# Analog and digital image quality

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***Background.*** *Lastly the X-ray facilities are moving to a slow, but continuous process of digitalization. The dry laser printers allow hardcopy images with optimum resolution and contrast for all the modalities. In breast imaging, the delay of digitalization depends to the high cost of digital systems and, at times, to the doubts of the diagnostic accuracy of reading the breast digital images.*

***Conclusions.*** *The Screen-film mammography (SFM) is the most efficient diagnostic modality to detect the breast cancer in early stage and with reasonable cost. The digital mammography (DM) with the independent capturing, displaying, processing, printing and archiving phases, makes possible an optimisation of the image quality for each, single phase, assuring a satisfactory diagnosis.*

*Kay words: mammography, screen-film , digital*

## Introduction

Lastly the X-ray facilities are moving to a slow, but continuous process of digitalization. The diagnostic digital modalities (nuclear medicine, digital substraction angiography, computed radiography, direct radiography, US, CT, MRI, PET) ask more and more advanced solutions for softcopy (workstation, computed-aided detection - CAD), as well as for the image management systems (picture archive communication systems - PACS, hospital information systems - HIS, radiology information systems - RIS). The dry laser printers (i.e. Kodak DryView Systems) allow hardcopy images with optimum resolution and contrast for all the modalities, with a great advantage for environment. The chemicals use is often limited to process the radiographic films for column, dental and mammography exams. In breast imaging, the delay of digitalization depends to the *high cost of digital systems* and, at times, to the *doubts of the diagnostic accuracy* of reading the breast digital images.

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## Screen-Film Mammography (SFM) and digital mammography (DM)

Today the SFM is the most efficient diagnostic modality to detect the breast cancer in early stage and with reasonable cost. Thanks to the technology improvements the SFM provide excellent image quality with tolerable dose to the patient, but constant and adequate *quality control procedures* are required. The *digital mammography* (full-field-digital-mammography: FFDM), with the independent capturing, displaying, processing, printing and archiving phases, makes possible an optimisation of the image quality for each, single phase, assuring a satisfactory diagnosis.

Main indicators of image quality in SFM *are contrast* (dynamic range), *resolution* (MTF: modulation-transfer-function), *noise* (graininess) and *dose,* all controlled from the sophisticated technologies of components of the image formation chain (x-ray tube, detector, processing, view box). Other, well known indicators are image artefacts and image tone. With DM new indicators of image quality have added and became more and more familiar: *detective-quantum-efficiency* (DQE) and *signal-to-noise ratio* (SNR).

### *Contrast*

In breast imaging the contrast is essential to enhance the intrinsic, low contrast of subject. From exposure to visualization, the image formation chain links are focused to get the optimal breast contrast that strongly depends from *detector response* (film-latitude) to the x-ray exposure with its *characteristic sigmoid* curve. Contrarily to analog film, the *linear response* of the digital detector, allows a very wide exposure *dynamic range:* in digital imaging the over-under-exposed images are at last impossible. The image processing in DM, thanks to the *algorithms* applied to row digital image data, permits the detectability of smallest pathologies (i.e. microcalcification), the optimum visualization of skin line and, at the same time, of the dense and fatty areas of breast parenchyma. The *contrast* enhancement of the digital image may balance the visible loss of spatial resolution in comparison to SFM.

### *Resolution*

Patient movement, x-ray unit geometry and detector itself influence the image resolution (sharpness) in mammography. Typical, objective measurement of resolution is MTF that quantifies the spatial frequency of a SFM system. In a MTF graph, the numbers always start high, then drop, as imaged objects become more fine. In SFM the detector features (i.e. screen thickness, mono-emulsion layer, screen-film contact.) might provide a minimum light spreading during the exposure to guarantee the maximum spatial resolution.

In DM detector resolution mainly depends to pixel size of the matrix and to the applied detector technology itself (indirect-or-direct). Normal matrixes have pixel sizes from 100 micron (18x24 cm FFDM) to 50 and 25 micron (Fischer slot-scanning technology). The spatial resolution of DM detector of 100μ can reach theoretically 5 lp/mm, while the SFM arrives to 15–20 lp/mm. Matrixes, with smaller pixel sixes (50 or 25μ), offer higher resolution image (10 lp/mm), but make more difficult the image data management, also because the great number of bits (12/14) required to get a very wide *grey scale range* of the single pixel.

Note that, for these reasons, a single (18x24 cm size) breast digital image will require a large file from roughly 9MB for a 100μ pixel, to 18MB for 50μ one! Data management in digital breast imaging must finally consider both storage space and network traffic.

### *Noise*

The only source of noise, in a theoretically ideal or perfect detector, would result from the incident x-ray quantum statistics alone: the final image noise can never be lower than this inherent noise. In SFM systems important, additional noise sources are: 1) film grain size, 2) screen absorption, 3) screen structure, while in DM further sources are introduced in varying amounts by the electronics chain.

Contrast, resolution and noise, in practical reading of breast images, can be considered interdependent: each one influences the other. In either SFM or DM images, a sharper or higher contrast image will result noisier; a higher image contrast allows an easy visualization of small breast details and outlines of structures that appear sharper.

### *Dose*

X-ray beam quality hardening in DM (i.e. higher kVp, Rh or Wo anode/filter use) does not cause an image contrast loss thanks to image contrast enhancement. This exposure setting optimisation and the very good efficiency of the digital detectors can allow lower dose (around 30%) with DM (FFDM) in comparison of the SFM.

### *Detective-quantum-efficiency (DQE)*

DQE is a transfer function that measures the output characteristics for a system compared to the input. Defined another way, it is a measure of the efficiency with which the SNR of the incident exposure is preserved in an image. Measures of DQE show better results of DM in comparison to SFM.

### *Signal-to-noise ratio (SNR)*

SNR can be used to describe the detectability of a particular object under specified exposure conditions. SNR can still control the image noise and exposure (dose) level, as well the special algorithms (filter) provide a final image noise perceived inferior to SFM, both in softcopy and hardcopy conditions. The x-ray exposure (mAs) will control the SNR of the digital detector: higher exposure (dose) will limit the noise presence, on the contrary the lower one will increase the noise perception in the image.

The transition from analog to digital systems is, anyway, inevitable also in breast imaging.

Till now, the comparative studies between the SFM and DM, confirmed that the best results achieved with DM (softcopy of a full-field-digital-mammography system) could be, at the maximum, equivalent to SFM. Nevertheless the figures show that on 150.000 women, with a suspicious breast cancer, examined every year with SFM, for several reasons there are from 15.000 to 45.000 cancers not detected!

The sigital mammography system (FFDM) today makes possible the integration of the mammography modality in the PACS.

In practice the DM exam technique (positioning, compression) remains the same of SFM and the higher speed of image capturing, pre-viewing and viewing stages consent an increase of productivity.

Radiologists, physics, radiographers must increase their knowledge of digital breast imaging by studying in depth the technical aspects which control the image quality from capturing to viewing, from processing to archiving and, at the same time, they must define their specific roles in new QA program for a digital mammography system. Recently the European Guide Lines for Quality Assurance in Screening Mammography have issued an " addendum" for the digital mammography (the document is available on website: www.euref.org).

Thanks to the further improvements (higher resolution) of new digital-direct-detectors and softcopy systems (LCD monitors), to the CAD integration and to the radiologist confidence in digital images reading, an increase of the cancer detection rates could be achievable, as well an extra dose reduction and lower cost are expected too.

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