Assessment of the Impact of Dark Signal on Image Quality in Computerized Mammography

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Abstract

The aim of this study is to examine the impact of dark signal on assessing the image quality in computerized mammography. A GE analogue mammography unit was calibrated to be used with an Agfa CR35-X system. Tests for quality control were performed and Image Plates (IPs) were erased by the CR system. All IPs were first exposed to known amounts of scatter radiation and then used to take mammographic images of phantoms with varying density (a PASMAM-1054 Phantom with PMMA and Al inserts). Since high Signal-to-noise ratio (SNR) and high Contrast-to-noise ratio (CNR) are of great importance in mammographic image quality, we measured SNR and CNR of the taken images. Our results show the effect of scatter radiation on SNR and CNR. Scatter radiation increases SNR and decreases CNR. The impact of background signal was found not to be negligible. Dark signal deteriorates image quality in CR mammography. Consequently, further investigation may be warranted and daily erasure of the IPs is recommended in order to limit dark signal effect on image quality.

Key words: Computerized mammography, dark signal, SNR, CNR, CR

Introduction

Breast cancer is nowadays one of the most frequent cancer types in the world. In the battle against breast cancer, X-ray mammography has turned out to be a practical, cost-efficient, widely used screening technique for its early detection.

Due to the fact that the number of deaths related to breast cancer is perpetually growing, much attention must be paid in providing mammograms of high image quality. That is the reason why assessing the impact of dark signal on image quality in computerized mammography is of great importance.

Materials and Methods

In Computerized Radiography and therefore in Computerized Mammography reusable photostimulable phosphor plates are used instead of films as image receptors. Whenever these Image Plates (IPs) are exposed to x-rays, a stored latent image is created. By the use of a digitizer this latent image will be read out and a mammographic image will be acquired. At the same time the latent image will be erased from the phosphor plate and therefore the IP will be available to be used again.

During the time that intervenes between an IP's erasure and its next use, the IP is exposed to ambient radiation. This means that IPs are affected by dark signal that comes either from background radiation or from nearby sources. Since dark signal may affect the next image that will be recorded on a plate, it is important to assess its impact on image quality.

For that purpose, a GE analogue mammography unit was calibrated to be used with an Agfa CR35-X system. Tests for quality control[1, 2, 3, 4] were then performed and the IPs were erased by the CR system. However, a method had to be found so as to be able to determine the dark signal.

In order to create dark signal, an IP was chosen, it was erased and it was placed near the antiscatter grid of the mammography unit in such a way that it wouldn't be affected by the primary beam but at the same time it would be exposed to as much scattered radiation as possible. A dosemeter was placed onto the IP and at the edge of it. A phantom was irradiated and the Air Kerma was measured with the dosemeter so as to have a rough estimation of the scattered radiation to which the IP was exposed. That way, the IPs were exposed to known amounts of scattered radiation, which would compensate for the dark signal. Afterwards, the IP was read out and Regions of Interest (ROIs) were defined at the image in order to perform measurements. The logarithm of Pixel Value Index (PVI) and its Standard Deviation (sd) were both estimated.

Nevertheless, the purpose of this study is the determination of the impact of dark signal on the quality of the image. High Signal-to-noise ratio (SNR) and high Contrast-to-noise ratio (CNR) are important factors in computerized mammography since they affect image quality. SNR compares the level of the desired signal to the level of the background noise, while CNR evaluates the ability of a detector to distinguish between objects in an image and the image noise.

Consequently, the impact of dark signal on image quality will be determined by assessing the impact of dark signal on SNR and CNR. U-shaped PMMA attenuation plates were used as an equivalent to tissue phantom for these measurements. On top of the PMMA plates were placed two inserts one next to the other -a PMMA one and an Aluminium one. This would enable a comparison between the contrast object (Al) and the background region (PMMA).

