Patient Dose Measurements in Fluoroscopically Guided Procedures using the TN-RD-51 Dosimetry System

Introduction

During some interventional fluoroscopically and fluorographically guided procedures, patients are exposed to radiation levels that may be as large as those given to oncology patients. In the past, monitoring of radiation exposure has been largely reserved for medical personnel who work with radiation. Only in the last few years has there been a growing concern for the amount of radiation delivered to the patient during interventional work.

In some procedures, such as electrophysiological ablations and transjugular intrahepatic portosystemic shunt (TIPS), absorbed skin doses can range from 100 rads to 1000 rads, sufficient to induce deterministic effects such as epilation, radiation induced erythema and blistering.[1] To compound the situation, most radiation induced skin injuries are dormant for a period of at least one week and may not be apparent for years. It is entirely possible that the patient and general practitioner might not recognize the injury as being radiation induced, thus complicating recovery.

Because of reports of significant patient injuries incurred as a result of fluoroscopically guided procedures, the FDA has issued guidelines, and procedures.

In 1994 the FDA issued a Public Health Advisory to alert the radiological community and suggested action to be taken to reduce the potential for radiation skin injuries.[2] In 1995 the FDA issued a follow up suggestion recommending that:

1. The facility record in the patient's medical record information regarding absorbed dose to the skin for any procedure with the potential for a skin dose approaching or exceeding some threshold dose, 100 rads.

2. An estimate of the cumulative absorbed dose to each irradiated area be noted in the patient's record, or sufficient data provided to permit estimation of the absorbed dose to exposed areas of skin. (There was some clarification as to the type of patient, but no indication of measurement methods.)

Federal regulations on fluoroscopic and fluorographic equipment performance are not sufficient to ensure that deterministic effects will be avoided. This is because current FDA regulations apply to equipment output, not to procedure and duration of medical treatment.

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The wide range of energies used in fluoroscopic procedures, patient weight and physical characteristics, make calculation of absorbed skin dose very difficult, especially with the potentially large dose contribution (up to 40%) due to backscatter.

The TN-RD-51 is a commercially available dosimetry system used extensively in radiation oncology. In the work presented here the TN-RD-51 was calibrated using tube potentials indicative of fluoroscopic X-ray units at the National Research Council (Ionizing Radiation Standards, Ottawa, Canada). Preliminary results are presented of measurements made during a series of neurologic embolizations at the University of Texas.[3]

Fluoroscopic Dose Methods

Several methods are available for monitoring radiation exposure. Some facilities measure radiological outputs such as kVp, mA, and focus-skin distance during lengthy procedures and calculate an entrance dose. Thermoluminescent dosimeters (TLDs) and photographic film are often placed on the patient's skin to make dose measurements.[4] The major disadvantage for both film and TLD is that they are not real-time dosimeters. Fluoroscopy requires real-time dosimetry to ensure maximum safety for the patient.

TN RD-51 Direct Reading Dosimetry System

The RD-51 dosimetry system consists of three distinct components:

1. The MOSFET dosimeter on a thin (2 mm wide) flexible circuit connected to a 65 cm long cable. The semiconductor device has a very thin active region, making it ideal for skin dose measurements. (See Technical Note No. 4).
2. A dc bias supply to which the MOSFET dosimeters are connected during exposure to increase sensitivity. A maximum of 20 MOSFET dosimeters can be used at one time.
3. A reader system that when activated reads the dosimeters. Calibration factors can be input to the microprocessor to convert readings into absorbed skin dose (see appendix A).

Calibration at NRC (Ottawa)

RD-51 calibration was performed at the National Research Council Ionizing Radiation Standards, using low energy X-rays with tube potentials of 40 kVp, 60 kVp, 80 kVp and 100 kVp. Figure 1. shows the spectral analysis of the four calibrations.

In radiotherapy, skin injury is reduced by the use of megavoltage energy which has a skin sparing effect. This is not possible in fluoroscopic imaging systems. To reduce the dose due to non-penetrating low energy photons, a 2.5 mm Al filter is required by regulation. This removes from the beam very low energy X-rays that contribute nothing to the image and only contribute to skin dose. Increasing the filtration to an equivalent of 3.5 mm of Al or 0.1 mm of Cu can reduce skin dose by as much as 25% without degrading image quality.[1]

In the NRC exposures, the following Cu filters were used: 0.2 mm, 0.6 mm, 2.0 mm, and 5.0 mm for tube potentials of 40 kVp, 60 kVp, 80 kVp and 100 kVp respectively. The resultant spectrum is a well defined narrow beam centred around a mean keV. Diagnostic x-ray tubes exhibit spectra that are much broader. When the MOSFET response is determined with spectra typical of diagnostic x-ray tubes, it is flat and renders the dosimeter ideal for dosimetry in the 50 kVp to 120 kVp energy range.

