



Assessment of Medical X-Ray Radiographic Screen-Films in Different Spatial Frequencies According To Detective Quantum Efficiency Computation

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ABSTRACT

In medical imaging, to make better images there are some measures such as detective quantum efficiency (DQE) and noise equivalent quanta (NEQ) used to evaluate the image quality of each imaging system. Detective quantum efficiency (DQE) is one of the important measures in the assessment of image quality and detector performance. DQE of two types of screen-films namely Lanex Regular/T-Mat G/RA and Lanex Regular/T-Mat L/RA were determined using MTF and NPS data, separately. Moreover, gamma was calculated from characteristic curves for each screen film and photon fluence was estimated using published literature. DQE of the screen-films were computed for three optical densities 0.7, 1.0 and 1.4. The results show Lanex Regular/T-Mat G has better DQE than Lanex Regular/T-Mat L -especially at low frequency with higher contrast for diagnostic radiology purposes.

Key words: Detective Quantum Efficiency (DQE), Diagnostic Radiology, Image quality, Screen-film

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INTRODUCTION

Diagnostic imaging is widely used every year. There are many imaging techniques available to patients, such as, radiography, radionuclide imaging, and ultrasound imaging systems, computed tomography (CT), magnetic resonance imaging (MRI) and digital radiography. Diagnostic imaging enables us to see inside the human body and is less invasive than surgery. The high-quality radiographic image is one of the major aims of diagnostic radiology. In medical imaging there are a few quantities to evaluate the image quality. They are modulation transfer function (MTF), noise power spectrum (NPS), noise equivalent quanta (NEQ) and detective quantum efficiency (DQE). A good radiographic image results in better diagnosis in diseases. Detective Quantum Efficiency the ratio of noise equivalent quanta to the actual number of exposure quanta from which the image was made (Martin, Sharp, & Sutton, 1999), which can also be viewed as the fraction of photons that are detected “correctly” (Prince & Links, 2006). Screen-films which are used in projection radiography systems utilizing X-rays are one of the famous radiology techniques which most of people have experienced it at least once in their

life. In this work, the DQE of Lanex Regular/T-Mat G/RA and Lanex Regular/T-Mat L/RA screen-film systems were determined and compared in order to understand the relative quality among the two screen-films.

MATERIALS AND METHODS: CALCULATION OF MTF AND NPS

The MTF and NPS values were obtained from data of previous work [3], which were calculated with X-ray source of 81 kVp. MTF and NPS were interpolated to obtain spatial frequencies in range of 0 to 7.8 cycles/mm by 0.1 cycles/mm steps.

DETECTIVE QUANTUM EFFICIENCY (DQE)

DQE in one dimension for screen-film radiography is defined by (Metz et al., 1995), (Martin et al., 1999), (Lemoigne, Caner, & Rahal, 2007), (Doi, 2006), (Commission, 2007):

$$DQE(u) = \frac{(\log_{10} e)^2 \gamma^2 MTF^2(u)}{Q \times NPS(u)} \quad (1)$$

Where u is the spatial frequency in terms of cycles/mm, γ is the gamma of film, $MTF(u)$ is the modulation transfer function in one dimension, $NPS(u)$ is noise power spectrum (Weiner spectrum) in one dimension and Q is photon flocnce (quanta incident on the detector per unit area) in terms of photons per mm^2 . In some texts photon flocnce is presented by symbol Φ (Johns, 1983), (Beutel, 2000).

CALCULATION OF GAMMA OF FILM

Gamma of film can be calculated as the slope of the straight line of the characteristic curve (optical density versus logarithmic exposure) (Curry et al., 1990) of the screen-film using the equation (Dainty & Shaw, 1974), (Bushberg, 2002)

$$\gamma = \frac{D_2 - D_1}{\log_{10} X_2 - \log_{10} X_1} = \frac{D_2 - D_1}{\log_{10}(X_2/X_1)} \quad (2)$$

where D_1 and X_1 are the optical density and exposure of one point on the graph and D_2 and X_2 are the corresponding values for another point on the straight line portion of the characteristic curve. The characteristic curves of two mentioned screen-films were calculated using data from previous work(Hassan, Saridan, Munajat, & Sahibuddin, 2004).

ESTIMATION OF PHOTON FLUENCE

To estimate photon flocnce, the formula relating photon flocnce to exposure was used, (Hendee & Ritenour, 2002),

$$\frac{\Phi}{X} = \frac{0.00873 (J)}{h\nu(\mu_{ab}/\rho)_{air} (kg.R)} \quad (3)$$

where Φ/x is photon fluence per roentgen in unit of (photons $m^{-2} R^{-1}$), X is exposure in Roentgen, ($h\nu$) is energy in joules and $(\mu_{ab}/\rho)_{air}$ is mass absorption coefficient in air (m^2/kg). Moreover, mass absorption coefficient in air was interpolated for 81 kVp from standard tables (Hubbell & Seltzer, 1996). According to standard (IEC, 2008) flocnce must be in unit of (photons/ $mm^2 \cdot \mu Gy$), and the photon fluence was changed to this unit. Finally, logarithmic exposures in optical densities 0.7, 1.0 and 1.5 were calculated from characteristic curves for each screen-film and multiplied by Φ/x to obtain photon fluence Q (or Φ) which must be in unit of (photons/ $mm^2 \cdot \mu Gy$). Three optical densities 0.7, 1.0 and 1.5 were used to compare screen-films performance at low, medium and high optical densities (Monnin, Gutierrez, Bulling, Lepori, & Verdun, 2005).

