A study on the minimum transmission dose for image formation in X-ray imaging of forearm, femur and ankle joint

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Article History:
Received on: 14 Oct 2020
Revised on: 14 Nov 2020
Accepted on: 16 Nov 2020

Keywords:
Exposure dose, Absorbed dose, Surface dose, Interactive 3D surface plot, Plot profile

ABSTRACT

Excellent performance of the digital detector can generate medical images at a lower dose. However, if a certain level of dose exposure of the sensor detector can generate an image to recognize it. In this study, the exposure conditions of the forearm, femur, and ankle joint tests currently used in clinical trials were tested with lower doses. The resolution pattern was analyzed using the Image J program, and the results were obtained by analyzing the Interactive 3D Surface Plot. In addition, by measuring the surface dose and absorbed dose, the digital detector finds the minimum conditions to make an image and also checks the effect of dose reduction. The image of the obtained resolution pattern was analyzed by Plot profile using Image J program. It was confirmed that the gray value width decreased at the same pixel distance as the exposure conditions decreased. Even if the exposure conditions were lowered from step 1 to step 4, which is the standard condition of the forearm test, the resolution showed no difference at 1.4 Lp/mm. In the Interactive 3D Surface Plot, as the range of the grayscale lowered the exposure condition, the shape of the surface contours gradually became blurred, and the contrast of black and white shades decreased. The resolution from step 1 to step 3, which is the standard condition of the femur bone test, was 1.2 Lp/mm, indicating no difference. Even if the exposure conditions were lowered from step 1 to step 4, which is the standard condition for ankle examination, the resolution showed no difference at 1.4 Lp/mm. It is thought that it is necessary to accumulate a lot of data by further subdividing the stage of exposure conditions according to the thickness in more areas.

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INTRODUCTION

The digital X-ray imaging system has a wider dynamic range and dose linearity compared to the film-sensing system, which reduces the re-shooting rate and achieves a certain level of image quality by adjusting the grayscale. The dynamic range in the digital detector can be expressed by the ratio of the maximum and minimum values of the pixel and is effective only when the absorbed dose of the detector and the pixel value is in a linear relationship (Huda et al., 1997; Rong, 2001; Floyd et al., 2001). Owing to this advantage, excessive doses could be used without degrading the image quality, and in turn, constant image quality could be main-
tained even at small doses. The use of medical radiation can be helpful as well as the patient community. However, excessive use of radiation can be dangerous for patients and users. Therefore, appropriate protection and management of medical radiation have been proposed, and the principle of medical radiation shielding lies in the justification and optimization of behavior (Körner, 2007; Yaffe and Rowlands, 1997).

If the benefit of the purpose of the examination can be obtained more than the damage to the patient from the radiation examination, the justification is determined by careful judgment (Kroft et al., 2006). And optimization is to keep the exposure dose as low as possible while obtaining optimal results from radiographic examinations performed on patients. Living radiation examining a patient using medical radiation requires constant effort and research (Hamer et al., 2005).

As system use and management become more convenient, careful management and effort are required by the user, the Radiological Technologists. Replacing the existing film/screen system inspection with digital radiography, there have been remarkable advances in the management of patient dose and image quality of radiography (Rapp-Bernhardt et al., 2003).

In chest radiography, the amorphous silicon flat plate detector showed a significant reduction in both effective dose and entrance skin dose (ESD) compared to film/screen system and CR system, and the image quality was also reduced. It appeared to be more improved than the field (Strotzer et al., 1998). In addition, in the skeletal system examination, the dose could be reduced without deterioration. In the study using the hand phantom, the image quality was superior to that of the film/screen system under the same exposure conditions, and the diagnostic value was not degraded. Showed a decrease in dose (Strotzer et al., 2000; Bergh et al., 2000).

**MATERIALS AND METHODS**

Based on the average exposure conditions of the forearm, femur, and ankle joints used in clinical exposure conditions, the experiment was conducted by lowering the tube voltage and tube current step by step for the human phantom. Images are acquired for each condition, and surface and absorbed doses are measured. The X-ray lead bar phantom is photographed under each stage of exposure conditions to obtain an image. The acquired image is analyzed using an image analysis program, Image j.

**Resolution pattern test**

An image is acquired by photographing the X-ray lead bar phantom under exposure conditions at each stage. The resolution of the X-ray lead bar phantom to the visible section was measured, as shown in Figure 1.

![Figure 1: Huttnner standard X-ray lead bar phantom TYP 5](image1)

The acquired image is analyzed to as profile plot as shown in Figure 2 using an image analysis program, the image j.

![Figure 2: X-ray lead bar phantom image exposed at each stage condition](image2)

**Interactive 3D surface plot**

Interactive 3D surface plot analysis is performed on the images acquired using the image analysis program Image j, as shown in Figure 3.