Measurements of SNR and CNR were made in two steps:

1. IPs were exposed to known amounts of scattered radiation at the same way as before.

2. These IPs were used to take mammographic images. That is, immediately after the 1st step, the IP was placed at the mammography unit, the phantom was irradiated, the IP was read out, ROIs were defined and PVI and sd were measured in order to calculate SNR and CNR. SNR[1] and CNR[5,6] were calculated by the following formulas:

$$SNR = \frac{PVI_{PMMA}}{sd_{PMMA}}$$

$$CNR = \frac{PVI_{PMMA} - PVI_{Al}}{\sqrt{sd_{PMMA}{}^{2} + sd_{Al}{}^{2}}}$$

where PVIPMMA and sdPMMA are the PVI and standard deviation obtained from a ROI at the PMMA insert equally and PVIAl and sdAl are the PVI and standard deviation obtained from aROI at the Al insert equally.

The measurements were repeated for different exposure settings, that is irradiating the phantom by using clinical settings at first and lower exposure settings afterwards.

Results and Discussion

The results of evaluation of the PVI caused only by scattered radiation (without irradiating the phantom) are depicted in figures 1 and 2. It was found that Air Kerma values lower than 2.5 μGy are associated with zero PVI, while higher Air Kerma values cause a significant increase in PVI. This means that low scattered radiation is negligible most probably due to the fact that it is either too low to affect the IP or it is lower than the amount of radiation that can be detected by the CR system. So, dark signal affects PVI.

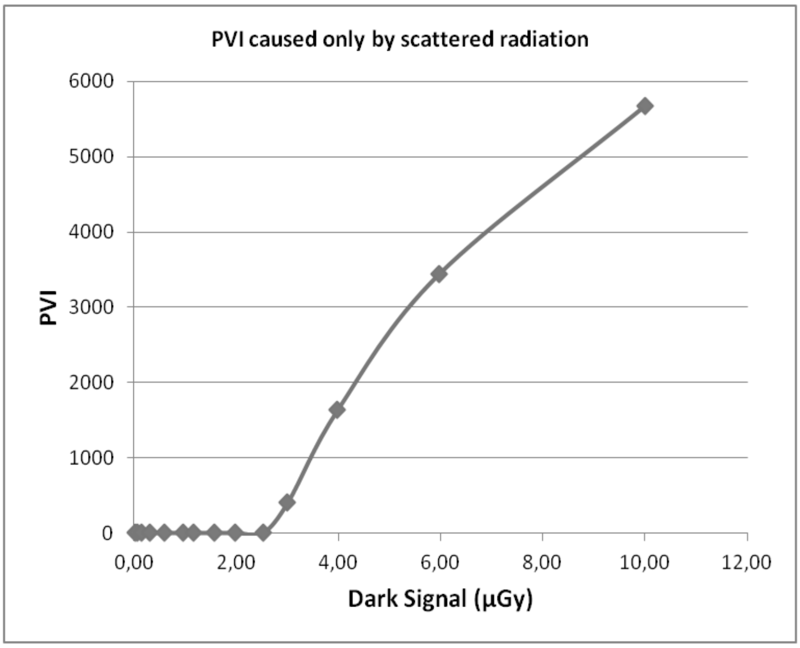

Figure 1. PVI with varying Dark signal caused by scattered radiation. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV. PVI measurement is available by the CR system when reading out the IP that had previously been exposed to scattered radiation[7].

