Journal of Medical Imaging and Radiation Sciences xx (2016) 1-7

Journal of Medical Imaging and Radiation Sciences

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

www.elsevier.com/locate/jmir

How Much Does Lead Shielding during Fluoroscopy Reduce Radiation Dose to Out-of-Field Body Parts?

Andrew S. Phelps, MD*, Robert G. Gould, ScD, Jesse L. Courtier, MD, Peter A. Marcovici, MD, Christina Salani, RT(R)(ARRT) and John D. MacKenzie, MD

Department of Radiology & Biomedical Imaging, UCSF Benioff Children's Hospital, University of California, San Francisco, California, USA

ABSTRACT

Background: Fluoroscopy technologists routinely place a lead shield between the x-ray table and the patient's gonads, even if the gonads are not directly in the x-ray field. Internal scatter radiation is the greatest source of radiation to out-of-field body parts, but a shield placed between the patient and the x-ray source will not block internal scatter. Prior nonfluoroscopy research has shown that there is a small reduction in radiation dose when shielding the leakage radiation that penetrates through the collimator shutters. The goal of this in vitro study was to determine if there was any radiation dose reduction when shielding leakage radiation during fluoroscopy.

Methods: This was an in vitro comparison study of radiation doses using different collimation and shielding strategies during fluoroscopy. Ionization chamber measurements were obtained during fluoroscopy of an acrylic block with and without collimation and shielding. Ionization chamber readings were taken in-field at 0 cm and out-of-field at 7.5, 10, and 12.5 cm from beam center.

Results: Collimation reduced 87% of the out-of-field radiation dose, and the remaining measurable dose was because of internal scatter. The radiation dose contribution from leakage radiation was negligible, as there was not any measurable radiation dose difference when shielding leakage radiation, with P value of .48.

Conclusion: These results call into question the clinical utility of routinely shielding out-of-field body parts during fluoroscopy.

Keywords: Collimation; dose; shielding; scatter; radiation

RESUMÈ

Contexte : Les technologues en fluoroscopie place toujours un écran de plomb entre les la table de radiographie et les gonades du patient, même si celles-ci ne sont pas directement dans le champ de rayonnement. La diffusion interne est la principale source de radiation pour les parties du corps hors-champ, mais un écran placé entre le patient et la source ne bloquera pas la diffusion interne. Les recherches antérieures dans d'autres champs que la fluoroscopie ont démontré que l'écranage des fuites de radiation par l'obturateur du collimateur permet une faible réduction de la dose de rayonnement. Le but de cette étude in-vitro était de déterminer si l'écranage des fuites de radiation pendant la fluoroscopie pouvait permettre une réduction de la dose de rayonnement.

Méthodologie : Il s'agit d'une étude comparative in-vitro des doses de rayonnement pour différentes stratégies de collimation et d'écranage durant la fluoroscopie. Les mesures de chambre d'ionisation ont été prises durant la fluoroscopie d'un bloc d'acrylique avec et sans collimation et écranage. Les lectures de chambre d'ionisation ont été prises dans le champ à o cm du centre du faisceau et hors du champ à 7,5, 10 et 12,5 cm du centre du faisceau.

Résultats : La collimation a permis de réduire la dose de rayonnement hors-champ de 87 %, la dose mesurable restante étant attribuable à la diffusion interne. La contribution des fuites de radiation à la dose de rayonnement était négligeable, l'écranage des fuites de radiation ne montrant aucune différence mesurable dans la dose de rayonnement, avec une valeur p de 0,48.

Conclusion : Ces résultats remettent en question l'utilité clinique de l'écranage de routine des parties du corps hors-champ durant la fluoroscopie.

Introduction

Fluoroscopy technologists routinely place a lead shield between the x-ray table and the patient's gonads, even if the gonads are not directly in the x-ray field. For example, a

Funding sources: None.

* Corresponding author: Andrew S. Phelps, MD, Department of Radiology & Biomedical Imaging, Benioff Children's Hospital C1758N, 1975 4th Street, San Francisco, CA 94158, USA.

E-mail address: Andrew.Phelps@ucsf.edu (A.S. Phelps).

http://dx.doi.org/10.1016/j.jmir.2015.12.082

technologist might shield the gonads during an esophagram although the x-ray beam is collimated to the chest. The area excluded by collimation is referred to as "out-of-field." The justification for out-of-field shielding is to block the x-rays that penetrate through the collimator shutters. This source of radiation is referred to as "leakage radiation." Nonfluoroscopy research has shown that leakage radiation has a small, but measurable contribution to patient radiation dose [1–10]. To the authors' knowledge, there has not been a study evaluating shielding of leakage radiation in fluoroscopy. The authors hypothesized that shielding leakage radiation during fluoroscopy should reduce radiation dose.

