Use of a Glass Dosimeter for Quality Control in Diagnostic X-ray

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INTRODUCTION

In recent years some approaches have been made to measure entrance surface doses in many hospitals in Japan. The method most generally used is Non Dosimeter Dosimetry Modify (NDD) that adopted Birch’s theory (1,2,3). NDD dose not require a dosimeter. However, in order to achieve accuracy of NDD, the outputs of an X-ray high voltage generator must be controlled strictly. Although a non-invasive type X-ray analyzer is becoming more and more popular as one appliance of measuring the outputs, this is very expensive. Thus there is no telling how popular the appliance will become in the future.

The simpler, more accurate and inexpensive method will be evaluated to control the outputs in every hospital.

In this paper, we would like to examine the availability of measuring the outputs of the high voltage generator in diagnostic X-ray by using a glass dosimeter (GD-403).

\[ D = \text{NDDM}(f) \times \text{mAs} \times (1/\text{FSD})^2 \]

- \( D \): entrance surface dose with NDD (mGy)
- \( \text{NDDM}(f) \): coefficient of tube voltage and total filtration
- \( \text{mAs} \): tube current time product
- \( \text{FSD} \): focus surface distance (m)

METHOD AND MATERIAL

In the first place, we examined the variation in measured values with twenty elements of GD-403. The absorbed dose in skin was calculated with the exposure dose and the effective energy by GD-403 was analyzed by Chiyoda Technol Corporation at Oarai laboratory. The irradiation conditions were as follows, 80kV(36.8keV), 400mA, 160ms, FSD=168cm. The ionization chamber dosimeter (chamber) was also irradiated at identical conditions.

In the second place, we examined the energy dependency of GD-403. The calibration by substitution with chamber was adopted. The calibrations were set 8 points within the energy range of 28 to 45keV in diagnostic X-ray (except mammography). The measured values were used for the mean values of five times irradiation with chamber, and two elements with GD-403. An exposure dose was about 100mR (2.58*10^-5C/kg). We examined at identical conditions in Fujita Health University and Nagoya University.

In the last, we compared the NDD results calibrated using an absorbed dose of GD-403 with the chamber results.

<table>
<thead>
<tr>
<th>Table 1. Material and apparatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author’s hospital</td>
</tr>
<tr>
<td>(A)</td>
</tr>
<tr>
<td>X-ray tube assembly</td>
</tr>
<tr>
<td>High voltage generator (type)</td>
</tr>
<tr>
<td>Total filtration (mmAl)</td>
</tr>
<tr>
<td>Ionization chamber</td>
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<tr>
<td>Glass dosimeter</td>
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</table>

RESULTS AND DISCUSSION

Table 2 shows unbiased values with twenty elements of GD-403. Coefficient variation (CV) of the
absorbed dose is 2.35%. Comparing GD-403 with the chamber for the same conditions, the effective energy of GD-403 increases to 115% of that in the chamber. However, the absorbed dose decreases by about 4%. The reason in this comparison is as follows. Calculation of the absorbed dose requires a conversion factor that is given by the effective energy. The conversion factor in skin varies little with the effective energy (4). Thus, that will be heavily influenced by the exposure dose.

<table>
<thead>
<tr>
<th>N=20</th>
<th>Exposure dose (10⁻⁴C/kg)</th>
<th>Effective energy (keV)</th>
<th>Absorbed dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>0.221</td>
<td>42.33</td>
<td>0.791</td>
</tr>
<tr>
<td>s</td>
<td>0.005</td>
<td>0.522</td>
<td>0.019</td>
</tr>
<tr>
<td>CV (%)</td>
<td>2.36</td>
<td>1.23</td>
<td>2.35</td>
</tr>
<tr>
<td>chamber</td>
<td>0.231</td>
<td>36.8</td>
<td>0.823</td>
</tr>
<tr>
<td>GD-403/chamber</td>
<td>0.958</td>
<td>1.15</td>
<td>0.961</td>
</tr>
</tbody>
</table>

In addition, a practical number of samples is derived from a statistical method. For example, the next expression is used in an attempt to limit a maximum error to 5% in a reliable range of 99% (5).

\[
N = \left( \frac{z ( \alpha /2) * s}{E} \right)^2 = \left( \frac{2.58 * 0.019 / 0.791 * 0.05}{0.05} \right)^2 = 1.54
\]

N: number of samples
E: maximum error

As a result, GD-403 will achieve the accuracy ±5% or less (p<0.01) in case of using two elements.

