A Retrospective Study of Chest Tomosynthesis as a Tool for Optimizing the use of Computed Tomography Resources and Reducing Patient Radiation Exposure

Åse A. Johnsson, MD, PhD, Jenny Vikgren, MD, PhD, Magnus Båth, PhD

Rationale and Objectives: To investigate potential benefits and drawbacks of the clinical use of chest tomosynthesis (CTS), to what extent CTS obviates the need for chest computed tomography (CT), and what reduction in radiation dose thereby can be achieved.

Materials and Methods: The Regional Ethical Review Board approved the follow-up study of patients examined with CTS as part of clinical routine. For each case, two radiologists in consensus determined whether CT would have been performed, had CTS not been an option, and whether CTS was an adequate examination. Thereafter, it was determined whether the use of CTS instead of CT in retrospect was beneficial, neutral, or detrimental for the radiological work-up. The radiation dose to the patient population was determined both for the actual clinical situation and for the alternative scenario that would result, had CTS not been available.

Results: During 1 month 3.5 years before the survey, 149 patients (74 women, age 18–91 years) had undergone CTS for clinical purposes. It was judged that CT would have been performed in 100 cases, had CTS not been available, and that CTS obviated the need for CT in 80 cases. CTS was judged as beneficial, neutral, and detrimental for the radiological work-up in 85, 13, and two cases, respectively. For the entire study population, the use of CTS decreased the average effective dose from 2.7 to 0.7 mSv.

Conclusions: The present study indicates that CTS may have benefits for the radiological work-up as it has the potential to both optimize the use of CT resources and reduce the effective dose to the patient population. A drawback is that CTS examinations may fail to reveal pathology visible with CT and in clinically doubtful cases further investigations including other imaging procedures should be considered.

Key Words: Chest; radiography; tomosynthesis; radiation dose.

Chest tomosynthesis (CTS) refers to the technique of acquiring multiple low-dose projection radiographs of the chest over a limited angular range and using these radiographs to reconstruct section images. In this way, a volumetric representation can be obtained at radiation doses lower than reported for computed tomography (CT) (1,2). Although the volumetric representation is not as isotropic as in CT, the section images contain much less of the overlaying anatomy than conventional chest radiographs (CXR). As the disturbance because of this anatomy may be the main limiting factor for detection of pathology in CXR (3–6), it can be anticipated that its reduction will lead to improved diagnostic accuracy with CTS in comparison to CXR.

A significant improvement for CTS in comparison to CXR in detection of pathology has been reported. The main focus of recent research has been detection and/or visibility of parenchymal nodules. Dobbins et al. (7) found that 70% of CT-proven nodules were visible with CTS in contrast to 22% with CXR. Vikgren et al. (8) obtained similar results, where 92% of CT-proven nodules were visible with CTS and 28% with CXR. This increased visibility of pulmonary lesions achieved with CTS has been reported to increase the diagnostic accuracy and confidence (9,10). Additionally, Vikgren et al. (8) performed a detectability study and showed that only 16% of the CT-proven nodules were detected using

Acad Radiol 2014; 21:1427–1433

From the Department of Radiology, Sahlgrenska University Hospital, Gothenburg, Sweden (Å.A.J., J.V.); Department of Radiology, Institute of Clinical Sciences, The Sahlgrenska Academy at University of Gothenburg, Gothenburg, Sweden (Å.A.J., J.V.); Department of Medical Physics and Biomedical Engineering, Sahlgrenska University Hospital, Gothenburg, Sweden (M.B.); Department of Radiation Physics, Institute of Clinical Sciences, The Sahlgrenska Academy at University of Gothenburg, Gothenburg, Sweden (M.B.). Received September 17, 2013; accepted June 5, 2014. This work was supported by the Swedish Research Council (2011/488, 2013/3477); the Swedish Radiation Safety Authority (2010/4363, 2012-2021, 2013-2982, 2014-2641); the Swedish Federal Government under the LUA/ALF agreement (ALFGBG-136281); and the Health and Medical Care Committee of the Region Västra Götaland (VGFOUREG-12046, VGFOUREG-27551, VGFOUREG-81341). **Address correspondence to:** Å.A.J. e-mail: ase.johnsson@vgregion.se

http://dx.doi.org/10.1016/j.acra.2014.06.002

CXR, whereas 56% were detected with CTS. The threefold increase in sensitivity thus reported by Vikgren et al. has later been confirmed in studies by Yamada et al. (11), Jung et al. (12), Zachrisson et al. (13), and Asplund et al. (14).

