AGFA
RADIOLOGY
SOLUTIONS

Is detector pixel size a determining parameter for perceived clinical image quality?

The outcome of a clinical observer study in cooperation with the University Hospital Leuven, Belgium

White paper

AGFA Agfa

Table of contents

Introduction	3
Material and methods	4
Further technical aspects	4
Technical evaluation	5
Clinical evaluation	6
Detailed results	7
Technical evaluation	7
Clinical evaluation	7
Clinical revelance	8
Conclusion	9
Original publications	10
Literature (selection)	10
About the authors	11
Acknowledgements	11

AGFA RADIOLOGX SOLUTIONS

Introduction

The question of detector pixel size remains part of an ongoing debate between clinicians, medical physicists and representatives of the medical X-ray device manufacturers. What pixel size is required in projection imaging? The answer will depend to some extent on the application and the imaging task. It is not surprising that the subject was studied intensively in the early days of digital mammography, where the crucial question was the pixel size required to readily resolve microcalcifications. This debate has been largely resolved, with the consensus settling on a pixel pitch of 50 to 100 µm.

The situation is somewhat different for dedicated Genrad applications, despite several studies over the years that have examined the optimal pixel size for a range of applications, including neonatal, orthopedic and dynamic imaging [1], [2], [3], [4]. Pixel size is not expected to have a strong influence on detector imaging metrics such as modulation transfer function (MTF) and detective quantum efficiency (DQE). However, the general question as to the pixel size that produces images with the image quality required for typical Genrad applications, especially extremity examinations, remains largely unanswered.

This White paper summarizes the outcome of a recent observer study carried out by Agfa in cooperation with the University Hospital of Leuven, Belgium (Department of Radiology & Medical Radiation Physics). The study investigated in depth the influence of the pixel size of direct radiography (DR) X-ray detectors on the perceived clinical image quality of orthopedic and chest radiography images.

Material and methods

Seven Cesium Iodide (CsI)-based X-ray detectors from different vendors, with pixel sizes ranging from 76 µm to 175 µm, were assessed at five detector air kerma (DAK) levels, from 1.3 µGy to 7.4 µGy.

Table 1: Overview of the detectors included in the study

Flat panel detector	Code	Pixel spacing (mm)	Pixel matrix	x (cm)	y (cm)
Konica AeroDR	A_{175}	175	2426 x 1974	42.5	34.5
Agfa DR10e	B_{150}	150	1536 x 1920	23.0	28.8
Agfa DR10s	C_{148}	148	1920 x 1500	28.4	22.2
Canon CXDI-810C	D_{125}	125	2192 x 2800	27.4	35.0
Agfa DX-D 45C	E_{124}	124	2032 x 2536	25.2	31.4
VAREX XRpad2	F_{100}	100	2508 x 3004	25.1	30.0
DR-TECH EVS 2430 C	G_{76}	76	3840 x 3072	29.2	23.3

The Agfa DX-D 45C was used as the reference for the scoring and relative visual grading analysis (VGA).

Further technical aspects:

Pixel size has a direct, first-order impact on the technical image quality factors of a DR detector, through the Nyquist frequency. This frequency, defined as 1/(2 x p) with p equal to the pixel size in mm, determines the cut-off frequency and hence the usable frequency range of the panel. It also directly influences the limiting spatial resolution of the detector, which is usually measured with a line pair test object. On the other hand, pixel size, has a second-order impact on the X-ray detector's MTF and DQE. Several other design parameters influence these metrics, including the fill-factor of the panel; i.e, the ratio of usable area for capturing usable X-ray quanta within a pixel, and the thickness of the Cesium Iodide scintillation layer in the detector.

MTF and DQE figures of the tested panels are shown with the following graphs:

