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Evaluation of the detector linearity response of the DR system in different x-ray bean filters

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Abstract: In the recent past, at Brazilian radiology services, direct digital radiography (DR) systems are replacing Computed Radiography (CR). This situation provides several significant advantages such as improving digital image quality, patient effective dose reduction, and improved speed of examinations performed. To evaluate DR systems, various organizations have published protocols with guidelines concerning quality assurance and acceptance tests for DRs. In these protocols, there are methodologies for evaluating several parameters, such as the detector linearity response (DLR). To test the DLR, different methodologies are proposed by the organizations, such as the application of different additional filters on the X-ray beams spectrum to promote the X-ray doses suitable to produce the latent image in the DR. The objective of this work was to evaluate the results of different protocol methodologies for carrying out the DLR test of a DR flat panel. An analogic radiology equipment, a primary ionization chamber, a DR system and images unprocessed were used in this study. As indicated by the protocols, the spectra of the X-rays were modified by additional filters of copper (Cu) with aluminum (Al); Al; Cu; and polymethylmethacrylate (PMMA). The spectra of the X-rays were modified to achieve the exposure range of 0.1 to 7 mR. The results showed that the DLR curves adjustment were R^2>0.99, for a logarithmic equation, type y=a.ln(x)+b. For the filters of 0.5 mmCu with 1.0 mmAl; 11.5 mmAl; 1.0 mmCu; 21 mmAl the mean pixel values showed 0.9% of the coefficient of variation (COV), while for 10 cm PMMA filters, the COV increased to 2.7%. The study showed that methodologies using Al, Cu and Al with Cu filters DLR have similar responses while using PMMA, the response was slightly different.

Keywords: direct digital radiography, linearity, image quality, filtration.

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Avaliação da resposta de linearidade da placa DR em diferentes filtrações do feixe de raios X

Resumo: Nos últimos anos, nos serviços de radiologia brasileiros, os sistemas de radiografia digital direta (DR) têm substituído os sistemas de radiografias computadorizadas (CR). Esta situação oferece diversas vantagens como a melhoria da qualidade da imagem digital; a redução da dose efetiva no paciente e o aumento da velocidade dos exames realizados. Para avaliar sistemas DRs, diversas organizações publicam protocolos como diretrizes relativas à garantia de qualidade da imagem e testes de aceitação para DRs. Nestes protocolos são encontradas metodologias para avaliar vários parâmetros, como a linearidade da resposta do detector (DLR). Para o DLR, as organizações propõem diferentes metodologias como a aplicação de diferentes filtros adicionais nos espectros dos feixes de raios X, para promover as doses adequadas e produzir a imagem latente na placa DR. O objetivo deste trabalho foi avaliar os resultados de diferentes metodologias apresentadas nos protocolos, para a realização do teste de DLR. Foram utilizados no estudo um equipamento de raios X analógico, uma câmara de ionização para feixe primário, um sistema DR e imagens não processadas. Conforme indicado pelos protocolos, os espectros dos raios X foram modificados adicionando filtros de alumínio (Al); cobre (Cu) com Al e polimetilmetacrilato (PMMA). Os espectros dos raios X foram modificados para exposições no intervalo de 0,1 a 7 mR. Os resultados mostraram que as curvas DLR apresentaram ajustes com R^2>0,99, para uma equação logarítmica do tipo y=a.ln(x)+b. Para os filtros de 0,5 mmCu com 1,0 mmAl; 11,5 mmAl; 1,0 mmCu e 21 mmAl, os valores dos pixels médios apresentaram coeficiente de variação (CV) de 0,9% enquanto que, para o filtro PMMA de 10 cm o CV aumentou para 2,7%. O estudo mostrou que as metodologias que utilizam filtros de Al, Cu e Al com Cu as DLRs apresentaram-se semelhantes, enquanto que para o PMMA a resposta foi sutilmente diferente.

Palavras-chave: radiografia digital, linearidade, qualidade da imagem, filtração.

1. INTRODUCTION

In the recent past, at Brazilian radiology services, direct digital radiography (DR) are replacing Computed Radiography (CR) systems. This situation provided several significant advantages as improving digital image quality; patient effective dose reduction and improved speed of examinations performed [1].

