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Radiation exposure to the hands of operators during angiographic procedures

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Abstract

The hands of those undertaking angiographic studies are close to the X-ray beam and may receive high doses. However, during recent years little information is available on these doses. The exposure to the left and right hand was measured with thermoluminescent dosemeters during several conventional angiographic procedures. Mean doses to the left hand ranged from 0.24 to 0.96 mSv and to the right hand from 0.12 to 0.71 mSv, related to the type of procedure performed. The protection provided by new flexible lead gloves was estimated. The dose reduction with the glove was 19.5%. Operators can approach the dose limit to hands set by the International Commission on Radiological Protection (ICRP) during high workload. The data presented emphasize the importance of wearing lead gloves.

Keywords: Radiations, exposure to patients and personnel; Radiations, measurement; Angiography, exposure

1. Introduction

The radiation doses from conventional angiographic procedures to the unprotected parts of the operator have been reported in several studies, especially during the 1970s [1–3]. These procedures can deliver high radiation doses compared with other radiological methods, due to the long screening time and the operator's close proximity to the unshielded ionizing beam. However, although the rate of conventional angiographic studies remains high, little information is available on the radiation exposure delivered by newer equipment during abdominal and cerebral angiographic investigations. The majority of operators wear a lead apron, thyroid shield and lead glasses to reduce the exposure to the corresponding parts of the body. Radiation protection of the hands requires particular consideration not only because hands may be exposed directly to primary X-ray beam, but also because many find lead gloves heavy and awkward to wear. Information on the value of protective gloves is limited [4]. The effect of new flexible lead gloves on hand dose has not been estimated so far.

The purpose of this study is to assess the radiation dose to the hands of operators during common angiographic studies, and to determine the maximum number of each type of angiographic procedure which may be performed during one year, according to the dose limits set by the International Commission on Radiological Protection (ICRP). This study also aimed to evaluate the dose reduction using new flexible lead gloves.

2. Materials and methods

One hundred lithium fluoride (LiF) thermoluminescent dosemeters were prepared to measure radiation dose in this study. All dosemeters were in the form of a chip. They were annealed by heating the crystals for 1 h at 400°C followed by 24 h at 80°C. The calibration of the lithium fluoride was performed by

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comparison with a 3 cm^3 ionization chamber and RADCAL 2025 electrometer (Radcal Corp., Monrovia, California, USA), the calibration of which was traceable to the National Physical Laboratory. TLD chips and ionization chamber were simultaneously exposed to an X-ray beam with a 81 KVp tube potential. The dosemeters were then read by a Victoreen 2800 M reader. These measurements were also made for 70 and 102 KVp X-ray beams. The change in sensitivity with respect to the calibration in 81 KVp was found to be less than 1%. TLD crystals with a reading which differed from the average value by more than 2 S.D. were excluded from the study. The sensitivity of a particular dosemeter was taken into account for each dose determination. Background radiation was measured with TLD chips in the angiography room placed far away from the X-ray unit.

TLD chips encased in plastic finger bands were attached to the front of the dorsum of the middle phalanx of each operator's index finger before the donning of sterile gloves.

Thirty examinations were performed by two experienced radiologists. Selective supraaortic, abdominal aortography with selective catheterization of visceral arteries and abdominal aortography in combination with lower extremities angiographic examinations were included in the present study. During lower extremities angiography, the operator remained on the left side of the patient with the hands at approximately 20–30 cm from the center of the X-ray field. During abdominal and supraaortic angiography, the operator stood on the right side of the patient with the hands at approximately 40–50 cm from the center of the X-ray field for carotid studies, and 20–30 cm distance for abdominal studies. The total fluoroscopy time, age, gender, date and type of examination were recorded for each examination. From the average dose per hand per examination, the maximum number of each type of procedure which may be performed over a period of 1 year, without exceeding the dose limits for hands, can be estimated. This estimation should be based on the dose limit to the extremities set recently by the ICRP, which is 500 mSv/year [5].

The contrast medium was injected with a power injector in all procedures. It must be emphasized that the operator did not remain in the angiography room during serial radiography procedure. Hence, exposure of the hands was due to scattered radiation from fluoroscopy.

The X-ray equipment was a C-arm Philips Maximus CM 100 with a Polydiagnost UPI table. This unit consists of an overcouch X-ray tube and an undercouch image intensifier connected to a television system.

Commercial lead gloves (F and L Medical Products, USA) were used in order to evaluate the dose reduction using the glove. Protection at 60 KVp, 80 KVp, 100 KVp and 120 KVp as reported by the manufacturer is 32%, 25%, 18% and 14%, respectively. One of the operators was asked to perform 10 angiographic procedures using the above gloves. The use of two TLD crystals, one attached to the left index finger under the glove and one over the glove, provided information about the attenuation properties of the glove. The dose reduction factor was obtained by averaging dose reduction percentages for the 10 angiographic examinations. The comfort of the gloves was evaluated by the operator. At the end of each examination, a comfort score was given with values ranging from 0 to 10, with high scores corresponding to comfort use; 10 corresponds to gloves as comfortable as routine surgical gloves.

Data are presented as mean values. Linear regression analysis was used to determine the relationship between dose and fluoroscopy time.

