Radioprotection 2018, 53(2), 139–144
https://doi.org/10.1051/radiopro/2018012

Available online at:
www.radioprotection.org

ARTICLE

Assessment of image quality and radiation dose in some models of digital radiography systems – A Pehamed FLUORAD A + D phantom study

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Received: 27 November 2017 / Accepted: 21 March 2018

Abstract – Digital radiography (DR) systems have been recently introduced as a developed technology that is replacing conventional film–screen systems in many countries around the world. Ideal situation in radiography is to maximize the image quality while minimizing the patient dose. The purpose of this study was to compare image quality and radiation dose in different digital radiography systems. Four different digital systems are compared in terms of their image quality performance and dose area product (DAP). Images of Pehamed FLUORAD A + D phantom were obtained for each DR system. Image quality parameters (contrast resolution (CR), spatial resolution (SR), and contrast-to-noise ratio (CNR)) and DAP were significantly different between different digital systems. It was shown that all four quantities increased with increasing exposure parameters in all systems. Image quality parameters of the SEDECAL system were higher than that in other systems ($p \leq 0.05$). At the stable DAP (100 mGy.cm^2), means of CR, CNR, and SR in the SEDECAL system were 6.38 ± 0.797, 29.70 ± 0.85 and 3.10 ± 0.38 lp/mm, respectively. The results of this investigation can be taken into consideration in the selection and purchasing of new systems in order to preserve patients as well as radiographers from unnecessary radiation dose.

Keywords: digital radiology / image quality / dosimetry / phantom

1 Introduction

Recently, digital radiography systems are quickly replacing the conventional film–screen systems in many radiology departments around the world. Digital radiography systems have advantages including a wide dynamic range, flexibility in image display, possibility in changing image quality parameters, digital image management by using Picture Archiving and Communication System (PACS) and then reduction of costs associated with processing, managing, and storing films (Fischmann *et al.*, 2005). However, in the digital radiography systems, large amounts of exposure can be compensated by detector-computer system and then it is relatively easy to unknowingly overexpose the patient and increase the risk of effects induced by ionizing radiation (Nahangi and Chaparian, 2015).

There is a trade-off between the radiation exposure to the patient and image quality especially in digital radiographies. Based on the principle of "as low as reasonably achievable" (ALARA), digital radiographies should provide image quality adequate to enable an accurate diagnosis with the lowest achievable radiation dose (Khong *et al.*, 2013). Detectors with higher detection quantum efficiency can create better images with lower radiation exposure (Sun *et al.*, 2012).

Several studies have compared images obtained with DR or computed radiography (CR) with conventional screen film radiographs (Fink *et al.*, 2002; Fischbach *et al.*, 2002; Bacher *et al.*, 2003; Lu *et al.*, 2003, Fischmann *et al.*, 2005; Muhogora *et al.*, 2011; Sun *et al.*, 2012), but few studies compared different models of DR systems (Strotzer *et al.*, 2002). Therefore, the purpose of this study was to compare image quality parameters (in terms of spatial resolution, contrast resolution, and contrast-to-noise ratio) as well as patient dose (in terms of dose area product (DAP) values) in different digital radiography systems using an appropriate phantom.

2 Material and methods

2.1 Imaging systems

In this survey, image quality and patient dose (DAP) were compared among four different digital systems.

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Table 1. Information and technical specifications of the four different digital systems installed in four hospital investigated in this study.

