X Congreso Regional Latinoamericano IRPA de Protección y Seguridad Radiológica
"Radioprotección: Nuevos Desafíos para un Mundo en Evolución"
Buenos Aires, 12 al 17 de abril, 2015
SOCIEDAD ARGENTINA DE RADIOPROTECCIÓN

Comparison between film-screen and computed radiography systems in Brazilian mammography

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ABSTRACT

Since 2004 the Public Health Office of the State of Minas Gerais in Brazil has established the Image Quality Control Program in Mammography. It evaluates the image quality based on an accredited phantom of the Brazilian College of Radiology (CBR). This phantom follows international standards such as masses, specks, fibers, contrast details and spatial resolution. The contrast index (CI) is accessed through optical density (OD) measurements. Although OD is defined under film-screen (FS) scope, among all accessible mammographic systems under the health office surveillance, almost 80% are computed radiography (CR) based. A necessity to adapt the protocol has emerged to consider OD as a conformity parameter.
Objective: To verify the OD accessibility under CR´s printed out films and the feasibility to calculate contrast index, in comparison with FS´s.
Results: A total of 56 images were evaluated with three different CBR phantoms. They were equally divided into FS and CR systems and a densitometer was used to read out their OD values. The correlation between their contrast-to-noise ratio (CNR) was found to be in the order of 0.77 (±0.14). The samples were not significantly different (inside 5% incertitude) for every phantom. The CNR correlation coefficient was 0.871. For OD, correlation coefficient was 0.989 and a log-fit function has shown good agreement with detector response. The OD-normalized standard deviation difference between CR and FS for every different phantom was 36.6%, 2.8% and 20.2%. A CI range for CR´s lying between 0.13 and 0.69 was found.
Conclusions: Different phantoms were successfully tested in both CR and FS to evaluate the feasibility in use contrast index as a conformity parameter since their correlations are strictly related to calibration curve, as provided by phantom manufacturer. The relative CR-FS OD σ-difference provides a spreading indicator, where the first and last phantoms are considerably out of expectation. Such differences are probably due to their batch production. In terms of CI, a practical conformity range for CRs has been accomplished.

1. INTRODUCTION

Quality assurance (QA) programs in mammography have proven themselves to be effective to assess critical performance indicators through a systematic approach [1]. In a clinical setting, it must be essentially practical to implement. In the Public Health Office of Minas Gerais /Brazil (VISA/MG), the program is called PECQMamo and since 2004 it is evaluating and monitoring the image quality and equipments of approximately 130 services, audited directly by the local sanitary officers. The conformity indicators used by VISA/MG are based on an accredited phantom of the Brazilian College of Radiology (CBR) and present internal structures as masses, specks, fibers, contrast details and spatial details. Optical Density (OD) is also accessed by some greys levels located aside the mentioned structures and it allows one to obtain the Contrast Index (CI), which is simply defined by the ratio between the first and last OD measurements and their respective grey level difference.

By definition, CI is valid only for conventional film-screen (FS) systems due to their short dynamic non-linear range in comparison to Computed Radiography (CR) systems, which has a broader linear range [2,3]. Several studies [3-8] have been published comparing both systems. However, as stated at [2], the quantification of how wide these ranges are in a clinical practice is not well documented. He concludes that, based on ACR phantom data, CR can handle an exposure range at least four times wider than FS. In our study, among all accessible mammographic systems under the VISA/MG surveillance, almost 80% are CR-based. A necessity to verify and adapt the CI as a conformity indicator for such systems and for the CBR-phantom has then emerged as a possibility, even considering the extension of the FS exposure range.

2. METHODOLOGY

Among all mammographic services registered on the Health Public Office of Minas Gerais / Brazil, three of the most used CBR phantom models were chosen. Their relative quantities in comparison with the entire amount of services (127 in total) are 22%, 16% and 11%.