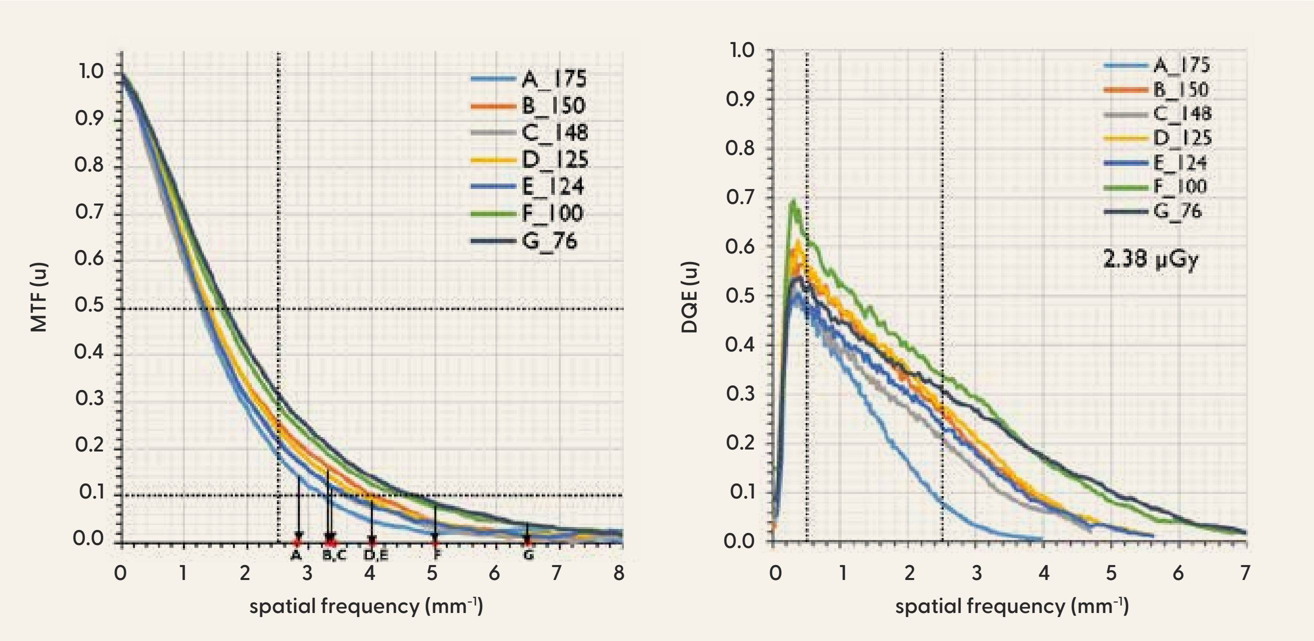

Figure 1: MTF (left) and DQE at 2.38 µGy measured at RQA3 beam quality (right).
A to G indicate the Nyquist cut-off frequency of the individual panel, as defined by the pixel size.

Technical evaluation:

A Leeds TO20 test object was used to acquire contrast-detail data.

The contrast of the embedded discs is taken as a measure of imaging performance: the lower the threshold contrast, the better the imaging performance. Three contrast-detail images were acquired at each detector air kerma level, using a technical beam quality of 70 kV and 1 mm Cu filtration added. No clinical imaging processing was applied. The images were scored by four medical physicist readers experienced in scoring test object images.

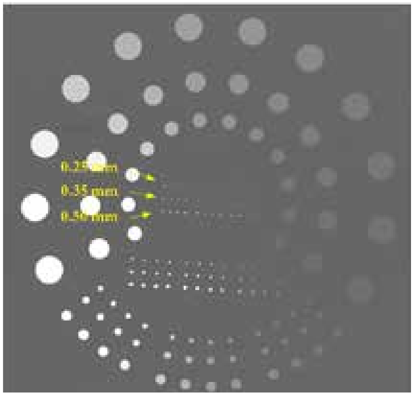

Figure 2: TO20 contrast-detail test object with the layout of the discs. The smallest 0.25 mm, 0.35 mm and 0.50 mm discs are indicated.

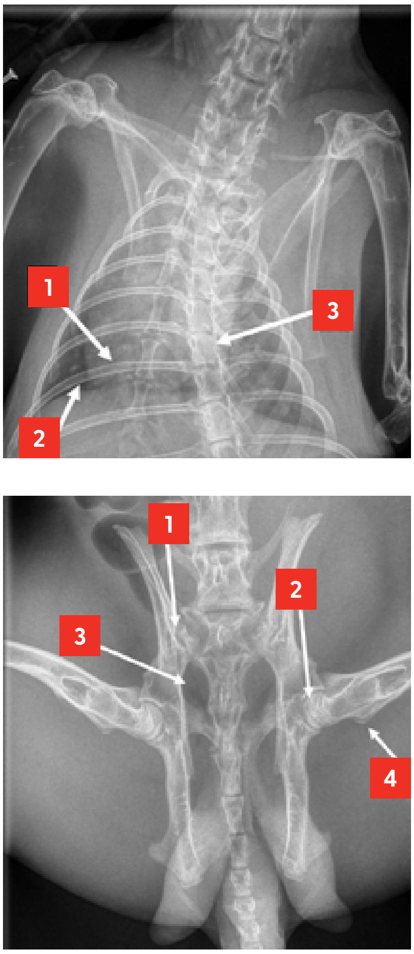

Figure 3: Examples of key features in two of the four body parts evaluated

Clinical evaluation:

