Radiation Exposure to Patient’s Skin During Percutaneous Coronary Intervention for Various Lesions, Including Chronic Total Occlusion

Shigeru Suzuki, MD; Shigeru Furui, MD; Hiroshi Kohtake, MD; Naoyuki Yokoyama, MD*; Ken Kozuma, MD*; Yoshito Yamamoto, MD*; Takaaki Isshiki, MD*

Background Radiation skin injuries have been reported as a result of various procedures, so in the present study the patients’ entrance skin dose (ESD) during percutaneous coronary intervention (PCI) was evaluated.

Methods and Results ESDs were assessed during 97 procedures (13 for chronic total occlusion (CTO), 14 for multivessel stenoses, 22 for single-vessel multiple stenoses, and 48 for single stenosis). The patients wore jackets that had 48 or 52 radiosensitive indicators placed on the back during the PCI procedures, with 8 other indicators placed on both upper arms. After the procedure, the color of the indicators was analyzed with a color measuring instrument, and the patients’ ESDs were calculated from the color difference of the indicators. The average maximum ESDs of the patients were 4.5±2.8 Gy (median: 4.6 Gy) for CTO, 2.3±0.7 Gy (median: 2.4 Gy) for multivessel stenoses, 1.8±1.0 Gy (median: 1.5 Gy) for single-vessel multiple stenoses, and 1.4±0.9 Gy (median: 1.2 Gy) for single stenosis.

Conclusions Skin injury can occur during PCI, especially for CTO, so it is important to estimate each patient’s ESD and attempt to reduce it. (Circ J 2006; 70: 44–48)

Key Words: Angiography; Angioplasty; Catheterization; Dosage

As a result of the increasing number of percutaneous coronary interventions (PCI), radiation skin injuries are being reported more frequently.1–5 Of the procedures, PCI for chronic total occlusion (CTO) is a major challenge6–15 because examination time tends to be long, and the rate of repeat PCI is relatively high.6 However, to our knowledge, the patient’s entrance skin dose (ESD) for PCI has not been assessed in the literature and this became the purpose of the present research.

Methods

Ninety-seven patients (22 women, 75 men; mean age, 70.3±8.7 years (range: 47.8–85.0)) underwent PCI procedures from July 2004 to April 2005. Of these, 13 procedures were for CTO, 14 procedures were for multiple target lesions in multiple vessels (multivessel stenoses), 22 procedures were for multiple target lesions in 1 vessel (single-vessel multiple stenoses), and the remaining 48 procedures were for single target lesion in 1 vessel (single-stenosis).

AdvantX LC (single-plane) and AdvantX LC/LP (biplane; both from General Electric Medical Systems, Milwaukee, WI, USA) were the angiographic systems used, although AdvantX LC/LP was used as a single-plane system during the procedures in the present study. The image intensifiers of both units were renewed in April 2004. Each unit consists of an undercouch tube and an overcouch image intensifier with 3 fields of view (9, 6 and 4.5 inch in diameter) and we selected the 6-inch field of view. In both units, the total filtration is equivalent to 2.7-mm aluminum. Fluoroscopy was performed in pulse mode. The period of use was 9 years for both units.

Each patient wore a jacket with 48 radiosensitive indicators (Nichiyu Giken Kogyo Co, Ltd, Saitama, Japan) placed on the back (Fig 1a). The radiosensitive indicators have a functional dyestuff that changes color from pellucid to red with X-ray absorption (Fig 1b). They were arranged in 6 rows (from top to bottom: 1, 2, 3, 4, 5, and 6) and 8 columns (from left to right: A, B, C, D, E, F, G, and H) at intervals of 7 cm. In 89 patients, an additional 4 indicators were placed in the 7th row (C7, D7, E7, and F7) and all patients had another 8 indicators placed on the acromion, olecranon, and 2 points trisecting the upper arm (from proximal to distal: 1, 2, 3, and 4) on both arms (left: L, right: R). Procedures were performed by 7 experienced cardiologists, using standard techniques. The study was approved by the institutional review board and all patients gave informed consent.