Hospital name	Afshar	Mehriz	Sadoughi	Rahnemoon
System type	General radiography (Ceiling)	General radiography (Ceiling)	General radiography (Ceiling)	General radiography (Ceiling)
Brand	APELEM	SEDECAL	MEHRAN TEB (A)	MEHRAN TEB (B)
Model	Da vinci premium	MILLENNIUM	DMT.II	DMT.II
Manufacture Country	France	Spain	Iran*	Iran*
Year of manufacturing	2013	2015	2013	2013
kVp max	150	150	150	150
mA max	560	400	400	560
Generator Type	3-phase 80 Kwh	3-phase 80 Kwh	3-phase 65 kwh	3-phase 65 kwh
Permanent Filtration mm (Al)	2 AL/75KV	0.8 Al /75KV	0.9 Al/75KV	0.9 Al/75KV
Detector manufacturer	TRIXELL	TRIXELL	Drtech	Drtech
Detector material	Cesium Iodide – scintillator	Cesium Iodide – scintillator	TFT-amorphous Selenium (Direct Conversion)	TFT-amorphous Selenium (Direct Conversion)
Detector name, model and size	Pixium RAD 4600 $17^{in} \times 17^{in}$	Pixium RAD 4600 $17^{in} \times 17^{in}$	Flaatz 750E $17^{in} \times 17^{in}$	Flaatz 750E $17^{in} \times 17^{in}$

* Mechanically designed by SYFM Company of South Korea.

These systems are representative of the X-ray systems being used in our region. Information and technical specifications of the studied systems were summarized in Table 1. Imaging parameters were selected with exposure time of 20 ms, tube current of 100, 250, 360, 400, 560 mA, and tube voltage of 50, 60, 70, 75, 80 kVp, respectively. Three images were obtained in each setting. Source to image distance was set at 100 cm for all exposures. A total of 300 images were obtained using above parameters (5 tube current stations × 5 tube voltage stations × 3 images × 4 systems).

2.2 Pehamed FLUORAD 30 A + D phantom

The phantom used in this study was Pehamed FLUORAD 30 A + D. The picture of phantom is shown in Figure 1. Spatial resolution and contrast resolution can be measured by this phantom. The overall dimensions of the test phantom were 300 mm × 300 mm × 18.5 mm. It included a 1.5 mm thick copper plate with the details objects which was embedded between PMMA plates; The color of phantom was white, so that the collimated light field could also be seen under unfavorable lighting conditions in the X-rays room. There were 8 low contrast objects with 10 mm diameter for determinning of contrast resolution and there were a bar pattern (0.5 to 5 lp/mm) rotated 45° for determining of spatial resolution.

2.3 Measurement of dose area product

The dose area product (DAP) values were measured by a DAP meter (VacuDAP OEM, VacuTec, Germany) mounted on the X-ray system and displayed on the console monitor. The displayed DAP values were recorded during image acquisition for different imaging parameters in all radiography systems. The accuracy of DAP values were checked with the calibrated DAP meter (PTW, Freiburg, Germany).

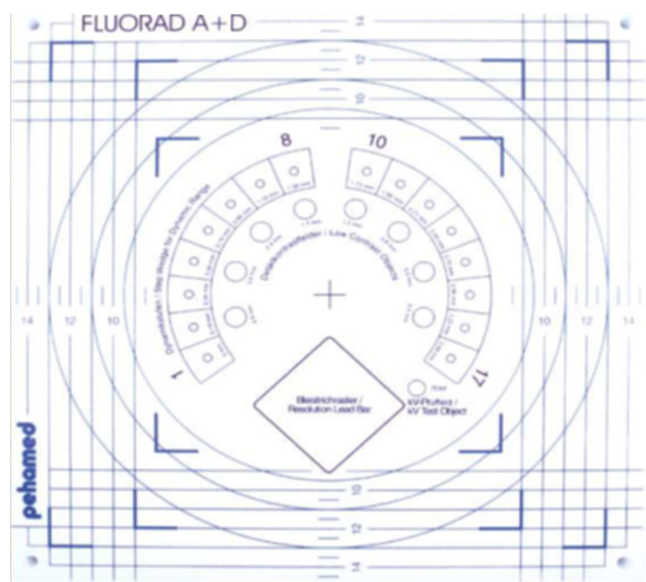

Fig. 1. Image of Pehamed FLUORAD A + D.