For the clinical part, four anatomical regions – human cadaver hand, human cadaver foot, rabbit cadaver pelvis and living rabbit chest – were imaged with an Agfa DX-D 100 mobile X-ray system at tube voltages of 50, 55 or 60 kV, depending on anatomical region. An X-ray source-to-image receptor distance of 100 cm was selected for all exposures. The Agfa MUSICA3 image processing (skeleton package) was applied to all raw images.

A visual grading analysis (VGA) study was set up, using the Agfa DX-D 45C as reference detector, as it has an intermediate pixel size of 124 µm.

Images were acquired at a median DAK level between 2.7 µGy to 3.8 µGy, depending on the application.

Four board radiologists read the images, scoring the sharpness of specific anatomical features on a scale from -2 to +2, from worse to better than the reference. Noise and overall quality were also scored, from -5 to +5. An ordinal logistic regression was applied to evaluate the effect of detector type (i.e., as a function of pixel size) and DAK on perceived sharpness and noise. The reader agreement was assessed using intra-class correlation coefficient (ICC).

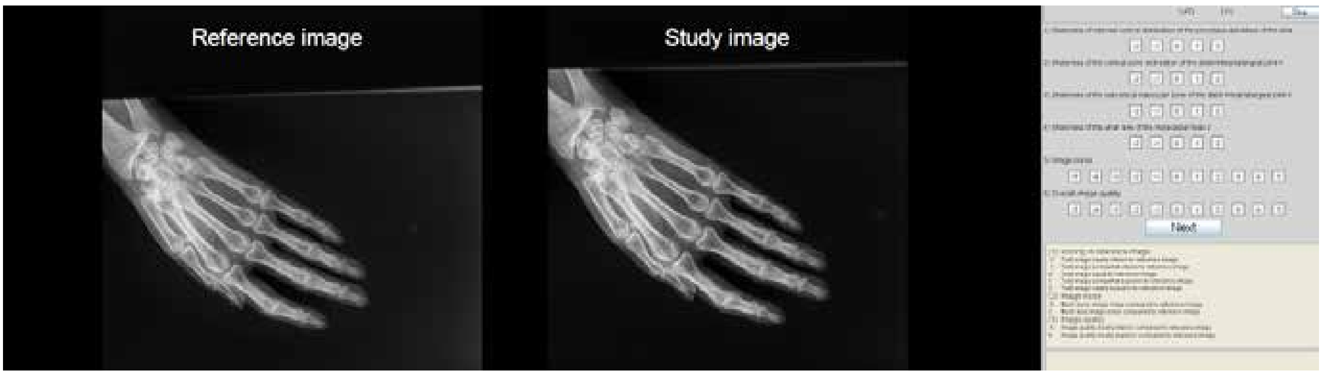

Figure 4: Reading scheme and software-supported evaluation tool VIEWDEX 3.0 [6]

Detailed results

Technical evaluation:

The averaged threshold contrast scores for all readers and detectors are shown in the figure on the right.

While the lowest threshold contrasts were found for detectors F100 and G76 (at 1.10 µGy and 2.28 µGy) and F100 and B150 (at 5.88 µGy), there was no obvious link between the threshold score and the pixel size.

