Proposal of Dose optimization method in digital radiography
based on the noise characteristics for Chest X-ray Image

Poster No.: C-0179
Congress: ECR 2015
Type: Scientific Exhibit
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Keywords: Image verification, Radiation safety, Radiation effects, Digital radiography, Thorax
DOI: 10.1594/ecr2015/C-0179

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Aims and objectives

With the remarkable digitization of X-ray imaging systems, the screen-film (S/F) system as an image-forming device for general imaging has been replaced by digital radiography (DR) system, such as computed radiography (CR) and flat-panel detector (FPD).

The proper radiation dose is obtained by the automatic density adjustment mechanism in the DR system. Therefore, in DR, there is no concept corresponding to sensitivity, which is an important imaging condition in the S/F system. Accordingly, it is difficult to set up imaging parameters in DR, because no method to systematically set the appropriate imaging parameters has been established, contrary to the case in the S/F system. According to the report of the International Commission on Radiological Protection (ICRP), the problem of increased dose in DR as compared to that in the S/F system has been pointed out, and standardization of the imaging parameters is now being sought.

The physical performance of the S/F system can be evaluated comprehensively by using noise equivalent quanta (NEQ), which is the square of the output signal-to-noise ratio (SNR). However, the use of detective quantum efficiency (DQE), which is defined by the ratio of the squared input SNR to the squared output SNR, is advocated for the evaluation of DR, because there is no index for sensitivity in DR.

DQE can be obtained by the ratio of the mean number of photons per unit area which are absorbed to form an image by DR and the mean number of incident photons; namely, it represents the efficiency for detecting photons. Therefore, in an ideal imaging system in which all the incident photons are used to form an image, the DQE should be 1. From this, it may be considered that the noise characteristics, which becomes a denominator of the definitional equation for NEQ and is directly influenced by the imaging dose, would be useful to determine the imaging parameters for DR. However, there have been no reports on methods to determine the imaging dose by using the root mean square (RMS) or Wiener spectrum (WS), both of which are used as parameters to evaluate the incident dose and noise characteristics.

Herein, we focused on the relationship between the noise characteristics and the imaging dose, and defined the intersection of the low-dose region, that is affected by the quantum mottle, and the linear approximation in the high-dose region, which depends on the system noise, as the threshold for dose optimization in X-ray imaging in which the dose and image quality are well balanced. The purpose of this study was to estimate the appropriate imaging dose in DR based on the threshold obtained from the noise characteristics, according to the RMS and WS and the imaging doses.
Methods and materials

The chest X-ray images were prepared using a Konica computed radiography system Rejus 170 (CR), with the distance between the focus and stimulable phosphor plate set as 200 cm and the tube voltage set at 120 kV. A chest phantom was prepared with acryl and aluminum plates. Regarding the acquisition conditions of CR, setting the baseline at a dose at which the film density of the standard sensitivity, S/F system was the same as those for the pulmonary, lungs rib, and mediastinum, 5 steps of 2-fold serial doses were set: 1/4, 1/2, 1, 2, and 4. The S/F system at standard doses was 85 mGy in the imaging performed using RADCAL CORPORATION #Monitor Model 9015#Chamber. Model 10×5#6#. I show The Geometric arrangement of RMS & WS#Figure 1 shows the layout of the experiment to measure RMS and WS.

An area of 256 × 256 pixels in the display screen center was selected as the calculation range of the RMS granularity by using the region of interest (ROI) designation function. The standard deviation of this range was obtained from an average of the 5 images used for the calculation. The WS measurements were performed by the two-dimensional Fourier transformation (2DFT) process that conforms to the International Electrotechnical Commission (IEC) standard##. As to the calculation range of the 2DFT method, a 256 × 256 pixel image in the ROI was set as 1 segment. Trend correction of this area was determined by obtaining the two-dimensional approximated surface using the Legendre polynomial, then subtracting the data from the original image for correction and using a total of 320 segments of 5 images, in which 64 segments per image were obtained by 2DFT.
Fig. 1 Experimental layout of RMS and WS using CR system Konica Regius 170.

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**Fig. 1**

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Fig. 2  Result of vertical Wiener spectrum calculated by two dimension Fourier transform method by Regius 170.

Fig. 2

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Fig. 3  Relationship between the root mean square (RMS) and exposure dose using Regius 170.

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Fig. 4  Relationship between the Wiener spectrum and exposure dose using Regius 170.

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Results

A total of 320 segments of ST images (pixel size: 0.175 mm) were evaluated by the 2DFFT process to obtain the WS value in the vertical direction. There were no significant variations in the WS values in any of the areas of spatial frequency, because the values were smoothed by the frequency bins and each sample was averaged by 64 segments.

The RMS values and WS values showed remarkable decrease as the imaging doses increased in the low-dose region (Fig.2). This was presumably because the granularity and noises were improved by the quantum mottle, which was inversely proportional to the imaging dose. A smooth decrease (improvement) was seen in the high-dose region. We thought that this was because the quantum noise was dominant in the low-dose region, while the influence of the system noise became dominant as the imaging dose increased.

Therefore, from the relationship between the RMS and WS values and the imaging doses, the appropriate dose was determined based on the threshold of the intersection of the linear approximation in the low-dose region affected by the quantum mottle, and in the high-dose region affected by the system noise, which depends on the system noise. It was estimated from the WS and RMS that the imaging dose in CR can be reduced by approximately 30% (60µGy) as compared to the reference dose in the S/F system, which suggests that this can be used as a parameter to optimize the imaging dose.
Conclusion

Setting the imaging parameters for DR imaging is a challenging task, because no systematic method has been devised to establish the appropriate imaging parameters for DR. We investigated a method to optimize the X-ray imaging dose based on the WS values and imaging doses in the low-spatial frequency region. The results of this study suggest that the imaging dose in CR can be reduced to about 70% using the ratio of the reference dose in the S/F system and the threshold of the imaging dose optimization estimated from the WS and RMS values of CR.

From the ratio of the reference dose of the S/F system and the threshold of the imaging dose optimization estimated from the WS and RMS values of CR, it was shown that the imaging dose in CR can be reduced to about 70%. Noise measurement with WS and RMS is easy to use in analyses and experiments as compared to the visual evaluation method, and the method of determining the imaging dose by using the threshold is simple and useful as a systematic method for determining the X-ray imaging conditions in digital imaging. From these results, this method is considered to be applicable to clinical imaging.
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References


