DETERMINATION OF THE ABSORBED DOSES IN SHANKS OF INTERVENTIONAL RADIOLOGISTS

Natalia Golnik[1], Krzysztof Szczepański[1], Piotr Tulik[1] and Barbara Obryk[2]
[1]Institute of Precision and Biomedical Engineering, Warsaw University of Technology, Sw. A. Boboli 8, PL 02-525 Warsaw, Poland
[2]Institute of Nuclear Physics, Radzikowskiego 152, 31-342 Kraków, Poland
e-mail: golnik@mchtr.pw.edu.pl

INTRODUCTION

Complicated procedures of interventional radiology require usually a much longer investigation time, comparing to the conventional radiography. Moreover, interventional radiology procedures require the presence of the medical staff next to the patient in order to perform the procedure. This results in higher risk for health professionals. Even though these persons reasonably keep away from the primary X ray beam, they are under the effects of scatter radiation due to the interaction of the primary beam with the patient. The protection aprons, thyroid protectors and shielding glasses are used in order to minimize the doses for the staff, but lower parts of legs remain usually unprotected and the absorbed doses in shanks are not recorded. The paper presents the measured values of the absorbed dose in lower extremities of medical staff, involved in the procedures of interventional radiology, completed with the measurements of air kerma under the patient table.

Measurements were performed in one of big hospitals in Warsaw during all the procedures performed in six weeks. Majority of the procedures constituted angioplasty or angioplasty with vascular stenting, uterine fibroid embolization and cholangiography.

In the angioplasty procedure, imaging techniques are used to guide a balloon-tipped catheter into an artery and advance it to where the vessel is narrow or blocked. The balloon is then inflated to open the vessel, deflated and removed. In vascular stenting, which is often performed with angioplasty, a small wire mesh tube (a stent) is permanently placed in the newly opened artery to help it remain open.

In a uterine fibroid embolization procedure, the image guidance is used in order to place an embolic agent (synthetic material) inside one or more of the blood vessels that supply the fibroid tumors with blood. As a result, these vessels become occluded, or closed off, and the fibroid tissue shrinks.

Percutaneous transhepatic cholangiography is a way of examining the bile duct system in the liver. During the exam, a thin needle is inserted through the skin (percutaneous) and through the liver (transhepatic) into a bile duct. Then dye is injected, and the bile duct system is outlined on x-rays.

Our measurements consist of three parts:

- Measurements of kerma in air, under the patient table, in dependence on the dose rate and the distance from the X-ray tube, along the table.
- Measurements of kerma in air under the table during real interventions and comparison with the DAP values.
- Measurements of the individual doses in shanks of medical personnel, using TLD dosemeters.

MATERIAL AND METHODS

All the measurements were performed at PHILIPS INTEGRIS XTV-16 machine. Air kerma was measured using an air-equivalent ionization chamber with VAJ-15 dosemeter, placed under the patient table, 20 cm over the floor in the line of the physician's foot. Anthropomorphic phantoms of human trunk and head were placed on the table during the measurements (Figure 1).

The measurements were performed along the patient table, at several distances from the X-ray tube axis, for different operating modes of the machine. The readings were recorded every second.