2.4 Image evaluation

Phantom images were presented to the three experienced specialists in digital radiography at the same time in random order. Each specialist analyzed image quality independently on a computer workstation. Image analysis was done in the best viewing circumstance and there was no restriction on using magnifying tools and viewing distance. The number of low contrast objects as a scale of contrast resolution, and the number of resolution lead bar pattern as spatial resolution were measured on each image. Then, the mean values and standard deviations of each parameter were calculated based on the three specialists reports.

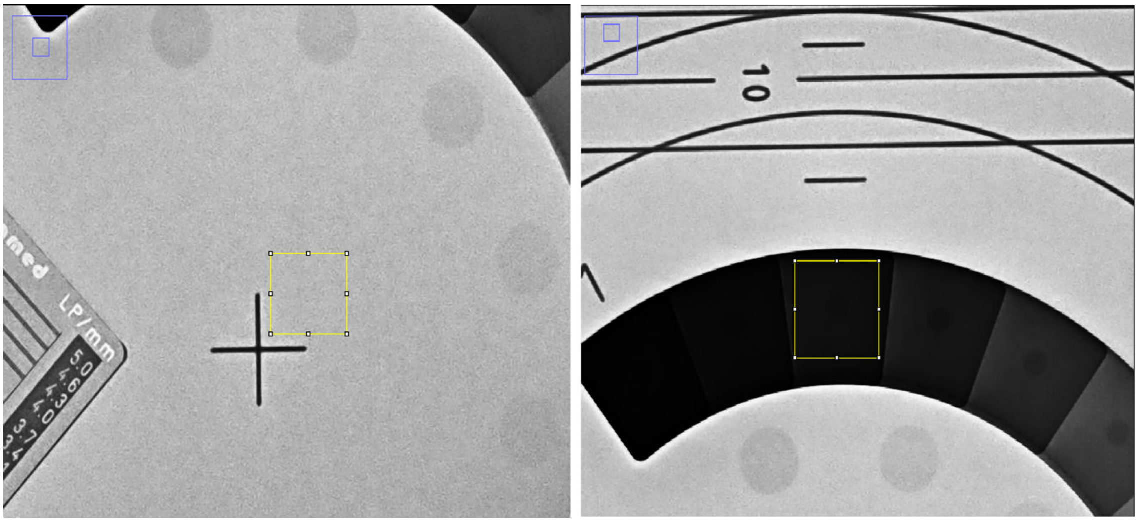

Fig. 2. Region of interest (ROI) to measure contrast-to-noise ratio.

2.5 Measurement of contrast-to-noise ratio

Contrast-to-noise ratios for all the images were measured according to the following procedure:

– two regions of interest (ROI) should be defined in all images (original images); one of these regions was background of the image and another ROI was chosen as seen in Figure 2;
– mean pixel value (MPV) and standard deviations (SD) of all ROI were determined with imageJ 1.44p software;
– contrast-to-noise ratio was measured according to the following equation (Muhogora *et al.*, 2011):

$$\mathrm{CNR} = \frac{|\mathrm{MPV}_{\mathrm{background}} - \mathrm{MPV}_{\mathrm{ROI}}|}{\sqrt{1/2(\mathrm{SD}^2_{\mathrm{background}} + \mathrm{SD}^2_{\mathrm{ROI}})}}. \quad (1)$$

3 Results

The changes of the DAP values as a function of different exposure parameters (beam voltage (kVp) and tube current (mA)) for four digital radiography systems are shown in Figures 3–6. Considering these charts, it is clear that the DAP values increase with increasing the exposure parameters. The highest DAP values were observed at 80 kVp while the lowest DAP were observed at 50 kVp for all digital radiography systems.

