Implementation of the qualities of radiodiagnostic: mammography

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Abstract. The objective of the present study was to evaluate the expanded uncertainty of the mammographic calibration process and present the result of the internal audit performed at the Laboratory of Radiological Sciences (LCR). The qualities of the mammographic beams that are references in the LCR, comprises two irradiation conditions: no-attenuated beam and attenuated beam. Both had satisfactory results, with an expanded uncertainty equals 2.1%. The internal audit was performed, and the degree of accordance with the ISO/IEC 17025 was evaluated. The result of the internal audit was satisfactory. We conclude that LCR can perform calibrations on mammography qualities for end users.

1. Introduction
The Laboratory of Radiological Sciences (LCR), belonging the university of the state of Rio de Janeiro (UERJ), is already accredited to perform calibrations on area and individual monitors. With the objective of attending to society providing calibration services as a laboratory tracked to the National Laboratory of Metrology of Ionizing Radiations (LNMRI / IRD / CNEN), the LCR is increasing its scope of calibration and implementing the calibration service for the mammography qualities, in order to fill a gap that exists between ionizing radiation users and the Primary Standard Dosimetry Laboratory (PSDL) [1], in addition to providing metrology training of ionizing radiation, to improve calibration techniques and to keep its traceable standard to a primary laboratory with recalibration every 3 years [2, 3]. To do so, the LCR will be treated as a Secondary Standard Dosimetry Laboratory (SSDL).

It is desirable that the influence quantities of a SSDL have a relative standard uncertainty less than 0.1% [4]. The influence of the magnitudes relative to the user's detector is not considered here. The objective of the present study was to evaluate the expanded uncertainty in this scope increase and present the result of the internal audit performed.

2. Material and method
For the quality of radiation in no-attenuated and attenuated mammography beam, the Comet MXR-160/22 industrial tube with tungsten target and additional 0.060 mm nominal molybdenum filtration was used to obtain a similar energetic spectrum as a tube with Mo target and 0.030 mm Mo filtration [5], like those used in clinic.
For the mammographic qualities under attenuated condition, 2 mm of nominal Al are inserted, under conditions already obtained previously. Tables 1 and 2 shows the mammographic qualities that are references in LCR calibrations for end users. To calculate the relative uncertainty, we used equation (1), with 16 input quantities, discriminated in Table 3.

\[
\left( \frac{u_G}{G} \right)^2 = \sum_{i=1}^{16} \left( \frac{u_i}{M_i} \right)^2 \tag{1}
\]

where \(u_i\) is the standard uncertainty of the i-th quantity and \(M_i\) is the value of the i-th quantity of influence.

**Table 1. Mammographic qualities for non-attenuated condition (0.060 mm Mo)**

| Quality     | Voltage (kV) | HVL (mm Al) | Filtration (mm Mo) | HC |
|-------------|--------------|-------------|--------------------|----|
| W23_60Mo    | 23           | 0.3318      | 0.060              | 0.81 |
| W25_60Mo    | 25           | 0.3499      | 0.060              | 0.82 |
| W28_60Mo    | 28           | 0.3520      | 0.060              | 0.79 |
| W30_60Mo    | 30           | 0.3626      | 0.060              | 0.80 |
| W35_60Mo    | 35           | 0.3905      | 0.060              | 0.76 |

**Table 2. Mammographic qualities for attenuated condition (0.060 mm Mo + 2.0 mm Al)**

| Quality         | Voltage (kV) | HVL (mm Al) | Filtration (mm Mo) | HC |
|-----------------|--------------|-------------|--------------------|----|
| W23_60Mo_2Al    | 25           | 0.5246      | 0.060+2.00         | 0.93 |
| W25_60Mo_2Al    | 28           | 0.5780      | 0.060+2.00         | 0.90 |
| W28_60Mo_2Al    | 30           | 0.6359      | 0.060+2.00         | 0.89 |
| W30_60Mo_2Al    | 35           | 0.7133      | 0.060+2.00         | 0.87 |

If \(u_i(\%) = \left( \frac{u_i}{M_i} \right) \times 100\), we can replace in (1):

\[
\left( \frac{u_G}{G} \right) = \sqrt{\sum_{i=1}^{16} u_i(\%)^2} \tag{2}
\]

where \(u_G\) is the combined uncertainty concerning the ionization chamber reading unit, Coulomb (C), and \(G\) is the reference value of the charge. Doing \(u_r = \left( \frac{u_G}{G} \right)\) the relative combined standard uncertainty, we have:

\[
u_r = \sqrt{\sum_{i=1}^{16} u_i(\%)^2} \tag{3}
\]
To find the expanded uncertainty, with a confidence level of approximately 95% and a coverage factor equals to 2, simply multiply (3) by 2.

3. Results
Table 3 presents the results referring to the sources of uncertainties considered, as well as the expanded uncertainty.

