Dosimetry of Occupational Eye Lens Dose Using a Novel Direct Eye Dosimeter, DOSIRIS, during Interventional Radiology Procedures

1) *Department of Radiology, Kyushu University Beppu Hospital, Japan*
2) *Department of Radiology, Beppu Medical Center, Japan*
3) *Department of Internal Medicine, Beppu Medical Center, Japan*
4) *Department of Surgery, Kyushu University Beppu Hospital, Japan*
5) *Department of Clinical Radiology, Graduate School of Medical Sciences, Kyushu University, Japan*

Masakazu Hirakawa[1)2)], Hiroshi Nakatake[2)], Satoru Tsuruta[3)], Shuji Matsuura[2)], Yuushi Motomura[1)], Yoshiki Hiraki[1)], Koshi Mimori[4)], Kousei Ishigami[5)]

Abstract

In response to the recommendation by the International Commission on Radiological Protection to lower the equivalent eye dose limit, the Japanese Government in April 2021 lowered the equivalent dose limit for the eye lens for occupational exposure. A considerable number of interventional radiology operators are exposed to levels above the new limit. For this reason, a need exists to more accurately evaluate eye lens dose in interventional radiology operators by using a novel direct eye dosimeter, the DOSIRIS™(IRSN, France), which is capable of measuring a 3-mm dose equivalent under protective glasses. The DOSIRIS is a thermoluminescent dosimeter that exhibits good energy dependence and better directional properties than other dosimeters. Dosimetry using DOSIRIS might be accurate and compatible with the latest regulations.

Key words: interventional radiology, eye dose, DOSIRIS

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Introduction

Interventional radiology (IR) has become increasingly important as a medical technique in recent years due to its minimal invasiveness, and radiologists increased opportunities for involvement in IR procedures. Recently, IR procedures have become more time-consuming due to increased technical complexity, which led to an increase in adverse events such as skin disorders from greater radiation exposure in patients, together with concerns over greater exposure for IR operators. The International Commission on Radiological Protection (ICRP) Statement from the 2011 Seoul Meeting recommended that the equivalent dose limit for the eye lens should be "20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv" [1, 2]. In response to the recommendation by the ICRP to lower the equivalent eye dose limit, the Japanese Government in April 2021 lowered the equivalent dose limit for the eye lens for occupational exposure and made revisions to the Ordinance on Prevention of Ionizing Radiation Hazards, including changes to the dose measurement and calculation methods. The previous equivalent dose limit for the lens of the eye was 150 mSv/year, but the revised regulations lowered this to "an equivalent dose for the lens of the eye of ≤ 100 mSv over 5 years and ≤ 50 mSv over 1 year", and they also added measurement at a 3-mm dose equivalent to the dosimetry method. Following this latest reduction in the dose limit for the eye lens, a considerable number of IR operators are found to demonstrate doses

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Correspondence Author: Masakazu Hirakawa, E-mail: hirakawa.masakazu.988@m.kyushu-u.ac.jp

above the limit when measured using the current method of eye lens dosimetry with a glass badge without protection [3]. Consequently, a need exists to more accurately assess the eye lens dose in IR operators using a novel direct eye dosimeter the DOSIRIS™ (IRSN, France), which is capable of measuring a 3-mm dose equivalent under protective glasses.

In this review, the basic features of DOSIRIS, efforts to reduce exposure, and our measurement of eye lens doses in operators using DOSIRIS during IR procedures such as transcatheter arterial chemoembolization (TACE) for hepatocellular carcinoma (HCC) are described.

Basic Features of DOSIRIS

DOSIRIS was developed as a dosimeter by the French Institut de radioprotection et de sûreté nucléaire. It can be worn under protective glasses and measure the dose equivalent at a depth of 3 mm. It is compatible with the International Atomic Energy Agency (IAEA) Guideline recommendation that "the equivalent dose to the eye lens at 3 mm depth, Hp(3), with a dosimeter worn as close as possible to the eye."

