Radiography 25 (2019) 143–147

Contents lists available at ScienceDirect

Radiography

journal homepage: www.elsevier.com/locate/radi

Does software optimization influence the radiologists' perception in low dose paediatric pelvic examinations?

H. Precht [a, *], D. Waaler [b], C.B. Outzen [a], J.B. Brock Thorsen [c], T. Steen [c], M.B. Hellfritzsch [c], H. Aagesen [d], A.K. Holst [e], P. Le [e], S. Lindequist [f], L. Rasmussen [g], A. Tingberg [h]

[a] Conrad Research Programme, Health Sciences Research Centre, UCL, Niels Bohrs Allé 1, 5230, Odense M, Denmark
[b] Norwegian University of Science and Technology, Teknologiveien 22, Gjoevik, Norway
[c] Aarhus University Hospital, Radiology Department, Nørrebrogade 44, 8000, Aarhus C, Denmark
[d] Lillebaelt Hospital, Radiology Department, Skovvangen 2-8, 6000, Kolding, Denmark
[e] Odense University Hospital, Department of Radiology, Sdr. Boulevard 29, 5000, Odense C, Denmark
[f] Hospital of Southwest Denmark, SVS Esbjerg, Radiology Department, Finsensgade 35, 6700 Esbjerg, Denmark
[g] Hospital of Southern Jutland, Radiology Department, Kresten Philipsens Vej 15, 6200 Aabenraa, Denmark
[h] Medical Radiation Physics, Department of Clinical Sciences, Lund, Sweden & University, Skaane University Hospital, 205 02, Malmö, Sweden

ARTICLE INFO

Article history:
Received 29 May 2018
Received in revised form
10 December 2018
Accepted 17 December 2018
Available online 1 January 2019

Keywords:
Image quality
Software optimisation
Paediatric femur
Visual Grading Analysis

ABSTRACT

Purpose: To investigate whether software optimisation can improve an observers' perception of image quality in low dose paediatric pelvic examinations.
Methods: Twenty-five consecutive patients (3–7 years old) were referred for a pelvic digital radiography (DR) examination. They were prospectively enrolled in the study over a 3-month period. Images were taken at 80 kV and 2–4 mAs depending on pelvic thickness (9–15 cm). A small focal spot, 130 cm SID: 10 cm air gap and 1 mm Al and 0.2 mm Cu additional filtration were also utilised. Images were acquired on a Canon DR detector and optimised using five different combinations of the multi-frequency processing software (Canon DR system version NE, Version 7.1 with SPECTRA) to comply with the ALARA principle. Image quality was blindly evaluated using the subjective Visual Grading Analysis (VGA) by five experienced musculoskeletal radiologists, including the evaluation of six anatomical image quality criteria (scored from 1 to 5).
Results: Consistently, the VGA results indicated that by using software optimised parameters, image quality was suitable for diagnosis in 48–71% of all images. Based on a VGC analysis all software optimised images did have significant better image quality then the one with just the clinical settings. Noise reduction was the software setting which influenced the image quality the most, area under the curve (AUC) of 0.8172 95%CI 0.7953–0.8375.
Conclusion: Software optimisation improve the radiologists' perception of image quality and should thus be thoroughly considered within clinical practise. Noise reduction is the software parameter which has the greatest influence.
© 2019 The College of Radiographers. Published by Elsevier Ltd. All rights reserved.

Introduction

In modern digital radiography (DR), new optimisation developments are often focused on post-processing software which seeks to increase image quality and/or lower radiation dose.[1,2] The software setup, however, can be hard to understand by the users, as the software has become more advanced and offers multiple possibilities to adjust parameters individually to create customised protocols.[3] The advantage of multi frequency processing (MFP) is to produce images with an optimal balance between contrast enhancement, spatial resolution, and image noise suppression.[4–6] As image optimisation software possibilities are rarely used to their full extent,[7,8] the question if low dose paediatric examinations could be optimised is still undecided. Dose reduction is of particular interest in paediatric imaging based on their increased radiation sensitivity.[5,9]

The aim of this study was to examine whether optimisation of software parameter settings might improve the radiologists'

* Corresponding author. Fax: +45 63 18 32 26.
E-mail addresses: hepr@ucl.dk, hellepan@hotmail.com (H. Precht).

https://doi.org/10.1016/j.radi.2018.12.013
1078-8174/© 2019 The College of Radiographers. Published by Elsevier Ltd. All rights reserved.

perception of image quality in low dose paediatric pelvic examinations. The processing parameters explored include dynamic range, edge enhancement, noise reduction and contrast boost, respectively and in combination.