Various organizations have published protocols with guidelines concerning quality assurance and acceptance tests for CRs and DRs to evaluate DR systems, and these protocols can be applied to CRs and DRs since both promote digital images. There are methodologies for evaluating several parameters in these protocols, one being the detector linearity response (DLR). These organizations propose different methodologies for testing the DLR. In this study, the protocols applied were from the American Association of Physicists in Medicine (AAPM), report 93; Navy Diagnostic Imaging Equipment Performance Survey Manual, technical manual TM-6470; International Atomic Energy Agency, TECDOC 457 and TECDOC-1958. [2, 3, 4, 5]. The use of additional filters on the X-ray spectra promotes the X-ray doses suitable to produce the latent image in the DR [6]. This study was conducted with the objective of evaluating multiple protocol methodologies for carrying out the DLR test of a DR flat panel.

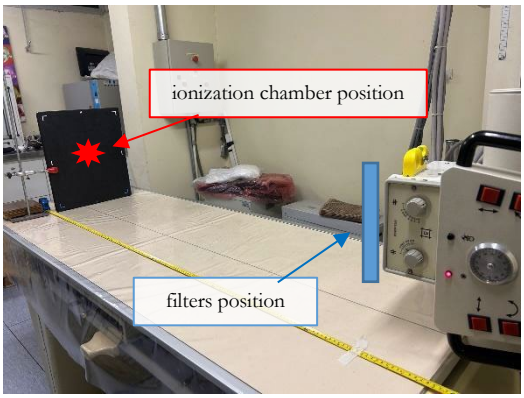
2. MATERIALS AND METHODS

The study took place at Universidade Federal de São Paulo (UNIFESP), within the Department of Diagnostic Image of its Medical Hospital School – Hospital São Paulo (HSP).

Using an analogic radiology equipment Philips Compacto Plus 500, the X-ray emission spectra were changed using always 80 kVp and the product current x time (mAs) in steps

between 0,5 to 100 mAs (achieved range of 0.1 to 7 mR); 180 cm from the X-ray spot focal and maximum aperture of the collimator on DR, a primary ionization chamber Radcal, model Accu-Dose-6cc. was used to measure the exposure on the DR, Konica Minolta Aero DR system. A total of 3 acquisitions to 5 different mAs were done for each protocol. This resulted in a total of 72 acquisitions - or images - to be analyzed. Only images unprocessed were used in the study. As indicated by the protocols, the spectra of the X-rays were modified by additional filters of copper (Cu) with aluminium (Al); Al; Cu; and polymethylmethacrylate (PMMA). In Figure 1, it is possible to see the image of the geometry used in the DLR test with an indication in red, the position of the ionization chamber and in blue, the position of the additional filters.

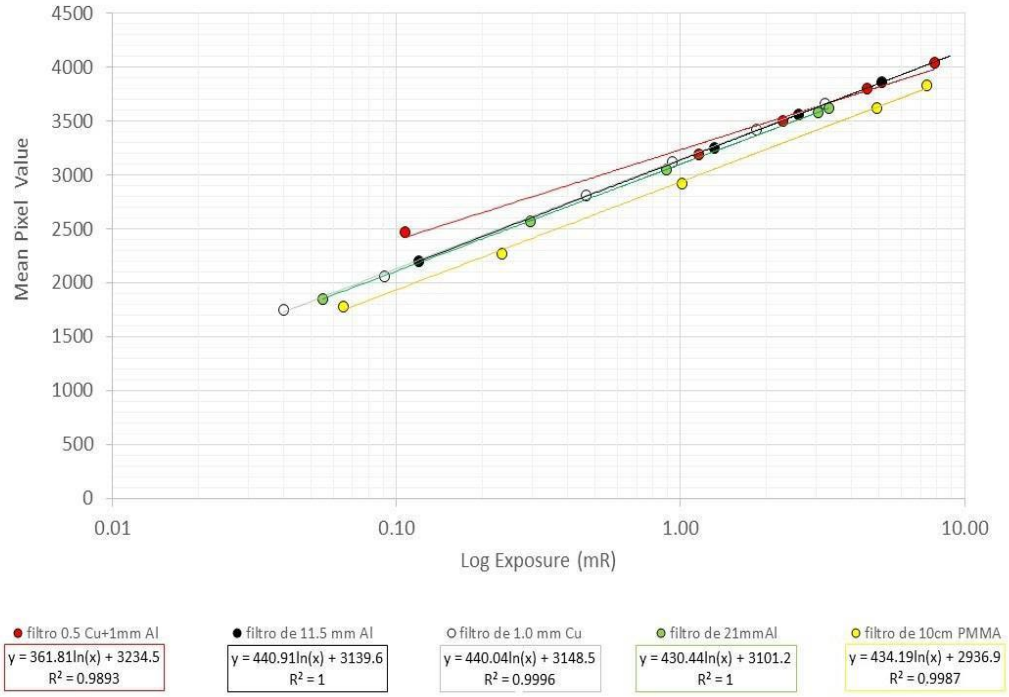
Figure 1: Image of the geometry used in the DLR test with indication in red , the position of the ionization chamber.