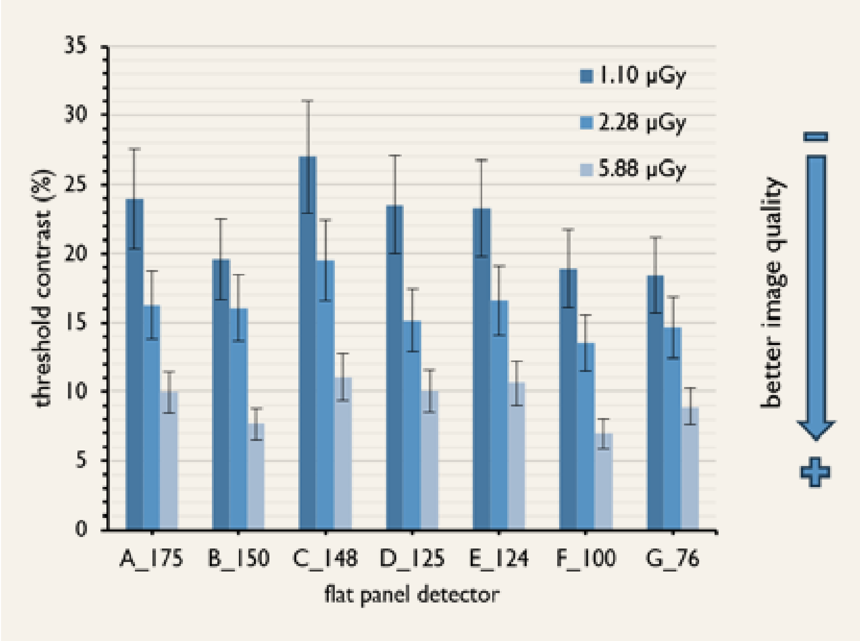

Figure 5: TO20 threshold contrast results acquired at detector air kerma levels of 1.10, 2.28 and 5.88 µGy/image for the 0.25 mm diameter disc

Clinical evaluation:

Inter-reader agreement was substantial, with ICC values ranging from 0.62 to 0.83.

Pixel size did not significantly influence perceived sharpness, except for the following cases:

(1) the detectors with a pixel size of 76 µm and 100 µm scored better (p=0.036, odds ratio (OR)=28 and p=0.029, OR=31) than the reference detector for sharpness in the chest
(2) detectors with a pixel size of 148 µm and 175 µm had lower sharpness ratings for the foot (p=0.04, OR=0.057, and p=0.001, OR=0.0035)
(3) sharpness in the pelvic bones and the hand was scored worse for the 175 µm pixel detector (p=0.01, OR=0.027 and p=0.04, OR=0.032)

Logistic regression showed that dose significantly influenced perceived sharpness and noise (p<0.0001 for all 4 anatomies) with odds ratios (OR) from 4.5 to 27, indicating higher ratings when increasing dose.

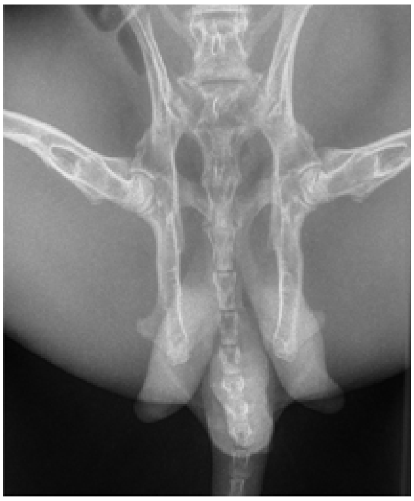
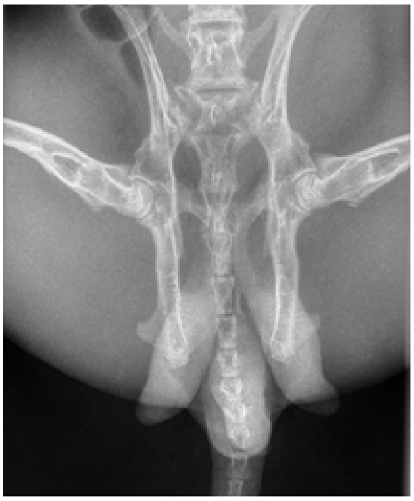


Figure 6: Illustration of image elements (processed pelvis images) with increasing quality score (left = worst to right = best) and 3 different pixel sizes (left = 175 µm, middle = 125 µm, right = 150 µm)

Clinical relevance

For routine, plain radiological applications, the benefit of a small pixel-size detector is limited, while the choice of dose level remains important: while the median score for anatomical sharpness in general rises with increased dose, the score stays constant regardless of – and hence independent of – pixel size (with the exceptions mentioned above (1) to (3)).

This is illustrated in figure 7 and 8.