3. Results

Thirty examinations were performed in the same X-ray unit. Table 1 shows the average radiation dose and fluoroscopy time for hands for each type of procedure. The number of examinations is also included. The maximum recorded dose received by an operator was 1.8 mSv to the left hand, received during a difficult lower extremities angiography. Average doses for the right hand were lower than doses received by the left hand in abdominal and supraaortic angiographic studies (Table 1). In contrast, in lower extremities examinations, the

Table 1
Average dose and screening time for hands during various angiographic studies

Examination	Number of examinations (*n*)	Fluoroscopy Time (sec)	Finger Dose (mSv)	
			Right hand	Left hand
Selective supraaortic	7	230 (169–840)	0.12 (0.06–0.18)	0.24 (0.04–0.44)
Abdominal angiography	9	383 (180–690)	0.54 (0.42–1.35)	0.96 (0.05–1.38)
Lower extremities	14	154.5 (55–600)	0.71 (0.29–1.7)	0.24 (0.19–1.8)

Numbers in parentheses are ranges.

Table 2
Estimated maximum number of each type of procedure which may be performed over a period of 1 year without exceeding the dose limits for the hands

Procedure	Number of examinations
Selective supraaortic	2092
Abdominal angiography	520
Lower extremities	704

left had received lower doses than the right hand. The above dose measurements may be used to determine the maximum number of examinations which may be performed in order to stay within the annual occupational dose limit for hands. The results for each type of procedure are shown in Table 2. In these calculations, an assumption has been made that protective gloves are not worn.

No significant correlation was found between dose and fluoroscopy time in all types of procedures ($P > 0.05$).

The average dose reduction using the lead gloves was 19.5%. The average comfort score of the gloves was 8.2 ± 0.6 (range 7–9).

4. Discussion

Many studies have documented the amount of radiation received by personnel during various angiographic studies. The radiation exposure depends on the angiographic equipment used, the proximity of the operator to the X-rays, the operating techniques and the protective measures taken. That explains why large differences in doses among laboratories have been found for the angiographic studies performed. Mean exposure of the dorsum of the hand was found to be 199 μSv (19.9 mR) per examination for selective abdominal examination and 74 μSv (7.4 mR) for selective cerebral arteriography by Riley et al. [1]. Santen et al. [2] measured hand exposure in several angiographic procedures; the average dose during renal arteriographic and aortographic procedures was 667 μSv (66.7 mR) and 297 μSv (29.7 mR), respectively. In the above studies, angiographic units were equipped with undertable X-ray fluoroscopy tubes and examinations were performed with a manual injector. Burgess and Burhenne [6] drew attention to finger doses for a variety of special fluoroscopy procedures. Recorded average finger dose was 0.14 mSv per examination for 69 angiographic studies (31 femoral angiograms, 26 abdominal angiograms, four thoracic angiograms and eight angioplasties). Tryhus et al. [7] measured 399 μSv (39.9 mrad) for abdominal angiography and 71 μSv (7.1 mrad) for cerebral angiography with undertable X-ray fluoroscopy tube and power injection of contrast media.

Our results indicate higher doses to the hands than those reported previously. This may be explained by different examination protocols and equipment used. Using a recent technique, introducer sheaths were placed in the common femoral artery of all patients by means of fluoroscopy in order to facilitate non-traumatic manipulations of the catheter. This placement, as well as a test injection of contrast media through the sheath, increases screening time and dose. Also, an overcouch X-ray tube was used in the present investigation, whereas undertable tubes were used in all previous studies. If the operator's hands enter the primary beam, the dose is higher with overtable than with undertable X-ray tubes. Scattered radiation associated with an overcouch geometry is also greater than that produced with undercouch tubes [8].

Theoretically, disregarding all other work involving radiation dose to the hands, each operator may perform about 2092 supraaortic examinations annually without the finger dose exceeding the dose limit to the extremities set by the ICRP. Variations in hand dose between centres imply that annual limits to the number of examinations are only indicative. Universal limits based upon workload only cannot be applied.

According to our results, the absorbed dose during abdominal studies is higher than in peripheral vascular angiography. In contrast, although screening time was longer for carotid studies than for lower extremities examinations, there is significantly less absorbed dose to the hands during supraaortic studies. This may be due to lower scattering radiation from the area of the carotid arteries and to the greater distance of the hands from the X-ray field compared with abdominal and peripheral vascular angiography.

As our results indicate, doses are always higher for the hand which is closer to the X-ray beam. Hence, in abdominal and supraaortic studies with the operator at the right side of the patient, the left hand received a higher dose than the right hand. In lower extremities, with the femoral approach being performed on the left side of the patient, the right hand received a higher dose than the left hand.

As already mentioned, the operator usually uses a lead apron, lead spectacles and thyroid shields in order to reduce radiation exposure to the body. However, although the use of lead gloves is also advisable for hand protection, many find them cumbersome and do not use them. Another explanation for the lack of interest in wearing lead gloves is the lack of risk information provided by those responsible for radiation protection. The results of the present study show the need for shielding the hands as operators can approach the dose limits in high workload. The availability and use of flexible lead gloves is an important operator-dependent parameter affecting dose to the hands. Protective gloves evaluated in the present study can reduce radiation exposure and, generally, give good touch and flexibility. Although two of the examinations involving complex manual work were difficult, protective gloves did not decrease comfort significantly.

The ICRP has suggested that the occupational dose should be as low as reasonably achievable (ALARA concept). Radiation protection measures can be applied for each laboratory. Fluoroscopy time should be reduced as much as possible. However, the lack of correlation which has been found between dose and screening time means that doses to hands cannot be estimated by screening time. The X-ray beam should be collimated as much as possible, and the distance between the hand and the scattering source should be as great as possible. The direct exposure of hands to the primary X-ray beam can be avoided with very careful utilisation of the light beam [9]. The operator can keep the light beam illuminated continuously during critical stages of the examination. By observing the beam area, the hands can be kept away from the irradiated area.

The results presented here show that operators can approach the dose limit to hands in high workload. It is important that adequate protection measures are taken to reduce the hand dose, especially for those with high workloads and those involved with complex procedures.

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