Survey of Mammography Practice: Initial Results from Serbia

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**Abstract.** The purpose of this paper is preliminary evaluation the mammography practice in Serbia, having in mind the annual number of examinations and fact that part of examination is performed on women without any clinical signs. For initial evaluation, five hospitals with highest workload have been selected, representing the typical mammography practice in Serbia. The methodology consists of initial image quality evaluation and assessment of relevant imaging chain parameters using dedicated Protocol for Quality Control (QC) in mammography. Evaluation of performance of mammography x-ray units and image processing units include parameters of x-ray tube and generator, mechanical safety, automatic exposure control performance, patient dosimetry, and temperature of developer, time of film processing and presence of artefacts. Image grading in three hospitals with highest workload resulted in very high percentage of images with poor quality, ranging from 13% up to 70% for cranio-caudal projection and from 8% to 66% for medio-lateral oblique projection. Overall rejection rate was less than 2%. Patient exposure in terms of mean glandular dose ranged from 0.12 mGy to 2.8 mGy. This preliminary survey of mammography practice highlighted the need for optimization of mammography practice. Developed QC protocol, based on actual practice and resources, includes equipment testing and maintenance, staff training and QC management and allocation of responsibilities, should be applied on the national scale.

**KEYWORDS:** mammography, quality control, image quality, dose

1. Introduction

Breast cancer is the most common type of cancer among the women. Mammography is method of choice for early detection of breast cancer [1, 2]. The annual number of new breast cancers in Serbia is approximately 4000 [3]. In Serbia, mammography is performed only clinically, although there is a long term plan to introduce mammography as screening method. Currently there are more than 60 mammography units in practice in Serbia, resulting with approximately 70 000 mammography procedures annually.

Serbia does not have a national screening programme, however the number of mammography examination performed for screening purposes is increasing. As mammography is technically one of the most demanding radiographic techniques, image quality and patient dose critically depend on equipment and its performance, as well as of radiographer’s skill. Only strict Quality Control (QC) can ensure high quality diagnoses together with low radiation risk. The objective of any mammography screening is to identify breast cancer at early stage using mammography examination. This examination is only of benefit if small lesions are detected, which requires obtaining and maintaining high quality mammography by rigorous and comprehensive QC. The screening programme must be well justified in terms of radiation protection.

Although the use of ionizing radiation in medicine in Serbia is controlled by several pieces of legislation, the legal framework does not cover the area of Quality Assurance (QA) and QC in medicine, including clinical mammography and mammography screening. Concerning that fact, in addition to legal documents, national guidelines should be developed to include different quality control parameters in the quality management system, which should be in operation in every radiology department performing mammography. In addition, operating staff must have sufficient knowledge about their equipment and their responsibility in optimizing daily practice. Initial training, followed by the training on the regular basis should be developed.

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At present, performance of mammography centres in Serbia is annually evaluated by licensed external technical services, by checking only few basic parameters of the X-ray tube and generator and evaluation of radiation safety issues. QC of the film processing, viewing boxes, image quality assessment and systematic patient dosimetry has never been performed before.

The purpose of this paper is preliminary evaluation the mammography practice in Serbia, having in mind the annual number of examinations and fact that part of examination is performed on women without any clinical signs.

2. Materials and Methods

2.1 Quality Control Protocol

The objective of this project is to perform the dose and image quality survey with the main purpose to explore the real status of the clinical practice and existing potential for implementation of European guidelines for quality assurance in breast cancer screening and diagnosis [4].

The QC of the physical and technical aspects must guarantee that the following objectives are met:

1. The radiologist is provided with images that have the best possible diagnostic information obtainable when the appropriate radiographic technique is employed. The images should at least contain the defined acceptable level of information, necessary to detect the small lesions [5];
2. The image quality is stable with respect to information content and optical density and consistent with that obtained by other participating screening centres;
3. The breast dose is As Low As Reasonably Achievable (ALARA) for the diagnostic information required.

