QA, image quality and dose in screening with digital mammography

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Learning objectives

The European Commission states in its council recommendation of 2 Dec 2003 that mammography screening in women aged 50 to 69 is justified if performed in accordance with the European Guidelines on Quality Assurance (QA). This recommendation and the Directive 97/43/Euratom on medical exposures, made QA an important part of screening programmes. Physico-technical aspects of digital mammography are to be included in QA programmes.

As with film-screen systems, both acceptance tests, (half) yearly tests and constancy tests are necessary. Acceptance tests and yearly tests evaluate the performance of the system and the dose settings from blocks of PMMA. Special attention is given to the spatial characteristics of the (digital) detector, the noise properties and the signal-difference-to-noise-ratio. In the European guidelines, performance is ultimately assessed from of contrast threshold values for a series of disk diameters. We discuss the use of the CDMAM phantom along with alternative approaches such as detectability indices \( d' \) (Monnin, Verdun, Marshall et al.) for systems in our QA network.

The automatic exposure controller should ultimately be tested in real cases. Patient dose investigations are more important than before. In digital mammography, and especially with direct digital detectors, patient dose surveys can be automated.

Constancy checks have to guarantee an optimal quality every day. We will illustrate typical artefacts that occur with digital detectors and viewing stations. Daily homogeneity tests of the detector along with an automatic evaluation of DICOM tags allow both the detection of sudden problems as well as a long term follow-up of performance.
1 Introduction

Achieving quality in breast cancer screening activities is a must-do, see the EC council recommendation of 2 December 2003 on cancer screening. In successive projects, European Guidelines have therefore been developed. Many of these documents are being used in EC member states.

Quality assurance of the physic-technical aspects of breast cancer screening is typically achieved at 2 levels:

1. Conformity tests of the equipment, by a medical physics expert (MPE) at (half) yearly visits
2. Daily or weekly QA of mammography system and monitor, with tests performed by local radiographers and radiologists, and supervised by MPEs.

2 Conformity tests

European Guidelines prescribe to test the complete mammography environment on a yearly or half yearly basis. Tests can be further subdivided:

1. Control/Characterization of the X-ray tube
   • Aspects of radiation safety
   • Performance of the tube, beam quality, …
   • All measurements to prepare patient dosimetry (HVL, transmission factor of the paddle, …)

2. Control/Characterization of the detector
   • Response curve,
   • MTF, NPS,
   • Homogeneity, ghost and lag
   • New items in updated protocols: analysis of the noise,
3. Verification of AEC settings

4. Dose, signal difference to noise ratio and dose

- The European Guidelines put limiting values on contrast detail readings and signal difference to noise ratio (SDNR) measured using clinical exposure conditions. (Fig 1 & 2)

- Dose, contrast detail and SDNR are linked (Fig 3).

- Some systems don’t pass these severe limits and readjustment is often required. This is typically done by exploring different dose levels (Fig 4)


Data processing and data acquisition can be largely automated!


5. Monitor and viewing conditions

The use of the TG18 test patterns and a luminance meter is central in these tests.

The most severe test is the GSDF conformity test. A typical example is shown in Fig 5.

Most challenging is getting the ambient light low enough.

Updates of the European Guidelines may require less strict ambient light conditions for LCD monitors.

3 Daily or weekly QC measurements

- Challenges are:

  - Get it implemented!

  Capture raw data of phantom acquisitions

  Extract relevant data

  Send data to center for Quality supervision

  - Get the analysis automated!
Read, organize feedback, report and store data

Fig 12 illustrates our network that connects at this moment 99 mammography units (3/4rd digital) to the computer of the MPEs. In our organization, we evaluate the results from 2 screens. A typical example is shown in Fig 14 and 15. In absence of a daily problem, analysis takes less than 2 minutes/day / center.

In case a detector artifact is detected with potential impact on image quality, we retrieve patient images of the same day for correlation and detailed study of the problem. Typical examples are shown in Figs 7 & 8 and Fig 9 & 10.

Daily QC of monitors is another challenge. Following our national legislation, a test pattern that is variable over time is required. We have developed the MoniQA pattern for this purpose (Fig 6). This allows a complete evaluation of the monitor in less than 2 minutes/monitor/session.

4 Image quality

Following the European Guidelines, image quality evaluation is often performed by means of the CDMAM phantom. Manual reading is however cumbersome and automated procedures are being developed.