Figures 7–9 indicate that spatial resolution, contrast resolution and contrast-to-noise ratio are different between digital systems. All three quantities increased with increasing imaging parameters in all systems. The CNR in the SEDECAL system was higher than that in other systems ($p \leq 0.05$) (Fig. 7). At the stable DAP (100 mGy.cm^2), the highest mean of CNR (29.70 ± 0.85) was related to SEDECAL system ($p \leq 0.05$). Figure 8 represents that the spatial resolution at fixed DAP of 100 mGy.cm^2 for the SEDECAL and Applem- R302/A DR systems were 3.10 ± 0.38 lp/mm and 3.12 ± 0.11 lp/mm, respectively, which were significantly higher than that in other systems ($p \leq 0.05$). As it is shown in Figure 9, SEDECAL system has also significantly higher CR at stable DAP (100 mGy.cm^2); 6.38 ± 0.797 and the Applem- R302/A DR system with CR of 4.07 ± 0.42 is located on the next rank ($p \leq 0.05$). Figures 7–9 indicate that to obtain images with a fixed image quality (CR, SR and CNR), different DAP values are needed in different digital radiography systems. Also, it is inferred that the SEDECAL system needs the lowest DAP at all image quality parameters

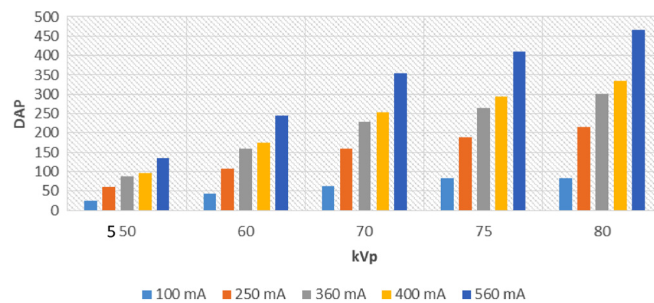

Fig. 3. The changes of the DAP values as a function of different exposure parameters (beam voltage (kVp) and tube current (mA)) for in Applem- R302/A Digital radiology.

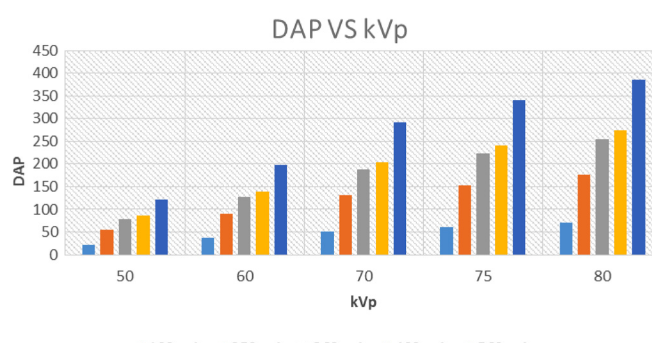

Fig. 4. The changes of the DAP values as a function of different exposure parameters (beam voltage (kVp) and tube current (mA)) for in MEHRAN TEB (B) Digital radiology.

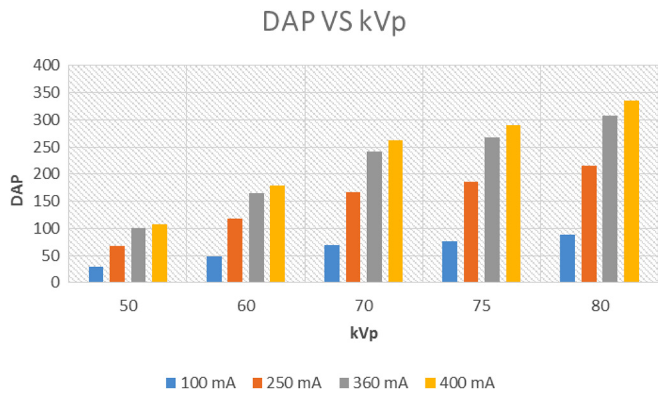

Fig. 5. The changes of the DAP values as a function of different exposure parameters (beam voltage (kVp) and tube current (mA)) for in MEHRAN TEB (A) Digital radiology.