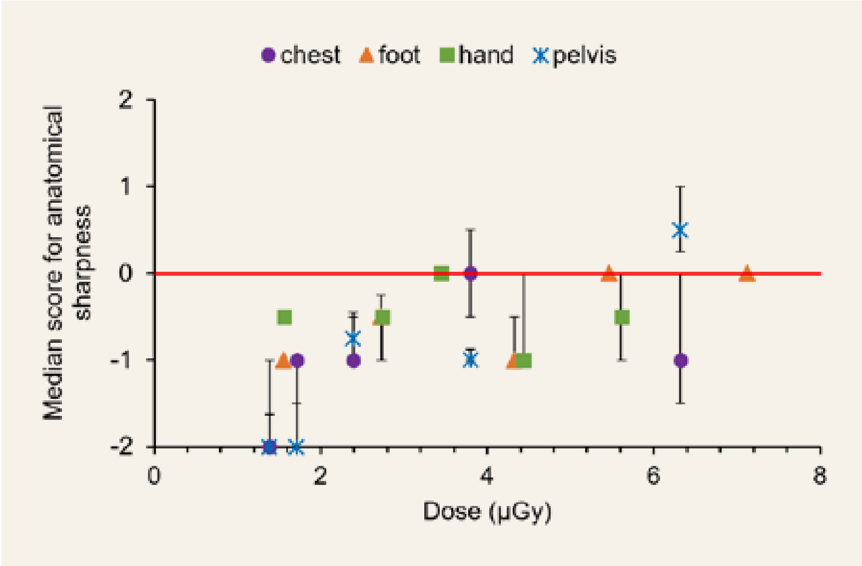

Figure 7: Example of dose dependency: median subjective ratings for anatomical sharpness as a function of dose [µGy] for the detector with 175 µm pixel size. The scores are the median values of four readers, and for each anatomical region separately. The error bars indicate the interquartile range of the scores of the four readers. Ratings are relative to the reference detector with a pixel size of 124 µm.

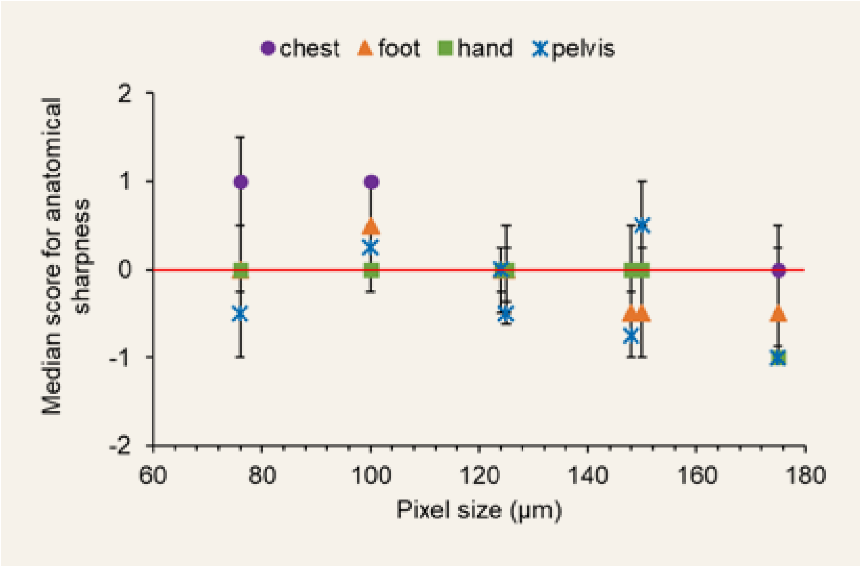

Figure 8: Median subjective ratings for anatomical sharpness as a function of detector pixel size for the four readers, and for each anatomical region separately. The error bars indicate the interquartile range of the scores of the four readers. Ratings are relative to the reference detector with a pixel size of 124 µm. All ratings presented here are for the medium dose level of 2.7 µGy for hand and foot, and 3.8 µGy for pelvis and chest.

Conclusions

Low-frequency DQE (~ 0.5 mm-1) is more important than high-frequency DQE (~ 2.5 mm-1) for the imaging tasks investigated. Even a 150 µm detector with limited high-frequency DQE can perform very well in terms of sharpness assessment and contrast-detail analysis. This is possible if the detector is well-designed (i.e., good low-frequency DQE, low electronic and structural noise).

For the clinical tasks, a significant reduction in perceived sharpness was only found for the 175 µm pixel detector (hand and pelvic bones) compared to the reference 124 µm pixel detector at the same dose, whereas using pixel sizes as small as 76 µm did not significantly improve sharpness scores. Dose, and thus noise, was the dominant factor in perceived clinical image quality.