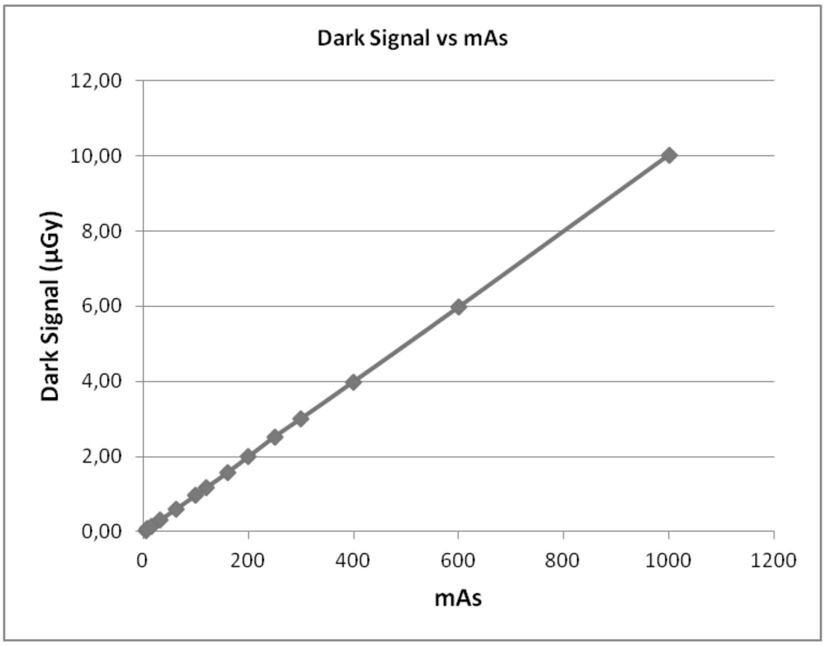

Figure 2. Dark signal caused by scattered radiation with varying mAs. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV[7].

Figures 3, 4, 5 and 6 show the results of the measurements taken using clinical settings to irradiate the phantom,

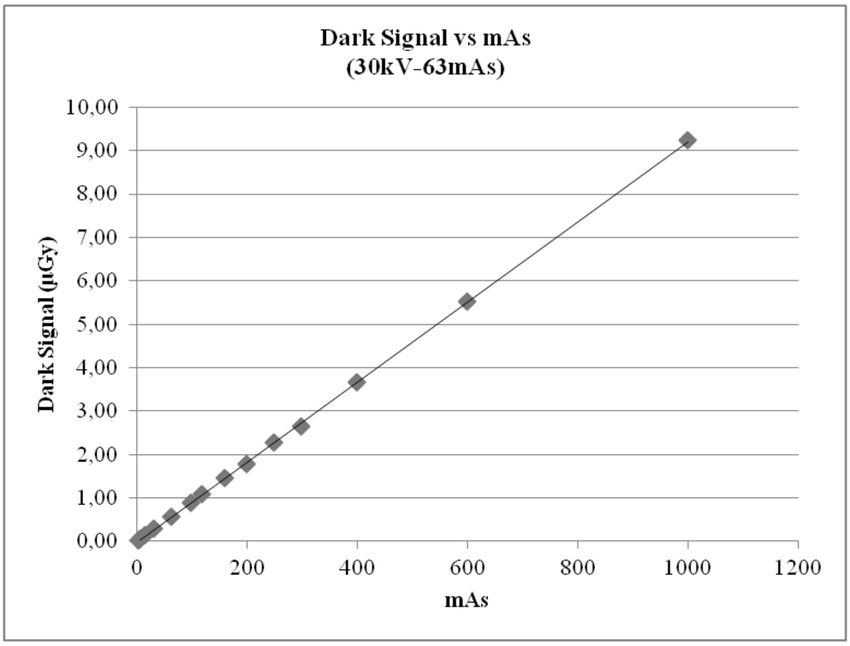

Figure 3. Dark signal caused by scattered radiation with varying mAs. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV[7].

