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### Advances in digital chest radiography: impact on reader performance

De Boo, D.W.

**Publication date**  
2012

[Link to publication](#)

#### **Citation for published version (APA):**

De Boo, D. W. (2012). *Advances in digital chest radiography: impact on reader performance*. [Thesis, fully internal, Universiteit van Amsterdam].

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# Introduction



## Introduction

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Chest radiography is still the most commonly used imaging technique to rule out cardiopulmonary disease, to study the effect of treatment, and to follow-up patients. Up to thirty years ago the radiographic technique was based on conventional film-screen, however, in the late 80ties the first digital radiographic technique, so called computed radiography (CR), was introduced. CR systems use a storage phosphor plate that has a comparable function as the amplifier screen in conventional film-screen radiography. The storage phosphor plate retains the information of the incident photons as a latent image, which is later retrieved by stimulation by a read-out laser. The emitted light is amplified, digitized and transferred into grey values for the radiographic image. About 10 years later a second digital radiographic technique was introduced: direct radiography (DR). DR uses flat-panel detectors which are characterized by a direct read-out matrix of electronic elements that are made of thin layers of amorphous silicon thin-film transistors (aSi-TFT elements) that are deposited on a piece of glass. This TFT layer is coupled with an X-ray absorption medium. The absorbed X-ray energy is either directly transferred into electronic charge (direct systems) or via an intermediate conversion into visible light (indirect or opto-direct systems) before transferred to grey values to produce a radiographic image. Compared to conventional film-screen radiography, both CR and DR have a much wider dynamic range for displaying attenuation differences and thereby offer an improved image quality<sup>(1,2)</sup>. Additionally, DR allows for reducing acquisition dose as compared to both, film-screen radiography and CR, based on its higher dose efficiency<sup>(4-7)</sup>. The options for dose reduction on one side and improvement of image quality on the other side have to be outweighed and determined with respect to the clinical indication and the diagnostic requirements. Together with the rapid development of computer technology and digital storage capacity, digital radiography facilitated the upcoming of Picture Archiving and Communication Systems (PACS). Digital images are now centrally archived and are accessible throughout the hospital by all clinicians. Besides this organizational advantage associated with PACS, the digital format of the images also induced the development of several processing tools. Nowadays basic tools such as magnification, window / level adjustments, and grey-scale reversal are available on every PACS workstation. Recently more elaborate post-processing tools designed to support the readers' detection and diagnostic performance were introduced. Factors contributing to detection errors in chest radiographs include image

quality, type of pathology, superposition of anatomical structures (e.g., ribs), the presence of accompanying abnormalities, and last but not least the radiologists' experience and perception capacity. Several processing techniques were introduced to lower the effects of anatomical structures or 'anatomic noise'. Energy subtraction produces images of the chest without overlapping osseous structures by subtracting two datasets recorded at the same time with low and high photon energies. Similar effects but without the expense of two exposures, can be achieved by digitally suppressing ribs and clavicles (SoftView; Riverain, Miamisburg, Ohio). Temporal subtraction aims to selectively enhance interval changes by subtracting the previous radiograph from the current one. Though all techniques delivered promising results under study conditions, they are not (yet) in broad clinical use<sup>(8-12)</sup>. In order to reduce the amount of perception errors made by radiologists computer-aided detection software (CAD) was developed. The software marks candidate regions to alert radiologists towards a potential lesion. Several algorithms have been developed of which only a minority is approved by the United States Food and Drug Administration (FDA). They all have in common that they analyze the chest radiographs in the background and show candidate lesions on demand. Subsequently the reader can either accept the candidate as a true positive or dismiss it as a false positive. The potential of CAD to increase the radiologist's sensitivity for pulmonary nodules has been acknowledged. Two studies reported that 35% and 47% of bronchogenic tumors missed in the original reports were correctly marked by a FDA approved CAD<sup>(13,14)</sup>. Both studies, however, tested only the CAD software alone (stand-alone performance) without taking the reader – CAD interaction into account. The effects of CAD on actual reader performance, however, will decide over its clinical utility and last but not least its acceptance by the radiologists' community.

## Outline of this thesis

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The aim of this thesis is to evaluate how actual reader performance is influenced by some of the advances offered by digital chest radiography. **Chapter 2** focuses on bedside chest radiographs of patients admitted to the Intensive Care Unit. Mobile CR and DR units were compared with respect to image quality and the potential for dose reduction. Detectability of monitor material and interobserver agreement were used as criteria to assess the effects of image quality on reader performance. In **Chapter 3** the effect of gray-scale reversal on nodule detection in chest radiography was tested. Inexperienced and experienced observers participated in a reader study to determine whether there would be any benefit from this rather simple processing tool available with a single mouse click on the PACS workstation. **Chapter 4** provides an overview of the published data on the performance of CAD for the detection of pulmonary nodules and small bronchogenic tumors. It also critically reviews the limitations of those studies and the considerations that have to be taken into account when drawing conclusions from the results. The effects of two FDA approved CAD systems available for chest radiography were tested in two observer studies. In **Chapter 5** chest radiographs of the Dutch-Belgian lung cancer screening trial (NELSON) with proven primary lung cancer were included, whereas in **Chapter 6** the test lesions were small pulmonary nodules seen on radiographs of older patients with so called "dirty lungs". Finally in **Chapter 7** the effect of short-term feedback on readers' ability to discriminate true from false positive CAD candidates was tested.

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