There was no clinical task found in this study for which small pixels significantly improved the perceived image quality.

In summary, DR detectors with a pixel size ranging from 76 µm to 150 µm yield a similar perceived clinical image quality, when compared to a reference panel with a pixel size of 124 µm.

Original publications

Seven general radiography x-ray detectors with pixel sizes ranging from 175 to 76 µm: technical evaluation with the focus on orthopaedic imaging
NW Marshall et.al., Phys. Med. Biol. 68 (2023), https://doi.org/10.1088/1361-6560/acf642

Does detector pixel size have an effect on perceived clinical image quality?
Cockmartin L et.al., RSNA 2021 (scientific poster)

Literature (selection)

[1] Jonsson A, Laurin S, Karner G, et al. Spatial resolution requirements in digital radiography of scaphoid fractures, a ROC analysis. Acta Radiologica 1996;37:555-560

[2] Manjeshwar RM, Wilson DL. Optimization of detector pixel size for interventional X-ray fluoroscopy. SPIE 2001;4324:23-34

[3] Smet MH, Breysem L, Mussen E, et al (2018) Visual grading analysis of digital neonatal chest phantom X-ray images: Impact of detector type, dose and image processing on image quality. Eur Radiol 28:2951–2959. https://doi.org/10.1007/s00330-017-5301-2

[4] Kevin R, Esser M, Spogis J, Gatidis S, Wanninger F, Schäfer JF (2022) Impact of Computed vs. Digital Radiography and Radiation Dose on Image Quality of Chest X-Rays in Neonates using a dedicated Neonatal Phantom, ESPR Marseille

[5] Båth M, Månsson LG (2007) Visual grading characteristics (VGC) analysis: a non-parametric rank-invariant statistical method for image quality evaluation. BJR 80:169–176. https://doi.org/10.1259/bjr/35012658

[6] Svalkvist A, Svensson S, Hagberg T, Båth M. VIEWDEX 3.0 Recent development of a software application facilitating assessment of image quality and observer performance. Radiat Prot Dosimetry. 2021 Oct 12;195(3-4):372-377. doi: 10.1093/rpd/ncab014

AGFA RADIOLOGY SOLUTIONS

About the authors

Friedrich Wanninger is based in Munich, Germany. As application lead, he is one of Agfa's experts in X-ray image quality and flat panel detectors. He holds a MSc degree in Medical Physics.

Dr. Dirk Vandenbroucke has a wide background in technical image quality analysis in X-ray imaging systems and is based in the Agfa HQ in Mortsel, Belgium. He has been an active member of international standard working groups (ISO, IEC).

Dr. Lesley Cockmartin obtained her PhD in 2015 in the medical physics department of KU Leuven, Belgium. Currently, she is clinical trial coordinator and researcher at the radiology department of University Hospitals Leuven, focusing on clinical image quality initiatives for different X-ray imaging modalities.

Prof. Nicholas Marshall is a medical physics expert in the Radiology Department of KU Leuven, Belgium, with over 30 years of experience in the field of diagnostic radiology physics. He has been an active member of several national and international working groups developing quality control protocols for X-ray systems. His current research focuses on performance evaluation and optimization of X-ray imaging devices at the component and system levels.

Prof. Hilde Bosmans is head of the medical physics team in the radiology department of the University Hospitals Leuven, Belgium. She coordinates the routine Quality Assurance tasks in the context of the Belgian radiation protection regulations, as well as several research projects. Evaluation and optimization of image quality are focal areas for all patient groups in the hospital, and for X-ray devices up to the latest CT modalities. The group selected research projects in cooperation with Agfa Radiology Solutions.

Acknowledgements

We thank radiologists Prof. Marleen Smet, Dr. Luc Breysem, Dr. Jeroen Desmet, Dr. Nathalie Noppe, Dr. Marilyn Pinas, Dr. Geert Vanderschueren and Dr. Nicole Natour (all KU Leuven, Belgium) for the image readings and constructive support throughout the study.

The authors would also like to thank the participating DR panel manufacturers for their hardware and software support. The manufacturers are listed in the introductory section.

AGFA
RADIOLOGX
SOLUTIONS

Follow us:

agfa.com » Septestraat 27 - 2640 Mortsel - Belgium

EN202311

AGFA