There are a number of methods recommended to reduce radiation dose during radiography [11, 12]. Lead shielding is one method to reduce radiation dose to body parts included in the direct x-ray beam [10, 13–21]. The area included in the direct x-ray beam is referred to as "in-field." Shielding also reduces radiation dose to body parts excluded from direct x-ray beam by using collimation. The area excluded by the direct x-ray beam is referred to as "out-of-field." However, the radiation dose reduction from shielding out-of-field body parts is small, unless the shield can be curved to block internal scatter originating from in-field body parts [1–9]. An example of this would be shielding the arms from scatter radiation exiting the patient's torso by placing a shield between the arms and torso.

There are four sources of out-of-field radiation: (1) internal scatter within the patient, (2) off-focus radiation from electrons hitting the edges of the anode, (3) leakage radiation through the collimator shutters, and (4) leakage radiation through the tube housing (Figure 1) [22]. Of these sources, internal scatter is the leading contributor to radiation dose [6, 7, 10]. Internal scatter originates from the patient and is not image-forming. In contrast, the three nonscatter radiation sources originate from the x-ray source and are image-forming (Figure 2). Of the three nonscatter radiation sources, leakage

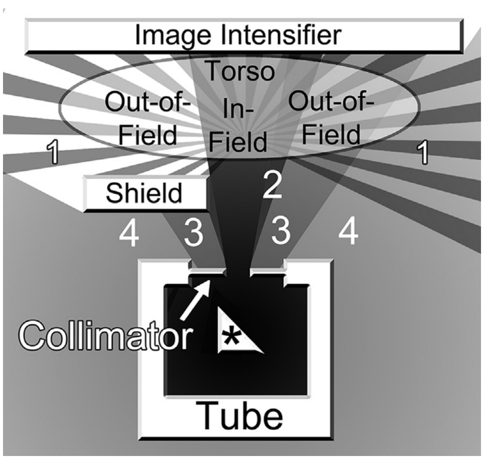

Figure 1. This diagram shows the different sources of out-of-field radiation, which are indicated with shades of gray. The anode is indicated with an asterisk. The "out-of-field" radiation sources are: scatter radiation (1), off-focus radiation (2), collimator leak (3), and tube leak (4).

radiation through the collimator shutters contributes the most to radiation dose. Collimator shutters are thin, which allows for higher mobility, but it also allows some of the x-rays to pass through to out-of-field body parts. In contrast, tube housing is very thick, so x-ray leakage from the tube housing is minimal. The contribution to radiation dose from off-focus radiation is also minimal, because it only affects a thin rim at the boundary of the in-field and out-of-field areas [22].

Leakage radiation through collimators results in image formation of out-of-field body parts. An example of this is shown in Figure 2A and B. Figure 2A shows a lower-extremity limb length survey in a 23-month-old female with gait abnormality. The examination in this patient was performed erect with digital radiography in two exposures, lower and upper, which were then stitched together. In Figure 2B, the same stitched radiograph is rewindowed to reveal the patient's torso with a breast shield present. In this example, the detector was not quite large enough to include all the legs, so a second exposure was required to cover the pelvis and upper femurs. Collimation was used during the second exposure to exclude the torso, yet image formation of the torso still occurred on the detector. This is because of radiation leakage through the collimator shutters. The breast shield blocks image formation from the leakage radiation. Radiology technologists will routinely see the image-forming effects of leakage radiation to out-of-field body parts. Seeing the out-of-field image-formation reinforces a technologist's desire to shield radiosensitive out-of-field body parts, as was done for the breasts in the clinical example previously mentioned. A technologist sees how a shield can block image formation from leakage radiation and assumes that shielding must also reduce skin-entrance dose to the patient. Radiologists, who interpret the radiographic images and report on the radiation dose, may not even know if out-of-field shielding was performed, because the technologists will routinely crop out the out-of-field image with postprocessing software [23]. It is important for radiologists to be aware of this shielding practice, as the radiologists are ultimately responsible for the care of patients in the radiology department.

Shielding out-of-field body parts has been shown to provide only a small reduction in radiation dose, but it may be beneficial for pediatric patients. Radiation dose reduction is clinically relevant in children because the lifetime risks of ionizing radiation are higher for children than for adults [24–27]. The most conservative approach is to assume any amount of radiation is harmful, and the effects of radiation are cumulative. The principle of ALARA stands for "as low as reasonably achievable" and acknowledges the tradeoff between patient safety and diagnostic accuracy. Although computed tomography contributes the most to overall diagnostic radiation dose [28, 29], fluoroscopy is still a significant source of radiation in children as it is a frequent examination. To the authors' knowledge, there is not any prior pediatric fluoroscopy research investigating out-of-field shielding, likely the consequence of ethical barriers. The current recommendations for reducing radiation to children during fluoroscopy