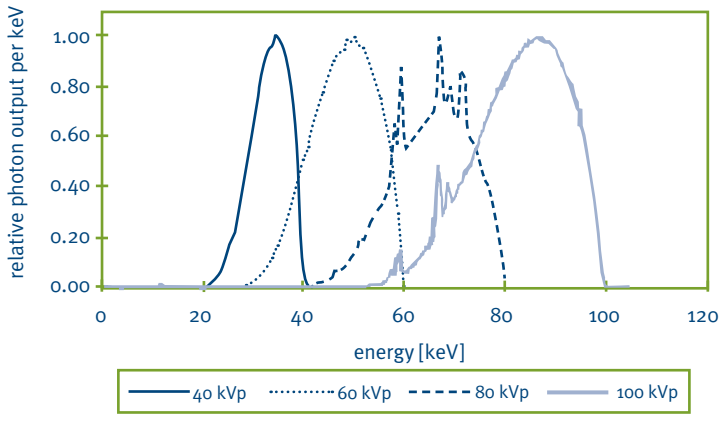

FIGURE 1. Spectra for the NRC calibrations

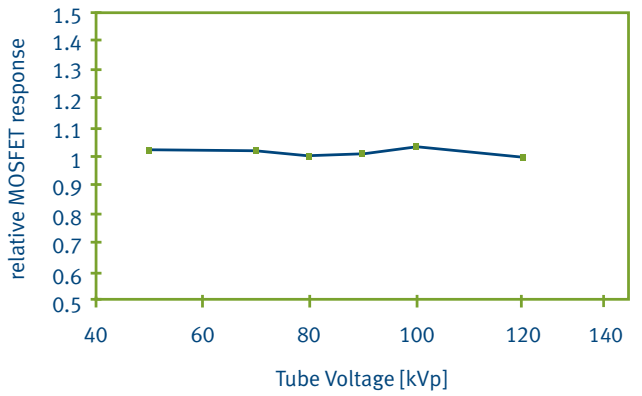

FIGURE 2. MOSFET sensitivity relative to its response at 80kVp using an x-ray tube filtered with 3mm Al.

Calculated	MOSFET
499R	478R
198R	170R
79R	67R

TABLE 3. Air Kerma exposure and MOSFET measurements compared.

Figure 2 shows MOSFET sensitivity relative to response at 80 kVp using a diagnostic x-ray tube filtered with 3 mm Al. At each energy, response is based on an average of 7 incremental dose measurements (15 rads) with σ= 0.06.

Applications to Fluoroscopic Dosimetry

Work is being done at the University of Texas Houston Medical School/Hermann Hospital, Department of Diagnostic Radiology, to monitor doses to patients during intra cranial and abdominal interventional procedures. Average entrance skin doses are of the order of 150 rads and range up to 500 rads for very long procedures. These data, are collected along with information on machine parameters, kVp, mA and fluorography technique. The measured doses are compared to anticipated doses calculated for such techniques. The data indicate excellent agreement between calculated and measured doses. Examples covering the range of doses observed are shown in Table 3.[3]

Conclusion

In this work we have identified the need for monitoring skin exposure during fluoroscopic and fluorographic procedures. Federal regulations regarding the use of equipment have no bearing on the susceptibility of patients to serious skin damage. Since many of the symptoms of radiation damage are latent, appearing weeks after exposure, it is imperative that proper dose measurements and records be kept.

The TN-RD-51 dosimeter unit has been shown to lend itself to measuring absorbed skin dose at energies indicative of fluoroscopic imaging. MOSFET dosimeters can be placed anywhere on the patient's body and read *in-situ* while the physician carries out the procedure.

References

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4. Farjardo, L.C., Geise, R.A., Ritenour, E.R. " A Survey Of Films For Use As Dosimeters In Interventional Radiology", Health Physics, April, 1995 Vol. 68., No. 4..