Radiation dose to the interventional radiology staff, especially nurses

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Learning objectives

• To show the current occupational radiation dose to interventional radiology (IR) staff (physicians, nurses, and technologists).

• To understand the importance of radiation protection for IR staff.

• To demonstrate the need for using two badges to accurately evaluate the occupational dose in IR staff in both physicians and non-physicians.
Background

- Studies of the occupational radiation dose in IR have focused mainly on the physician. There are limited data on the exposure of other medical staff, such as nurses and radiology technologists (RTs).

- IR staff are at high risk of radiation-induced eye injury and should consider eye protection to avoid cataracts.

- Today, we consider the threshold for radiation-induced cataract development to be lower than was previously estimated. The 2011 statement of the ICRP recommended an equivalent dose limit for the lens of the eye of 20 mSv per year, averaged over defined periods of 5 years, for occupational exposure.
Methods

In Sendai-Kosei Hospital (Sendai city, Japan), the occupational radiation exposure of 18 IR physicians, seven IR nurses, and eight IR RTs during cardiac catheterization, including percutaneous coronary intervention (PCI), was evaluated. 

We used a combination of two additional commercial lead shielding devices: table side drapes (0.5-mm lead-equivalent) and lead acrylic shields suspended from the ceiling (0.8-mm lead-equivalent).

The IR staff (physicians, nurses, and RTs) wear a protective apron (usually 0.35-mm Pb-equivalent) during the procedures.

Evaluation among occupational doses

The occupational radiation exposure (effective dose (EfD) and dose equivalent (DEq)) of the IR staff during cardiac catheterization, including PCI, was determined using a silver-activated phosphate glass dosimeter (Glass Badge, Chiyoda-Technol, Japan). Two glass badges were worn: one under the personal lead apron (0.35-mm lead equivalent) at the chest or waist and one outside the personal lead apron at the neck. With the two-badge method, the EfD and DEq were determined following the method recommended by the Radiation Council of the Ministry of Education, Culture, Sports, Science, and Technology of Japan (Japanese regulations) as follows:

\[ EfD = 0.89D_{c,1.0} + 0.11D_{n,1.0} \]
\[ DEq = 1.00D_{n,0.07} , \]

where \( D_{c,1.0} \) is the chest or waist badge dose (1-cm dose equivalent, under the lead apron), \( D_{n,1.0} \) is the neck badge dose (1-cm dose equivalent, outside the lead apron), and \( D_{n,0.07} \) is the neck badge dose (70-µm dose equivalent, outside the lead apron).

Comparison of the one- and two-badge methods

We also compared the occupational radiation exposure (EfD, DEq) of the IR staff using the two-badge method (outside and under the lead apron) with that using the one-badge method (under the lead apron only) in the same individuals, i.e., we compared the occupational radiation obtained two glass badges and that obtained using a single glass badge (under the lead apron).
In the one-badge method, the EfD and DEq were also determined following the method recommended by the Japanese regulations, as follows:

$$\text{EfD} = 1.00D_{c_{1.0}}$$ and $$\text{DEq} = 1.00D_{c_{0.07}},$$

where $$D_{c_{0.07}}$$ is the chest or waist badge dose (70-µm dose equivalent, under the lead apron).

**Statistics**

Fisher’s post-hoc test was used to compare the data for the three groups (occupational dose of physicians, nurses, and RTs). Student's t-test was used to compare the data for the two groups (occupational dose using the one- and two-badge methods). Statistical significance was defined as $$p < 0.05.$$

**Results**

The annual mean ± SD EfD (range) dose to the physicians, nurses, and RTs using two badges was 3.00 ± 1.50 (0.84-6.17), 1.34 ± 0.55 (0.70-2.20), and 0.60 ± 0.48 (0.02-1.43) mSv/year, respectively (Physicians vs. Nurses, $$p<0.01$$; Physicians vs. RTs, $$p<0.001$$; and Nurses vs. RTs, $$p=0.231$$).

Similarly, the annual mean ± SD DEq was 19.8 ± 12.5 (7.0-48.5), 4.73 ± 0.72 (3.9-6.2), and 1.30 ± 1.00 (0.2-2.7) mSv/year, respectively (Physicians vs. Nurses, $$p<0.01$$; Physicians vs. RTs, $$p<0.001$$; and Nurses vs. RTs, $$p=0.486$$).

Thus, both the EfD and DEq occupational doses were in the order physicians > nurses > RTs.

