

Assessment of a high occupational single exposure – false or true?

[Widmark A, anders.widmark@nrpa.no, Norwegian Radiation Protection Authority]

Purpose

The Norwegian Radiation Protection Authority (NRPA) is monitoring occupational radiation doses to exposed staff at the Norwegian hospitals. For the period of July and August a dose of 69.9 mSv was recorded on the personal dosimeter of a surgeon. The surgeon had performed only four ERCP during the 2-month period, and NRPA initiated an assessment to explain the high dose.

Estimation of the ESD to the patient

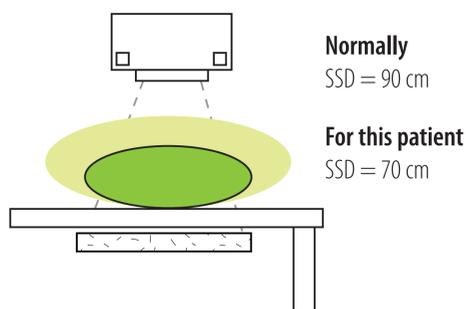
A typically set-up for a radiographic procedure for an adult patient, weighting 70–80 kg, is a 90 cm source-skin distance (SSD), assuming a source-image distance (SID) of 110 cm. The radiographic voltage is typically 75 kVp, resulting in an ESD of approximately 10 mGy to the patient.

“Normal patient” ESD = 10 mGy / exposure

Due to the increased patient volume in this case, the Automatic Exposure Control (AEC) will increase the exposure, to get a sufficient signal to the detector. kVp values > 100 and high mAs values, which probably will increase the ESD by 6–8 times, are supposed.

Patient volume correction $7 \times 10 \text{ mGy} = 70 \text{ mGy} / \text{exposure}$

The increased patient volume will decrease the SSD. The ESD is hence corrected to a SSD of 70 cm by the inverse square law.



Distance (SSD) correction $ESD_{70 \text{ cm SSD}} = \frac{90^2}{70^2} \times 70 \text{ mGy} = 115.7 \text{ mGy} / \text{exposure}$

Finally the ESD per image must be multiplied with the total number of images which were eleven. The total estimated ESD is rounded up to 1300 mGy, by adding a small symbolic fraction from the unknown fluoroscopic exposure.

Total no. of images $11 \times 116 \text{ mGy} = 1276 \text{ mGy} \sim 1300 \text{ mGy}$

Discussion and conclusions

The high radiation dose to the surgeon can be explained by the obese patient, associated exposure settings and the working technique, in addition to the over-couch tube geometry. This case shows the necessity to pay special attention to staff doses, during situations like the one described. ERCP is not recommended to be performed with over-couch geometry.

The effective dose to the surgeon is difficult to assess exactly. Many factors like e.g. half-value layer, exposed area of the surgeon, design of the lead apron and additional thyroid shielding will affect the effective dose. The actual value of the effective dose, will be somewhere between 10 and 40 % of the dosimeter reading. This will give an effective dose to the surgeon between 7 and 28 mSv, which should be compared with the annual dose limit of 20 mSv for occupational exposures, proposed by the International Commission on Radiological Protection (ICRP).

The assessment shows that it is possible to make rough assessments of dosimeter readings if common values for patient exposure and scatter are known, in addition to working technique for the actual procedure.

References

1. Paulsen GU, Sekse T, Widmark A. Årsrapport fra persondosimetertjenesten ved Statens strålevern 2003. StrålevernRapport 2004:11. Østørd: Statens strålevern, 2004.
2. Statens Institutt for Strålehygiene (SIS). Strålefyssikk, -terapi, -hygiene og -biologi. Østørd: SIS, 1973.
3. Franken Y. Guidance on the use of protective lead aprons in medical radiology. Protection efficiency and correction factors for personal dosimetry. In: 6th European ALARA Network Workshop, Madrid, October 23–25, 2002. Occupational exposure optimization in the medical field and radiopharmaceutical industry: Proceedings. Madrid: European ALARA Network, EANL, 2002: 135–139.
4. International Commission on Radiological Protection (1990). Recommendations of the International Commission on Radiological Protection. ICRP Publ 60, Ann ICRP 21 (1–3).