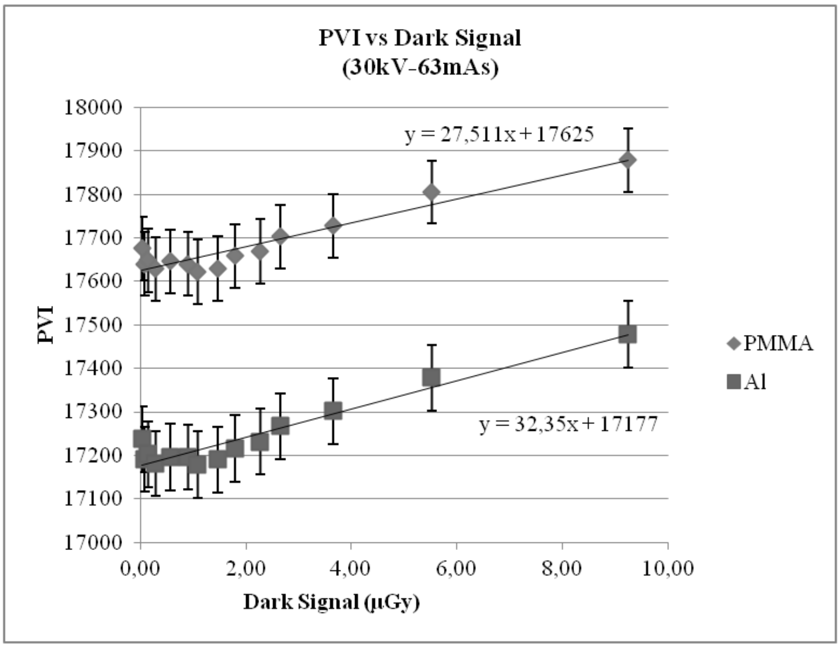

Figure 4. PVI measured for both PMMA and Al with varying Dark signal caused by scattered radiation. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV. That IP is afterwards exposed to 30kV-63mAs in order to make SNR and CNR measurements. PVI measurements within ROIs fitting to the quadratic marking of both an Al and a PMMA insert are available by the CR system[7].

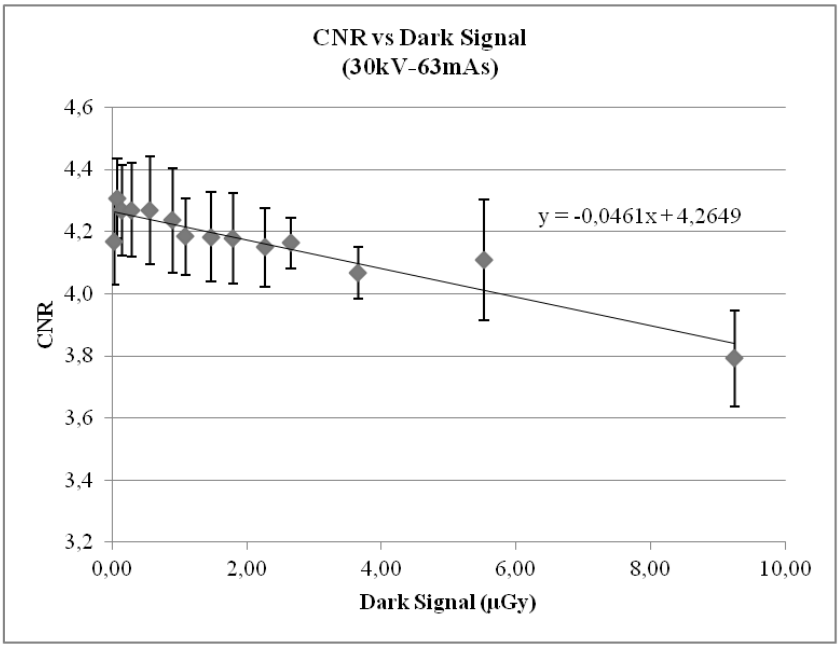

Figure 5. CNR with varying Dark signal caused by scattered radiation. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV. That IP is afterwards exposed to 30kV-63mAs in order to make CNR measurements. PVI measurements within ROIs fitting to the quadratic marking of both an Al and a PMMA insert are available by the CR system[7].

