Dose evaluation in clinical study of contrast-enhanced spectral mammography (CESM) for Japanese women

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Authors: M. Watanabe¹, M. Mizutani¹, M. Mori¹, Y. Suwabe¹, M. Ohkubo¹, M. Tsuzaka²; ¹Anjo/JP, ²Nagoya/JP
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Purpose

Contrast-enhanced spectral mammography (CESM) will be a splendid new technology to realize a breakthrough for a breast imaging. Clinical results of CESM have been reported (1-2). At Mikawa Breast Cancer Clinic we introduced CESM in January 2011.

As for the dose of CESM Dromain et al. reported that average glandular dose (AGD) in CESM is 1.2 times higher than that in the standard mammography (MMG)(1-2). How about Japanese Women? The clinical data of Asian breast has not been shown.

The purpose of this study is to evaluate dose in the clinical data of Japanese breast by using the AGD.

Methods and Materials

Patients:

From January to July 2011, 72 Japanese women underwent CESM. A mean age was 49.8 (range 27-87). The Clinical study was approved by Institutional Review Board. Informed consent was obtained after fully explanation.

CESM examination:

CESM examinations were performed with the digital mammography system Senographe DS Laverite (SenoBright) that can acquire dual-energy images (GE Healthcare). Dual energy exposures were taken in 2min after the injection of 1.5ml/kg of an iodinated contrast agent (Omnipaque 350, Daiichi-Sankyo Japan). We used a power injector (Nemoto Kyorindo, Japan) at a rate of 3ml/s. One view had a pair of low- (26-32kVp) and high-energy (45-49kVp) exposures. Exposure mode in CESM was selected "CESM AUTO", the automatic exposure control mode developed for SenoBright. The parameters including the order and timing of CESM is shown in Figure 1. Combined images with contrast agent uptake information were processed after image acquisitions. A series of low-energy and combined images in the clinical study is shown in Figure 2.

Dose evaluation:

We investigated the AGD displayed (displayed AGD) on the screen of Senographe DS Laverite (GE Health care). Before that we checked the accuracy of displayed AGD
compared with the reference AGD measured by ACR method (for low energy)(3) and Boone’s method (for high energy)(4).

The reference AGD for low-energy was calculated using DgN selected by kVp-HVL combination. The ionization chamber (Radcal 10×5-6M 9015 electrometer, Radcal Corp) and RMI 156 phantom were used for the measurement. Aluminum plates (07-434, Victoreen) was used for HVL measurement. ACR methods (3,5,6) were used for the calculation of displayed AGD in the images on the screen of Senographe DS Laverite. Atmosphere correction was all done for measured values.

The reference AGD for high-energy was calculated using Boone’s method (4). We transferred measured HVL to Eeff by using tables of X-Ray Mass Attenuation Coefficients by J. H. Hubbell et al (7,8). And we calculated AGD using DgN by the equation(4). The experimental values are shown in Table 1.

<table>
<thead>
<tr>
<th>Target/Filter</th>
<th>kVp (kV)</th>
<th>mAs (mAs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo/Rh</td>
<td>26</td>
<td>50</td>
</tr>
<tr>
<td>Rh/Rh</td>
<td>29</td>
<td>40</td>
</tr>
<tr>
<td>Rh/Rh</td>
<td>32</td>
<td>63</td>
</tr>
<tr>
<td>Mo/Cu</td>
<td>46</td>
<td>125</td>
</tr>
<tr>
<td>Rh/Cu</td>
<td>48</td>
<td>140</td>
</tr>
</tbody>
</table>

Table 1. Experimental values in checking accuracy of the displayed AGD compared with the reference AGD

The displayed AGD in CESM was compared with that in the standard MMG by the automatic exposure control modes (Automatic Optimization of Parameters: AOP) selected in the standard MMG. Three modes (STD: standard mode, CNT: contrast mode and Manual: manual mode) were used. CNT was used for thin breast (< 2cm). Manual was used for thick breast (> 5cm) because those images have much noise in diagnosing for Japanese breast. The parameters (low- and high- exposure’s kVp, mAs, exposure time after injection, the combination of target and filter, compressed breast thickness, compressed pressure and the displayed AGD) were recorded and analyzed. The usage of clinical images and information was approved by the Institutional Review Board of Nagoya University Health Science (No.10-321).

Images for this section:
Fig. 1: Parameters of CESM examination in this study We started the compression and exposures of the right Medio-Lateral Oblique (MLO) view when a patient had unresolved findings with MMG or US of the right breast. And the right Cranio-Caudal (CC) view, the left CC view, the left MLO view and the right MLO view are following.
Fig. 2: The low-energy and combined images from a case of this study (a 79 year-old patient with palpable mass on the left breast). Upper images are low-energy images and lower images are combined images. In the left MLO and CC images highlight lesion can be founded and its lesion proved to be invasive ductal carcinoma by biopsy.
Results

Figure 3 shows the accuracy of the displayed AGD. The differences between the displayed AGD and the reference AGD were within 5%.

![Graph showing AGD measurements](image)

**Fig. 3:** The displayed AGD and the reference AGD measured.

**References:** Mikawa Breast Cancer Clinic - Anjo/JP 2013

The total AGD delivered to the patient for a pair of low- and high-energy images was between 0.95 and 4.20 mGy (see Table 2).