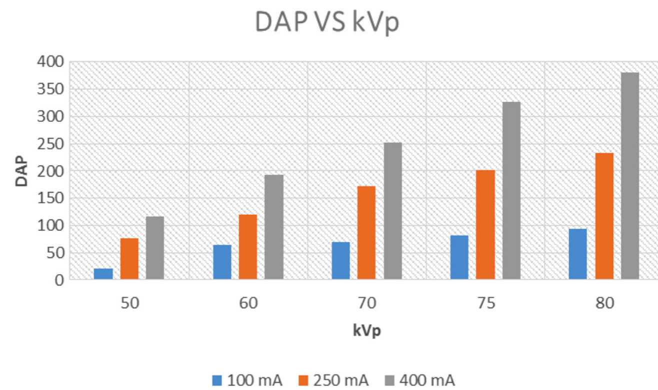

Fig. 6. The changes of the DAP values as a function of different exposure parameters (beam voltage (kVp) and tube current (mA)) for in SEDECAL Digital radiology.

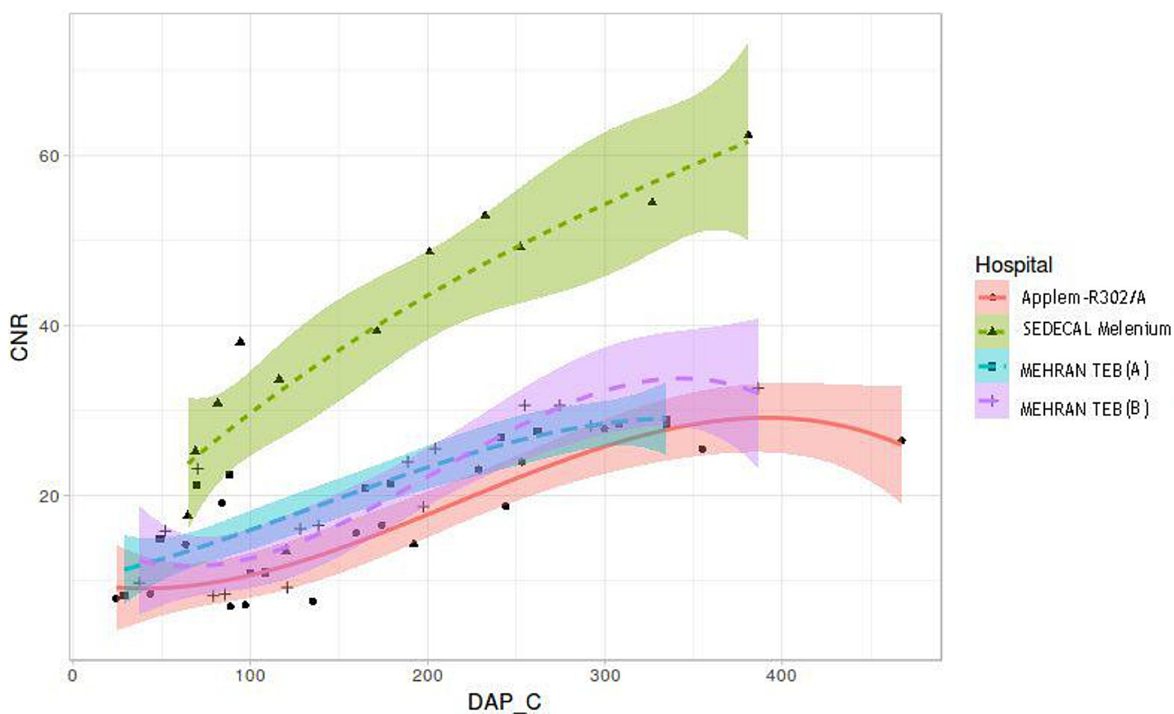

Fig. 7. The relationship between CNR and DAP in different digital radiology systems.

($p < 0.05$). At fixed CR of 4 and CNR of 25, DAP value obtained in SEDECAL system was lower than others ($p \leq 0.05$) (Fig. 9) and at fixed SR of 3.36 lp/mm, DAP values in SEDECAL and Applem- R302/A were lower than two other systems ($p \leq 0.05$) (Fig. 8).