A total of 56 images were analyzed, divided in two main groups, FS and CR. A X-rite portable transmission densitometer and an imaging software (*ImageJ*) were used to read and analyze. The first was restricted to the printed images and the second to the digitalized images. The OD and the contrast-to-noise ratio (CNR) were measured in five points on the processed/printed film, according to a set of different levels located at the border of the phantom. The sixth point was located in the middle of the phantom itself, corresponding to the background optical density. About 45% of the images were irradiated using GE x-ray machines, 27% by Siemens, 13% by VMI (local manufacturer), 11% by Philips and 5% by Lorad.

The printed images were scanned using a mikrotek scamaker 9800XL model at 16 bit-RGB color depth. The CNR was calculated according to the following equation:

$$CNR = \frac{\left(\frac{\overline{m_2}}{\sigma_2} - \frac{\overline{m_1}}{\sigma_1} \right)}{\sigma_2} \qquad (1)$$

where **m** is the mean gray value divided by the number of pixels in a circular region [9] of 100 pixels in diameter and **σ** is its standard deviation. Their respective indexes indicate the measurements made on each level, followed by the next level.

The CNR/OD variations were calculated by:

$$\% = \frac{\left(\overline{m_2} - \overline{m_1} \right)}{\left(\overline{m_2} + \overline{m_1} \right)} \times 100 \qquad (2)$$

One may note that, in equation 2, the index **m** refers to OD measurements when concerning printed films and to mean gray values when concerning digitalized films.

3. RESULTS

The plot for OD against the calibrated grey levels of each phantom model and for each processing type is shown in Figure 1. In Figures 2 and 3, one can see the FS/CR correlation plots for both OD and CNR while in Figure 4 the relationship between the mean standard deviation for every model is shown. Table 1 presents the correlation between the contrast indexes for each model.

