Journal of Medical Imaging and Radiation Sciences 46 (2015) 65-77

Journal of Medical Imaging and Radiation Sciences

Journal de l'imagerie médicale et des sciences de la radiation

www.elsevier.com/locate/jmir

Research Article

Dose Optimization in Lumbar Spine Radiographic Examination by Air Gap Method at CR and DR Systems: A Phantom Study

Charles T.P. Chan, PgD, MPhil, BSc* and Karl K.L. Fung, PhD, MSc, FIR

Department of Health Technology and Informatics, Faculty of Health and Social Sciences, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China

ABSTRACT

Objective: This study aims at investigating the feasibility of replacing an antiscatter grid with an air gap to achieve dose reduction for lumbar spine radiography while retaining image quality at an acceptable diagnostic level.

Methods: Frontal and lateral projections of lumbar spine radiographic examinations were performed on an anthropomorphic phantom. Nongrid images of both the computed radiography (CR) and digital radiography (DR) systems with air gap thickness ranging from 0 to 25 cm were produced and compared with their corresponding grid images. Dose measurements using thermoluminescent dosimeters at the ovary and testes regions of the phantom were conducted. The image quality of all the images was evaluated by five radiographers using image quality score and visual grading analysis tests. Data on dose measurements and image quality tests were input for statistical analysis. The dose area product (DAP) of all the examinations was recorded and input for the computation of effective doses using a PC-based Monte Carlo program (PCXMC 2.0; STUK, Helsinki, Finland).

Results: Significant dose reduction effects on the ovaries of 60.2%–74.1% and 55.1%–73.3% were found, respectively, at the frontal and lateral projections of nongrid lumbar spine examinations compared with their corresponding grid ones in both the CR and DR systems. Results on the image quality score and visual grading analysis tests showed that nongrid images with 10-cm and 5-cm of air gap thicknesses respective to the frontal and lateral images of the lumbar spine were rated with the highest scores. In general, a dose reduction effect using the air gap method was found to be more pronounced in the CR system compared with the DR system. Nevertheless, the CR system delivered a 2.4–4.5 times higher ovary dose respective to the frontal and lateral projections of lumbar spine examinations compared with the DR system.

Conclusions: Ten and 5 centimeters were found to be the optimal air gap thicknesses respective to the frontal and lateral lumbar spine radiographic examinations of the tested Rando phantom (Alderson Laboratories, Stamford, CT) in both the CR and DR systems. Significant dose reduction effects on both the ovary and testes regions of the nongrid examinations were shown. The effective dose computed from PCMCX 2.0 reflected that the risk of cancer induction was halved when an antiscatter grid was replaced by the nongrid method with an optimal air gap thickness in the tested examinations. Further reduction on cancer risk could be achieved by using DR instead of the CR system.

RESUMÈ

Objectif : Cette étude vise à examiner la faisabilité du remplacement d'une grille anti-diffusion par un espace d'air pour obtenir une réduction de la dose dans la radiographie de la colonne lombaire, tout en conservant une qualité acceptable pour le diagnostic.

Méthodologie : Des examens radiographiques en projections frontale et latérale ont été effectués sur un fantôme anatomique de colonne lombaire. Des images sans grille ont été prises à l'aide d'un système de radiographie informatisée (CR) et d'un système de radiographie numérique (DR), avec une couche d'air d'une épaisseur variant entre 0 à 25 cm et comparées avec les images avec grilles correspondantes. Des mesures de doses par dosimètre thermoluminescent (TLD 100) ont été prises dans les régions correspondant aux ovaires et aux testicules du fantôme. La qualité des images a été évaluée par cinq radiographes à l'aide des tests IQS (Image Quality Score) et VGA (Visual Grading Analysis). Les données de mesure de dose et de qualité de l'image ont été saisies pour analyse statistique. Le produit dose-surface (PDS) de tous les examens a été enregistré et saisi pour le calcul des doses efficaces au moyen d'un programme Monte Carlo sur PC (PCXMC 2.0).

Résultats : Un effet marqué de réduction de la dose aux ovaires a été noté, atteignant respectivement 60,2 % à 74,1 % et 55,1 % à 73,3 % sur les projections frontale et latérale de l'examen sans grille de la colonne lombaire par rapport aux examens avec grille correspondants, tant sur les systèmes CR que les systèmes DR. Les résultats des tests IQS et VGA montrent que les images sans grille avec une couche d'air de 10 cm et de 5 cm pour les images frontales et latérales respectivement ont reçu les notes les plus élevées. En général, il a été

The author(s) have no financial disclosures or conflicts of interest to declare.

* Corresponding author: Charles T.P. Chan, PgD, MPhil, BSc, Room Y921, 9/F, Department of Health Technology and Informatics, Lee Shau Kee Building, The Hong Kong Polytechnic University, Hung Hom Kowloon, Hong Kong, China.