Mammography should only be performed using modern dedicated X-ray equipment and appropriate image receptors. In addition, to accomplish basic QA/QC objectives i.e. of maintaining standards in imaging and working towards minimizing patient and number of rejected films, a number of physical parameters that affect the performance of X-ray imaging system are to be measured. Quality control should be subdivided in three phases: acceptance tests, constancy test and periodical status tests. Several measurements can be performed by the local staff. The more elaborate measurements should be undertaken by medical physicists who are trained and experienced in diagnostic radiology and specifically trained in mammography QC. Comparability and consistency of the results from different centres is best achieved if data from all measurements, including those performed by local technicians or radiographers are collected and analyzed centrally. The generic list of parameters includes the following categories:

1. Visual inspection, mechanical stability and ambient conditions (presence of sharp edges, temperature, humidity, compression device, orientation of cassettes and film boxes…);
2. Film processing (ambient temperature, humidity, temperature of developer, development time, light leakage, sensitometry, artefacts, dose rate in the darkroom);
3. X-ray tube and generator (radiation leakage, focal spot size, accuracy and reproducibility of tube voltage, half-value layer (HVL), output, exposure time, alignment of x-ray field);
4. Automatic Exposure Control (AEC): long term reproducibility, object thickness and tube voltage compensation, optical density control step, exposure time;
5. Anti scatter grid;
6. Image receptor (inter cassette sensitivity, screen-film contact);
7. Viewing conditions (luminance and homogeneity of viewing boxes, ambient light level);
8. Image quality (spatial resolution, threshold contrast visibility);
9. Dosimetry (average glandular dose for a standard breast).

The QC protocol was developed based on European guidelines for quality assurance in breast cancer screening and diagnosis [4] and adjusted to local circumstances and available equipment. The protocol
includes a list of parameters to be tested, frequency of testing and criteria of acceptability for each parameter. Written procedures are prepared and evaluated for each parameter. In addition to QC, the overall QA programme include: equipment procurement, testing and maintenance, staff training and performance and management of QA/QC including allocation of responsibilities.

For the assessment of the parameters of x-ray tube and generator, multimeter Barracuda (RTI electronics, Molndal, Sweden) with a calibrated solid state detector MPD and 1cm$^3$ Magna ionizing chamber was used.

Optimal use of ionising radiation in medicine, i.e. mammography is based on balancing the image quality and patient dose. Therefore, although both parameters are part of the routine QA/QC programme, they are discussed separately.

### 2.2 Patient dose

The estimation of dose to breast is important part of the QC of the mammographic examination. Knowledge of breast dose is essential for the design and performance assessment of mammographic imaging system [6]. The dose for a standard breast was assessed using 45 mm block of Perspex as breast substitutes. Air kerma at the top of Perspex block was measured. Then, conversion factors were used to convert air kerma to the average glandular dose (AGD) for the standard breast [4].

For the air kerma measurements the 1cm$^3$ Magna ionizing chamber with multimeter Barracuda (RTI electronics, Molndal, Sweden) was used.

### 2.3 Image quality assessment

Image quality is an important subject in imaging sciences. The basic parameters as Modulation Transfer Function (MTF), the Wiener spectrum, the dynamic range and contrast are measurable quantities. However, efficiency of mammography depends directly upon visualisation task and it is known that human brain allows to a certain extent the compensation of the image quality parameter by another one [7]. The first step in image quality assessment is definition of necessary diagnostic information. This is, however, a subject of variation and depends on type of examination and breast composition.

For image quality assessment two methods were implemented. Initially, in three hospitals with highest workload image quality was assessed by at least one experienced radiologist in each hospital. The image quality criteria from European Guidelines on Quality Criteria for Diagnostic Radiographic Image [5] were used to reduced interobserver variability and to guide the radiologist how to assess the image quality. The quality criteria were not used for image quality scoring. Instead, each image was graded as A, B or C [8]. Grade A means full acceptability without any remarks. Grade B includes images that are acceptable with certain remarks or observations, while images graded as C should be rejected. In addition, images graded as B or C were additionally classified according to type of remark, as over exposed/underexposed, presence of artefacts or unsharp reproduction of anatomical details according to European Guidelines on Quality Criteria for Diagnostic Radiographic Images [5]. At least 100 mammograms for cranio-caudal (CC) and medio-lateral (MLO) projection are evaluated in each hospital.

Subsequently, the image quality was evaluated using images of the TOR (MAS) test object (Leeds Test Object, Leeds, UK). The TOR (MAS) test object has embedded high contrast resolution pattern used for evaluation of the threshold resolution in the condition of minimal geometrical unsharpness and noise, low contrast linear details used for assessment of detectability of fibrous strands in breast (interrelation of sharpness, contrast and signal to noise ratio), low contrast circular details (5.6 mm diameter) used for detection of tumour masses, high contrast details (0.25 mm and 0.5 mm diameter) used for assessment of microcalification visualisation and grey scale step wedge [9]. The test object was placed on the top of the 35 mm Perspex stack and imaged using clinical exposure parameters. In addition to resolution and detail visibility analysis, base plus fog optical density, speed index and
contrast index were determined. Optical density in reference points was measured using a calibrated densitometer Lullus 1.21 (Wellhofer, Scanditronix, Germany). Optical density close to value 1.0 on the image of the step wedge is Speed Index (SI), while Contrast Index (CI) was assessed as a difference of the maximal optical density and SI [10]. The CI represents the difference among 100% glandular and 100% fatty tissue in image.

