can also mimic nodules, resulting in false positives. While CT does eliminate the anatomical overlap allowing higher sensitivity for pulmonary nodules, it also requires substantially more radiation dose (even low dose CT), compared to a chest X-ray.[2]

The development of tomosynthesis aims to eliminate overlapping anatomy thus providing greater sensitivity in nodule detection at a lower dose and cost compared to CT examinations. Tomosynthesis combines the benefits of CT and conventional radiography to provide greater accuracy in nodule detection and improved reader confidence.[2,6,14,15]

There have been three main clinical studies to evaluate the sensitivity of tomosynthesis compared to chest radiography in humans. The tests use roughly similar techniques based on optimal image acquisition to obtain the tomosynthesis images. All three studies by Dobbins et al., Johnsson et al. and Vikgren et al. found that three times more nodules were detected using tomosynthesis than with plain film.[4,11,16] CT was used as a baseline to determine the true number of nodules that could be detected. In the 2008 study by Dobbins et al., CT detected a total of 175 pulmonary nodules ranging from 3.5 mm to 25.5 mm in diameter. On average tomosynthesis detected 70% of those nodules, while the PA radiograph only detected 22% (p value <0.0001).[4] For both modalities the sensitivity increases with increasing nodule size (Fig. 2).

The studies by Vikgren et al. and Dobbins et al. both indicated tomosynthesis to be beneficial in the detection of small nodules. The greatest difference in sensitivity seen by Dobbins et al. was for the smallest group of nodules between 3 and <5 mm where over seven times the number of nodules detected on X-ray were seen with tomosynthesis.[4] In the study by Vikgen et al. the greatest sensitivity difference was seen for nodules >6–8 mm and the second greatest difference was for nodules less than or equal to 4 mm[11]. This may be due to only 15 out of 131 nodules were in the >6–8 mm group, providing a very small sample size compared to the other groups. While this study demonstrated the sensitivity of tomosynthesis to be nearly as good as CT, Dobbins et al. did not. However overall both studies found tomosynthesis at least three times more effective in identifying nodules compared to plain film imaging. Out of 131 pulmonary nodules 92% were detected with tomosynthesis and 28% with a PA radiograph.[11]

Studies of some specific patient groups have been undertaken and they reveal similar results. The 2012 study by Jung et al., focused on pulmonary nodules in colorectal cancer patients, revealing a three-fold increase in the sensitivity of tomosynthesis compared to conventional radiography, identifying 83% and 27% respectively of nodules detected on CT.[17]

Although the results of all these studies showed that tomosynthesis had greater nodule detection sensitivity, these results have yet to be examined in a large-scale study. A soundly planned prospective study mimicking realistic clinical conditions is needed to determine how useful chest tomosynthesis could be.[4,6,10,18]

Conversely, while tomosynthesis shows improved sensitivity in nodule detection, an increased number in false negatives has been noticed. Both Vikgren et al. and Jung et al. noted that on average at least double the number of false positives were being detected on tomosynthesis compared to X-ray.[11,17] The number of false positive nodules varied for each radiologist, possibly indicating a difference in reading ability. However all radiologists' ability to detect true positives was comparable. Furthermore, the literature states that a high level of reading and interpreting tomosynthesis can be achieved within a short period of time, without a significant change