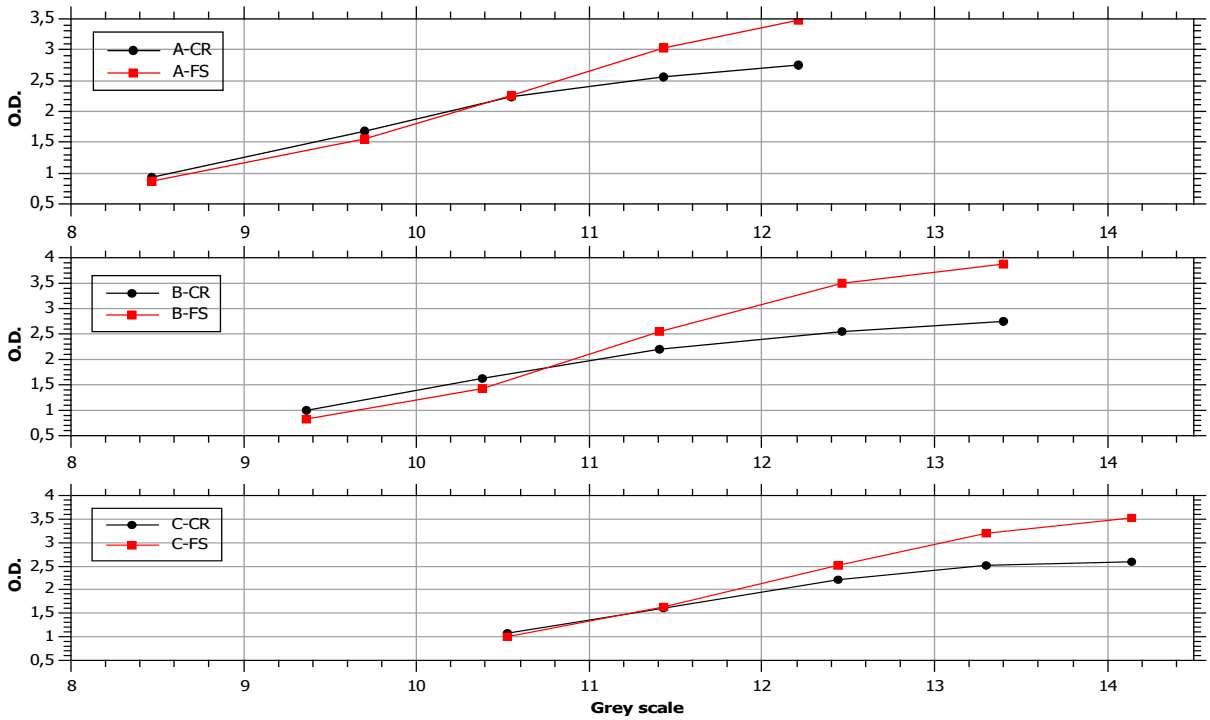

Figure 1. Optical densities plots against the calibrated grey levels for each phantom model. The higher the level, the higher the OD difference between CR/FS. The maximum OD variations are 5.8% (A), 8.5% (B) and 7.6% (C).

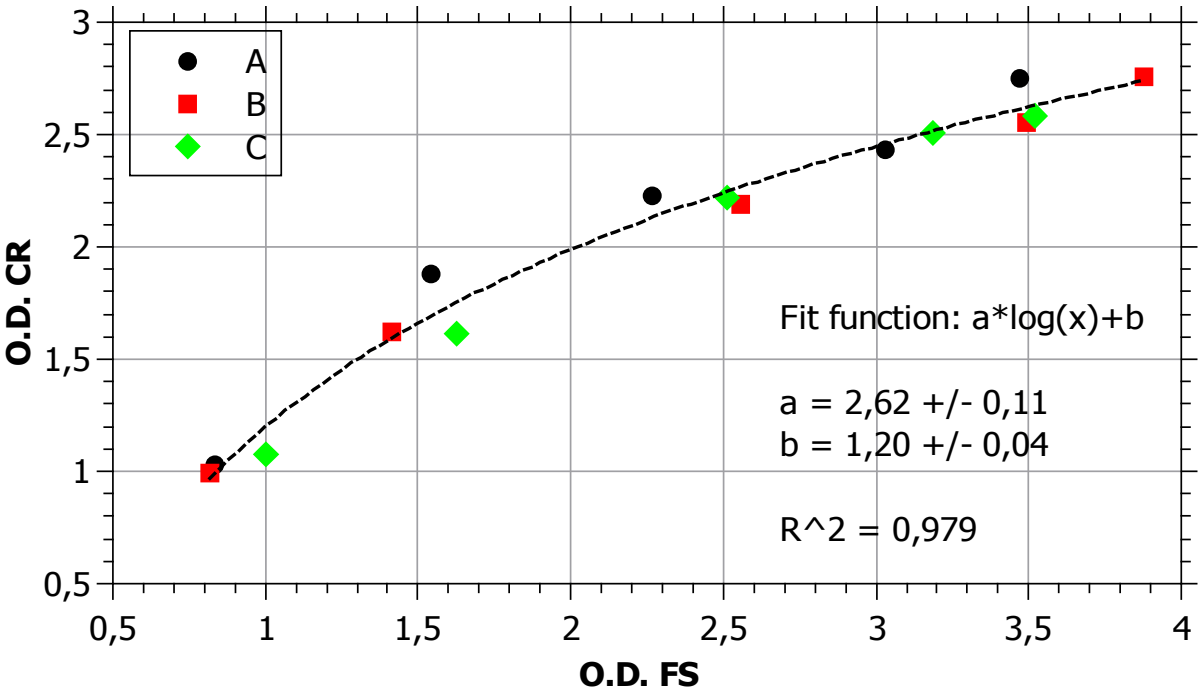

Figure 2. Optical Density correlation between CR/FS. Logarithmic behavior is explained by the dynamic response of the conventional processing. The determination coefficient is about 0.98.