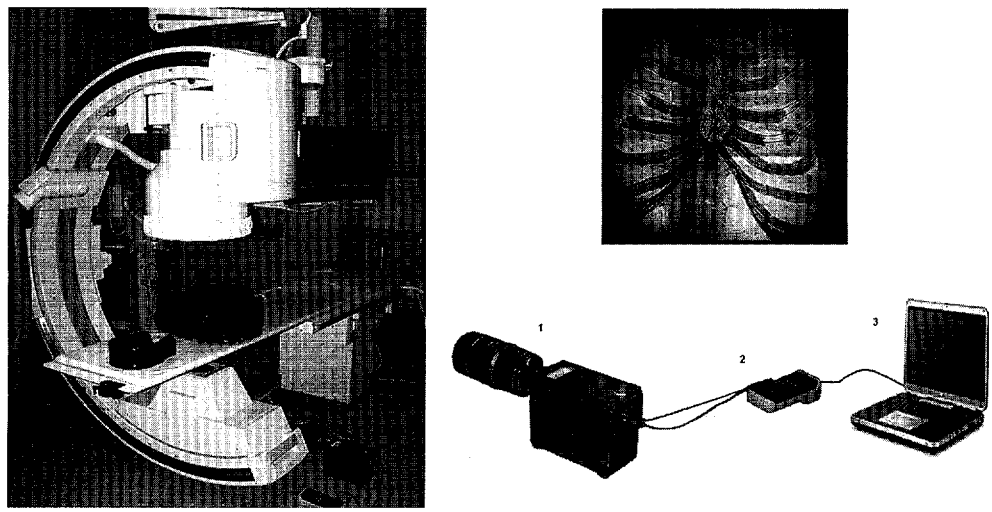

Figure 1. Human chest and head phantoms on the patient table, radiograph of the phantom and measuring equipment with VAJ-15 dosemeter.

The absorbed dose at the surface of the shanks was measured during real interventions, using MCP-N (LiF:Mg,Cu,P) thermoluminescence detectors (TLD), packed in the black, 0.1 mm thick polyethylene foil and attached to the socks of medical personnel (physicians, nurses and technicians) involved in interventional radiology procedures. The detectors were initially calibrated free-in air in reference field of ^{137}Cs source and then irradiated free in air and on the anatomic phantom of human leg in X-ray beams of several energies in the range from 40 kV to 100 kV (Figure 2).

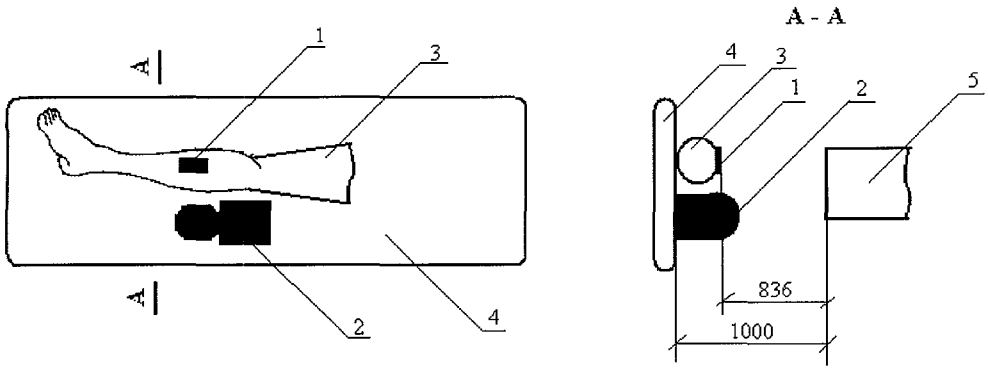

Figure 2. Calibration of the TLD detectors on the leg phantom. 1 TLD detectors, 2 VAJ-15 dosemeter, 3 Anatomic phantom, 4 Table, 5 X-ray tube. The phantom and the dosemeter were placed consecutively in the measuring point.

The scatter coefficients were calculated from the detectors' reading and used for evaluation of the doses recorded in the hospital.

RESULTS

Air kerma measurements

The X-ray machine can be used in one of three operating modes: High, Norm and Low. Values of air kerma measured under the table at the position of the physician's feet (when the angioplasty procedure is performed) are shown in Figure 3. The ratio of the air kerma rate is approximately 1:1.5:2.5 for the Low, Norm and High operating modes.

It is generally known, that the dose of scattered radiation decreases as the square of the distance from the table, in the direction perpendicular to the table. Our measurements showed that in the direction along the table, the air kerma decreased in a linear manner with the increase of the distance from the X-ray tube axis.