4 Discussion

The basic goal of optimization in X-ray examinations is to minimize the patient dose while still providing image quality adequate for correct diagnosis. The performance of each imaging equipment can infuence both image quality and the patient dose. The simplest technique for assessing the performance of each equipment is to use a phantom under ideal conditions, away from problems related to clinic. Thus, in this survey, image quality was evaluated using the phantom and, simultaneously, radiation exposure was measured. There are two important findings in this survey: Firstly, different digital radiography systems have different performance. So, imaging parameters for one system should not be used for others and imaging parameters should be optimized individually for each system. Secondly, a system with the best performance that produces better image quality at lower doses was identified.

In this survey, the diagnostic performance of four different digital radiography systems has been assessed in terms of image quality and DAP using the Pehamed phantom. While, CR and SR assessments were based on observation of three experienced specialists, CNR evaluations were based on

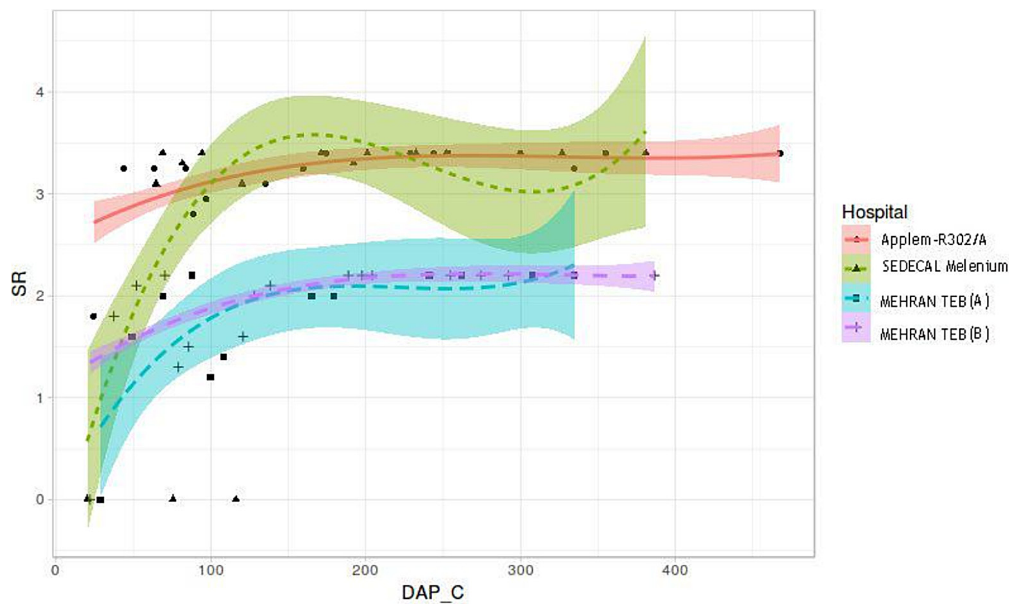

Fig. 8. The relationship between SR and DAP in different digital radiology systems.

