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.

Main

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)
   • New items in updated protocols: computerized reading of contrast-detail images. Example using the method by K. Young, SPIE 2009.

Data processing and data acquisition can be largely automated!

(we made our tools available on our website: http://www.kuleuven.be/radiology/lucmfr/projects.html; http://www.kuleuven.be/radiology/lucmfr/bianqa/)
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…

Images for this section:
## 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 (^{18}) [µm]</th>
<th>Threshold contrast using Mo/Mo 28 kV [%]</th>
<th>Equivalent gold thickness (^{11}) [µm]</th>
<th>Achievable value</th>
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</thead>
<tbody>
<tr>
<td>5*</td>
<td>&lt; 0.85</td>
<td>0.056</td>
<td>&lt; 0.45</td>
<td>0.032</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&lt; 1.05</td>
<td>0.069</td>
<td>&lt; 0.55</td>
<td>0.038</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>&lt; 1.40</td>
<td>0.091</td>
<td>&lt; 0.85</td>
<td>0.056</td>
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<tr>
<td>0.5</td>
<td>&lt; 2.35</td>
<td>0.150</td>
<td>&lt; 1.60</td>
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<tr>
<td>0.25</td>
<td>&lt; 5.45</td>
<td>0.352</td>
<td>&lt; 3.80</td>
<td>0.244</td>
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<tr>
<td>0.1</td>
<td>&lt; 23.0</td>
<td>1.68</td>
<td>&lt; 15.8</td>
<td>1.10</td>
<td></td>
</tr>
</tbody>
</table>

\(^{*}\) This diameter size is optional

**Frequency**

Yearly.

**Equipment**

Contrast detail phantom.
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>CNR² [%]</th>
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<tr>
<td>2.0</td>
<td>&gt; 115</td>
</tr>
<tr>
<td>3.0</td>
<td>&gt; 110</td>
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<td>&gt; 103</td>
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<tr>
<td>6.0</td>
<td>&gt; 95</td>
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<tr>
<td>7.0</td>
<td>&gt; 90</td>
</tr>
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</table>

Every six months, PMMA: a set of 10 mm thick PMMA plates covering the complete detector area, 0.2 mm thick Al object (for example: the filters which are used for the HVL measurement).

Unique
Even more of a challenge

Fig. 2
Typical solution: increase the dose

Fig. 4
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

Fig. 5
Fig. 6
Fig. 7
Typical result

- Patient dose distribution & phantom measurements

Fig. 8
Typical example of a problem

- Scan line artifacts

Fig. 9
Typical example of a problem

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

Fig. 11
Fig. 12
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. 13
Courtesy J Jacobs, LUCMFR, Leuven

Fig. 14
References


European Guidelines on QA in breast cancer screening and diagnosis. Chapter 2: Physico-technical QA.

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Mission of LUCMFR:

To support the radiological team in our hospital and far beyond our campus with physical or technical analyses, optimisation studies, continuing image quality maintenance and more fundamental research projects.

Expertise:

- Acceptance tests of medical equipment following the most recent protocols
- Application of the ALARA principle in practice: optimisation of image quality and radiation dose in X-ray imaging

- MRI physics support

- MR sequence optimisation for clinical and research examinations

- Evaluation of new imaging modalities

- Evaluation of image processing / tomosynthesis reconstruction

- Automated patient dosimetry

- Statistical data processing (ROC, FROC, …)

- Set-up of observer performance studies