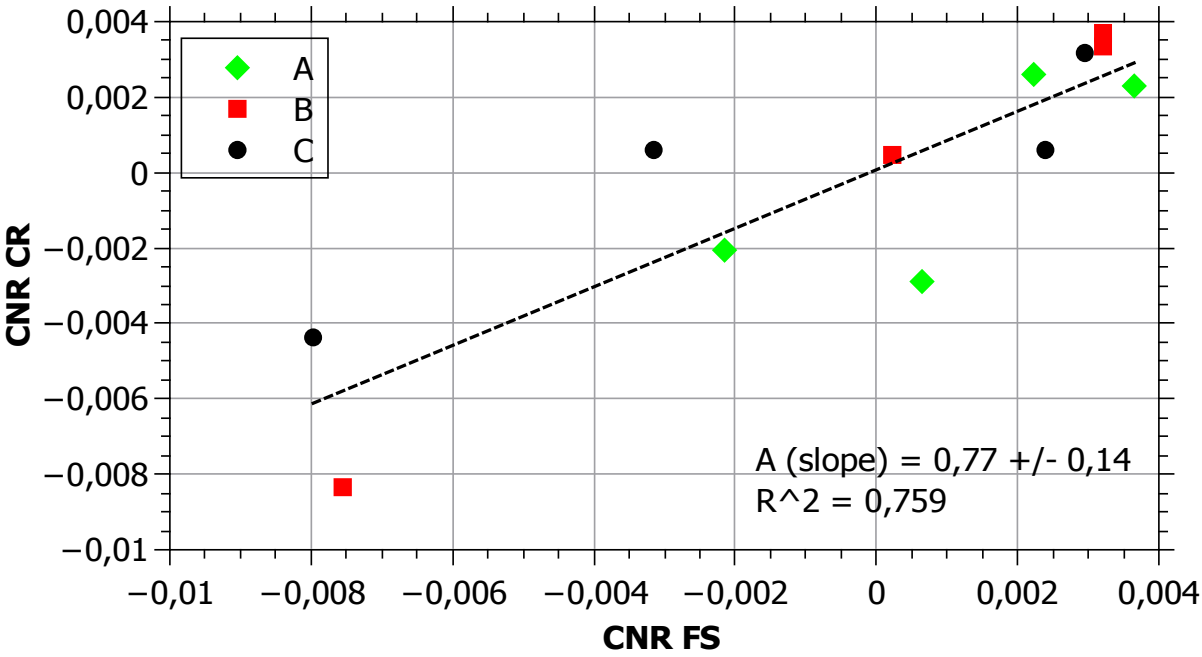

Figure 3. CNR correlation between CR/FS. Correlation is 0.77 (±0.14). Model A has shown the higher deviation.

