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Technical Report

Effective dose reduction in spine radiographic imaging by choosing the less radiation-sensitive side of the body

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Abstract

BACKGROUND CONTEXT: X-ray absorption is highest in the organs and tissues located closest to the radiation source. The photon flux that crosses the body decreases from the entry surface toward the image receptor. The internal organs absorb x-rays and shield each other during irradiation. Therefore, changing the x-ray projection angle relative to the patient for specific spine procedures changes the radiation dose that each organ receives. Every organ has different radiation sensitivity, so irradiation from different sides of the body changes the biological influence and radiation risk potential on the total body, that is the effective dose (ED).

PURPOSE: The study aimed to determine the less radiation-sensitive sides of the body during lateral and anterior-posterior (AP) or posterior anterior (PA) directions.

STUDY DESIGN: The study used exposure of patient phantoms and Monte Carlo simulation of the effective doses.

PATIENT SAMPLE: Calculations for adults and 10-year-old children were included because the pediatric population has a greater lifetime radiation risk than adults.

OUTCOME MEASURES: Pediatric and adult tissue and organ doses and ED from cervical, thoracic, and lumbar x-ray spine examinations were performed from different projections.

METHODS: Standard mathematical phantoms for adults and 10-year-old children, using PCXMC 2.0 software based on Monte Carlo simulations, were used to calculate pediatric and adult tissue and organ doses and ED. The study was not funded. The authors have no conflicts of interest to declare.

RESULTS: Spine x-ray exposure from various right (RT) LAT projection angles was associated with lower ED compared with the same left (LT) LAT projections (up to 28% and 27% less for children aged 10 and adults, respectively). The PA spine projections showed up to 64% lower ED for children aged 10 and 65% for adults than AP projections. The AP projection at the thoracic spine causes an excess breast dose of 543.3% and 597.0% for children aged 10 and adults, respectively.

CONCLUSIONS: Radiation ED in spine procedures can be significantly reduced by performing x-ray exposures through the less radiation-sensitive sides of the body, which are PA in the frontal position and right lateral in the lateral position.

Keywords: Dosimetry; Effective dose; Positioning; Projection; Radiography; Spine

FDA device/drug status: Not applicable.

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Introduction

Spine radiography usually includes two-dimensional exposures: lateral (LAT) projection, and either anterior-posterior (AP) or posterior-anterior (PA) projection. Because the spine is located in the middle of the body for the lateral projection, practitioners often choose the lateral positioning method—right lateral view (RT LAT, ie, left x-ray projection) or left lateral view (LT LAT)—without knowing the influence of the effective dose (ED). The AP or PA, as well as the LT LAT or RT LAT, projections are used without considering the potential for major differences in ED. Choosing the side of the body that is less sensitive to radiation can significantly reduce the ED during spine radiography for all patients, including children. Fig. 1 illustrates various spine x-ray projections.

Greater lifetime radiation risk for exposed children has been estimated [1,2]. There is no doubt that every effort should be made to reduce the ED for adults and children based on the "as low as reasonably achievable" (ALARA) principle. This can be attained simply by using x-ray projection toward the less radiation-sensitive sides of the body.

