Development of Methods for Evaluation and Optimization of Chest Tomosynthesis

AKADEMISK AVHANDLING

som för avläggande av medicine doktorsexamen vid Sahlgrenska akademin vid Göteborgs universitet kommer att offentligen försvaras i hörsal Arvid Carlsson, Medicinaregatan 3, Göteborg fredagen den 16 december 2011 kl. 13.00

Av
Angelica Svalkvist

Fakultetsopponent:
Professor Mats Nilsson
Radiofysikavdelningen, Skånes universitetssjukhus Malmö, Malmö

Avhandlingen är baserad på följande delarbeten:

I. Svalkvist A, Månsson LG and Båth M
Monte Carlo simulations of the dosimetry of chest tomosynthesis
Radiat. Prot. Dosimetry 2010; 139(1-3): 144-152

II. Svalkvist A and Båth M
Simulation of dose reduction in tomosynthesis
Med. Phys. 2010; 37(1): 258-269

III. Svalkvist A, Håkansson M, Ullman G and Båth M
Simulation of lung nodules in chest tomosynthesis
Radiat. Prot. Dosimetry 2010; 139(1-3): 130-139

IV. Svalkvist A, Johnsson ÅA, Vikgren J, Håkansson M, Ullman G, Boijsen M, Fisichella V, Flinck A, Kheddache S, Molnar D, Månsson LG and Båth M
Evaluation of an improved method of simulating lung nodules in chest tomosynthesis
Submitted

GÖTEBORGS UNIVERSITET

Development of Methods for Evaluation and Optimization of Chest Tomosynthesis

Angelica Svalkvist
Department of Radiation Physics, Institute of Clinical Sciences at Sahlgrenska Academy, University of Gothenburg, SE−413 45 Gothenburg, Sweden

Abstract

Tomosynthesis is a low-dose technique that has attracted increasing interest from the medical imaging community during the past decade. Tomosynthesis refers to the technique of acquiring a number of projection radiographs using extremely low exposure over a limited angular range, and using these radiographs to reconstruct slices of the imaged object. These reconstructed slices contain much less overlaying anatomical structures than conventional radiographs, which improves the possibility of obtaining relevant diagnostic information from the examination. The work described in this thesis concerns the development of methods for the evaluation and optimization of tomosynthesis for chest imaging.

Conversion factors between exposure and the resulting effective dose to the patient are available for established X-ray procedures. In the present work, corresponding conversion factors were determined for different chest tomosynthesis system configurations and patient sizes using the Monte Carlo technique. Using these conversion factors, the resulting effective dose from a tomosynthesis examination can be estimated using only information on the total exposure resulting from the examination.

According to the ALARA (as low as reasonably achievable) principle, all medical imaging should be performed using the lowest possible exposure of the patients to produce images of satisfactory diagnostic quality. To determine the lowest reasonably achievable exposure it is necessary to evaluate images acquired using various amounts of exposure. A method of simulating dose reduction in tomosynthesis was developed in this work. The method is based on the creation of a noise image that can be added to an image to simulate acquisition of the image at a lower dose. By using information about the noise power spectrum (NPS) of the system at different detector dose levels, and by establishing the relationship between pixel value and pixel variance as a function of dose, the noise image can be filtered with a frequency filter to obtain the correct NPS and pixel values. In this way, possible variations in detective quantum efficiency can be accounted for in the dose simulation process. Results from an evaluation of the method indicate that the method is appropriate for simulating dose reduction of tomosynthesis projection radiographs.

In order to thoroughly evaluate the performance of chest tomosynthesis in nodule detection, images containing nodules of different sizes and densities, located in different regions of the lung parenchyma, are needed. A method of simulating lung nodules in chest tomosynthesis was developed and evaluated. The method is based on the creation of three-dimensional artificial nodules that are inserted into the tomosynthesis projection images before reconstruction of the section images. The signal spread in the detector, the scattered radiation and patient motion were accounted for in the simulation process. The sensitivity for the simulated nodules was shown to be similar to that for real nodules, and experienced radiologists had difficulty in visually differentiating between real and simulated nodules. The nodule simulation method can be used to investigate the limitations in detection of lung nodules in chest tomosynthesis, without introducing any substantial bias compared to the use of clinical images.

Keywords: Chest tomosynthesis, Evaluation, Optimization, Simulation, Image quality, Dosimetry, Dose reduction, Nodule simulation, Validation

ISBN: 978-91-628-8223-5
E-publication: http://hdl.handle.net/2077/26593