Basic structure

Since it uses lightweight materials, DOSIRIS weighs only 12 g, is barely noticeable when worn, and reduces the burden on the wearer. The device has an articulated arm that can be adjusted to a variety of head and face shapes, and the position of the detector can be finely adjusted at the corner of the eye behind protective glasses (**Fig. 1a and b**); however, the author felt slight discomfort and mild pain on the head and face after wearing the device for a long period. Recently, DOSIRIS could be attached to the left side of protective glass and could be placed close to the left side of the left eye under protective glasses (**Fig. 2**), improving the discomfort and pain could.

Measurement of 3-mm dose equivalent

The detector is a thermoluminescent dosimeter (TLD) that uses ^{7}LiF:Mg,Ti as the TLD element and is encapsulated in a 3-mm-thick polypropylene capsule (**Fig. 3**, DOSIRIS TLD element). This TLD element demonstrates good energy dependence because the main component is LiF, which exhibits a low effective atomic number. A metal filter is normally used to correct for the energy dependence of TLD elements, but angular dependence is poorer when using a metal filter [4].

Because of its good energy dependence, DOSIRIS does not require the use of a metal filter for correcting energy dependence, and this is one of the reasons for its good angular dependence. During IVR procedures, adjusting the angular direction of the X-ray tube is sometimes necessary, which also changes the direction of scattered radiation. Additionally, the operator is often required to change the position of head during procedures. Therefore, it is crucial that the dosimeter demonstrates good angular dependence so that eye lens exposure can be evaluated accurately. DOSIRIS is ideal for this purpose.

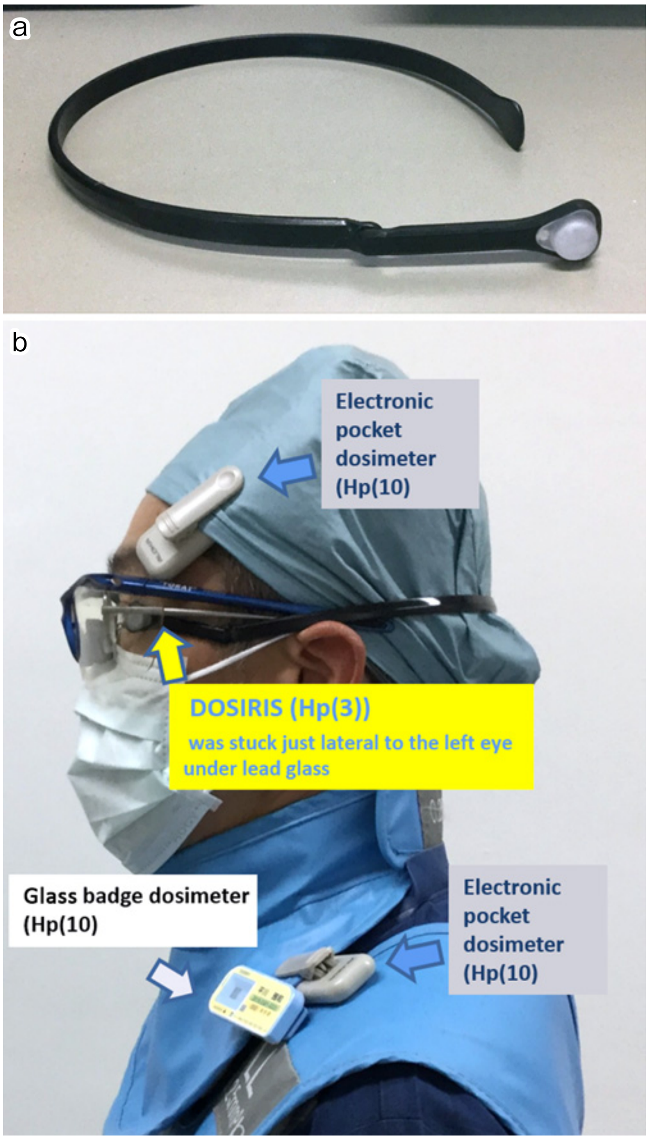

Figure 1. The positions of the dosimeters during the procedures of the author. The eye dosimeter (DOSIRIS, Fig. 1a) was worn just lateral to the left eye under protective glass, and the personal dosimeter (glass badge) was worn outside the Pb apron to the left of the neck. Additionally, electronic pocket dosimeters were on left side of cap and outside the Pb apron to the left of the neck.