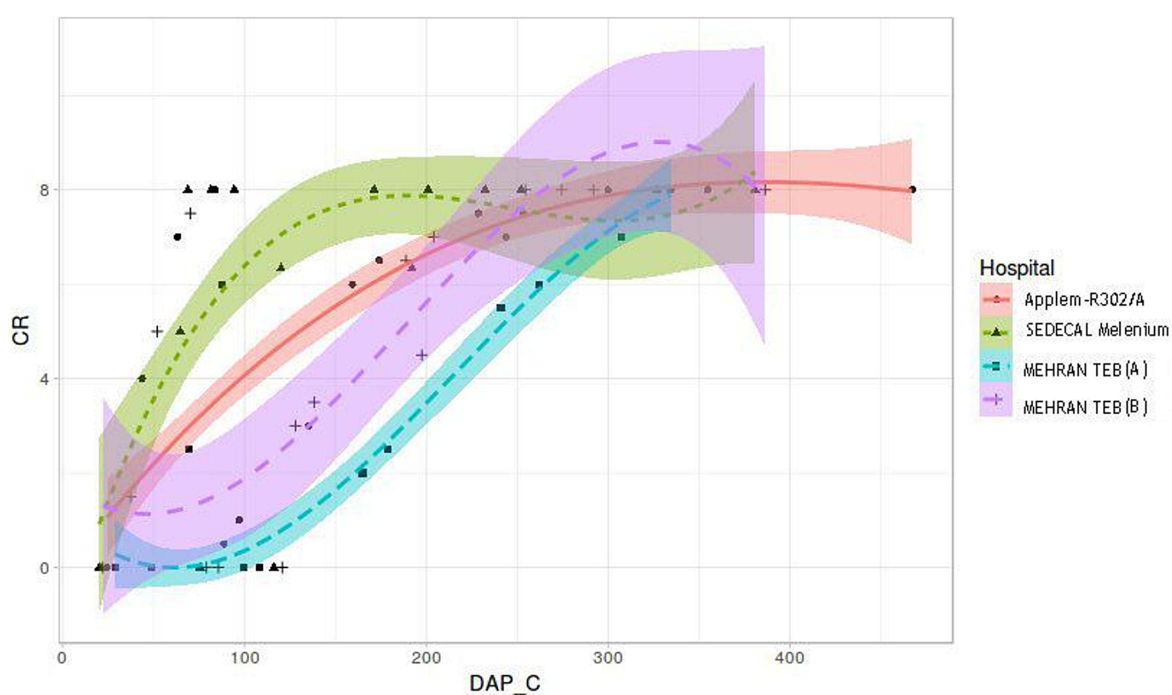

Fig. 9. The relationship between CR and DAP in different digital radiology systems.

calculations performed by the imageJ software. Image quality assessments in other studies were also based on either observations of specialists (Fink *et al.*, 2002; Bliznakova *et al.*, 2003; Fischmann *et al.*, 2005) or CNR calculations (Hess and Neitzel, 2011, 2012; Mori *et al.*, 2013) or both methods (Saarakkala *et al.*, 2009; Muhogora *et al.*, 2011).

In this study, it was demonstrated that different digital systems have different performance. The reason for these results is that CR and CNR are almost similar criterias for image quality assessment and influenced by same pararmeters such as contrast characteristics of the receptor and display system, but SR is influenced by dexel size of detector and by factors unrelated to the image receptor such as focal spot size, pixel size of displying monitor. In the survey conducted by Sun *et al.* (2012), similar conclusion have been reported. Of course, they assessed the performance of three computed radiography and three direct radiography systems in terms of their image noise and entrance skin dose.

This study suffers from some limitations. The major limitation of this study was that a comparison of the current and the previous surveys was difficult because there were few studies that evaluated the performance of different digital radiography systems. Another limitation was that, there were few models of digital radiography in this study. Further work is required to evaluate other models of digital radiography systems to complete these results.

5 Conclusion

This study aimed to apply a simple method based on phantom measurements to find the best digital system model among the four DR systems. Overall performance of SEDECAL digital radiography system is superior to that of other systems. SEDECAL system has higher CNR, CR and SR at stable DAP and and *vice versa* lower DAP at stable image quality parameters. The results of this investigation can be taken into consideration in the selection and purchasing of new systems in order to preserve patients as well as radiographers from unnecessary dose consistent with the radiation protection principle ALARA.

Acknowledgments. The authors would like to thank the assistance of the radiographers from the following hospitals at Yazd for our study: Shahid Sadoghi Hospital, Shahid Rahnamoon (Farokhi) Hospital, Fateme Al-Zahra Hospital, and Afshar Hospital.