**Fig. 2** on page 8  **Fig. 3** on page 9

**Tables 1 and 2** show the mean ± SD EfD and DEq for the physicians, nurses, and RTs obtained using the one- and two-badge methods. The mean ± SD EfD for the physicians was 1.02 ± 0.74 and 3.0 ± 1.5 mSv/year for the one- and two-badge methods, respectively ($$p<0.001$$).

Similarly, the mean ± SD EfD for the nurses ($$p=0.186$$) and RTs ($$p=0.726$$) tended to be lower using the one-badge method. The mean ± SD DEq for the physicians was 1.00 ± 0.72 and 19.8 ± 12.5 mSv/year with one and two badges, respectively ($$p<0.001$$). Similarly, the mean ± SD DEq for the non-physicians, especially nurses ($$p<0.001$$), was significantly lower using one badge.
<table>
<thead>
<tr>
<th>TABLE 1</th>
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<tbody>
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<td>Physicians</td>
<td>3.00 ± 1.50 (mSv/y)</td>
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<td>Nurses</td>
<td>1.34 ± 0.55</td>
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Table 1. Annual effective dose (EfD, mSv/y) for IR staff in the cardiac laboratory comparing the one- and two-badge methods.

<table>
<thead>
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<tr>
<td>Physicians</td>
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Table 2. Annual dose equivalent (DEq, mSv/y) for the IR staff in the cardiac laboratory comparing the one- and two-badge methods.

Discussion

As is the case with IR physicians, the evaluation of occupational dose to IR nurses is important because many IR nurses are close to the source of scatter radiation (such as the patient). Nevertheless, no detailed report has described the annual occupational dose for IR nurses. Therefore, we compared the annual occupational dose obtained using the two-badge method among IR staff.

Our hospital performs many cardiac catheterizations, including PCI. Nevertheless, the annual occupational dose (EfD and DEq) to all of the IR staff (physicians, nurses, and RTs) was much lower than the maximum allowable radiation limits for radiation workers. One probable reason for this is that appropriate radiation safety education for the IR staff helps optimize radiation protection during the procedures. In other words, radiation safety/protection education/training for non-physicians (nurses and RTs) is very important.

Currently, two monitoring badges are used to evaluate the IR physician dose in most cardiac laboratories. Nevertheless, most other IR staff (i.e., non-physicians) wear a single badge under the apron. In this study, the annual occupational doses were measured using two monitoring badges in physicians and non-physicians (nurses and RTs).
The annual occupational dose (EfD and DEq) to IR nurses was significantly lower than that to IR physicians but tended to be higher than that to RTs, although the difference was not significant because in many cases, most RTs stand farther from the patient during procedures. Hence, an accurate evaluation of the occupational doses of non-physicians, especially nurses, is necessary.

We found that using only a one badge (under the apron) in non-physicians during procedures underestimates both the EfD and DEq. As the dose to all non-physicians is not uniform, the two-badge method should be used to evaluate the occupational dose during IR procedures accurately, not only in physicians but also in other IR staff.
Fig. 1: A digital cine single-plane angiography unit with an under-table x-ray tube system was used (Infinix Celeve-i INFX-8000V, TOSHIBA). Digital cine acquisition was performed at 15 frames/s for the procedures. Pulsed fluoroscopy (7.5 pulses/s) and a 20-cm mode flat-panel detector with an anti-scatter grid were also used.

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**Table 1.** Annual effective dose for IR staff in the cardiac laboratory comparing the one- and two-badge methods.

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**Fig. 2:** Table 1. Annual effective dose (EfD, mSv/y) for IR staff in the cardiac laboratory comparing the one- and two-badge methods.

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Table 2. Annual dose equivalent for the IR staff in the cardiac laboratory comparing the one- and two-badge methods.

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**Fig. 3**: Table 2. Annual dose equivalent (DEq, mSv/y) for the IR staff in the cardiac laboratory comparing the one- and two-badge methods.

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Conclusion

- Radiation protection and dose evaluation are important for IR staff.

- IR nurses are not exposed to significant levels of radiation that could pose a health hazard using appropriate portable shielding and positioning.

- Although IR nurses generally have lower exposure levels than IR physicians do, the annual dose to nurses is the highest among non-IR-physicians.

- The occupational dose determined using one badge under the apron was far lower than the dose obtained with two badges in both physicians and non-physicians.

- We recommended that two monitoring badges be used to evaluate IR nurses as well as IR physicians.
References

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