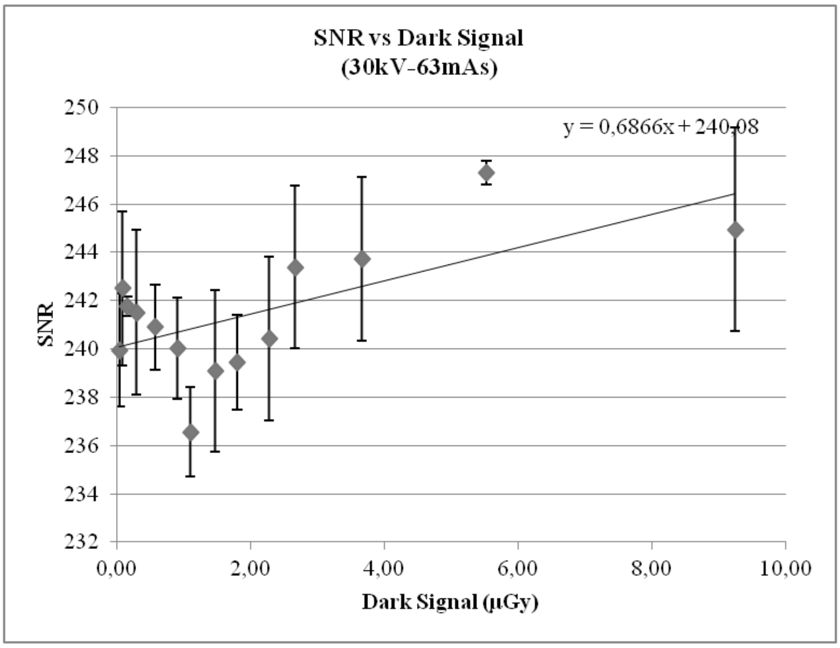

Figure 6. SNR with varying Dark signal caused by scattered radiation. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV. That IP is afterwards exposed to 30kV-63mAs in order to make SNR measurements. PVI measurements within ROIs fitting to the quadratic marking of a PMMA insert are available by the CR system[7].

while figures 7, 8, 9, and 10 depict the ones taken using low exposure settings.

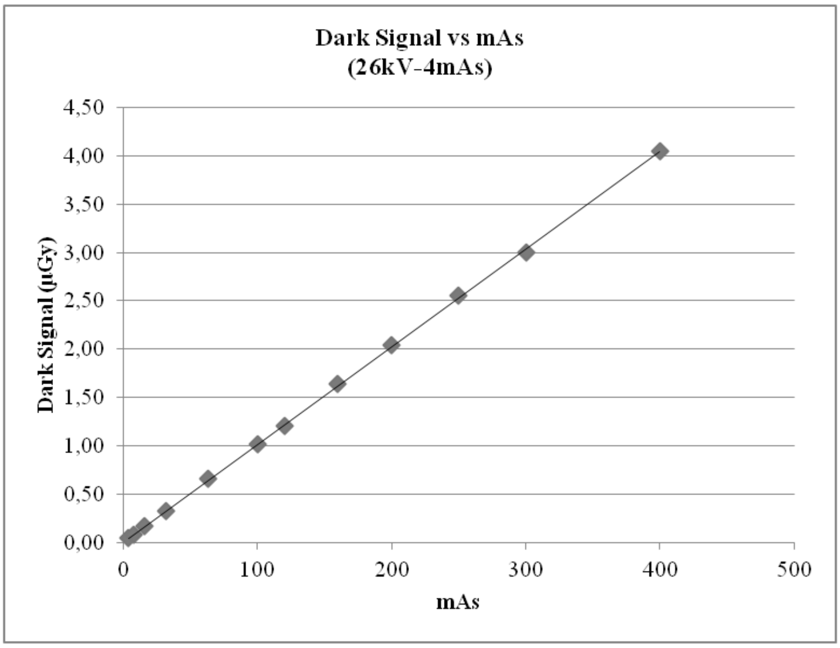

Figure 7. Dark signal caused by scattered radiation with varying mAs. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV[7].