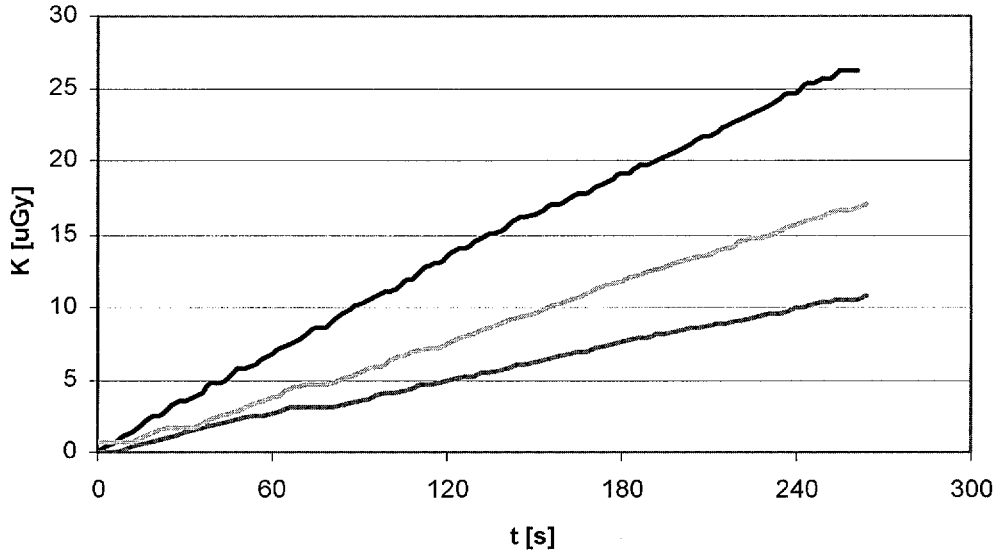

Figure 3. Air kerma under the patient table recorded for three modes of X-ray machine operation – High (upper line), Norm (middle line) and Low (lower line).

Examples of the air kerma values recorded during uterine fibroid embolization and cholangiography are shown in Figure 4.

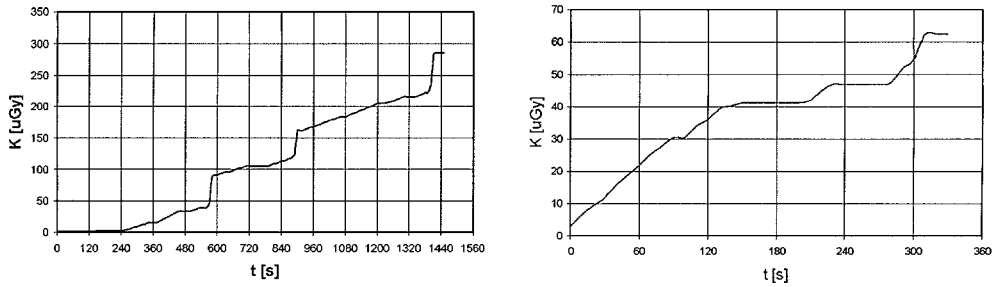

Figure 4. Air kerma under the patient table recorded during uterine fibroid embolization (left) and cholangiography (right).

Air kerma measurements, performed under the patient table during real interventions showed a good correlation between the obtained kerma values and dose area product (DAP) values recorded in protocols of particular interventions ($R^2 \geq 0.99$ for 32 different procedures).

Measurements of the individual doses

Using TLD as detectors for the estimation of the doses to the lower extremities is very convenient, so practically no other method is used. However, the results are reported in the literature using several different quantities – $H_p(0.07)$, "dose equivalent" or simply "dose". In this paper we decided to calculate the averaged dose equivalent to the left leg, from 10 cm up to 30 cm above the floor. The energy of the scattered radiation was assumed to be 40 keV (the lowest energy at which we could determine the scatter factor k=1.37, from the phantom of the leg).