After the procedure, the color of the indicators was analyzed with a color measuring instrument (Chroma Meters CR-300; Konika Minolta Holdings, Inc, Tokyo, Japan), and the doses were calculated from the color difference of the indicators (Fig 1c,d). The most widely used system to express the color of objects is color space, based on the L*a*b* model, which was standardized by the Commission Internationale d’Eclairage in 1976.16 Color difference in this color space is defined as the distance between the color locations. We determined the absorbed dose by a validation study17 in which we used AdvantX UNV (General Electric Medical Systems) as the angiography equipment (80 kVp tube voltage, 400 mA tube current,
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We irradiated indicators on the lower surface of Tough Water Phantom WE type (Kyoto Kagaku Co, Ltd, Kyoto, Japan) with 20.0-cm thickness, and the doses were calibrated with an ionization chamber (Radcal Model 9010; Radcal Co, Monrovia, CA, USA). With this indicator, the response was almost linear with the natural logarithm of the dose within 10 Gy. The regression equation was \( D = \exp(DE^* \times 0.0537 – 1.6894) \), where \( D \) was the absorbed dose (Gy) and \( DE^* \) was the color difference of the indicator.

In the present study, we evaluated the ESDs of all 56 or 60 points, as well as the maximum ESD and its location. The height, weight, and body mass index of the patients, total fluoroscopic exposure time, total number of cine frames, and the maximal ESDs were compared between the 4 procedure groups (PCI for single-stenosis, single-vessel multiple stenoses, multivessel stenoses, and CTO). The Kruskal-Wallis H test was used for statistical analysis. Dunn tests were used as the post tests following the H test. \( P<0.05 \) was considered to represent a statistically significant result.

We analyzed the relationships between the total fluoroscopic time and maximal ESD, and the total number of cine frames and maximal ESD by means of the Pearson correlation coefficient \( (r^2) \).

Results

For 97 procedures, the total fluoroscopic time was 21.3±13.6 min and the total number of cine frames was 2,564±1,518 (Table 1). The average maximum ESD of each patient was 2.0±1.6 Gy. The maximum ESD exceeded 1 Gy in 75 procedures, 3 Gy in 16 procedures, and 5 Gy in 6 procedures (Fig 2).

In 48 procedures for single-stenosis (39 stenting, 5 cutting, and 3 plain old balloon angioplasty), the average total fluoroscopic time was 14.6±8.0 min and the average total number of cine frames was 1,851±594. The average maximum ESD of each patient was 1.4±0.9 Gy (median, 1.2 Gy).

In 22 procedures for single-vessel multiple stenoses (21 stenting and 1 cutting), the average total fluoroscopic time was 20.8±10.4 min and the average total number of cine frames was 2,512±1,137. The average maximum ESD of each patient was 1.8±1.0 Gy (median, 1.5 Gy).
In 14 procedures for multivessel stenoses (13 stenting and 1 cutting), the average total fluoroscopic time was 25.1±8.0 min and the average total number of cine frames was 3,050±804. The average maximum ESD of each patient was 2.3±0.7 Gy (median, 2.4 Gy).

In 13 procedures for CTO (8 stenting, 1 rotational atherectomy, and 4 failures), the average total fluoroscopic time was 42.6±17.0 min and the average total number of cine frames was 4,763±2,558. The average maximum ESD of the patients was 4.5±2.8 Gy (median, 4.6 Gy).

To evaluate the inter-procedure distribution of the ESDs in the 97 procedures, we summarized the point with the maximal ESD in each procedure (Fig 3) and found that maximal ESD was distributed among 33 points.

There were no significant differences in the height, weight, or body mass index of the patients in the 4 groups of PCI procedures (Table 1), but there were significant differences in total fluoroscopic exposure time, total number of digital subtraction angiography frames, and the maximum ESD (p<0.0001) in H tests.

There were significant correlations between the total fluoroscopic time and maximal ESD (r^2=0.738, p<0.0001) (Fig 4), and the total number of cine frames and maximal ESD (r^2=0.487, p<0.0001) (Fig 5).

**Discussion**

Radiation skin injuries have increased with the increased use of PCI. Early transient erythema, permanent epilation, and delayed dermal necrosis can occur at 2 Gy, 7 Gy, and 12 Gy, respectively.18,19 The International Commission on Radiological Protection (ICRP) recommended recording the maximum skin dose and its location when the maximum cumulative skin dose is thought to be 3 Gy or more (1 Gy or

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**Table 1 Comparison of Percutaneous Coronary Intervention Procedures**