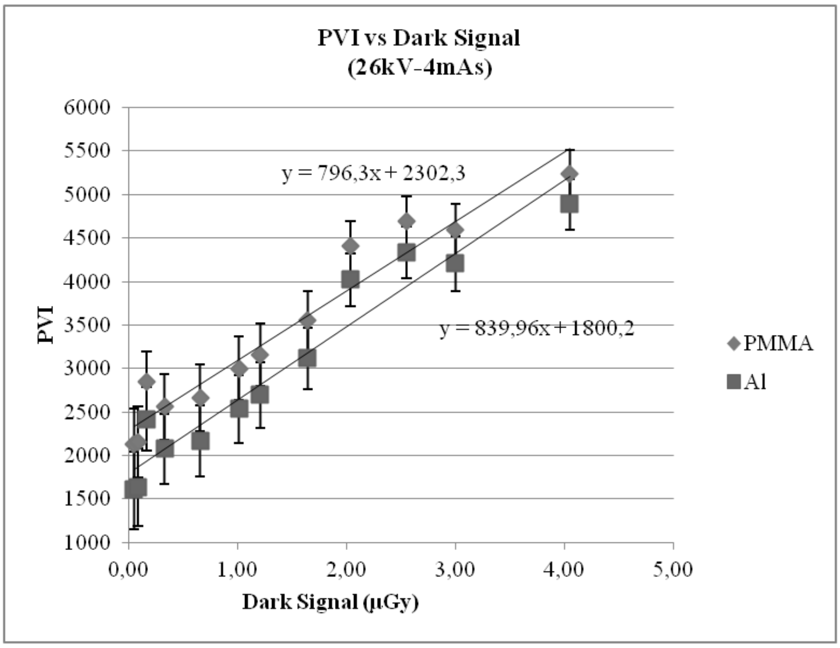

Figure 8. PVI measured for both PMMA and Al with varying Dark signal caused by scattered radiation. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV. That IP is afterwards exposed to 26kV-4mAs in order to make SNR and CNR measurements. PVI measurements within ROIs fitting to the quadratic marking of both an Al and a PMMA insert are available by the CR system[7].

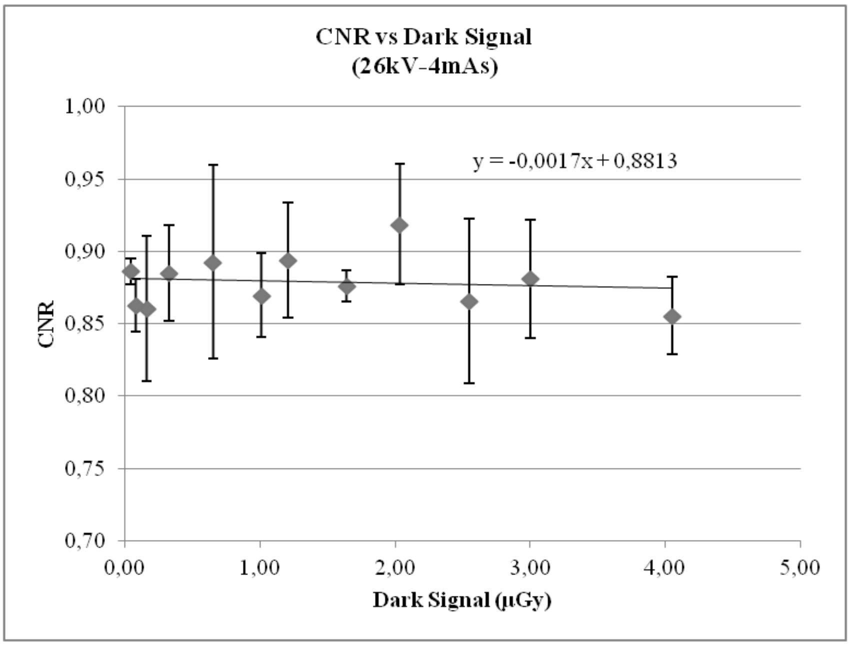

Figure 9. CNR with varying Dark signal caused by scattered radiation. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV. That IP is afterwards exposed to 26kV-4mAs in order to make CNR measurements. PVI measurements within ROIs fitting to the quadratic marking of both an Al and a PMMA insert are available by the CR system[7].