The readings of TLD were corrected for scattering and then the entrance doses to the soft tissue and bones were calculated as:

$$D_t = S \cdot \left(\frac{\mu_{en}}{\rho} \right)_a^t = 1.052 \; S \tag{1}$$

$$D_b = D_t \cdot \left(\frac{\mu_{en}}{\rho} \right)_t^b = 4.63 \; S \tag{2}$$

where S is the TLD reading corrected for scattering, and D_t and D_b are the entrance doses in soft tissue and bone, respectively.

Then, the average value H_T was calculated, using a simple anatomic model and taking into account attenuation of the radiation in the leg. Finally, the relation $H_T \approx 2S$ was found. The results are shown in Figure 5.

The recorded values of the equivalent doses comprised in the range from 1.5 mGy to 44 mGy per six weeks of work. The doses received by physicians were about 20 times higher than the doses of nurses and technicians.

CONCLUSIONS

The measurements of the individual doses to lower extremities were performed for small group of health personnel, therefore they have no statistical value. Recorded H_T values were in agreement with the data published in the literature [1-3]. High extremity doses can be expected in interventional radiology suites, especially at large workload and in the hospitals were complicated procedures are performed. From the three monitored types of workers, the physicians received the highest dose. The doses to the assisting technicians and nurses were significantly lower due to their larger distance from the X-ray tube and patient region. The results confirm that the routine use of a protective lead

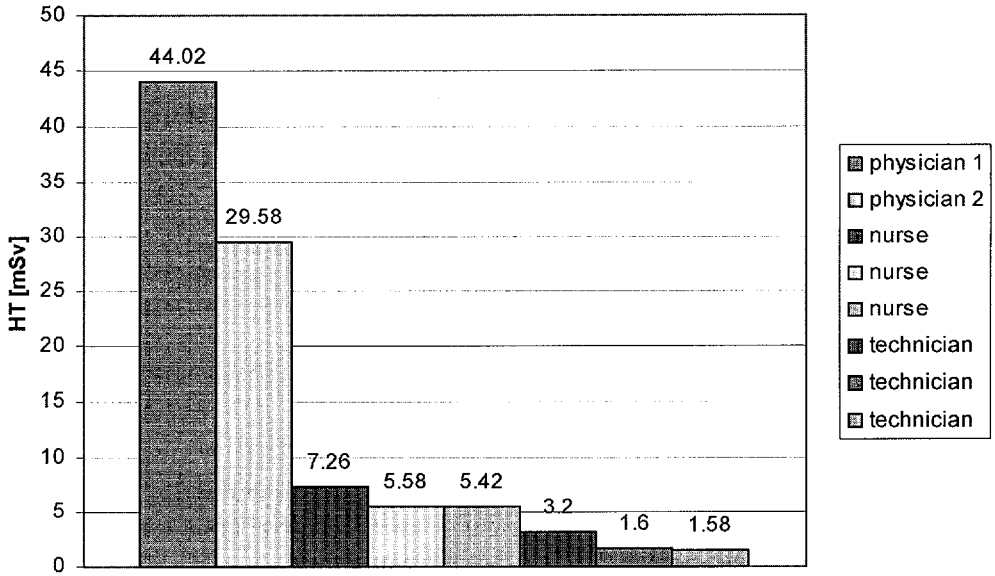

Figure 5. Distribution of the absorbed doses in shanks of the health professionals, recorded during a six-week period.

curtain should be recommended on all C-arm interventional radiologic equipment.

The main point of the work was to prove correlation between air kerma measured under the table and DAP. It was found that both quantities are strongly correlated, so the DAP values can be used for the first estimation of the doses to low extremities of physicians. Much better accuracy can be obtained if the kind of procedure is taken into account, so the expected position of the physician at the table can be estimated and the linear decrease of the air kerma along the table can be taken into account.

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