<table>
<thead>
<tr>
<th>Lesions</th>
<th>Single-stenosis</th>
<th>Single-vessel multiple stenoses</th>
<th>Multivessel stenoses</th>
<th>CTO</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>69.0±9.1</td>
<td>72.1±9.1</td>
<td>70.6±7.1</td>
<td>71.6±8.3</td>
<td>70.3±8.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161.0±6.6</td>
<td>158.0±8.9</td>
<td>156.5±12.2</td>
<td>155.1±8.7</td>
<td>158.9±8.5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.9±8.4</td>
<td>56.9±10.1</td>
<td>56.5±7.9</td>
<td>54.3±7.8</td>
<td>58.5±8.9</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.5±3.0</td>
<td>22.7±2.8</td>
<td>23.2±3.4</td>
<td>22.6±2.8</td>
<td>23.2±3.0</td>
</tr>
<tr>
<td>Total fluoroscopic time (min)</td>
<td>14.6±8.0</td>
<td>20.8±10.4</td>
<td>25.1±18.0</td>
<td>42.6±17.0</td>
<td>21.3±13.6</td>
</tr>
<tr>
<td>Total no. of cine frames</td>
<td>1,851±594</td>
<td>2,512±1,137</td>
<td>3,050±804</td>
<td>4,763±2,558</td>
<td>2,564±1,518</td>
</tr>
<tr>
<td>Maximum entrance skin dose of the patient (Gy)</td>
<td>1.4±0.9</td>
<td>1.8±1.0</td>
<td>2.3±0.7</td>
<td>4.5±2.8</td>
<td>2.0±1.6</td>
</tr>
</tbody>
</table>

Bars indicate the significant difference in Dunn tests.

CTO, chronic total occlusion.
more in repeated cases). Furthermore, when the presumed skin dose is 3 Gy or more, the ICRP recommends that a medical examination should be performed 10–14 days after the procedure in order to check for any effects on the skin. In addition, patients should be informed about radiation injury before they give their consent for a procedure with possible high-radiation dose exposure.

In the present study, the average maximal ESD during procedures for single-stenosis was 1.4±0.9 Gy, which agrees with the findings of Hwang et al who reported that the mean skin dose of 25 single-stent cases was 1,529±601 mGy. Of the present 97 PCI procedures, the maximal ESDs exceeded 1 Gy and 3 Gy in 75 and 16 procedures, respectively. The exposure dose is affected by the type of angiographic unit, the mode of operation for fluoroscopy and image acquisition, and the protocols used for the PCI procedures. Therefore, the present results cannot be applied to PCI procedures performed at other institutions, but serve as a reminder that it is important to know the dose rate of fluoroscopy, the dose per cine frame, and the patients’ skin dose during standard operating procedures.

The average total fluoroscopic time, average total number of cine frames and average ESD during the procedure for CTO were approximately 3-fold greater than those during the procedure for single-stenosis. Furthermore, the maximum ESDs during the procedure for CTO exceeded 5 Gy in 6 of the 13 procedures. Therefore, it is essential to evaluate the patients’ skin dose and make efforts to prevent radiation skin injuries during PCI for CTO. According to Ge et al, the initial success rate of procedures for CTO is 83.9%, but in the present study 4 of 13 procedures for CTO failed and so the repeat procedure for the same lesion is not uncommon. In addition, the restenosis rate is not low, reportedly 9.2% and 33.3% for sirolimus-eluting stent and bare metal stent, respectively. According to Buller et al, the rates of percutaneous revascularization for the target vessel and any vessels during 6-month follow-up after stenting for CTO were 6.9% and 12.4%, respectively. Therefore, reduction of the cumulative dose in the same area of skin during repeat procedures is important in PCI...
for CTO, in addition to reducing the patient’s skin dose during each procedure.

Ionizing chambers are widely used to assess the radiation exposure21–22 and most of the more recent angiographic systems have built-in ionizing chambers. However, the dose–area product does not give the patient’s skin exposure, because it does not take into account skin exposure site and scattered radiation. In PCI, the X-ray beam can enter the patient from many directions, and it is not easy to evaluate the distribution of the patient’s skin dose. In contrast, our method with multiple indicators at 7-cm intervals can show both the patient’s skin dose and its distribution,17 which will help reduce the cumulative dose in the same area during repeat procedures. Before the cumulative skin dose approaches the threshold of severe radiation injuries, it can be reduced by marking that area of skin with a radiopaque material and excluding the marker from the irradiation field.

Conclusion

Skin injury can be induced in PCI, especially for CTO, and it is important to estimate the patient’s ESD and make efforts to reduce it.

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References