Methods and materials

The monitoring system consists of lithium fluoride (LiF:Mg,Ti) thermoluminescent chips (TLD-100; Harshaw-Bicron, Newbury, OH) and a Harshaw model 6600 TLD reader. Each monitoring period is two months and the dosimeters are worn unshielded, over the apron, which usually gives an overestimation of the effective dose.

The glow-curve for the TLD was controlled and found normal, indicating that the dose to the dosimeter was correct. The surgeon had only performed four ERCP's during the period. One patient, treated with papillotomy, had a weight of +150 kg. Due to weight limitations at the common X-ray laboratory, another laboratory with over-couch tube geometry and photostimulable phosphor plates as sensors, were chosen. No dose record was available, but 11 radiographs and an unknown amount of fluoroscopic exposures were taken during the procedure. During the assessment of the dose, common values for doses and scattered radiation modified to the actual situation, were used.

The assessment was done in two following steps:

1. Estimation of the entrance surface dose (ESD) to the patient
2. Estimation of the scattered fraction from the patient to the dosimeter



The scattered fraction from the patient

For diagnostic X-ray beams the scattered radiation is dependent on field size, beam energy, tissue volume and the type of tissue irradiated. For an entrance field of 400 cm² and a beam energy of 80 kVp, this value may be estimated to be approximately 1 % of the incident radiation of the patient, at 1 m 90 degrees to the incident radiation beam.

A high kVp of 100–110 is assumed which will give a larger fraction of scatter compared to 80 kVp, thus increasing the scattered radiation.

A higher proportion of fatty tissue will also contribute to a larger amount of scatter to the surgeon.

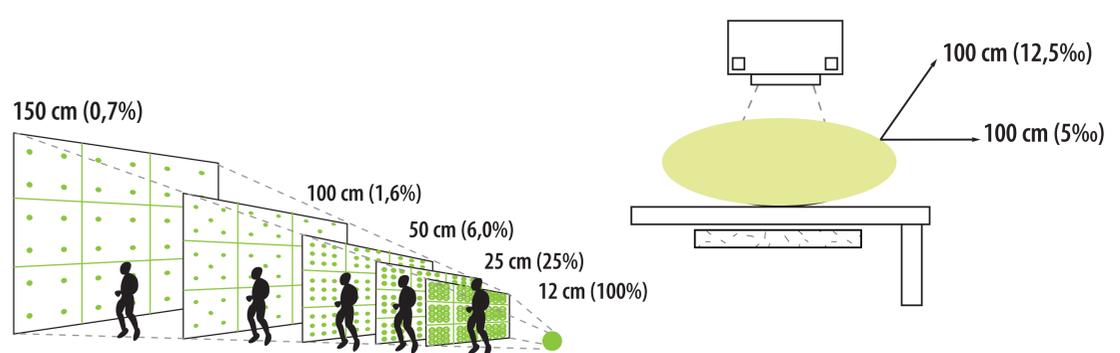
Finally, a large entrance field is assumed because of likely difficulties of centring the area of interest, due to limited image contrast, poor anatomical overview and a small light field for centring the projections.

High kVp, large proportions of fatty tissue and a large entrance field, will probably give a scattered fraction of approximately 5 % at 1 m, 90 degrees to the incident radiation beam.

Total scatter corrected for kVp, tissue and entrance field 5 %

With a standard over-couch X-ray geometry there will be about 2.5 times more scattered radiation at shoulder level compared with the same distance at 90 degrees to the incident radiation beam. Since the personnel dosimeter is attached at shoulder level this will increase the dosimeter reading.

Scattered fraction at shoulder level $2.5 \times 5 \% = 12.5 \%$



During the exposures, the surgeon has to remain near the patient. With the described patient size and the limited length of the scope, it is probably not possible to use distance as an efficient radiation protection tool. The earlier suggested large entrance field will further decrease the distance to the surgeon. Entrance field to dosimeter distance is estimated to be 40–60 cm. A correction to 50 cm, by the inverse square law, will give:

Dosimeter-entrance field distance correction $Dose_{50 \text{ cm}} = \frac{100^2}{50^2} \times 12.5 \% = 50 \% = 5 \%$

Dose to the surgeon

From the estimated ESD to the patient of 1300 mGy, and the scatter fraction of 5 % to the surgeon, it is possible to calculate the dose to the dosimeter.

Calculated scatter from the ESD to the dosimeter $5 \% \times 1300 \text{ mGy} = 65 \text{ mGy}$