Materials and method

Ethical considerations

All procedures were performed in accordance with local and federal regulations in compliance with the Helsinki declaration. The patients' parents signed written consent to participate in the study, and all collected data was anonymised.

Study population and DR acquisition

Twenty-five consecutive paediatric patients with pelvic symptoms, referred for a pelvic DR examination, were prospectively enrolled (Table 1). Images were taken as low dose examinations, meaning that the mAs were lower than normal procedure in clinical practise. The exposure setting (mAs) were based on pelvic thickness (9–15 cm).[2–4] Patient data and technical parameters are shown in Table 1. The images were taken using a DR detector (CXDI-70C, Canon Inc, Japan), and optimised using six different MFP software settings (Canon DR system version NE, Version 7.1 with SPECTRA). In order to compare the image quality before and after software optimisation, a clinical software protocol, normally used for images taken at higher dose levels (later referred to as "software 1"), was included in the study. When optimising the software it is important to include combined settings in accordance with theory and preferences by specialised radiographers. Based on ten paediatric pelvis images, three specialist radiographers agreed on an optimal software parameter combination (referred to as "software 2"). In addition, four other software parameter combinations (referred to as "software 3-6"), focussing on dynamic range, edge enhancement, noise reduction and contrast boost, respectively, were also included in the study (Table 2).

Image quality analysis

The image quality of the 25 patient images were evaluated using absolute Visual Grading Analysis (VGA).[10–12] A total of 150 images (25 patients and 6 software settings) were evaluated blindly in a random order by five musculoskeletal radiologists, all having 10–25 year of experience in paediatric radiology, from five different specialised Danish hospitals. The radiologists were only informed that the study consisted of image quality optimisation and given no further details. The VGA assessments included image quality criteria (Table 3), scored from 1 (poorly reproduced) to 5 (very well reproduced), respectively. The image quality criteria were based on Bontrager's international procedural book,[13] the European Guidelines,[9] and approved by all the radiologists participating in the VGA study. All images were evaluated using Viewer for Digital Evaluation of X-ray images (ViewDex, Gothenburg, Sweden).[14,15] Each observer's individual quality ratings were stored and subsequently exported into Microsoft Excel. The images were displayed on a 10-bit grayscale 1600 × 1200 pixels 20.1" TFT Dicom-14 monitor with max luminance level of 250 cd/m^2 (Olorin, MedicLine MC200D; Fineman, Birkerød, Denmark). The monitor was calibrated according to the Digital Imaging and Communications in Medicine (DICOM) part 14.[16] In order to reduce bias in the VGA scores, the radiologists were given 'unlimited' time and allowed to work undisturbed. The VGA experiment was undertaken at the same physical location, with the same diagnostic monitor and physical surroundings.

Statistical analysis

The study was conducted in a paired design, as each of the images for the 25 patients were processed with six different software combinations and compared. All statistical analyses were performed using STATA 12.[17] The VGA score for each software and image criteria was visually shown as a graph. Image "criteria 6" regarding approval for diagnostic use was only evaluated using percentage scores.

The scores from the VGA were used in a VGC analysis. The score for each criterion, observer and image was used in the analysis, by counting the number of times the score "1" was given, the number of times the score "2" was given, and so on. The VGA data from two software settings were used in a number of VGC analysis to search for differences in image quality between the two settings. The frequency of each VGA score (i.e. the number of "1", "2", etc.) from the two software settings that was going to be compared was fed into Rockit.[18]

Results

Fig. 1 displays the VGA scores for the clinical software combination (software 1) and the optimised software settings ("software 2-6"). The overall VGA score results of the software optimised images showed that there were some general differences depending on both choice of processing parameter settings and image criteria.

Table 1
Patient and technical examination data.

Patient data	
Age (years), mean ± SD	4.8 ± 1.5
Sex, male/female	13 (46%)/15 (54%)
Height (cm), mean ± SD	109 ± 14
Weight (kg), mean ± SD	19 ± 5
BMI (kg/m^2): body mass index, mean ± SD (min − max)	16 ± 2 (12.4–20.8)
Circumference of pelvis (cm), median (min–max)	57 (49–77)
Pelvic AP thickness (cm), median (min–max)	12 (9–15)
Technical examination data	
kV	80
mAs [manual mode], median (min–max)	3.2 (2–4)
Source to image distance (SID in cm)	130
Air gap (cm)	10
External filtration	1 mm Al & 0.2 mm Cu
Focal spot size	Small
DAP (mGy × cm), median (min–max)	12.5 (4–27)
REX[a], median (min–max)	360 (209–583)
EI (Exposure Index), median (min–max)	203 (22–334)

[a] REX is the Reached Exposure Index value on the Canon DR system.