![Figure 3: Interactive 3D surface plot analysis using Image J](image3)
Absorbed dose and Surface dose

Forearm, femur, and ankle joints, surface dose and absorbed dose are measured using a human phantom for each condition. Measurements were performed using the Unifors RaySafe Xi Semiconductor dosimeter shown in Figure 4.

RESULTS AND DISCUSSION

The image of the obtained resolution pattern was analyzed by Plot profile using Image J program. It was confirmed that the gray value width decreased at the same pixel distance as the exposure conditions decreased as shown in Figure 5.

In the forearm test conditions step 1, step 2, step 3, and step 4, the resolution was 1.4 Lp / mm and in step 5, it was 1.2 Lp / mm. Under the forearm test exposure condition, step 5, the absorbed dose decreased by 73.38% compared to step 1. The surface dose was reduced by 71.99% compared to step 1 in exposure condition step 5 as shows in Table 1.

In the femur test conditions step 1, step 2, step 3, and step 4, the resolution was 1.4 Lp / mm and in step 5 it was 1.2 Lp / mm. Under the femur test exposure condition, step 5, the absorbed dose decreased by 68.63% compared to step 1. The surface dose was reduced by 65.15% compared to step 1 in exposure condition step 5 as shows in Table 2.

In the ankle joint test conditions step 1, step 2, step 3, and step 4, the resolution was 1.4 Lp / mm and in step 5 it was 1.2 Lp / mm. Under the ankle joint exposure condition, step 5, the absorbed dose decreased by 84.52% compared to step 1. The surface dose was reduced by 81.19% compared to step 1 in exposure condition step 5 as shows in Table 3.

As a result of the analysis of the interactive 3D surface plot of the Forearm phantom image, it was confirmed that the shape of the surface contour is gradually blurred and the contrast of black and white shades decreases as shows in Figure 6.

As a result of the analysis of the interactive 3D surface plot of the Femur phantom image, it was confirmed that the shape of the surface contour is gradually blurred and the contrast of black and white shades decreases as shows in Figure 7.

As a result of the analysis of the interactive 3D surface plot of the Ankle joint phantom image, it was...
Figure 6: Comparative analysis of interactive 3D Surface Plot between Forearm step 1 condition and step 5 condition

Figure 7: Comparative analysis of interactive 3D Surface Plot between Femur step 1 condition and step 5 condition

Figure 8: Comparative analysis of interactive 3D Surface Plot between Ankle step 1 condition and step 5 condition
confirmed that the shape of the surface contour is gradually blurred and the contrast of black and white shades decreases as shown in Figure 8.

In this study, in order to find the minimum dose for which an image can be established, the exposure conditions currently used in clinical trials were examined step by step, and the original data were analyzed in various ways. In the resolution, the spatial frequency was 1.0–1.4 Lp/mm, and this value showed about 1.5 times higher resolution than the film image.

As a result of analyzing the Interactive 3D Surface Plot, it was found that as the exposure conditions decreased, the range of the grayscale decreased and the shape of the surface contour gradually disappeared, resulting in inferior contrast.

As a result of the visual evaluation, it was found that the Forearm test should use the exposure conditions of step 4 at least 56 kVp, 100 mA, 4 mAs. It was confirmed that the absorbed dose was reduced by 62.58%, and the surface dose was reduced by 61.18% compared to the step 1 condition. In the Femur test, it was found that as the exposure conditions of step 3 should be over 59 kVp, 200 mA, and 10 mAs. It was confirmed that the absorbed dose decreased by 53.18%, and the surface dose decreased by 50.01% compared to the step 1 condition. In the ankle joint test conditions, it was found that the exposure conditions of step 3, 49 kVp, 100 mA, and 4 mAs, should be used. It was confirmed that the absorbed dose was reduced by 57.14% and the surface dose was reduced by 54.41% compared to the step 1 condition.

CONCLUSIONS

This study was conducted using a human model phantom made of tissue-equivalent material. Forearm, femur, and ankle joint did not have any problems in conducting the experiment and analyzing the images, but it is expected to have difficulty inaccurate image evaluation because internal organs or spaces cannot be identified in the head or abdomen examination. In addition, due to the constant thickness of the human body model phantom, it was unfortunate that the results could not be obtained in various body types that could be blown by real patients. In this study, X-rays were exposed by dividing the condition into 5 stages in a total of 3 regions, and it is thought that the stages of the exposure conditions should be further subdivided according to the thickness into more regions to accumulate a lot of data. If these studies continue, you can expect to develop technology for digital detector sensors based on them.

Conflict of Interest

The authors declare that they have no conflict of interest for this study.

Funding Support

The authors declare that they have no funding support for this study.

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