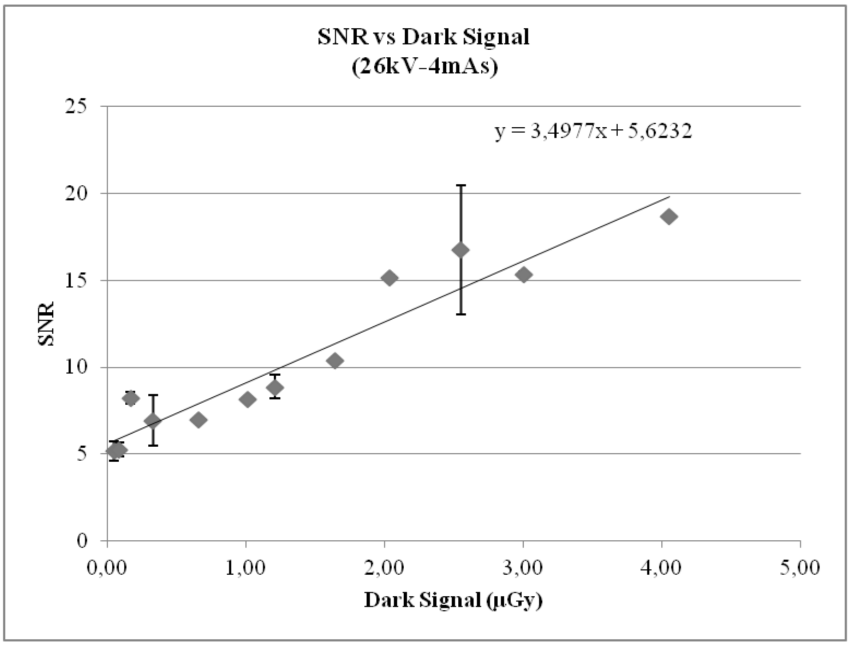

Figure 10. SNR with varying Dark signal caused by scattered radiation. Scattered radiation is estimated by measuring the Air Kerma on the surface of an IP placed near the antiscatter grid when irradiating a phantom with 28kV. That IP is afterwards exposed to 26kV-4mAs in order to make SNR measurements. PVI measurements within ROIs fitting to the quadratic marking of a PMMA insert are available by the CR system[7].

In all cases (meaning clinical settings and lower exposure settings) the Air Kerma and consequently the Dark signal increases linearly with used mAs (figures 2, 3 and 7).
As for PVI measurements, it is shown in figures 4 and 8 that PVI increases with Dark signal. This stands for both settings as well as for both PMMA and Al measurements.
According to figures 6 and 10 SNR increases with Dark Signal.
Scattered radiation decreases the quality of the image. Consequently, Dark Signal decreases CNR (figures 5 and 9).

Comparing the measurements taken using clinical (figures 4, 5 and 6) and low exposure settings (figures 8, 9 and 10), it is noted that PVI, SNR and CNR values are greater when using clinical settings.

Conclusion

As the impact of dark signal on image quality is not negligible, further investigation may be warranted. In particular, further work could also be conducted to compare measured ambient doses to dark signal and CNR effects, while little is known about the behavior of CR plates from different manufacturers. Daily erasure of the IPs is recommended in order to limit dark signal effect on image quality. Finally, a common protocol in CR-mammography worldwide is necessary.

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