Although initial clinical experiences of CTS have been reported (15,16), few evaluations of the technique in clinical routine have been published. Quaia et al. (17,18) have shown that the use of CTS may avoid the need for CT in about 75% of patients presenting with suspected lesions on CXR and that the per-patient diagnostic imaging costs decreased after CTS implementation (19). However, the long-term outcome of the use of CTS for a broader patient population has not been evaluated. Therefore, the purpose of the present study was to investigate potential benefits and drawbacks of the clinical use of CTS, mainly in terms of to what extent CTS obviates the need for chest CT and what reduction in radiation dose thereby can be achieved.

MATERIALS AND METHODS

The present retrospective study, in which the radiological outcome of CTS examinations at one institution was investigated, was approved by the Regional Ethical Review Board. CTS has been clinically available at our institution since December 2006. To evaluate the impact of CTS at a time point where the clinical use had stabilized (16), although still enabling a long-term follow-up of the outcome, a search for CTS examinations stored in the picture archiving and communication system (PACS) from March 1 to March 31, 2010 was performed. The survey was conducted in November 2013, that is, 44 months after the studied CTS examinations were performed. Data retrieved were; whether it was a clinical or radiological referral (the former refers to an examination that has been requested by a referring clinician, whereas the latter refers to an examination that has been requested by a radiologist after evaluating a CXR); indication for the CTS; patient age; patient sex; available CT data; exposure data related to the CTS examination; dose of CT examinations performed ±3 months from the CTS; and, finally, follow-up time in the hospital radiology information system (RIS). The date of the last radiological examination was noted as end of follow-up if the patient had expired during the follow-up period.

Imaging Procedure

The CXR examinations were performed on a GE Definium 8000 system (GE Healthcare, Chalfont St Giles, UK) and included a posteroanterior (PA) and a lateral (LAT) view. The PA was acquired at a tube voltage of 125 kV, using a total filtration equivalent to 3 mm Al + 0.1 mm Cu, whereas the LAT was acquired at 140 kV using 3 mm Al + 0.2 mm Cu. Automatic exposure control was used for both views. The CTS examinations were performed on the same system using the VolumeRAD (GE Healthcare, Chalfont St Giles, UK) option. Sixty low-dose projection radiographs were acquired over an angular range from −15° to +15° around the standard orthogonal PA projection. The tube voltage was 120 kV and the total filtration was equivalent to 3 mm Al + 0.1 mm Cu. The total exposure for the CTS examinations was determined by a scout view (a PA projection image). The tube load used for the scout view was multiplied by a factor of 10, then equally distributed between the projections, and finally rounded down to the closest Renard step (with the constraint of a minimum tube load of 0.25 mAs per projection) (1,20). The acquired projection radiographs were used to reconstruct approximately 60 coronal section images with a section interval of 5 mm.

Analysis of the use of CTS on the Radiological Outcome

The radiological outcome of each CTS examination was determined by two experienced thoracic radiologists in consensus, using information available in the hospital RIS and the PACS. Thus, the assessment was based on patient history in referrals, radiological reports, and radiological images. For each case, it was first determined whether CT would have been performed, had CTS not been an option, and whether CTS was an adequate examination. This decision was based on the state of the patient as well as on the clinical and radiological information available before the examination. Typical cases where the radiologists judged that CT would have been performed were patients undergoing follow-up of pathology deemed not visible on CXR. It was agreed that patients with minimal suspicion of pathology on CXR and no history of malignancy would not have been referred to CT.

For cases where it was judged that CT would have been performed, had CTS not been an option, it was determined whether the use of CTS instead of CT in retrospect was beneficial, neutral, or detrimental. The CTS examination was judged as beneficial if (1) the CTS examination verified a suspected lesion detected on CXR and resulted in adequate work-up with CT (alone or in combination with positron emission tomography [PET]) or could characterize the lesion without the need for further work-up with CT, or (2) the CTS examination correctly dismissed a suspected lesion, based on no reported adverse events (no occurrence of pulmonary pathology during the follow-up period) in the RIS, and thus obviated the need for CT. If there was a reported adverse event (occurrence of pulmonary pathology during the follow-up period) in the RIS, the CTS examination was judged as detrimental. In all other cases, the CTS examination was judged as neutral as it did not affect the radiological work-up and the patient still had to undergo CT.

Analysis of the use of CTS on the Radiation Dose

To determine the effective dose to the patients from the radiography examinations (CTS and CXR), dose data stored in the PACS were used to determine the patient-averaged dose-area product (DAP) for each type of examination. These data were converted to estimations of effective dose using conversion factors between DAP and effective dose of 0.26 (CTS and PA) and 0.27 (LAT) mSv/(Gy cm^2) (2). For a radiologically