E-mail address: charles.chan@polyu.edu.hk (C.T.P. Chan).

1939-8654/$ - see front matter
http://dx.doi.org/10.1016/j.jmir.2014.08.003

constaté que l'effet de réduction de la dose par la méthode de la couche d'air était plus marqué avec le système CR qu'avec le système DR. Malgré cela, les systèmes CR produisent une dose aux ovaires de 2,4 à 4,5 fois plus élevée respectivement pour les projections frontales et latérale que le système DR.

Conclusions : L'épaisseur optimale de la couche d'air a été établie à 10 cm et 5 cm respectivement pour l'examen radiographique frontal et latéral du fantôme Rando dans les systèmes CR et DR. Un effet marqué de réduction de la dose a été observé dans les régions correspondant aux ovaires et aux testicules des examens sans grille. La dose efficace calculée au moyen du programme PCMCX 2.0 indique que le risque d'induction du cancer est réduit de moitié lorsque la grille anti-diffusion est remplacée par la méthode sans grille avec une couche d'ai d'épaisseur optimale dans les examens mis à l'essai. Une réduction additionnelle du risque de cancer peut être obtenue par l'utilisation du système DR en remplacement du système CR.

Key Words: Air gap; dose optimization; lumbar spine

Introduction

Dose Concerns on Lumbar Spine

Globally, requests for radiographic examinations have grown rapidly in recent years [1]. Radiation dose has become a public concern, of which diagnostic x-ray accounts for 90% of the total population dose from all artificial sources [2]. Among all of the general radiographic examinations, lumbar spine radiographic examination contributes the highest collective population dose [2, 3]. In addition, the radiation-induced cancer risk of lumbar spine radiography is comparable with high-dose examinations like barium enema [4]. Hence, there is a need to reduce the radiation dose to those patients. The relatively high radiation dose delivered in lumbar spine examinations can be attributed to the fact that high-exposure parameters (ie, tube potential and tube current) have to be used for the successful penetration of the x-ray photons through this dense area of the human body [5, 6]. It is a general practice in radiography to apply an antiscatter grid on an area that is thicker than 10 cm, such as frontal and lateral examinations of the lumbar spine [7, 8]. As a result, image quality could be enhanced because the majority of the scattered radiation will be absorbed by the grid [9]. However, with an antiscatter grid in place, a higher tube potential (kVp) and tube current (mAs) have to be adopted because it will attenuate the energy of both the primary x-ray beam and the scattered radiation [8, 10]. To retain the image quality of the resultant image, the radiation dose to the patient will unavoidably be increased. It is always a trade-off between radiation dose to the patient and the image quality of the resultant image [11, 12]. Studies showed that mAs have to increase by at least one fold while an antiscatter grid is being used [6, 13].

Knowledge Gap on Dose Reduction

Previous studies showed that an excessive patient dose could be avoided by removing the antiscatter grid in some of the radiographic examinations that used to have the grid in place to absorb scatters [14–16]. By introducing an air gap between the patient and the image receptor (IR), not only could a substantial dose reduction be achieved, but it might also result in an improvement to the quality of the resultant image [14–17]. Despite the fact that an air gap cannot function as effectively as an antiscatter grid does to improve the image contrast, it does not absorb as much primary radiation quanta as the grid does [18, 19]. Because the primary beam is the only useful radiation that constructs the image at the IR, this almost zero absorption property on primary beam quanta of the air gaps may well outweigh their poorer scatter rejection properties. Studies also revealed that an air gap thickness of 20 cm could function with similar effectiveness to improve the signal-to-noise ratio (SNR) of the resultant image as if a highly selective grid is in place [19]. Depending on the density and thickness of the examined parts, a different air gap thickness has to be adopted to improve the image quality of the resultant image accordingly. Because there is no previous study on the effectiveness of dose reduction by the air gap method on frontal and lateral radiographic examinations of the lumbar spine, it is important to fill this knowledge gap for better protection of patients.

Air Gap Method

The air gap method is one of the traditional and effective methods for scatter rejection in diagnostic radiology, especially before the invention of the grid. Nowadays, it seems that this technique is gradually fading out because the antiscatter grid can essentially replace the air gap in terms of scatter rejection function [20]. Nevertheless, studies showed that the air gap method is still a useful and indispensable method for scatter rejection in many examinations, including the chest, cervical spine, and in pediatric radiology [21]. Moreover, with the introduction of digital radiography, it is likely that new insights or even a revolutionary reverted change on replacing the antiscatter grid with the air gap might have started [19].

Purpose of the Study

The present study aimed to investigate the feasibility of replacing an antiscatter grid with an air gap to achieve dose reduction in lumbar spine radiography while retaining image quality at an acceptable diagnostic level. The optimal air gap thickness for the frontal and lateral lumbar spine radiographic examinations of the tested phantom is examined, and the subsequent dose reduction on the effective doses and the gonad doses are determined.