DOSIRIS measures X-rays and gamma rays in the energy range from 25 keV to 1.25 MeV and beta particles at 0.8 MeV (mean energy). The dose reported by Chiyoda Technol Corporation [Tokyo, Japan] is a 3-mm dose equivalent of 0.1 mSv to 1 Sv.

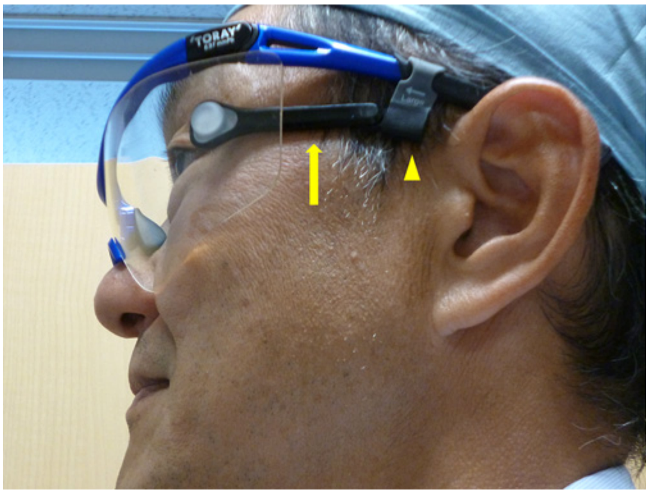

Figure 2. The eye dosimeter (DOSIRIS, arrow) was worn just lateral to the left eye under protective glass. The DOSIRIS was attached to left arm of protective glass by special attachment (arrow head).

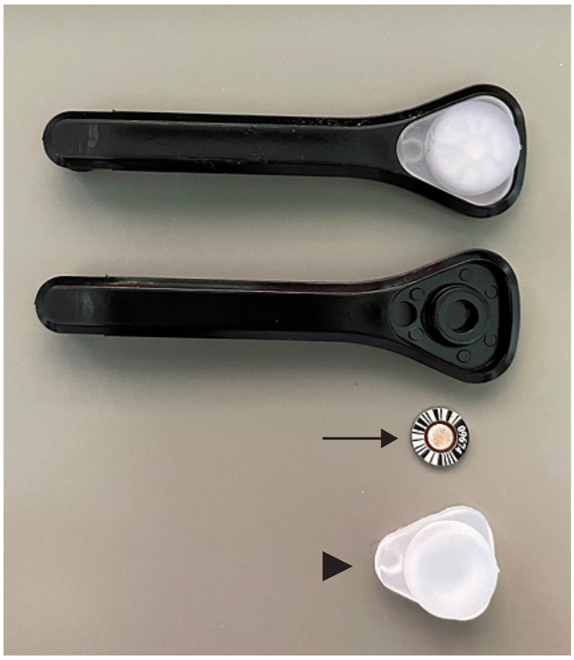

Figure 3. The detector is a thermoluminescent dosimeter (TLD, arrow) that uses ^{7}LiF:Mg,Ti as the TLD element and is encapsulated in a 3-mm-thick polypropylene capsule (arrow head).

Eye Lens Dosimetry with DOSIRIS during Transcatheter Arterial Chemoembolization (TACE) for Hepatocellular Carcinoma (HCC)

We measured the eye dose of operators performing TACE using DOSIRIS and the glass badges since 2017.

The angiography system used for the study was the Allura Xper FD20/20 (Philips, 2013) with conditions on the system set to reduce exposure below the default conditions for abdominal angiography. We presented the results of exposure during TACE for HCC using the exposure reduction mode to the Radiological Society of North America and other meetings. The exposure reduction mode involved the use of pulse fluoroscopy, 50% reduction in the imaging frame rate, lower radiation dose, and an exposure-reducing –0.4 mm Cu +1.0 mm Al accessory filter. Measurement based on numerical dose determination showed that the air kerma and dose area product in patients treated under exposure reduction mode could be reduced to approximately 65% of the values under the standard mode default setting on conventional systems. Almost no loss of image quality occurred, adverse events did not increase, and the therapeutic effect was the same [5].