3. Results and Discussion

3.1 Implementation of the Quality Control Protocol

The efficient use of ionising radiation in medicine involves three factors: radiographic technique, patient dose and image quality [7]. QA/QC is a mean to achieve these requirements. In the case of mammography stricter QA/QC programme has to be applied, since this is one of the most demanding imaging procedures, it includes radiosensitive breast tissue and it is used as a screening method for early detection of breast cancer worldwide [2].

The results of QC test have demonstrated significant variation of the measured values comparing to reference values. Although dedicated film-screen combinations were used in all hospitals, in four out of five hospitals non-dedicated film processor were used, without any QC. AEC was applied in three out of five hospitals, while in other two cases AEC was either non-functional or it was not technically available due to technological obsolesce. As an illustration, the results of the selected QC test in five mammography units are presented in Table 1.

Table 1. Results of the selected QC test in five mammography units. The tube voltage (U), current time product (I·t) and reference optical density (OD) refers to imaging of 45 mm Perspex phantom. High contrast resolution (HCR) was derived from images of the TOR (MAS) test object.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Model</th>
<th>Film Screen</th>
<th>T&lt;sub&gt;developer&lt;/sub&gt; [°C]</th>
<th>U [kV]</th>
<th>I·t [mAs]</th>
<th>Ref. OD</th>
<th>HCR [lp/mm]</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-A</td>
<td>Hologic Lorad M-IV Agfa Kodak</td>
<td>34</td>
<td>28</td>
<td>89</td>
<td>1.4</td>
<td>11</td>
<td>1.23</td>
<td></td>
</tr>
<tr>
<td>M-B</td>
<td>Hologic Lorad M-IV Kodak Kodak</td>
<td>36</td>
<td>28</td>
<td>61</td>
<td>1.8</td>
<td>8.9</td>
<td>1.54</td>
<td></td>
</tr>
<tr>
<td>M-C</td>
<td>Planmed Sophie Agfa Fuji</td>
<td>36</td>
<td>27</td>
<td>105</td>
<td>1.2</td>
<td>10</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>M-D</td>
<td>Siemens Mammomat 1000 CAWO Kodak</td>
<td>34</td>
<td>28</td>
<td>89</td>
<td>2.8</td>
<td>7.1</td>
<td>2.13</td>
<td></td>
</tr>
<tr>
<td>M-E</td>
<td>Siemens Agfa Agfa</td>
<td>30</td>
<td>28</td>
<td>25</td>
<td>1.4</td>
<td>8.0</td>
<td>1.03</td>
<td></td>
</tr>
</tbody>
</table>

It has been demonstrated that x-ray tube and generator are the most reliable and the most stable elements of the mammography diagnostic chain, since the most of the QC criteria were fulfilled. The most significant sources of instability were image processing and image viewing conditions. Regular sensitometry is part of the daily practice in only one hospital, while dedicated viewing boxes were used in two out of five hospitals. It was common finding that films and screens were not spectrally matched and that number of cassettes was not enough for full functionality of the mammography units. Frequently, the film processors were used for other purposes, while cleaning of cassettes and working surfaces in the darkroom is not regular. In many film artifacts were presented due to scratches on the screens.

The most of the physical parameters can be corrected by regular service maintenance and effective cooperation among all members of the team. Regular implementation of QC, in that sense, is essential. Still, some units included into the survey (E in Table 1) do not fulfil requirements either for clinical or...
for screening mammography due to technological obsolesce (manual exposure control, manual compression).

### 3.2 Patient Dose

The AGD to the standard breast ranged from 0.12 to 2.8 mGy. Except a single mammography unit, all results were below the reference level of 2.5 mGy [4].

### 3.3 Image Quality

The reference dose has to link to the image quality. However, in this study very high percentage of images with poor image quality was observed in all hospitals, ranging from 13% up to 70% for CC projection and from 8% to 66% for MLO projection (Table 2). The most frequent reasons of poor image quality for CC and MLO projections are presented in Table 3. It is worth mentioning that reject analysis initiated in three hospitals has resulted with reject rate of less than 2% which indicates high tolerance level of radiologist with respect to acceptable image quality.