Table 2
The five combinations of software processing settings used in this study.

Software parameters	1: Clinical settings	2: Basis optimization	3: Increased dynamic range in dark regions	4: Edge enhancement	5: Noise reduction	6: Contrast boost
Look Up Table (LUT)	SB	SB	SB	SB	SB	SB
Brightness	−3	−3	−3	−3	−3	−3
Contrast	5	5	5	5	5	5
Dynamic range – dark region	3	1	15	5	5	20
Dynamic range – bright region	6	10	10	10	10	10
Noise reduction	0	2	2	2	9	2
Edge frequency	2	5	3	6	5	7
Edge enhancement	8	12	12	17	12	12
Contrast boost	5	10	10	8	10	20

Table 3
Image criteria used in the VGA evaluation.

Number	Image Criteria	Image score	Related image quality characteristic
1	Sharp demarcation of compacta and spongiosa	1–5	Sharpness
2	Sharpness of the trabecular structures	1–5	Spatial resolution
3	Homogeneity of the soft tissues	1–5	Noise
4	Visualization of the greater trochanter	1–5	Contrast
5	Visualization of the acetabulum	1–5	Contrast
6	Approved for diagnostic use	Yes/No	

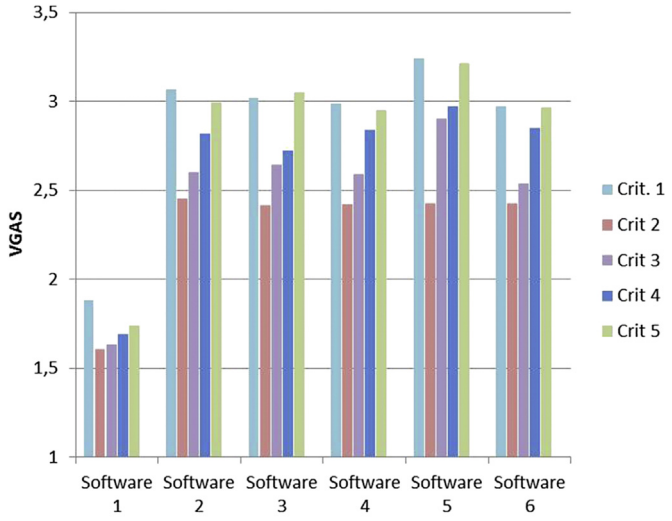

Figure 1. Average VGA scores (VGAS) over all 25 patients for the 5 radiologists for the six combinations of software settings and the six image quality criteria.

Focussing on VGA criteria 6, if the image could be approved for diagnostic use, none of the clinical images without software optimisation were approved, whereas for "software 5" (noise reduction), 71% of the images were approved. The other software parameter combinations (2, 3, 4 and 6) varied in approval rate from 48 to 58%, see Table 4.

Based on the VGC analysis the clinical software settings ("software 1") showed significantly inferior image quality than those of the optimised software combinations, Area Under the Curve (AUC): 0.7846–0.8172 and the corresponding 95% confidence intervals (CI) ranged from 0.7608 to 0.8375. Hereby, a clear distinction in image quality pre- and post MFP optimisation was found, see Table 5. "Software 5" (noise reduction) had the largest AUC, meaning the largest distinction from software 1 providing the best-evaluated image quality. Therefore, we tested if "software 5" were better than "software 2-4 and 6". These test showed that "software 5" proved to be significantly better than the other four software combinations, in terms of image quality, although with a quite similar outcome between "software 2-4 and 6", see Table 6.

Examples of the clinical images obtained with the clinical optimisation settings ("software 1") are shown in Fig. 2.

Discussion

Up to 71% of all software optimised images were approved for diagnostic use compared to none of the images using the 'original' clinical software processing settings. This difference is also visualised in Fig. 1 and clearly indicates that software optimisation in low dose paediatric pelvis examinations make significant a difference to the observers. In addition, the VGC analysis found statistically significant differences in perceived image quality between the clinical software settings and the software-optimised images ("software 2-6"). A clear difference in perceived image quality was found between pre- and post MFP optimisation in favour of the MFP optimised images.

As visualised in Fig. 1 and shown by the VGC analysis, a difference between the software parameter combinations (Tables 5 and 6) were found for all observers. So even though all five radiologists had several years of experience, this clearly indicates that image perception is governed by individual habits and preferences. In addition, because of the huge number of possible parameter setting combinations available, combined with a large variation in patient size, software optimisation is a rather complicated activity.