During TACE, the protective ceiling plate was interposed between a flat panel detector and the operator (**Fig. 3**). For eye lens protection, the operator wore a Panorama Shield® with an acrylic lens containing lead with a lead equivalence of 0.07 mm Pb (Toray Medical Co., Ltd. Tokyo, Japan). DOSIRIS was used as the dosimeter, and it was worn in the region of the left eye under protective glasses to measure the dose to the eye lens in accordance with the IAEA recommendation. The operator also wore a glass badge and a pocket dosimeter on the left side of the cap, and the dose measured by each dosimeter was compared. The glass badge was worn in the usual way behind a protector (**Fig. 1b**).

Mean eye lens dose during TACE: Comparison of dose measured by DOSIRIS and glass badge

By dividing the reported monthly eye lens dose from Chiyoda Technol by the number of TACE procedures performed per month, the eye lens dose per TACE procedure was estimated.

The eye lens dose measured by DOSIRIS was 34.8 μSv/TACE with protection, and the eye lens dose measured by glass badge was 57.6 μSv/TACE without protection.

The number of TACE procedures that can be conducted annually within the eye lens dose limit of 20 mSv/year is 347/year based on the glass badge measurement of eye lens dose and 574/year based on the DOSIRIS measurement. For reference, when an operator used the same angiography system in exposure reduction mode without any protective glasses, the eye lens dose measurements from both devices were very similar, at 240 μSv/TACE measured by DOSIRIS and 243.3 μSv/TACE measured by the glass badge. Under these conditions, the operator could perform 83 TACE procedures per year without exceeding the 20 mSv/year eye lens dose limit. Because IR operators must perform many high-dose procedures in addition to TACE, it is likely that the eye lens dose limit of 20 mSv/year would be exceeded without protective devices. Therefore, it is essential that IP operators have at least some personal protection from exposure. Previous literature on eye lens doses during TACE reported values of 270-1,070 μSv without protective devices, 16-64 μSv with protective devices [6], and a mean left eye lens dose of 421 μSv (range: 94-894 μSv) without protective devices measured by TLD [7]. These reports show very high eye lens doses without protection and highlight the importance of protective glasses and other protection.

Literature on Eye Lens Dosimetry Using DOSIRIS

Some published reports analyzed the differences and relationship between eye lens equivalent doses mainly in IR operators and stuffs as measured by DOSIRIS with protective glasses and by glass badges worn at the neck. In these reports, personal glass badge dosimeters at the neck tended to overestimate the eye lens dose measured by DOSIRIS, but both values correlated relatively well. Additionally, the Panorama Shield® protective glasses (Toray Medical Co., Ltd.) exhibit a reported a shielding rate of about 60% based on the eye lens dose measured by DOSIRIS. There are concerns that if IR operators do not use protective glasses, the eye lens equivalent dose measured by DOSIRIS would exceed 20 mSv/year [8, 9].

In this review, use of DOSIRIS to evaluate the eye lens dose during TACE for HCC was described. Of course, IR operators must various IR procedures under different imaging conditions for each modality. We are currently conducting a comparative study of eye lens doses measured by DOSIRIS and glass badges without protection during various IR procedures at our hospital.

Conclusion

The use of DOSIRIS under protective glasses to measure the 3-mm dose equivalent during IR procedures can provide accurate eye lens dose measurements and is ideal for this purpose. This method is also important for reducing the excessive number of IR operators whose exposure is above the dose limit. However, it might probably be practical to provide DOSIRIS to only IR operators, since providing all stuffs in the IR rooms with DOSIRIS might be high cost.

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Conflict of Interest: None

Author Contribution: MH, HN, ST, KM and KI were involved in the study design and data interpretation. SM, YM, and YH were involved in the data analysis. All authors critically revised the report, commented on drafts of the manuscript, and approved the final report.

The institution from which the work originated:
Department of Radiology, Kyushu University Beppu Hospital
4546 Tsurumihara, Beppu city, Oita 874-0838, JAPAN

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