RESULTS AND DISCUSSION CHARACTERISTIC CURVES

Figure 1 shows the characteristic curves of Lanex Regular/T-Mat G/RA and Lanex Regular/T-Mat L/RA. From the slope of straight part of characteristic curves, it is clear that Lanex Regular/T-Mat G/RA has bigger gamma value and higher contrast than Lanex Regular/T-Mat L/RA.

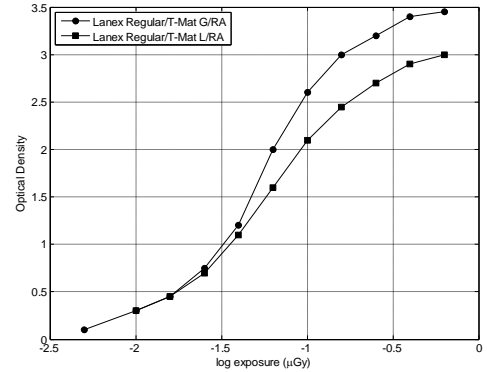
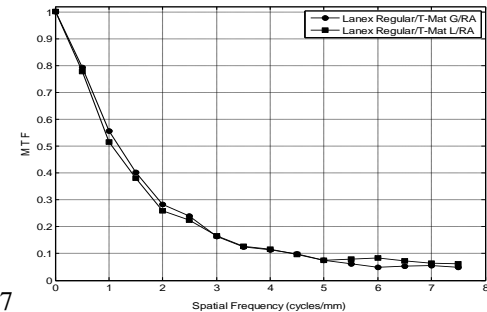


Fig.1. X-Ray Characteristic curves of the screen-films.

Moreover, two curves show that they are almost the same at toe, but are different near the shoulder. Gamma value for Lanex Regular/T-Mat G/RA from straight part of the curve was calculated, for optical densities 1.3 and 2.5 with their relative exposures, equal to 3.51 and similarly for Lanex Regular/T-Mat L/RA for optical densities 1.2 and 2.0 with their relative exposures, equal to 2.50. The values were derived from the curves using interpolation method.

MTF AND NPS

MTF and NPS of the two screen-films are shown in figures 2 and 3, respectively.



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Fig. 2. MTFs of screen-film systems

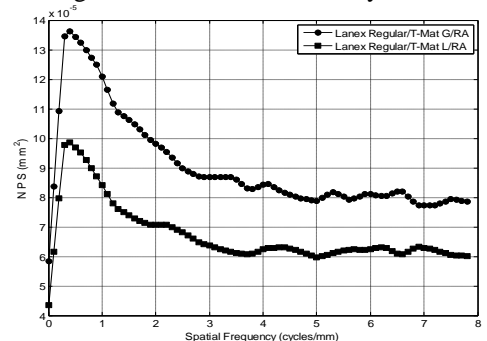


Fig.3. NPSs for two screen-film systems

Figure 2 shows slightly better MTF for Lanex Regular/T-Mat G/RA for spatial frequencies between 0.5 and 3.0 cycles/mm, but slightly better MTF for Lanex Regular/T-Mat L/RA for spatial frequencies between 5.2 and 7.0 cycles/mm. In other

ranges of spatial frequencies the MTF is the same for both screen-films. Figure 3 shows that NPS of Lanex Regular/T-Mat G/RA is almost one and a half times bigger than Lanex Regular/T-Mat L/RA.

DETECTIVE QUANTUM EFFICIENCY

Detective quantum efficiency was calculated by substituting relevant data and values into the DQE formula mentioned above.

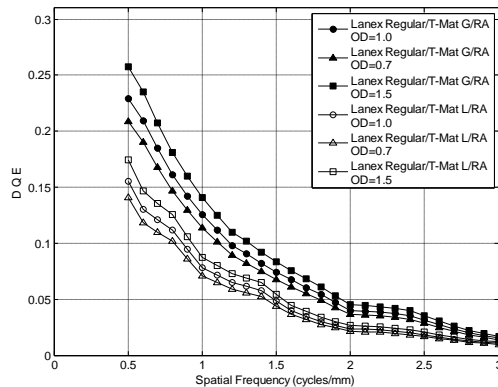


Fig.4. DQE for both screen-films

Figure 4 shows DQE of the two screen-films at three different optical densities (OD) of 0.7, 1.0 and 1.5 with different photon fluence. Each screen-film shows better DQE

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for high optical density. Figure 4 demonstrates DQE of Lanex Regular/T-Mat G/RA is bigger than Lanex Regular/T-Mat L/RA roughly by a factor of 1.5 for each optical density in low frequencies. The main reasons are better MTF and bigger gamma of film in Lanex Regular/T-Mat G/RA. More details on explanations and parameters also can be found in our published book (Khanmirzaei and Hassan, 2012). The DQE of both screen-film systems are closing to each other at high spatial frequencies.

CONCLUSIONS

The DQE of Lanex Regular/T-Mat G/RA and Lanex Regular/T-Mat L/RA screen-film systems were computed using a MATLAB program. In low frequencies, there is a better DQE for Lanex Regular/T-Mat G/RA in compare with Lanex Regular/T-Mat L/RA. In high spatial frequencies, the DQE of both screen-films are almost the same. As a result, the DQE of Lanex Regular/T-Mat G/RA was found higher than that of Lanex Regular/T-Mat L/RA. The DQE computed depends much on the quality of MTF and NPS data. The Lanex Regular/T-Mat G/RA shows better performance for diagnostic radiology purposes.

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