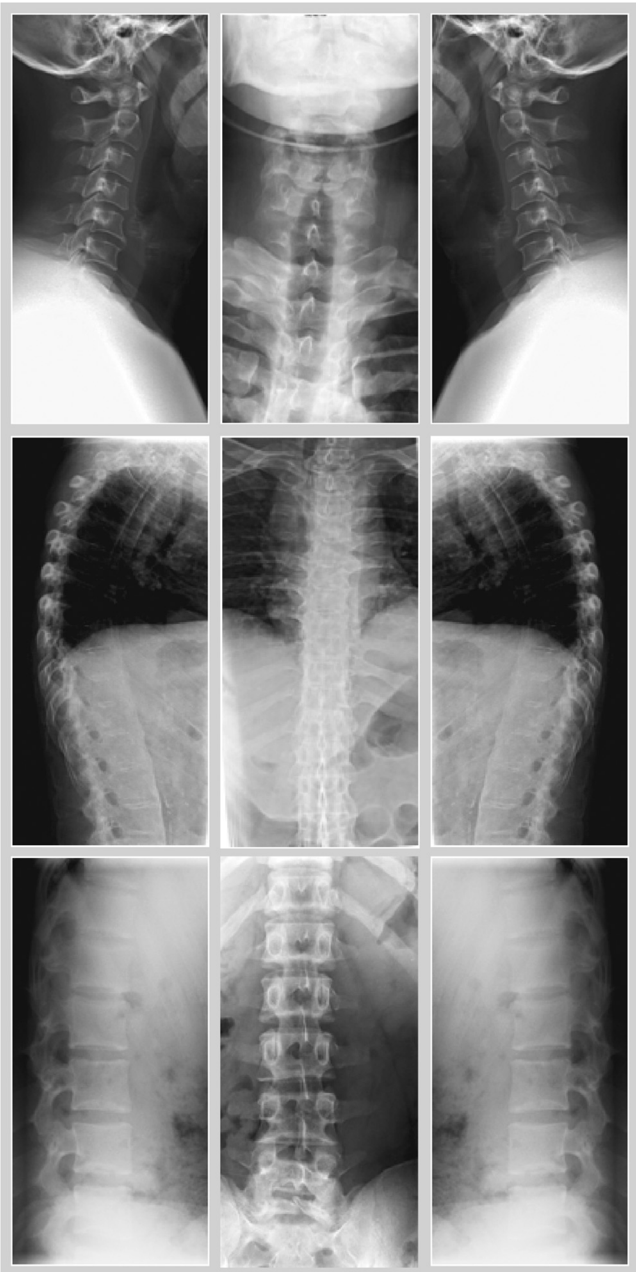

Fig. 1. Imaging of cervical, thoracic, and lumbar spine x-ray examinations.

Because of Compton and photoelectric interactions, the photon flux decreases inside the body from the entry area of the beam toward the image receptor. As it passes through the body, the number of photons diminishes, with decreasing absorbed dose to tissues and organs along the path. The organs and tissues located closest to the x-ray tube absorb the largest radiation dose.

Each organ and tissue has different radiation sensitivity. The International Commission on Radiological Protection set tissue weighting factors for radiation-sensitive tissues and organs that were chosen to represent the contribution of individual tissues and organs to the overall radiation detriment from genetic effects and stochastic effects like cancer [3]. The ED represents the total body radiation detriment from the exposure and is calculated by summing the mean absorbed dose of each tissue and organ multiplied by the relevant radiation tissue weighting factor, over all the radiation-sensitive organs and tissues (stochastic effects). The directional projection causes differences in the ED [4–6]. These differences arise from the asymmetrical position of tissues and organs inside the body, x-ray shielding of organs by other organs, and the unique radiation sensitivity of each organ.

This study focused on reducing the ED in models representing 10-year-old children and adults. Based on these models, we calculated the differences in ED with various imaging projections. We chose to demonstrate this phenomenon using conventional spine x-ray examinations, but the results can also be applied to spine fluoroscopy procedures.

Materials and methods

Monte Carlo simulations estimate the ED for the various organs and use the information to calculate the total body influence, that is, the ED [7]. Cervical, thoracic, and lumbar spine examinations were simulated to observe differences in ED obtained with AP, PA, RT LAT, and LT LAT x-ray projections. The simulation software PCXMC 2.0, published by the Radiation and Nuclear Safety Authority in Finland (STUK), was used [7]. The PCXMC 2.0 uses hermaphrodite mathematical phantoms. We chose the standard PCXMC 2.0 phantoms for children 10 years of age (139.8 cm in height, 32.4 kg in weight) and adults (178.6 cm in height, 73.2 kg in weight).

The PCXMC 2.0 simulation was performed with a focus on the skin surface distance of 100 cm. The beam filtration was taken as 2.5 mm Al. The ED calculations were based on The International Commission on Radiological Protection Publication 103 [3]. We located the phantom-simulated radiation field according to a common radiography method [8]. The tube voltage (kV) and the exposure charge (mAs) parameters of the examinations are presented in Table 1. Each value represents an average of three to seven datasets.