Radiological Protection of Patient and Operator in Interventional Radiology

Hironobu NAKAMURA

Professor and Chairman, Department of Radiology,
Osaka University Graduate School of Medicine

Abstract: Although marked progress has been made in interventional radiology (IVR), radiation exposure is on the increase among both patients and operators. The number of IVR cases is also increasing yearly and the exposure time has become prolonged due to recent sophisticated and complex techniques. Recent reports cite increasing dermatological disorders in patients after PTCA and stenting. No limits have yet been placed on patients’ exposure, but doses must be reduced to minimum necessary levels by enhancing protective efforts. Operators’ exposure levels depend on whether the fluoroscopy device employed is of the under-tube type or the over-tube. When an under-tube type is used and the operator always wears a protective garment during the procedure, exposure is expected to remain below the annual effective dose limit. On the other hand, operators working with an over-tube fluoroscopy are advised to wear protective goggles, since without them there is a risk of exposing the lens to doses in excess of the annual equivalent dose limits. To reduce the exposure, it is important for operators to have sufficient knowledge of radiological protection and always be on guard while conducting the procedure. It is also necessary to employ an X-ray device equipped with optimal protective functions.

Key words: Interventional radiology; Exposure of patient; Exposure of operator; Prevention from exposure

Introduction

Interventional radiology (IVR) is an effective treatment method that achieves steady result with less invasion. However, the problem of radiation exposure is attracting attention along with a marked increase in the corresponding cases. To be more precise, the skin injuries in the patient and lens disorder in the operator have been reported. In this respect, FDA (Food & Drug Administration) of USA issued a recommendation in relation to IVR. Furthermore, ICRP (International Commission on Radiological Protection) is also compiling a draft of
recommendation in relation to the exposure.

The facts about the exposure during IVR and the protective measures are described in the following.

Reasons for Increased Exposure

The term “interventional radiology” was used for the first time by Prof. Alexander R. Margulis at University of California San Francisco in his editorial that appeared in AJR 1967. The radiological exposure was already mentioned in this article as in the following.

According to Prof. Margulis, “the techniques in the category of IVR had been practiced since the time before 1967 but there was a hazard called “radiation exposure”. For example, an operator who treated fractures or luxations under direct fluoroscopy suffered radiological disorder. However, thanks to the recent progress of radiological devices, the exposure is on the decrease. As a result, therapeutic techniques that depend on fluoroscopy have been aggressively used. It is expected that IVR will be established as a subspecialty of radiology and will be developed increasingly more in the future.” In reality, IVR has been improved and developed more than Prof. Margulis predicted but the radiation exposure is again causing a problem.

The reasons for increased exposure during IVR are:

1. An increase in the number of cases due to the development of new techniques and increased scope of application;
2. Prolonged duration of treatment due to advanced techniques and complicated treatment.

For example, the cases of PTCA (percutaneous coronary angioplasty) against coronary diseases are showing a marked increase each year while cases of CABG (coronary artery bypass graft) are leveling off. Due to the use of stent in coronary artery, the cases of stenting are also showing a sharp increase (Fig. 1).

The catheter manipulating time in the TAE (transcatheter arterial embolization) was short in the initial stage because the embolization was conducted in the proper hepatic artery or the right and left hepatic artery at most. However, in the recent subsegmental TAE, the catheter goes through the tortuosity of hepatic artery into the subsegmental artery or its periphery. As a result, the fluoroscopic exposure time is prolonged. The use of microcatheter and microwire increased the frequency of conducting fluoroscopy at a high dose such as magnification fluoroscopy, which also increases the exposure.

Exposure of Patient

Reports on the radiation-induced skin injuries caused by IVR have been made since 1994,
Depending on the absorbed dose to the skin, the injuries range from mild and transient erythema, alopecia, etc. to severe symptoms such as necrosis of skin. Table 1 shows the relation between the dose and skin injuries, and the latency up to the onset. These injuries are called deterministic effects and occur when the dose exceeds a threshold. The severity of symptom in such case is dose-dependent. Accordingly, the dose irradiated can be estimated on the basis of severity of skin injury. The patient shown in Fig. 2 is considered to have been exposed to a dose of 20Sv or more.

The exposure of patient is classified as medical exposure and the dose is not limited in such case because the patient is expected to receive direct benefit from the medical deed (even if associated with radiation exposure) (the justification of a practice). Needless to say, however, maximum efforts should be made to protect the patient and the exposure should be reduced to the minimum (the optimization of protection).