Figure 1 shows the energy dependency of GD-403. The GD-403 results agree well with the chamber results between 28 and about 35keV. Those decrease gradually above 35keV, drop below 90% above 40keV. It should be emphasized that this tendency can be seen in every place. Further it is reported that GD-403 agree well with a chamber in the energy range of mammography (6). Thus GD-403 has the capability of measuring an absorbed dose with higher reliability below 35keV.

![Energy Dependency of GD-403](image.png)

**Figure 1.** Energy dependency of GD-403 based on the chamber, as a function of effective energy given by HVL.

Based on the results, we calibrated NDD using an absorbed dose of GD-403 between 30 to 35keV in each place. First, estimated accuracy of original NDD is shown in Figure 2. Each maximum error is 12% in A, 20% in B, 45% in C. And place C is evidently difference from other in depending on the effective energy.
Figure 2. Estimated accuracy of original NDD, as a ratio is based on the chamber

Next, estimated accuracy of calibrated NDD is shown in Figure 3. Every distribution never changes the form and parallel shift to x-axis, because of only one calibration point in this examination. As a result, the estimated values of calibrated NDD agree almost with the chamber values about A and B that do not depend on the effective energy. Each maximum error decreases to 6.6% in A, 5.0% in B. Although, the estimated accuracy in C is improved near the calibration point, that falls as the effective energy increases from the point. The maximum error decreases to 31%.

Figure 3. Estimated accuracy of calibrated NDD by GD-403, as a ratio is based on the chamber each calibration point is 32.7keV in A, 31.8keV in B and C

Averages of the eight estimated errors based on the chamber are shown in Table 3, in order that the availability of calibration by GD-403 is evaluated overall.

Table 3. Averages of the eight estimated errors based on the chamber, comparing the accuracy of original NDD and calibrated NDD by GD-403 (%)

<table>
<thead>
<tr>
<th></th>
<th>N=8</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>original</td>
<td>7.56</td>
<td>17.8</td>
<td>24.0</td>
<td></td>
</tr>
<tr>
<td>calibrated</td>
<td>3.40</td>
<td>2.91</td>
<td>15.3</td>
<td></td>
</tr>
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</table>

The average clearly decreases after calibration by GD-403 in every place. Particularly the average decreases to about 3% in A and B. Thus it would seem that the estimated accuracy of calibrated NDD by GD-403 should be identical to the reproducible accuracy of a chamber.

However, the average keeps on the 15% after calibration in C. The estimated errors in C are attributed to
the energy dependency. Further, the energy dependency can be attributed to two causes as follows. In this examine, C differs from A and B in the rectification type of high voltage generator. Thus, it could be suggested in NDD that the estimated errors of three-phase type are larger than those of inverter type in the range of higher energy. The other point is that the calibration factor of the chamber in C may have a problem, because eight years elapses after last calibration.

CONCLUSION

In this paper, we examined the availability of measuring the outputs of the high voltage generator in diagnostic X-ray by GD-403. Accordingly, GD-403 will achieve the accuracy $\pm 5\%$ or less (p<0.01) in case of using two elements. GD-403 agrees well with the chamber below 35keV. It was found that GD-403 has the ability of measuring the outputs of the high voltage generator in diagnostic X-ray below 35keV.

The estimated accuracy of calibrated NDD by GD-403 is improved clearly in every place. Particularly that of inverter type could be identical to the reproducible accuracy of a chamber.

If they have ordered GD-403 similarly to a personal dosimeter, they could measure the outputs of the high voltage generator in diagnostic X-ray without an original dosimeter. Further, high accurate entrance surfaced doses could be derived, if NDD is calibrated by the result of GD-403.

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