Table 2. Results of image quality assessment the three hospitals for CC and MLO projections

<table>
<thead>
<tr>
<th>Projection</th>
<th>Grade (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC</td>
</tr>
<tr>
<td>Unit</td>
<td>A</td>
</tr>
<tr>
<td>M-A</td>
<td>29</td>
</tr>
<tr>
<td>M-B</td>
<td>87</td>
</tr>
<tr>
<td>M-C</td>
<td>62</td>
</tr>
</tbody>
</table>

Assessing image quality using three-level scale reflects the observer’s perception of an acceptable image. This method is useful for detecting different dose levels and for optimisation of mammography practice within the mammography unit with respect to real clinical task.

Subsequently assessed image quality data from evaluation of the TOR (MAS) test object images are shown in Figure 1 and Figure 2. The minimum detectable contrast for 0.25 mm and 0.5 mm diameter details ranged from 30 % to 8.3 %, and from 21 % to 3.9 %, respectively. The threshold contrast at 5.6 mm varied from 3.9 % to 0.7 %.

Table 3. Major causes for B or C graded images for CC and MLO projections in three hospitals

<table>
<thead>
<tr>
<th>Mammography unit</th>
<th>CC projection</th>
<th>MLO projection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M-A</td>
<td>M-B</td>
</tr>
<tr>
<td>Unexposed/overexposed</td>
<td>19</td>
<td>46</td>
</tr>
<tr>
<td>Artefacts</td>
<td>57</td>
<td>54</td>
</tr>
<tr>
<td>Breast positioning</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Reproduction of skin structure along the pectoral muscle</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>Reproduction of all vessels and fibrous strands and pectoral muscle margin</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MLO projection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unexposed/overexposed</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>Artefacts</td>
<td>58</td>
<td>75</td>
</tr>
<tr>
<td>Reproduction of cranio-latelar glandular tissue</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>
Analysis of the results using another method, i.e. images of TOR (MAS) test object showed a wide range in image quality. The variation could be explained in part by subjective nature of the test. This variation also reflects instability of the imaging system in early detection of the breast cancer.

**Figure 1.** Threshold contrast measurement results for 5.6 mm circular details

![Figure 1](image1.png)

**Figure 2.** Threshold contrast measurement results for 0.25 mm and 0.5 mm circular details

![Figure 2](image2.png)

**Figure 3.** Contrast index versus reference optical density

![Figure 3](image3.png)

The gross OD measured in reference point of the 45 mm Perspex block image ranged from 1.2 to 2.8, while reference value is 1.4-1.9 [4, 9]. Insufficient OD could result in suboptimal visualisation of the clinically relevant details. Thus, the image quality in mammography directly depends on OD and CI is an indicator of such dependence, as presented in Figure 3. High OD means also increased patient dose, so careful optimisation should be implemented. Insufficient OD is characteristics of the initial phase of...
the QC but in the later phase, when optimal OD is set, correlation between CI and dose is less pronounced [10].

The image quality quantification is based on subjective interpretation of visual data and does not have an analytical definition. There was a little evidence on the correlation between physical measurements of the image quality using test object and clinical performance criteria, mostly due to difficulties in image quality quantification. Test object are useful tool in assessment of mammography system performance and to compare different mammography systems in quantitative manner. However, overall success of mammography is based on the ability of the system to visualise small changes of contrast in soft tissue and to detect lesions, according to observer’s individual perception.

4. Conclusion

For pilot implementation of Quality Control (QC) protocol in mammography, hospitals with highest workload have been selected, representing the typical mammography practice in Serbia. Developed QC protocol, based on European guidelines for quality assurance in breast cancer screening and diagnosis [4], actual practice and resources, includes equipment testing and maintenance, staff training and QC management and allocation of responsibilities. Subsequently, it should be applied on the national scale. The survey demonstrated considerable variations in technical parameters that affect image quality and patients doses. Mean glandular doses ranged from 0.12 to 2.8 mGy, while reference optical density ranged from 1.2 to 2.8. Main problems were associated with film processing, viewing conditions and optical density control.

The preliminary survey of mammography practice highlighted the need for optimization of radiation protection and training of operating staff, although the survey itself was very valuable learning process for all participants. The presented results, demonstrating significant variations in image receptors, radiographic technique and equipment and processor performance were used for identification of existing problems and making recommendations for necessary actions. The feedback from hospitals after implementation of corrective actions will be reported subsequently. Furthermore, systematic implementation of QC protocol should provide reliable performance of mammography units, maintain satisfactory image quality and keep patient doses as low as reasonably practicable.

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