Next to CDMAM images, alternative procedures are being developed too. This can be based on other phantoms or on more theoretical considerations such Model Observers. The Non-prewhitening-matched filter (with eye response) detectability index seems to correlate with CDMAM readings.

Other challenges include the evaluation of clinical image quality or more general, the quality in case of structured backgrounds.

5 Dosimetry

The Dance formula for mean glandular dose is generally used for assessing patient doses. It requires tube output measurements at the one hand and exposure settings of patients at the other hand. If DICOM headers contain all the information, like in DR systems, dose data collection can be automated and the analysis can be performed from many thousand patient cases (Fig 9). In our network, patient dose data from (powder) CR systems are significantly higher than dose data from DR (Fig 13).

6 Conclusion
• A lot of work, a lot of challenges, but it can work

• Have an IT specialist integrated in the MPE team

• Do we work well enough?
The final quality verification will come from cancer detection parameters: Detection rate, interval cancers…
# Limiting values in the EU Guidelines

## Image quality

<table>
<thead>
<tr>
<th>Diameter of detail [mm]</th>
<th>Radiation contrast using Mo/Mo 28 kV [%]</th>
<th>Equivalent gold thickness [\mu m]</th>
<th>Radiation contrast using Mo/Mo 28 kV [%]</th>
<th>Equivalent gold thickness [\mu m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5*</td>
<td>&lt; 0.85</td>
<td>0.056</td>
<td>&lt; 0.45</td>
<td>0.032</td>
</tr>
<tr>
<td>2</td>
<td>&lt; 1.05</td>
<td>0.069</td>
<td>&lt; 0.55</td>
<td>0.038</td>
</tr>
<tr>
<td>1</td>
<td>&lt; 1.40</td>
<td>0.091</td>
<td>&lt; 0.85</td>
<td>0.056</td>
</tr>
<tr>
<td>0.5</td>
<td>&lt; 2.35</td>
<td>0.150</td>
<td>&lt; 1.60</td>
<td>0.103</td>
</tr>
<tr>
<td>0.25</td>
<td>&lt; 5.45</td>
<td>0.352</td>
<td>&lt; 3.80</td>
<td>0.244</td>
</tr>
<tr>
<td>0.1</td>
<td>&lt; 23.0</td>
<td>1.68</td>
<td>&lt; 15.8</td>
<td>1.10</td>
</tr>
</tbody>
</table>

* This diameter size is optional

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly</td>
<td>Contrast detail phantom.</td>
</tr>
</tbody>
</table>

**Fig. 0**

© The European Guidelines
Limiting values in the EU Guidelines

Contrast to noise ratio

Table 1
CNR per PMMA thickness, see table for provisional limiting values. Compare CNR values with results at acceptance.

<table>
<thead>
<tr>
<th>PMMA Thickness [cm]</th>
<th>CNR [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>&gt; 115</td>
</tr>
<tr>
<td>3.0</td>
<td>&gt; 110</td>
</tr>
<tr>
<td>4.0</td>
<td>&gt; 105</td>
</tr>
<tr>
<td>4.5</td>
<td>&gt; 103</td>
</tr>
<tr>
<td>5.0</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>6.0</td>
<td>&gt; 95</td>
</tr>
<tr>
<td>7.0</td>
<td>&gt; 90</td>
</tr>
</tbody>
</table>

Even more of a challenge.

Fig. 0

© European Guidelines
Fig. 0

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Typical solution: increase the dose

Fig. 0

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A challenge
Requires calibration!

From Luminance response -> GSDF

• For a series of test patterns (p-values)
  - from $L_{\text{max}}$ and $L_{\text{min}}$ -> JNDS -> Ideal luminance ->
    dL/L & limiting values
  - measurements of L -> dL/L & compare to reference values

![Diagram](image)

Fig. 0

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Fig. 0

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Fig. 0

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Typical result

- Patient dose distribution & phantom measurements

![Graph showing MGD vs thickness for Siemens Inspiration system](image)

**Fig. 0**

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Typical example of a problem
• Scan line artifacts

Fig. 0

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Fig. 0

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Typical example of a problem

- Ghosting (Selenium systems)
  - lag ghost, sensitivity change
  - bad flat fielding

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Fig. 0

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Patient Mean Glandular Dose Distribution for DR and CR technology

Mean MGD (DR)= 1.91mGy; 9771 mammograms; 25 systems; Siemens 14; Hologic: 4; GE: 5; Sectra: 2
Mean MGD (CR) = 2.51mGy; 3247 mammograms; Fuji CR: 6; Agfa CR: 1

Fig. 0

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