### Exposure of Operator

The exposure of operator is one of the occupational exposures, and the ICRP recommendation regulates the annual dose. According to the recommendation made in 1990, the limit of effective dose was 20mSv/year (mean of 5 years) and the dose limit a year was 50mSv (Table 2). The level is based on the high incidence of malignant tumors at 200mSv or more in those exposed to the atomic bomb. The influence of this type has simply to do with the increased probability and has no threshold level. Accordingly, it is termed as “stochastic effects”. Stochastic effects include genetic effects but it has not been confirmed in human.

As the deterministic effects that the operator suffer are disorders in the lens and skin (especially the fingers of hand). In this regard, the

---

**Table 1** Threshold Dose in Skin Disorders and the Duration up to the Onset

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Threshold dose</th>
<th>Duration up to onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early transient erythema</td>
<td>2Sv</td>
<td>Several hours</td>
</tr>
<tr>
<td>Transient epilation</td>
<td>3Sv</td>
<td>3 weeks</td>
</tr>
<tr>
<td>Main erythema</td>
<td>6Sv</td>
<td>10 days</td>
</tr>
<tr>
<td>Permanent epilation</td>
<td>7Sv</td>
<td>3 weeks</td>
</tr>
<tr>
<td>Dry desquamation</td>
<td>10Sv</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Wet desquamation</td>
<td>15Sv</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Dermal necrosis</td>
<td>18Sv</td>
<td>10 weeks or more</td>
</tr>
<tr>
<td>Secondary ulceration</td>
<td>20Sv</td>
<td>6 weeks or more</td>
</tr>
</tbody>
</table>

---

Fig. 2 Case of skin necrosis caused by coronary angiography (2 times) and PTCA (quoted from Reference 4)
Dose limit is 150 mSv/year for the lens and 500 mSv/year for the skin.

**Dose the Patient is Exposed in IVR**

The essential element that determines the exposure dose in IVR is the fluoroscopy time. When the mean fluoroscopy time in vascular IVR conducted at Osaka University Hospital was compared with that of DSA (digital subtraction angiography) conducted for diagnosis, the IVR related to the heart took 43 minutes (26 minutes for diagnosis only) and that related to abdomen took 32 minutes (14 minutes). More than twice longer fluoroscopy time was required in the latter case. In the case of the former, the frequency of radiography was more than twice higher than that for diagnosis only, and the estimated exposure dose of the patient was mean 1.14 Sv.

Fluoroscopy longer than 60 minutes was conducted in 51 cases (7.2%) for the abdominal vascular IVR in 1997. TAE (39 cases) against hepatocellular carcinoma accounted for the largest number of these 51 cases, followed by catheter placement cases (9 cases) against metastatic liver cancer. There were also 1 case each of peripheral arterial angioplasty, stenting, and TIPS (transjugular intrahepatic portosystemic shunt). Including the radiography dose, the skin of these 51 patients was exposed to a mean dose far exceeding 3 Gy. Furthermore, 6 of them (0.85%) required the fluoroscopy time of 120 minutes or more, resulting in the mean dose of 6 Gy to which their skin was exposed. However, skin disorder was not reported as a problem in these cases. It was mainly because different sites of skin were irradiated, though the disorder may have been overlooked.

**Difference in Exposure of the Operator by Under-tube or Over-tube**

Whether an under-tube type or over-tube type fluoroscopy device is used makes a difference in the exposure dose, that is, whether the source is underneath or above the patient’s table (Fig. 3). In general, an under-tube is used in the vascular type IVR including TAE and PTA (percutaneous transluminal angioplasty) while an over-tube is frequently used in the non-vascular type IVR (biliary intervention etc.).

According to the data reported by Hayashi *et al.* who used phantom at Fukui Medical University, the exposure doses at the same position as the patient’s, at a position 50 cm higher than that of the patient’s and at a position 50 cm lower than that of the patient’s after 30 minutes of fluoroscopy were 0.75 mSv, 0.25 mSv, and 0.95 mSv, respectively in the case of the operator using an under-tube device. That is, the exposure dose after 30 to 60 minutes of fluoroscopy is 0.25–0.5 mSv at a 50 cm higher position with consideration to the exposure of eyes and thyroid gland. Assuming that each case requires mean 45 minutes of fluoroscopy, the dose does not reach the 150 mSv/year level unless more than 400 cases are handled. At the same position as that of the patient and at a 50 cm lower position, no problem occurs because the abdomen and lower half of the operator’s body are shielded by a protective garment.