Table 4
Image criteria – Percentage approval for diagnostic use presented for each software parameter setting.

	Software 1	Software 2	Software 3	Software 4	Software 5	Software 6
Approved images (%)	0%	57%	48%	54%	71%	58%

Table 5
Comparison between the clinical software settings (software 1) and the optimized software settings (software 2-6). All of the optimized software settings were significantly better in terms of image quality.

Software	Area Under the Curve (AUC)	Std Error	95% Confidence Interval (CI)
1 (Clinical settings)	Reference		
2 (Basic optimisation)	0.791	0.012	0.767–0.813
3 (Dynamic range)	0.785	0.012	0.761–0.807
4 (Edge enhancement)	0.786	0.012	0.762–0.808
5 (Noise reduction)	0.817	0.011	0.795–0.838
6 (Contrast boost)	0.786	0.012	0.762–0.808

Table 6
Based on the VGC analysis in Table 5, software setting 5 was compared to the other four optimised software settings. Software setting 5 proved to be significantly better than the other four, in terms of image quality.

Software	Area Under the Curve (AUC)	Std Error	95% Confidence Interval (CI)
5 (Noise reduction)	Reference		
2 (Basic optimisation)	0.546	0.014	0.518–0.573
3 (Dynamic range)	0.551	0.014	0.523–0.579
4 (Edge enhancement)	0.558	0.014	0.530–0.586
6 (Contrast boost)	0.558	0.014	0.530–0.586

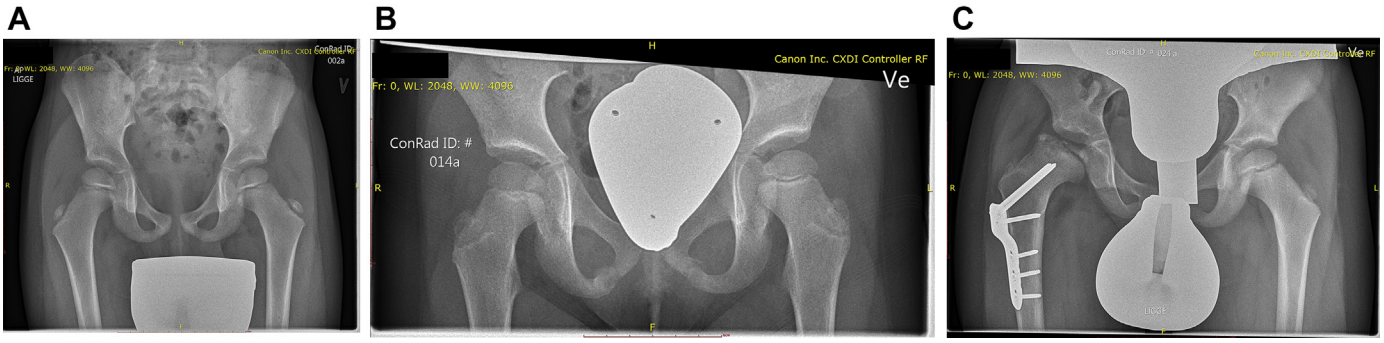

Figure 2. Examples of clinical images included in the project.

The software parameter combination noise reduction ("software 5") was found to be the one influencing the radiologists' evaluations the most, when compared to the all other MFP software optimised images (Tables 5 and 6). As all 25 pelvis images were relative low dose examinations, noise was clearly present on the images, reducing the visual quality of the anatomical structures. As the anatomy of paediatric patients consists of smaller and more detailed structures that are not yet fully calcified, photonic noise is expected to influence diagnostic performance even more in paediatric images, as reported in other studies.[19,20]

To our knowledge, only a few other studies have been published focussing on software optimisation and its possibilities in paediatric imaging. Two studies showed that similar image quality could be obtained at reduced radiation dose, and that diagnostic image quality could be maintained at ultra-low dose paediatric femur examinations by optimising the software settings.[1,2] These studies also found that the diagnostic image quality varied significantly among the different software parameter settings, emphasising the importance of optimising digital radiographs according to ALARA.[9] Another study[8] investigated image quality of lumbar spine using VGA on images optimised using Diamond View (Siemens AG Medical systems, Germany). This study showed an overall tendency for improved image quality using 'Diamond View'.

The main limitation of the present study is the number of patients. Therefore, further studies are warranted to further evaluate optimal software combinations in low dose paediatric pelvis examinations. It is also accepted that the definitions of low-dose and ultra-low-dose paediatric imaging is subjective. Within this study we sought to only evaluate images acquired at dose levels lower than would have normally been the case in routine clinical practise. Our study provides further weight that optimisation strategies must consider post-processing options in addition to the modification of standard acquisition parameters.