3. RESULTS AND DISCUSSIONS

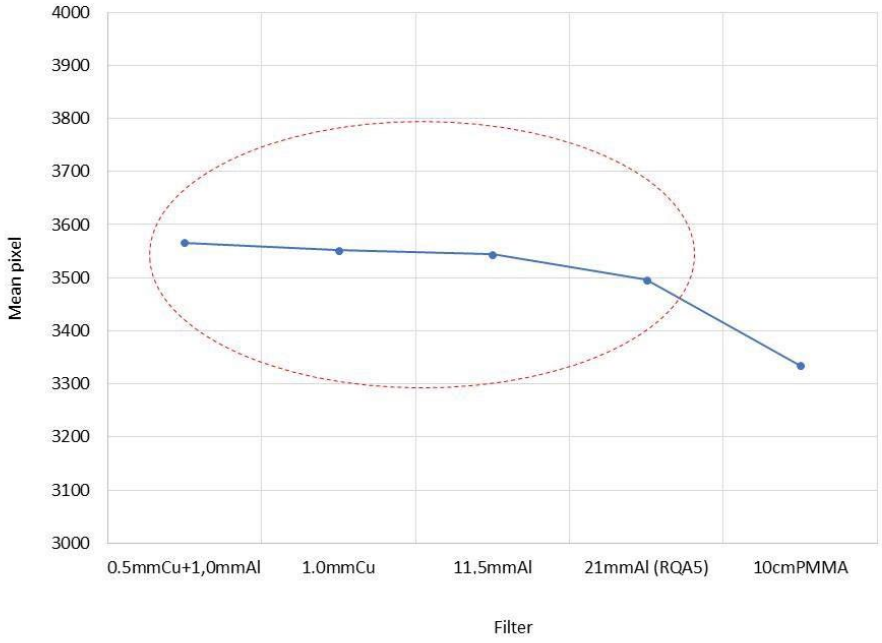
In the figure 2, there is the graphic of the dose in function of the mean pixel value to DLRs curves adjustment for the different protocols methodologies. To all curves that the R^2 was smaller than 0.99, for a logarithmic equation, type y=a.ln(x)+b studied.

Figure 2: Graphic of the dose exposure in function of the mean pixel value to DLRs curves adjustment for the different protocols methodologies. The error bars in the figure are smaller than 1%.



In figure 3, shows the mean pixel values calculated by the curves adjustment (figure 2) to the images used deferments filters. To the filters of 0.5 mmCu with 1.0 mmAl; 11.5 mmAl; 1.0 mmCu; 21 mmAl the mean pixel values showed COV near a 0.9% (inside of red line, in figure 3), while for 10 cm PMMA filters the COV increased to 2.7%.

Figure 3: Mean pixel values calculated by the curves adjustment (figure 2) to the images used different filters. In red line the results with better COV.



4. CONCLUSIONS

All methodologies indicated by different organizations promoted a good evaluation of DLR.

Using the Al, Cu and Al with Cu filters, the DLR results have similar responses, while using IAEA protocol (filter thickes10 cm of the PMMA) the response was slightly different.

To carry out the DLR test, attenuation of the X-ray beam is necessary. The results of this study suggest that to carry out the DLR test, any material can be used as a filter, as long as it has an attenuation equivalent to 11.5 mmAs.

CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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