<table>
<thead>
<tr>
<th>AGD CESM (mGy)</th>
<th>AGD CESM (mGy)</th>
<th>AGD CESM (mGy)</th>
<th>AGD CESM (mGy)</th>
<th>Range of AGD in CESM/MMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo/Rh 26kV 50mA</td>
<td>1.92</td>
<td>1.33</td>
<td>1.50</td>
<td>0.48</td>
</tr>
<tr>
<td>Rh/Rh 29kV 40mA</td>
<td>1.50</td>
<td>1.33</td>
<td>1.50</td>
<td>0.48</td>
</tr>
<tr>
<td>Rh/Rh 32kV 63mA</td>
<td>1.50</td>
<td>1.33</td>
<td>1.50</td>
<td>0.48</td>
</tr>
<tr>
<td>Mo/Cu 46kV 125mA</td>
<td>1.50</td>
<td>1.33</td>
<td>1.50</td>
<td>0.48</td>
</tr>
<tr>
<td>Rh/Cu 48kV 140mA</td>
<td>1.50</td>
<td>1.33</td>
<td>1.50</td>
<td>0.48</td>
</tr>
</tbody>
</table>
Table 2. Average displayed AGD of 72 cases

The range of compressed breast thickness was 18mm-86mm. The average compressed breast thickness was 45mm. The compressed breast thickness in the standard MMG was approximately equal to that in CESM. The mean AGD of all 72 cases was 1.92 mGy. Figure 4 shows the average displayed AGD of each AOP mode and total 72 cases.

Fig. 4: The average displayed AGD of 72 cases.

References: Mikawa Breast Cancer Clinic - Anjo/JP 2013

This AGD corresponds to about 1.4 times the AGD delivered for the standard MMG.
Figure 5 shows the displayed AGD depending on breast thickness.

**Fig. 5:** Comparison between the displayed AGD in the standard MMG and that in CESM. The solid line is the displayed AGD for one CESM view, and the dotted line is for one standard MMG view.

**References:** Mikawa Breast Cancer Clinic - Anjo/JP 2013

**Images for this section:**
Fig. 3: The displayed AGD and the reference AGD measured.
Fig. 4: The average displayed AGD of 72 cases.

![Graph showing AGD vs breast thickness]

Fig. 5: Comparison between the displayed AGD in the standard MMG and that in CESM. The solid line is the displayed AGD for one CESM view, and the dotted line is for one standard MMG view.
Conclusion

The differences between displayed AGD and reference AGD were within 5%. The accuracy of the displayed AGD was good. But there are the following points to consider.

1. There was the case that the displayed AGD estimated lower than the reference AGD measured.
2. The ways to calculate both the displayed AGD and the reference AGD are almost same using the coefficient by Monte Carlo simulation (4-6). And they are just simulations.

In this study we evaluated the dose by using the displayed AGD. The displayed AGD for one low-energy exposure (nearly equal to the standard MMG) was set as 1-1.2. It led the displayed AGD for one high energy exposure to be 0.2-0.4. The displayed AGD in CESM was about 1.4 times than that in the standard MMG.

The mean dose delivered to a patient in CESM was within 3mGy (See Figure 4). The AGD of compressed breast thickness of 45mm in this CESM study was 1.87mGy and also within 3mGy (See Figure 5). According to guideline made by Japanese society of radiological technology, the AGD of compressed breast thickness of 42mm at the 50%/50% mammary structure is less than 3mGy (hopeful less than 2mGy) per one view in the standard MMG. It was from the American College of Radiology. Dose delivered to a patient in CESM is acceptable.

Dromain et al. (1-2) reported that the dose in CESM was 1.2 times than that in the standard MMG. In our study it was about 1.4 times than that in the standard MMG. Because it depends on countries and facilities how to operate AOP mode taking the standard MMG, values are different on the comparison with the standard MMG. In some cases of our study the AGD in CESM was nearly equal to that in the standard MMG when Contrast mode was selected.

In this study there were only 72 cases to analyze. We need more cases for a detailed analysis of dose evaluation. CESM is still developing technology. We need further research of other parameters related to dose. Other parameters are shown in Figure 6.

The AGD in the clinical study of CESM corresponds to about 1.4 times the AGD delivered for the standard MMG. This result shows that CESM is acceptable concerning about the
dose. We make sure the effectiveness of CESM and will expand the clinical and basic research furthermore.

Images for this section:

Fig. 4: The average displayed AGD of 72 cases.
**Fig. 5:** Comparison between the displayed AGD in the standard MMG and that in CESM. The solid line is the displayed AGD for one CESM view, and the dotted line is for one standard MMG view.
Fig. 6: Parameters which need further research of CESM study

- **Iodinated Contrast Agent**
  - Omnipaque 350
  - Volume/kg 1.5ml/kg
  - Flow Rate 3ml/s

- **Compressed Pressure**
  - Equal to the standard MMG?

- **Exposure**
  - CESM AUTO?
  - Dose optimization by the image quality

- **Menstruation cycle**
  - Relationship between M cycle and signals
References


   http://www.nist.gov/pml/data/xraycoef/index.cfm


Personal Information

Megumi Watanabe, Radiographer at Mikawa Breast Cancer Clinic, Anjo, Japan and Department of Radiological technology Nagoya University, Nagoya, Japan ; watanabe.megumi@h.mbox.nagoya-u.ac.jp