On the other hand, the exposure doses were 0.65 mSv, 1 mSv, and 0 mSv, respectively at the above mentioned positions (the same as the
patient, +50 cm, −50 cm) when an over-tube fluoroscopy was used. The 1 mSv at the eye level is a critical dose because the dose exceeds the limit if 30 minutes of fluoroscopy is conducted 150 times a year. Since the fluoroscopy time of non-vascular type IVR takes mean 15 minutes or so at Osaka University, there is still some allowance. However, when the vascular type IVR is conducted using an over-tube device, it is possible that the dose exposure exceeds the limit when 2 cases a day are handled twice a week. It is advisable to wear protective goggles when operating an over-tube fluoroscopy.

As to the exposure of fingers of hands, a survey in which the operator wore a film ring (4th finger of left hand) was conducted at Osaka University Hospital for 2 months. The result indicated the highest exposure in the IVR related to the heart. The operator was exposed to mean 0.755 mSv a case. And, the operator who handled a largest number of abdominal IVR cases was exposed to mean 0.556 mSv per case that is a dose far below the limit of 500 mSv/year.

For Reducing the Exposure

Apart from the IVR that uses ultrasonography and MRI, the exposure in IVR is unavoidable to some extent so long as a radiological device is used. Accordingly, the operators engaged in IVR and medical staff should make an all-out effort to reduce the exposure. In this regard, the following two points should be stressed.

1. The operator should have sufficient knowledge of radiological protection and conduct the procedure always paying attention to prevent the staff including himself/herself and the patient from exposure

Operators’ lack in knowledge is a serious problem. The required knowledge was also lacking before I became a member of ICRP. Even a radiologist does not necessarily have sufficient knowledge. For example, I happened to witness the following scene: The operator was concentrating on the catheter and the wire, and was not paying attention to the distance from the source. He shouted angrily and turned off the fluoroscopy when a staff came into the room without protection. The distance between the source and the staff was more than 2 m but the operator did not know that it was a safe distance. Even though he seemed very attentive in avoiding exposure, he didn’t seem to mind using an over-tube fluoroscopy without protective goggles.

Probably, the problem lies in the medical care system itself in Japan. Whatever his/her specialty is, a physician, is allowed to handle a
fluoroscopy device and there is no penalty for being absent from the training course for protection from radiation exposure.

The second point to be stressed is that the operator is not necessarily conscious of the danger of exposure even if he/she has sufficient knowledge about it. If the operator is conscious of the exposure of the patient, the frequency of unnecessary radiography and fluoroscopy will be decreased and at the same time more attention will be paid to the irradiation field of the patient by always using collimation. If conscious of the exposure, the operator himself/herself will try to keep as much distance as possible from the source, not to mention of the protector and goggles. Even a distance of 10 cm further from the source makes a difference. Furthermore, a knowledgeable operator will try to improve his/her skill and to reduce the fluoroscopy time.

2. To improve X-ray devices, equip the device with exposure-reducing measures and to indicate the dose by real time

First of all, the use of an under-tube type fluoroscopy device should be encouraged even in the non-vascular IVR cases. At our institution, devices (Shimadzu Co.) which allow switch-over from over-tube to under-tube or vice versa are used. Therefore, over-tube is used only when necessary and the frequency of usage is very low.

As to the device itself, there is a problem of I.I. (image intensifier) deterioration. The relative sensitivity (Gx) of I.I. was reduced by half in about 5–7 years in 9 DSA devices at 5 institutions investigated. In other words, the fluoroscopic images markedly deteriorate after 5 years or so. As a result, the X-ray dose has to be increased to make up for the deterioration. It is advisable to update the X-ray devices at the soonest practicable occasion.

As to the indication of irradiated dose, our DSA devices are equipped with a PEMNET system that always indicates the total dose of fluoroscopy and radiography so that the operator can find the real time dose. Such a system should be standardized as soon as possible.

Conclusion

The exposure of patients and operators is definitely on the increase in IVR cases. To reduce the exposure, the operator should have sufficient knowledge about protection and should always bear in mind the danger of exposure while conducting the procedure. Furthermore, it is important to use X-ray devices provided with the best protective measures.

REFERENCES