Conclusion

Software optimisation appears to be able to compensate for reduced mAs in paediatric pelvis examinations when focussing on approval for diagnostic use and detailed image quality evaluation (VGA). All software optimised images showed significant better image quality than those with clinical 'routine' software setting. Noise reduction was the software combination influencing the image quality the most. Hereby, software parameter settings clearly influence radiologists' perception of image quality and should thus be thoroughly considered for use in clinical practise.

Conflicts of interest

None

Disclosures

None

Acknowledgement

The authors would like to thank Karen A. Wind, Cathrine Wiig, Heidi Pedersen, Nanet Petersen and Raheis Rajalingam for their hard work with the data analyses of the visual grading experiments, and the young patients and their parents involved in this project. We are also grateful for support from Nordic X-ray Technique (NRT) and Canon Europe for providing specific knowledge on the multi frequency software, thus making it possible for us to optimize the images for the project, and make all the back up of data in the process.

References

1. Precht H, Gerke O, Rosendahl K, Tingberg A, Waaler Ref D. Digital radiography: optimization of image quality and dose using multi-frequency software. *Pediatr Radiol* 2012;**12**:1112–8.
2. Precht H, Gerke O, Rosendahl K, Tingberg A, Waaler D. Large dose reduction by optimization of multifrequency processing software in digital radiography at follow-up examinations of the pediatric femur. *Pediatr Radiol* 2014;**44**:239–40.
3. The Royal College of Radiologists London. Making the best use of a department of clinical radiology. *Referral Guideline* 2003;**5**.
4. Reiner BI, Siegel EL, Siddiqui K, Musk AE. Quality assurance: the missing link. *Radiology* 2006;**238**:13–6.
5. Hart D, Wall BF, Shrimpton PC, Bungay DR, Dance DR. *Reference doses and patient size in pediatric radiology*. 2000. p. 1–37.
6. Comission European. *European guidelines on quality criteria for diagnostic radiographic images*. Luxemburg; 1996b.
7. Siebert J. Flat-panel detectors: how much better are they? *Pediatr Radiol* 2006;**36**(14):173–81.
8. Tilo Niemann, Clemens Reisinger, Laura Ruiz-Lopez, Georg Bongartz. Image quality in conventional lumbar spine radiography Evaluation using the post-processing tool Diamond View. *Eur J Radiol* 2009;**70**:357–61.
9. European Commission. *European Guidelines on quality criteria for diagnostic radiographic images in pediatrics*. Luxemburg; 1996a.
10. Båth M, Håkansson M, Hansson J, Månsson LG. A conceptual optimisation strategy for radiography in a digital environment. *Radiat Protect Dosim* 2005;**114**:230–5.
11. Båth M, Månsson LG. Visual grading characteristics (VGC) analysis: a non-parametric rank-invariant statistical method for image quality evaluation. *Br J Radiol* 2007;**80**:169–76.
12. Smedby O, Fredrikson M. Visual grading regression: analysing data from visual grading experiments with regression models. *Br J Radiol* 2010;**83**:767–75.
13. Bontrager KL. *Textbook of radiographic positioning and related anatomy*. 4th ed. Phoenix: Bontrager Publishing; 2002.
14. Börjesson S, Håkansson M, Båth M, Kheddache S, Svensson S, Tingberg A, et al. A software tool for increased efficiency in observer performance studies in radiology. *Radiat Protect Dosim* 2005;**114**:45–52.
15. Håkansson M, Svensson S, Zachrisson S, Svalkvist A, Båth M, Månsson LG. VIEWDEX: an efficient and easy-to-use software for observer performance studies. *Radiat Protect Dosim* 2010;**139**:42–51.
16. National Electrical Manufacturers Association. *Digital imaging and Communications in medicine (DICOM). Part 14: grayscale standard display function. PS 3*. 14 2004. Available at: http://medical.nema.org/dicom/2004/04_14PU.pdf. [Accessed 4 September 2018].
17. StataCorp. *Stata release 12. Statistical software*. College Station, TX: StataCorp LP. Texas, USA; 2011.
18. Metz CE. *ROCKIT 0.9B*. Department of Radiology. The University of Chicago; 1998.
19. Walter H. Assessment of the problem: pediatric doses in screen-film and digital radiography. *Pediatr Radiol* 2004;**34**(Suppl. 3):S173–82.
20. Verdun FR, Lepori D, Monnin P, Valley J-R, Schnyder P, Gudinchet F. Management of patient dose and image noise in routine pediatric CT abdominal examinations. *Eur Radiol* 2004;**14**:835–41.