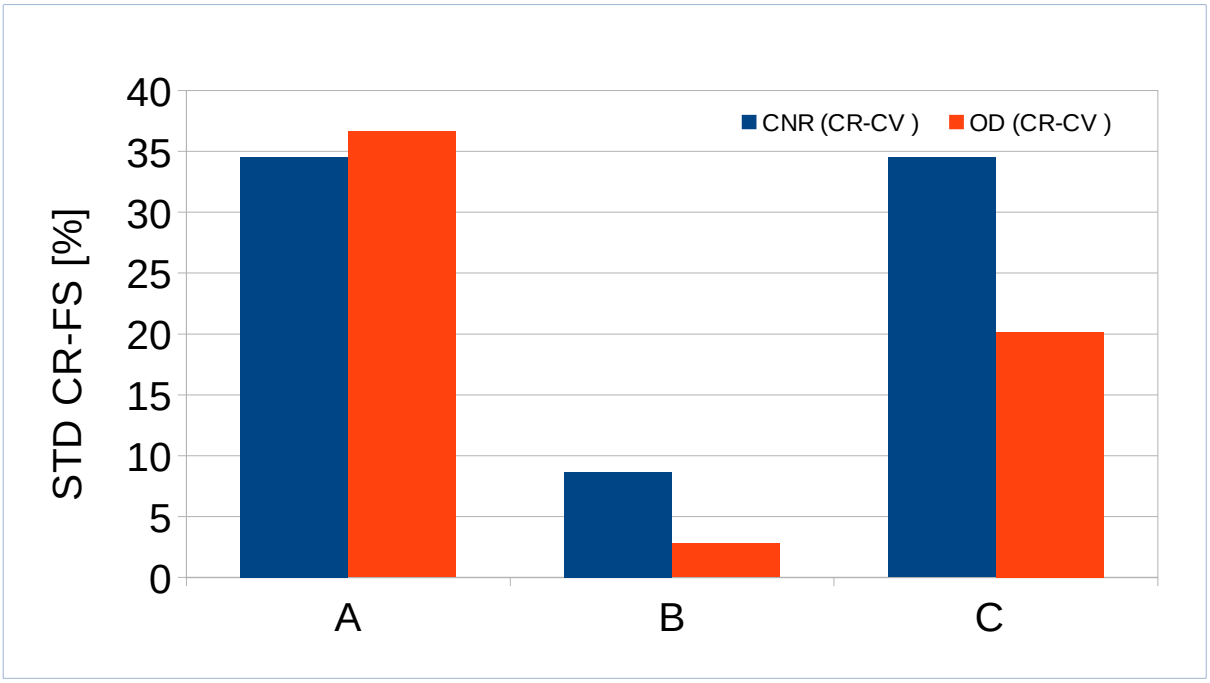

Figure 4. σ-variations for CNR and OD mean standard deviations for every model. Model B has presented the minor variation (about 8% in CNR and 2.5% in OD).

Table 1. Contrast Index correlation between CR/CF for each model. It varies from 57.5% up to 69.7%.

Phantom Model / System	CI for FS	CI for CR	% CR/FS
A	0.70	0.49	69.7%
B	0.76	0.44	57.5%
C	0.70	0.42	59.9%

4. DISCUSSION

In one hand, from Figure 1, one can see that the higher optical density difference is no greater than 9%, which corresponds to the B-phantom model. However, on other hand, from Figure 3, the CNR correlation for the same model is the minor one, which is also followed (Figure 4) by the variations of the standard deviation CR-FS. The OD difference is clearly explained by the very nature of the film processing and its radiation response. Higher the grey level, the higher the OD, which is not entirely the case for the CR printed films. The radiation response for this one is linear with the grey level.

The CR/FS correlations (Figure 2 and 3) have shown a good agreement since the correlation coefficients (R) are 99% and 87% for OD and CNR respectively. Model B has proved to be

the most adequate to our purposes due the fact it has presented the lower deviation for both CNR and OD. In the daily practice, the OD for FS is considered approved if it is in the range of 1.3 OD and 1.8 OD (Δ = 0.5 OD). Using the results of Virgil [2], the OD for CR systems may be four times broader, which means Δ = 2 OD. Considering then the log fit function from Figure 2, one have a practical OD for CR´s ranging from 0.3 OD and 2.3 OD. From Table 1, one sees the correlation between CI´s which therefore indicates the feasibility to use such parameter as a conformity index for CR´s.

For the approval, as seen in Table 1, the CI at FS systems may be within the range of 0.58 - 0.70. Considering the worst correlation (57.5%) and again from the results of Cooper, one obtain a range of 0.13 – 0.61 for CR´s. On other side, considering the best correlation of 69.7% one have 0.21 – 0.69. A roughly approximation would be then to consider a CI range for CR´s lying between 0.13 and 0.69.

5. CONCLUSIONS

A correlation between the film optical densities, contrast indexes and CNRs for conventional and digital mammography systems has been done and has shown the feasibility of using contrast index as an image monitoring parameter in CR systems. The related patterns for both quantities are inside the expected ones, that it is linear for CNR and logarithmic for optical density. A CI conformity range for CRs has been accomplished.

6. REFERENCES

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