Table 3. Considered influence quantities, relative combined standard uncertainty and expanded uncertainty, for a coverage factor k = 2, for the non-attenuated CMC.

| Condition: No-Attenuated / Attenuated | Relative combined uncertainty (%) | Expanded Uncertainty (%) |
|--------------------------------------|-----------------------------------|--------------------------|
| Input Quantity                       | Unity | Relative Uncertainty | 1.0%      | 2.1%      |
| Charge                               | nC    | 0.06%                |            |            |
| Temperature                          | °C    | 0.07%                |            |            |
| Pressure                             | kPa   | 0.00%                |            |            |
| Distance                             | nC    | 0.23%                |            |            |
| Time                                 | nC    | 0.14%                |            |            |
| Calibrated standard                  | nC    | 0.56%                |            |            |
| Electrometer resolution              | nC    | 0.00%                |            |            |
| Leakage                              | nC    | 0.05%                |            |            |
| Energy Dependence                    | nC    | 0.00%                |            |            |
| Loss by recombination                | nC    | 0.10%                |            |            |
| Positioning                          | nC    | 0.00%                |            |            |
| Homogeneity                          | nC    | 0.20%                |            |            |
| Spectral Difference                  | nC    | 0.00%                |            |            |
| Kerma Rate on Air                    | nC    | 0.13%                |            |            |
| Stability                            | nC    | 0.79%                |            |            |
| Polarity                             | nC    | 0.04%                |            |            |

3.1 Expanded uncertainty
Calibration and Measurement Capacity (CMC), defined as the smallest uncertainty that a laboratory can present within its scope of accreditation [6], is the smallest expanded uncertainty itself. In the LCR, the value was 2.1% for both no-attenuated condition and attenuated condition. Table 3 shows the relation of the influence quantities considered in the CMC calculation.

3.2 Increase of Scope
Considering the increasing demand for mammography examinations, it is necessary to trace the mammographic beam qualities practiced in the clinics, to focus on patient safety. Given the scientific importance of the LCR, an increase in scope was requested from the National Institute of Metrology, Quality and Technology (INMETRO) so that calibrations could be carried out.
3.3 Audit
The internal audit was carried out with the purpose of verifying the conformity of the operations referring to the request of the increase of scope with those required in ISO/IEC 17025, General Requirements for Testing and Calibration Laboratories Competence [7]. The no-conformities were corrected, thus allowing a CMC of 2.1% for both conditions.

4. Discussion
The uncertainty regarding the calibration of the LCR standard was obtained by dividing the value of the relative uncertainty given in the certificate issued by the secondary laboratory LNMRI, by the coverage factor 2, corresponding to a confidence level of approximately 95%.

With the addition of 0.060 mm Mo in a tungsten anode tube, we are simulating the X-ray spectrum of a conventional Mo-target mammograph and 0.030 mm Mo filtration. Since both laboratories used the same irradiation conditions, the uncertainty of the spectral difference is negligible. However, it will become significant when performing the calibration of the user’s detector, assigning the value of 0.46% in the uncertainty of the two spectra a [8].

The kerma rate in the air can be influenced by possible oscillations in the tube current as well as in the voltage. The uncertainty value associated with this oscillation was not considered to be 0.13%, following the literature [8].

For the calculation of the leakage current, measurements were made in the W28_60Mo quality, an electric charge accumulated in 1 minute. Thereafter, the tube was disconnected, and the charge variation within 5 minutes was evaluated. The uncertainty associated with the leakage current, given by the variation of such charge in time, was negligible.

The ion recombination loss in an ionization chamber is small, since its electric field is sufficient to collect almost all the charges released in the ionization process [8]. The value of this type B uncertainty was 0.03%.

The uncertainty associated with the focus-detector distance, which is 1000 mm, was 0.14%, as it was considered that it could vary by ± 5 mm. This value was considered because the measurement of the focus-detector distance was not performed with a laser but with a tape measure.

The positioning was analyzed by displacing the ionization chamber ± 2 mm perpendicular to the focus-detector axis, with no significant contribution, with an uncertainty of 0.00%.

The resolution of the electrometer had no influence on the result, being negligible. The same for energy dependence, because both LCR and LNMRI spectrum are same. The field size, or homogeneity of the field, has an assigned uncertainty of 0.20 %, where the anodic effect of the tube is the major contributor, since it has a 20 ° target angulation.

The stability of the system, i.e., its response over time, was evaluated in six months, and we obtained an uncertainty of 0.79%.

When the chamber polarity is changed of 300 V to -300V, the associated uncertainty is 0,04%.

5. Conclusion
As discussed above, we have concluded that the LCR is able to perform calibrations intended for users in the mammographic qualities presented in tables 1 and 2, since the expanded uncertainty, with a coverage factor equal to 2, is 2,1 %, which allows to deliver to the end user an uncertainty of less than 5%. [10].

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