References

Bacher K, Smeets P, Bonnarens K, De Hauwere A, Verstraete K, Thierens H. 2003. Dose reduction in patients undergoing chest imaging: digital amorphous silicon flat-panel detector radiography *versus* conventional film-screen radiography and phosphor-based computed radiography. *Am. J. Roentgenol.* 181(4): 923–929.

Bliznakova K, Bliznakov Z, Bravou V, Kolitsi Z, Pallikarakis N. 2003. A three-dimensional breast software phantom for mammography simulation. *Phys. Med. Biol.* 48(22): 3699.

Fink C, Hallscheidt PJ, Noeldge G, Kampschulte A, Radeleff B, Hosch WP, Kauffmann GW, Hansmann J. 2002. Clinical comparative study with a large-area amorphous silicon flat-panel detector: image quality and visibility of anatomic structures on chest radiography. *Am. J. Roentgenol.* 178(2): 481–486.

Fischbach F, Ricke J, Freund T, Werk M, Spors B, Baumann C, Pech M, Felix R. 2002. Flat panel digital radiography compared with storage phosphor computed radiography: assessment of dose *versus* image quality in phantom studies. *Invest. Radiol.* 37(11): 609–614.

Fischmann A, Siegmann K, Wersebe A, Claussen C, Muller-Schimpfle M. 2005. Comparison of full-field digital mammography and film-screen mammography: image quality and lesion detection. *Br. J. Radiol.* 78(928): 312–315.

Hess R, Neitzel U. 2011. Optimizing image quality and dose in digital radiography of pediatric extremities [Internet]. Philips Healthcare. Available from http://www.healthcare.philips.com/main/about/events/rsna/pdfs/DR_White_paper_Optimizing_image_quality_and_dose_in_digital_radiography_of_pediatric_extremities.pdf.

Hess R, Neitzel U. 2012. Optimizing image quality and dose for digital radiography of distal pediatric extremities using the contrast-to-noise ratio. *Rofo* 184(7): 643–649.

Khong P, Ringertz H, Donoghue V, Frush D, Rehani M, Appelgate K, Sanchez R. 2013. ICRP publication 121: radiological protection in paediatric diagnostic and interventional radiology. *Ann. ICRP* 42(2): 1–63.

Lu Z, Nickoloff E, So J, Dutta A. 2003. Comparison of computed radiography and film/screen combination using a contrast-detail phantom. *J. Appl. Clin. Med. Phys.* 4(1): 91–98.

Mori M, Imai K, Ikeda M, Iida Y, Ito F, Yoneda K, Enchi Y. 2013. Method of measuring contrast-to-noise ratio (CNR) in nonuniform image area in digital radiography. *Electron. Commun. Jpn.* 96(7): 32–41.

Muhogora W, Padovani R, Msaki P. 2011. Initial quality performance results using a phantom to simulate chest computed radiography. *J. Med. Phys./Assoc. Med. Phys. India* 36(1): 22.

Nahangi H, Chaparian A. 2015. Assessment of radiation risk to pediatric patients undergoing conventional X-ray examinations. *Radioprotection* 50(1): 19–25.

Saarakkala S, Nironen K, Hermunen H, Aarnio J, Heikkinen J. 2009. Comprehensive optimization process of paranasal sinus radiography. *Acta Radiol.* 50(3): 327–333.

Strotzer M, Völk M, Fründ Rd, Hamer O, Zorger N, Feuerbach S. 2002. Routine chest radiography using a flat-panel detector: image quality at standard detector dose and 33% dose reduction. *Am. J. Roentgenol.* 178(1): 169–171.

Sun Z, Lin C, Tyan Y, Ng K-H. 2012. Optimization of chest radiographic imaging parameters: a comparison of image quality and entrance skin dose for digital chest radiography systems. *Clin. Imaging* 36(4): 279–286.

Cite this article as: Kaheni H, Chaparian A, Nafisi-Moghadam R, Hamzian N. 2018. Assessment of image quality and radiation dose in some models of digital radiography systems – A Pehamed FLUORAD A + D phantom study. *Radioprotection* 53(2): 139–144